



УНИВЕРЗИТЕТ У НИШУ
UNIVERSITY OF NIŠ

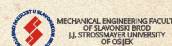
ФАКУЛТЕТ ЗАШТИТЕ НА РАДУ У НИШУ
FACULTY OF OCCUPATIONAL SAFETY



IN PARTNERSHIP WITH:
Faculty of Engineering, University of Porto,
Portugal



Mechanical Engineering Faculty,
J.J.Strossmayer University of Osijek,
Slavonski Brod, Croatia



Faculty of Fire Safety and Civil Protection
Bulgaria



UNDER AUSPICES OF:
Ministry of Education, Science and Technological
Development of Republic of Serbia



50 Years

of Higher Education
Science and Research in
Occupational Safety Engineering

PROCEEDINGS

The 18th Conference of the series
Man and Working Environment
INTERNATIONAL CONFERENCE
50 YEARS OF HIGHER EDUCATION, SCIENCE AND
RESEARCH IN OCCUPATIONAL SAFETY ENGINEERING



NIŠ, 6 - 7 DECEMBER 2018.



УНИВЕРЗИТЕТ У НИШУ
UNIVERSITY OF NIŠ

ФАКУЛТЕТ ЗАШТИТЕ НА РАДУ У НИШУ
FACULTY OF OCCUPATIONAL SAFETY



IN PARTNERSHIP WITH:
Faculty of Engineering, University of Porto,
Portugal



Mechanical Engineering Faculty,
J.J. Strossmayer University of Osijek,
Slavonski Brod, Croatia



Faculty of Fire Safety and Civil Protection
Bulgaria



UNDER AUSPICES OF:
Ministry of Education, Science and Technological
Development of Republic of Serbia



50 Years

of Higher Education
Science and Research in
Occupational Safety Engineering

PROCEEDINGS

The 18th Conference of the series
Man and Working Environment
INTERNATIONAL CONFERENCE
50 YEAR OF HIGHER EDUCATION, SCIENCE AND
RESEARCH IN OCCUPATIONAL SAFETY ENGINEERING

NIŠ, 6 - 7 DECEMBER 2018.

UNIVERSITY OF NIS
FACULTY OF OCCUPATIONAL SAFETY IN NIŠ

PROCEEDINGS

**The 18th Conference of the series Man and Working Environment
INTERNATIONAL CONFERENCE
50 YEARS OF HIGHER EDUCATION, SCIENCE AND
RESEARCH IN OCCUPATIONAL SAFETY ENGINEERING**

PUBLISHED BY:
FACULTY OF OCCUPATIONAL SAFETY IN NIS
Čarnojevića 10a, 18000 Niš

FOR THE PUBLISHER:
Prof. dr Momir Prašćević, dean

EDITORS OF PROCEEDINGS:
Prof. Dragan Cvetković, PhD
Prof. Ivan Krstić, PhD

GRAPHIC DESIGN AND PREPRESS:
Rodoljub Avramović

PRINTED BY:
„Unigraf X-copy“, Niš

CIRCULATION:
100 copies

Published in 2018.

CIP - Каталогизacija y yбубликации
Народна библиотека Србије, Београд

331.45/.46(082)
502/504(082)
614.8.084(082)

INTERNATIONAL Conference of the Series Man and
Working Environment (18 ; 2018 ; Niš)
International Conference 50 Year of Higher Education,
Science and Research in Occupational Safety Engineering:
proceedings / The 18th Conference of the Series Man and
Working Environment, Niš, 06-07 December 2018. ;
[editors of proceedings Dragan Cvetković, Ivan Krstić]. -
Niš : Faculty of Occupational Safety, 2018 (Niš : Unigraf
X-copy). - 326 str. : ilustr. ; 30 cm

Tekst štampan dvostubačno. - Tiraž 100. - Na vrhu nasl.
str.: Univerzitet u Nišu = University of Niš. - Napomene i
bibliografske reference uz pojedine radove. - Bibliografija
uz svaki rad. - Rezime.

ISBN 978-86-6093-089-9

- a) Заштита на раду - Зборници
- b) Животна средина - Заштита - Зборници
- c) Превентивно инжењерство - Зборници

COBISS.SR-ID 270808332

PROGRAMME COMMITTEE

- Dragan Cvetković, chairman, *Faculty of Occupational Safety, University of Niš, Serbia*
- Žarko Janković, vice-chairman, *Faculty of Occupational Safety, University of Niš, Serbia*
- Branislav Anđelković, *Faculty of Occupational Safety, University of Niš, Serbia*
- Nenad Živković, *Faculty of Occupational Safety, University of Niš, Serbia*
- Ljubiša Vučković, *Faculty of Occupational Safety, University of Niš, Serbia*
- Joan Manuel Abreu dos Santos Baptista, *Faculty of Engineering, University of Porto, Portugal*
- Olívia Maria de Castro Pinho, *Faculty of Engineering, University of Porto, Portugal*
- Mário Augusto Pires Vaz, *Faculty of Engineering, University of Porto, Portugal*
- Valentin Chochev, *Academy of the Ministry of Interior, Sofia, Bulgaria*
- Ivan Todorov, *Academy of the Ministry of Interior, Sofia, Bulgaria*
- Zdenek Dvorak, *Faculty of Special Engineering, University of Žilina, Slovakia*
- Ivan Samardžić, *Mechanical Engineering Faculty, J.J. Strossmayer University of Osijek, Slavonski Brod, Croatia*
- Pero Raos, *Mechanical Engineering Faculty, J.J. Strossmayer University of Osijek, Slavonski Brod, Croatia*
- Mitja Kožuh, *Faculty of Chemistry and Chemical Technology, University of Ljubljana, Slovenia*
- Lutvo Haznadarević, “Logos Centar“ *College Mostar, Bosnia and Herzegovina*
- Darko Petković, *Faculty of Mechanical Engineering, University of Zenica, Bosnia and Herzegovina*
- Šefket Goletić, *Faculty of Mechanical Engineering, University of Zenica, Bosnia and Herzegovina*
- Borislav Malinović, *Faculty of Technology, University of Banja Luka, Republic of Srpska*
- Mladen Todić, *Faculty of Mechanical Engineering, University of Banja Luka, Republic of Srpska*
- Strain Posavljak, *Faculty of Mechanical Engineering, University of Banja Luka, Republic of Srpska*
- Mihail Kochubovski, *Institute of Public Health of the Republic of Macedonia, Department of Environmental Health, Skopje, Macedonia*
- Dame Dimitrovski, *Faculty of Mechanical Engineering, University of Skopje, Macedonia*
- Maria Popa, *Faculty of Sciences, “1 Decembrie 1918” University of Alba Iulia, Romania*
- Mirjana Vojinović-Miloradov, *Faculty of Technical Science, University of Novi Sad, Serbia*
- Miodrag Hadzistević, *Faculty of Technical Science, University of Novi Sad, Serbia*
- Aleksandar Žunjić, *Faculty of Mechanical Engineering, University of Belgrade, Serbia*
- Svetlana Čičević, *Faculty of Transport and Traffic Engineering, University of Belgrade, Serbia*
- Nenad Krstić, *Faculty of Sciences and Mathematics, University of Niš, Serbia*
- Dragan Đorđević, *Faculty of Sciences and Mathematics, University of Niš, Serbia*
- Vlada Veljković, *Faculty of Technology in Leskovac, University of Niš, Serbia*
- Ivana Banković-Ilić, *Faculty of Technology in Leskovac, University of Niš, Serbia*
- Velimir Stefanović, *Faculty of Mechanical Engineering, University of Niš, Serbia*
- Nenad Pavlović, *Faculty of Mechanical Engineering, University of Niš, Serbia*
- Goran Ristić, *Faculty of Electronics, University of Niš, Serbia*
- Vera Marković, *Faculty of Electronics, University of Niš, Serbia*
- Jovica Jovanović, *Faculty of Medicine, University of Niš, Serbia*
- Aleksandra Stanković, *Faculty of Medicine, University of Niš, Serbia*
- Slaviša Trajković, *Faculty of Civil Engineering and Architecture, University of Niš, Serbia*

ORGANIZING COMMITTEE

- Ivan Krstić, chairman, *Faculty of Occupational Safety, University of Niš, Serbia*
- Evica Stojiljković, vice-chairman, *Faculty of Occupational Safety, University of Niš, Serbia*
- Ivan Mijailović, *Faculty of Occupational Safety, University of Niš, Serbia*
- Dejan Krstić, *Faculty of Occupational Safety, University of Niš, Serbia*
- Tatjana Golubović, *Faculty of Occupational Safety, University of Niš, Serbia*
- Aleksandra Ilić Petković, *Faculty of Occupational Safety, University of Niš, Serbia*
- Goran Janačković, *Faculty of Occupational Safety, University of Niš, Serbia*
- Darko Zigar, *Faculty of Occupational Safety, University of Niš, Serbia*
- Jelena Malenović-Nikolić, *Faculty of Occupational Safety, University of Niš, Serbia*
- Darko Mihajlov, *Faculty of Occupational Safety, University of Niš, Serbia*
- Dejan Vasović, *Faculty of Occupational Safety, University of Niš, Serbia*
- Ivana Ilić Krstić, *Faculty of Occupational Safety, University of Niš, Serbia*
- Lidija Milošević, *Faculty of Occupational Safety, University of Niš, Serbia*

CONFERENCE SECRETARIAT

- Milica Nikodijević, *Faculty of Occupational Safety, University of Niš, Serbia*
- Bojan Bijelić, *Faculty of Occupational Safety, University of Niš, Serbia*
- Rodoljub Avramović, *Faculty of Occupational Safety, University of Niš, Serbia*
- Aleksandra Petković, *Faculty of Occupational Safety, University of Niš, Serbia*

Welcome Message from the Organizing Committee Chair

Dear Colleagues,



On behalf of the CIRS Organizing Committee, it is my great pleasure to welcome you to the International Conference *50 YEARS OF HIGHER EDUCATION, SCIENCE AND RESEARCH IN OCCUPATIONAL SAFETY ENGINEERING*.

Since 1982, the Conference Man and Working Environment has made an extraordinary success, being held with different main themes. By promoting scientific research, continuous education and industrial applications, it has been established as the leading conference in the field of safety in this region.

The Conference host, Faculty of Occupational Safety in Nis, has recently celebrated fifty years of its existence as a higher education institution. Owing to the enthusiasm and efforts of all the Faculty staff from 1968 until today, the Faculty has developed as an integral part of the great academic community, following all societal changes and its needs, especially in the field of environmental protection and occupational safety.

This year, the Conference will bring together the delegates from 10 countries who will share with us their latest results, international expertise and experiences. As in previous conferences, poster and oral presentation sessions will provide all participants with the opportunity to discuss their results with other experts in the field.

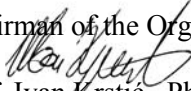
The themes of the 18th Conference of the series Man and Working Environment cover a broad set of issues in the field of safety:

- technologies and technical systems of safety
- physical and chemical aspects of occupational and environmental safety
- social and health aspects of occupational and environmental safety
- risk assessment and management

I would like to thank all those who contributed to this Conference, especially the authors and the participants who, due to their presence, have made it a success. Also, I thank the Programme Chairs for their suggestions and reviews. Last but not the least, this Conference would not be possible without support from the Ministry of Education, Science and Technological Development of the Republic of Serbia and other sponsors.

Sincerely,

Chairman of the Organizing Committee


Prof. Ivan Krstić, Ph.D.

CONTENT



CONTENT

SADRŽAJ

PLENARY PAPERS

PLENARNI RADOVI

Mirjana Vojinović-Miloradov Ivana Mihajlović	EMERGING HAZARDOUS SUBSTANCES IN OUTDOOR AND INDOOR ENVIRONMENT. STATE OF THE ART. CURRENT AND PAST RESEARCH. EMERGENTNE HAZARDNE SUPSTANCE U ŽIVOTNOJ I RADNOJ SREDINI. STANJE U OBLASTI NAUKE. TEKUĆA I PRETHODNA ISTRAŽIVANJA	1
Sandra Konstantinović Vlada Veljković	HUMAN HEALTH RISK AND TOXICOLOGICAL ASPECTS OF BIODIESEL PRODUCTION AND USE RIZIK PO LJUDSKO ZDRAVLJE I TOKSIKOLOŠKI UTICAJ PROIZVODNJE I KORIŠĆENJA BIODIZELA	9
Jovica Jovanović	SOCIAL - HUMANISTIC AND MEDICAL ASPECTS OF OCCUPATIONAL SAFETY SOCIJALNO-HUMANISTIČKI I MEDICINSKI ASPEKTI ZAŠTITE NA RADU	15
Vesna Nikolić Aleksandra Ilić Petković Mirjana Galjak Tamara Vukić	HIGHER EDUCATION IN THE FIELD OF OCCUPATIONAL SAFETY AND HEALTH IN INTERNATIONAL AND NATIONAL CONTEXT VISOKOŠKOLSKO OBRAZOVANJE ZA ZAŠTITU NA RADU U MEĐUNARODNIM I NACIONALNIM OKVIRIMA	21

TECHNOLOGIES AND TECHNICAL SYSTEMS OF SAFETY

TEHNOLOGIJE I TEHNIČKI SISTEMI ZAŠTITE

Milan Blagojević Radoje Jevtić Dejan Ristić	COMPARATIVE ANALYSIS OF RULES FOR SMOKE DETECTORS PLACEMENT IN FIVE LEADING STANDARDS KOMPARATIVNA ANALIZA PRAVILA ZA POSTAVLJANJE DETEKTORA DIMA U PET VODEĆIH STANDARDA	29
Darko Zigar Nikola Mišić Aca Božilov Dušica Pešić	THE ROLE OF FIRE BARRIERS IN FIRE SPREADING ACROSS BUILDING FACADES ULOGA POŽARNIH BARIJERA U ŠIRENJU POŽARA PREKO FASADE OBJEKTA	35
Igor Appolinarevich Kaibichev	WORLD INDEX OF AVERAGE NUMBER OF INHABITANTS PER ONE CAREER FIREFIGHTER GLOBALNI INDEKS BROJA STANOVNIKA NA JEDNOG PROFESIONALNOG VATROGASCA	41
Ivan Todorov Hristo Prodanov	THEORETICAL STUDY OF THE POSSIBLE APPROACHES FOR EVALUATION OF THE FIRE RESISTANCE OF STEEL COLUMNS ACCORDING TO EN 1993-1-2 TEORIJSKA STUDIJA MOGUĆIH PRISTUPA ZA ODREĐIVANJE VATRO-OTPORNOSTI ČELIČNIH GREDA PREMA EN 1993-1-2	43
Mile Vajkić Biljana Vranješ Mladen Todić	IMPROVING PREVENTIVE MEASURES FOR FIRE FIGHTING IN INDUSTRIAL SYSTEMS IN B&H POBOLJŠANJE PREVENTIVNIH MERA ZA BORBU PROTIV POŽARA U INDUSTRIJSKIM SISTEMIMA BIH	47

Simona Karamanolova Radoslav Kartov	FIRE HAZARDS OF PHOTOVOLTAIC SYSTEMS OPASNOSTI OD POŽARA FOTONAPONSKIH SISTEMA	53
Milan Protić Milena Mančić Milan Blagojević Miomir Raos Predrag Stanković	IGNITIBILITY STUDIES OF COMMON FOREST FUELS ISPITIVANJE UPALJIVOSTI TIPIČNIH ŠUMSKIH GORIVIH MATERIJALA . .	57
Martin Nachov Radoslav Kartov	DEVELOPING OF LIGHTNING PROTECTION SYSTEM FOR FIRE ALARMING SYSTEMS OPERATING AT A HIGHER RISK OF LIGHTNING STRIKES RAZVOJ SISTEMA GROMOBRANSKE ZAŠTITE U USLOVIMA VISOKOG RIZIKA OD UDARA GROMA	61
Marko Nikolić Stefana Janković Jelena Malenović-Nikolić	ACCIDENT VENTILATION AND A DOOR FAN TEST AT THE WORKSPACE HAVARIJSKA VENTILACIJA I FAN DOOR TEST RADNOG PROSTORA	65
Radoje Jevtić Milan Blagojević	SPECIAL CASES IN POINT FIRE DETECTORS ARRANGEMENT - ROOFS WITH MORE SLOPES SPECIJALNI SLUČAJEVI POSTAVLJANJA DETEKTORA VIŠESTRUKI KROVOVI	69
Martina Petković Uroš Jakšić Sanja Marković Biljana Nikolić Marijola Božović Lidija Milošević Dragan Knežević	INFORMATION TECHNOLOGIES IN SAFETY INFORMACIONE TEHOLOGIJE U ZAŠTITI	75
Veljko Radosavljević Mile Mitić	MEASURES FOR PROTECTION AGAINST DEMOLITION OF MINE ROOMS IN UNDERGROUND MINING MERE ZAŠTITE OD ZARUŠAVANJA JAMA U RUDNICIMA SA PODZEMNOM EKSPLOATACIJOM.	79

PHYSICAL AND CHEMICAL ASPECTS OF WORKING AND LIVING ENVIRONMENT FIZIČKI I HEMIJSKI ASPEKTI RADNE I ŽIVOTNE SREDINE

Zvonko Nježić Ivana Banković-Ilić Olivera Stamenković Vlada Veljković	ENVIRONMENTAL ASPECTS OF THE PRODUCTION AND USE OF CORN OIL BIODIESEL EKOLOŠKI ASPEKTI PROIZVODNJE I PRIMENA BIODIZELA IZ ULJA KUKURUZA	83
Milica Stojanović Danica Ćirić Raquel Nieto Anita Drumond Evica Stojiljković Luis Gimeno	TRACKING THE ORIGIN OF MOISTURE OVER SERBIA USING THE LAGRANGIAN METHOD PRIMENA LAGRANŽOVOG METODA ZA PRAĆENJE POREKLA ATMOSFERSKE VLAGE ZA SRBIJU	89
Maja Stanković Marija Cvetković Nenad Krstić Dragan Đorđević Miodrag Stanisavljević Ana Stojković Ivan Krstić	CHEMICAL CHARACTERIZATION OF SOLID INDUSTRIAL WASTE HEMIJSKA KARAKTERIZACIJA ČVRSTOG INDUSTRIJSKOG OTPADA	95

Nenad Krstić Maja Stanković Dragan Đorđević Vladimir Dimitrijević Marija Milivojević Dejan Krstić Aleksandar Bojić	ACTIVATED NATURAL ZEOLITE AS A POTENTIAL SORBENT FOR COPPER(II) ION FROM WASTE WATERS - PRELIMINARY STUDY AKTIVIRANI PRIRODNI ZEOLIT KAO POTENCIJALNI SORBENT ZA TEŠKE METALE - PRELIMINARNA ISPITIVANJA	101
Tatjana Golubović Ana Miltojević Slobodan Golubović Sreten Ilić	ASBESTOS-RELATED OCCUPATIONAL RISKS RIZICI USLED IZLOŽENOSTI AZBESTU U RADNOJ SREDINI	105
Maja Brborić Mirjana Vojinović- Miloradov Jelena Radonić Bojana Zoraja Maja Turk- Sekulić	OCCURRENCE OF POLYCYCLIC AROMATIC HYDROCARBONS AND POTENTIAL ECOTOXICOLOGICAL RISK IN FRESHWATER ECOSYSTEM OF THE DANUBE RIVER, SERBIA PRISUSTVO POLICIKLIČNIH AROMATIČNIH UGLJOVODONIKA I PROCENA EKOTOKSIKOLOŠKOG RIZIKA U SLATKOVODNOM EKOSISTEMU REKE DUNAV, SRBIJA	111
Nemanja Petrović Jasmina Radosavljević Ana Vukadinović	MITIGATING THE URBAN HEAT ISLAND SMANJENJE EFEKTA TOPLOTNOG OSTRVA	115
Milena Mančić Miomir Raos Milena Medenica Jelena Malenović-Nikolić Marko Mančić Milan Protić	APPLICATION OF THE ENERGY BALANCE METHOD ON THE MILK AND DAIRY PROCESSING PLANT PRIMENA METODE ENERGETSKOG BILANSIRANJA NA PRIMERU POSTOJENJA ZA PRERADU MLEKA	121
Žarko Vranjanac Goran Janačković	EFFECTS OF BIOFUEL PRODUCTION ON WORKERS AND THE ENVIRONMENT: INDICATOR-BASED ASSESSMENT UTICAJ PROIZVODNJE BIOGORIVA NA RADNIKE I ŽIVOTNU SREDINU: PROCENA BAZIRANA NA INDIKATORIMA	127
Sreten Ilić Tatjana Golubović Nataša Pajić Marjan Mirčevski	OPTIMIZATION OF DECONTAMINATION OF PEOPLE DURING THE REMEDIATION OF CHEMICAL ACCIDENTS OPTIMIZACIJA DEKONTAMINACIJE LJUDI U TOKU SANACIJE HEMIJSKOG UDESA.	133
Milan Protić Milena Mančić Miomir Raos Ana Miltojević	PROXIMATE ANALYSIS OF BIOMASS FUELS TEHNIČKA ANALIZA BIOMASE	137
Ana Miltojević Tatjana Golubović Marina Stojanović	POLYCYCLIC AROMATIC HYDROCARBONS IN THE WORKING ENVIRONMENT: TOXIC EFFECTS AND SAFETY ISSUES POLICIKLIČNI AROMATIČNI UGLJOVODONICI U RADNOJ SREDINI: TOKSIČNI EFEKTI I BEZBEDONOSNA PITANJA	141
Lidija Milošević Emina Mihajlović Martina Petković Ivan Mijailović	ANALYSIS OF AN EMERGENCY EVENT - HYDROCHLORID ACID LEAK IN RAIL TRANSPORT ANALIZA VANREDNOG DOGAĐAJA USLED ISTICANJA HLOROVODONIČNE KISELINE PRI ŽELEZNIČKOM TRANSPORTU	147
Vladimir Stanković Dejan Jovanović Dejan Krstić Vera Marković Nenad Cvetković	ELECTROMAGNETIC ENERGY FROM A 1.8 GHZ MOBILE PHONE ABSORBED IN A CHILD'S HEAD APSORBOVANA ELEKTROMAGNETSKA ENERGIJA U GLAVI DETETA OD MOBILNOG TELEFONA NA 1.8 GHZ	151

Simona Karamanolova	PHOTOVOLTAIC SYSTEMS FOR ELECTRICITY FOTONAPONSKI SISTEMI ELEKTRIČNE ENERGIJE	157
Srđan Glišović Žarko Janković Milena Petričević Nebojša Milkić	NANOSAFETY – AN OCCUPATIONAL AND ENVIRONMENTAL CHALLENGE OF OUR TIMES NANOBEZBEDNOST - IZAZOVI ZAŠTITE NA RADU I ZAŠTITE ŽIVOTNE SREDINE NAŠEG DOBA	161
Ana Stojković	RECYCLING PLASTIC MATERIALS AND IMPACT ON HUMAN HEALTH RECIKLAŽA PLASTIČNIH MATERIJAMA I UTICAJ NA ZDRAVLJE LJUDI	167
Mandalina Milosević Raša Milanov Tatjana Golubović Bojka Blagojević	FISHING AND THE RISK OF DECREASE IN MARINE DIVERSITY RIBARSTVO I RIZIK PO MORSKI BIODIVERZITET	173

SOCIAL AND HEALTH ASPECTS OF OCCUPATIONAL SAFETY

DRUŠTVENI I ZDRAVSTVENI ASPEKTI ZAŠTITE NA RADU

Žarko Ćulibrk	SOCIAL ASPECTS OF OCCUPATIONAL SAFETY - SOCIAL EMERGENCIES IN INDUSTRY DRUŠTVENI ASPEKTI ZAŠTITE NA RADU - DRUŠTVENE VANREDNE SITUACIJE U INDUSTRIJI	177
Vladica Sibinović Aleksandra Ilić Petković Vesna Nikolić	EDUCATION IN THE FIELD OF OCCUPATIONAL SAFETY AND HEALTH OF HEALTHCARE WORKERS IN PSYCHIATRIC INSTITUTIONS OBRAZOVANJE ZA BEZBEDNOST I ZDRAVLJE NA RADU ZDRAVSTVENIH RADNIKA U PSIHIJATRIJSKIM USTANOVAMA	181
Žarko Dimitrijević Aleksandra Ilić Petković	WORKPLACE STRESS OF EMPLOYEES IN PUBLIC ENFORCEMENT OFFICES STRES NA RADU ZAPOSLENIH U KANCELARIJAMA JAVNIH IZVRŠITELJA	185
Jelena Avramović Ana Veličković Vlada Veljković	THE SOCIO-ECONOMIC FACTORS OF BIODIESEL PRODUCTION SOCIO-EKONOMSKI FAKTORI PROIZVODNJE BIODIZELA	189
Aleksandar Trifunović Svetlana Čičević Aleksandar Žunjić Slobodan Mitrović Magdalena Dragović	NEW PEDAGOGICAL APPROACHES IN DIGITAL MEDIA - ENHANCED TRAFFIC SAFETY TRAINING FOR CHILDREN NOVI PEDAGOŠKI PRISTUPI - PRIMENA DIGITALNIH MEDIJA U OBUCI DECE O BEZBEDNOSTI U SAOBRAĆAJU	193
Ivana Ilić Krstić Aleksandar Ilić Danijela Avramović	THE THREE DIMENSIONS OF SUSTAINABLE DEVELOPMENT: ENVIRONMENT, ECONOMY AND SOCIETY OSNOVNE DIMENZIJE ODRŽIVOG RAZVOJA: ŽIVOTNA SREDINA, EKONOMIJA I DRUŠTVO	197
Biljana Nikolić Marijola Božović Martina Petković	ENVIRONMENTAL PROTECTION IN INTERNATIONAL AND NATIONAL FRAMEWORK ZAŠTITA ŽIVOTNE SREDINE U MEĐUNARODNIM I NACIONALNIM OKVIRIMA	203
Katarina Ilić	THE STRUCTURE OF RESEARCH ARTICLES IN THE FIELD OF OCCUPATIONAL SAFETY: HAVE SERBIAN ACADEMIC WRITERS REACHED INTERNATIONAL STANDARDS? STRUKTURA ISTRAŽIVAČKIH RADOVA IZ OBLASTI ZAŠTITE NA RADU: DA LI SU SRPSKI AUTORI DOSTIGLI MEĐUNARODNE STANDARDE?	207

Tamara Vukić Vesna Nikolić	METHODOLOGICAL CHARACTERISTICS OF ADULT EDUCATION IN THE SYSTEM OF SAFETY METODIČKE SPECIFIČNOSTI OBRAZOVANJA ODRASLIH U SISTEMU BEZBEDNOSTI I ZAŠTITE	213
Milica Stojković Milorad Bejatović	LEGAL PROTECTION FROM NOISE AND VIBRATIONS AND ECONOMY PRAVNA ZAŠTITA OD BUKE I VIBRACIJA I PRIVREDNI ŽIVOT	219
Slavenka Elek Ivan Mijailović	OCCUPATIONAL SAFETY AND HEALTH EDUCATION PLAN IN A ROAD CONSTRUCTION COMPANY - EXAMPLES OF GOOD PRACTICE PLAN OSPOSOBLJAVANJA ZAPOSLENIH ZA BEZBEDNOST I ZDRAVLJE NA RADU U PREDUZEĆU ZA PUTEVE – PRIMERI DOBRE PRAKSE	225
RISK ASSESSMENT AND MANAGEMENT PROCENA RIZIKA I UPRAVLJANJE RIZIKOM		
Marko Cvetković Joana Duarte Evica Stojiljković Lutvo Haznadarević Joao Manuel Abreu Dos Santos Baptista	PROFESSIONAL DRIVERS' POSTURES TRACKING - A REVIEW OF METHODOLOGIES AND APPLIED EQUIPMENT PRAĆENJE POKRETA TELA PROFESIONALNIH VOZAČA - PREGLED METODOLOGIJE I PRIMENJENE OPREME	231
Mučenski Vladimir Peško Igor Bibić Dragana Senjak Milena Dušica Savić Miodrag Hadžistević	ANALYSIS OF FALLS TO THE LEVEL BELOW IN CONSTRUCTION INDUSTRY OF SERBIA ANALIZA PADOVA NA NIVO ISPOD U GRAĐEVINSKOJ INDUSTRIJI SRBIJE	237
Kristina Smiljković Marko Bogdanović Ivan Krstić	IMPLEMENTATION OF PDSA ANALYSIS IN LEONI WIRING SYSTEM SOUTHEAST D.O.O. PROKUPLJE IMPLEMENTACIJA PDSA ANALIZE U LEONI WIRING SYSTEM SOUTHEAST D.O.O. PROKUPLJE	241
Nikola Mišić Aca Božilov Dušica Pešić Darko Zigar	CHECKLIST FOR FUEL TANK SAFETY ASSESSMENT ČEK LISTE ZA PROCENU RIZIKA REZERVOARA ZA GORIVO	247
Miliša Todorović Selma Hadžić Snežana Živković	MANAGING WORK SAFETY BY ANALISING INJURIES AT WORK UPRAVLJANJE ZAŠTITOM NA RADU KROZ ANALIZU POVREDA NA RADU	253
Aleksandar Žunjić Vladimir Sremčević Svetlana Čičević Aleksandar Trifunović Evica Stojiljković	THE EFFECTS OF INTERIOR DESIGN OF PUBLIC TRANSPORT BUSES ON PASSENGER SAFETY UTICAJ DIZAJNA ELEMENATA ENTERIJERA AUTOBUSA ZA GRADSKI PREVOZ NA BEZBEDNOST PUTNIKA	259
Goran Sekovski Blagoja Bogoevski Biljana Stavreska	ACCIDENTS AND SAFETY RISKS DURING INSTALLATION, MAINTENANCE AND MODERNISATION OF LIFTS NESREĆE I BEZBEDNOSNI RIZICI PRI MONTAŽI, ODRŽAVANJU I MODERNIZACIJI LIFTOVA	263
Jelena Malenović-Nikolić Marko Nikolić Milena Mančić Goran Janačković	OCCUPATIONAL INJURIES IN MINING AND ENERGY COMPLEXES POVREDE NA RADU U RUDARSKO-ENERGETSKIM KOMPLEKSIMA	269

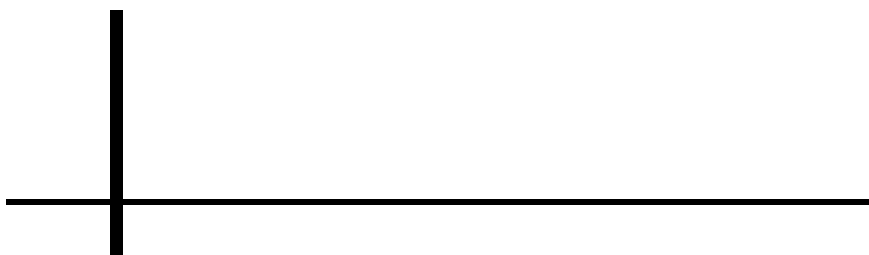
Sandra Stanković Dejan Vasović Ljiljana Takić	ECOSYSTEM SERVICES MANAGEMENT IN THE CONDITIONS OF EXTREME HYDROLOGICAL EVENTS UPRAVLJANJE EKOSISTEMSKIM USLUGAMA U USLOVIMA EKSTREMNIH HIDROLOŠKIH POJAVA	273
Bojan Bijelić Milena Stanković Miroljub Grozdanović	THE IMPORTANCE OF HUMAN RELIABILITY ANALYSIS IN RISK ASSESSMENT PROCESS ZNAČAJ ANALIZE LJUDSKE POUZDANOSTI U PROCESU PROCENE RIZIKA	277
Dejan Ristić Milan Blagojević Lutvo Haznadarević	RELIABILITY ANALYSIS OF FIRE DETECTION AND ALARM SYSTEMS ANALIZA POUZDANOSTI SISTEMA ZA OTKRIVANJE I DOJAVU POŽARA	281
Natalija Tošić Dejan Vasović	EMAS STANDARD APPLICATION EXPERIENCES IN THE REPUBLIC OF SERBIA ISKUSTVA U PRIMENI EMAS STANDARDA U REPUBLICI SRBIJI	287
Sveta Cvetanović Dejan Krstić Srđan Nikolić Goran Đorđević	RISK MANAGEMENT IN PREVENTIVE FOREST FIRE PROTECTION WITH A MODEL PLAN DEVELOPMENT FOR FOREST FIRE PREVENTION UPRAVLJANJE RIZIKOM U PREVENTIVNOJ ZAŠTITI ŠUMA OD POŽARA SA MODELOM IZRADE PLANOVA ZA SPREČAVANJE NASTANKA ŠUMSKIH POŽARA	293
Mile Mitić Veljko Radosavljević	ARAMIS METHODOLOGY: RISK ASSESSMENT IN CHEMICAL INDUSTRY ARAMIS METODOLOGIJA: PROCENA RIZIKA U HEMIJSKOJ INDUSTRIJI	299
Marijola Božović Emina Mihajlović Snežana Živković Uroš Jakšić Sanja Marković	INITIATIVES AND INSTITUTIONAL FRAMEWORK FOR ACCIDENT MANAGEMENT – ACCIDENT PROTECTION PLAN INICIJATIVE I INSTITUCIONALNI OKVIR UPRAVLJANJA UDESIMA - PLAN ZAŠTITE OD UDESA	303

STUDENT WORKS RADOVI STUDENATA

Anica Randelović Željko Milić	BIOLOGICAL HAZARDS AS A RISK FACTOR FOR HEALTH PROFESSIONALS BIOLOŠKE ŠTETNOSTI KAO FAKTOR RIZIKA ZDRAVSTVENIH RADNIKA	307
Tanja Ristić Marko Petrović	NOISE AS AN OCCUPATIONAL RISK FACTOR BUKA KAO FAKTOR RIZIKA U RADNOJ SREDINI	311
Željko Milić Anica Randelović	IMPACT OF EMERGENCIES ON HUMAN PSYCHOLOGICAL STATE UTICAJ VANREDNIH SITUACIJA NA PSIHOLOŠKO STANJE ČOVEKA	315
Marko Petrović Nikola Golubović Tanja Ristić	OCCUPATIONAL HAZARDS OF ELECTRICIANS NEGATIVNE POSLEDICE RADA ELEKTRIČARA	319



PLENARY SESSION



MIRJANA
VOJINOVIĆ MILORADOV¹
IVANA MIHAJLOVIĆ¹

¹University of Novi Sad,
Faculty of Technical Sciences

¹miloradov@uns.ac.rs
ivanamihajlovic@uns.ac.rs

EMERGING HAZARDOUS SUBSTANCES IN OUTDOOR AND INDOOR ENVIRONMENT. STATE OF THE ART. CURRENT AND PAST RESEARCH.

Abstract: *The state of the art of contamination by hazardous emerging substances (HEMS) in the outdoor and indoor environment based on the original results of authors and key literature references is presented. History of the newly-recognized group of HEMS is described. The key physico-chemical characteristics of HEMS are emphasized, especially pseudo-persistency of HEMS, non monotonic dose response, chemical cocktails, irreversible binding to proteins, followed by constants of partitioning and distribution and different forms of HEMS species in the aquatic environment (molecules, ions, cation and anions, and zwitter ions).*

Within this study review, representative original results of HEMS detected in the river Danube in the vicinity of Novi Sad, waste water, air and human milk are compiled, gained by numerous international and national projects, and in more than 30 papers published in the SCI journals and 40 full length papers printed at international and national conferences. Based on the concentration levels of HEMS, for the selected HEMS, risk assessment and RQ coefficients were calculated.

Key words: emerging substances, wastewater, Danube surface water, air, human milk, risk assessment.

INTRODUCTION

State of the art and historical overview

The term of emerging substances of concern (ESOC) was introduced for the first time in 2004. in Florida Report [1]. According to Florida report, ESOC are categorized in 6 groups:

- Global organic contaminants;
- Pharmaceuticals and personal care products;
- Endocrine-modulating compounds;
- Nanoparticles;
- Industrial chemicals (new and recently recognized);
- Biological metabolites and toxins.

Global Organic Contaminants include polybrominated diphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDs), perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), and siloxanes. PBDEs and HBCDs are flame-retardant chemicals that are applied to a wide variety of everyday items such as clothing, upholstery, foam cushions, electronics, and automobile interiors. PBDEs do not chemically bind to the substrates to which they are applied, and so they are easily liberated. These moderately long-lived molecules are primarily released into the atmosphere, where they can be transported globally and readily bioaccumulate in biological tissues.

Pharmaceuticals and Personal Care Products (PPCPs) include all prescription and over-the-counter drugs, diagnostic agents, dietary supplements, fragrances,

soaps, conditioners, sunscreens, cosmetics, caffeine, and nicotine. PPCPs also include antibiotics used prophylactically to prevent disease in livestock production (feedlot) operations. This diverse category of ESOC includes many water-soluble compounds. The most common mechanism for their entry into the environment is through wastewater discharges (municipal and septic drainage), land application of sewage sludge and manure, and landfill leachate. Depending on the type of treatment employed and the specific chemicals involved, wastewater or drinking water facilities may or may not be effective at removing these compounds from the effluent or drinking water.

PPCPs compounds include:

- Analgetics (Acetaminophen/Paracetamol, Diclofenac, Ibuprofen, Ketoprofen, Naproxen)
- Antibiotics/Antimicrobials (Ciprofloxacin, Erythromycin, Sulfamethoxazole, Trimethoprim, Triclosan)
- Antihyperlipidemics (Benzafibrate, Clofibrilic acid, Gemfibrozil)
- Fragrances (Galaxolide, Tonalide)
- Other compounds (Bisphenol A, Caffeine, Carbamazepine)

Endocrine-Modulating Chemicals (EMCs) include natural and synthetic hormones, surfactants, pesticides, tributyltin, polychlorinated biphenyls (PCBs), and dioxins/furans. Estrogens are excreted by humans and are readily degradable under aerobic conditions, but

they degrade slowly under anaerobic conditions. Nanomaterials are natural and man-made structures, ranging in size from 1 nanometer (nm) to 100 nm, that are widely used in nanotherapeutic pharmaceuticals, drug delivery, cosmetics, personal care products, energy storage products, fabrics, lubricants, and even recreational equipment such as golf and tennis balls. Their use is already so ubiquitous that one would find it very difficult to avoid exposure to at least some form of nanomaterials. Due to their extremely small size, nanomaterials can pass through biological membranes and the blood/brain barrier.

Moldovan was [2] among the first researchers who published the screening and target analyzes of pharmaceutical and personal care products (PPCPs) in the Somes River (Transylvania), which is one of the main rivers in Romania and belongs to the Danubian basin, therefore the Somes River is tributary of Tisa River and Tisa River is tributary of Danube river. Moldovan identified and quantified in his research 15 target compounds using GC/MS methods after extraction of analytes by SPE.

Caffeine was detected in the range of 430 to 9700 ng/l. Galaxolide and Tonalide were detected around of 300 ng/l and 100 ng/l, respectively. Due to environmental stability Galaxolide and Tonalide were selected as suitable tracers for musk fragrance. The detected concentrations of pentoxifylline are of 300 ng/l and 126 ng/l. The probable main source is the University Hospital of Cluj-Napoca, and untreated wastewater. The acetylaminophenazone (AAP) and formylaminophenazone (FAP) were detected in relative high quantity in every place. The AAP and FAP are metabolites of Metamizol (Noraminophenazone), a common analgesic and antipyretic drug. The Ibuprofen (NSAID) was detected in almost every sample of the effluent from Europe, which is probable a result of their high prescription extent and wide usage. In the UK effluents it was detected up to 1000 ng/l and in surface water from USA median values of 200 ng/l were reported. Carbamazepine is widely used as antiepileptic and is antidepressant drug and is known as a persistent substance. It has extremely low removal rate (fewer than 7%) in WWTP and is an excellent tracer substance for pharmaceutical agents in the environment. Carbamazepine was detected in quantities of 65, 72 and 75 of ng/l. Diazepam is a psychiatric drug used as tranquilizer. In the WWTP effluent was found in the maximum quantity of 40 ng/l but in rivers was not detected above 30 ng/l.

Codeine is an analgesic often detected in surface water. It was detected in quantity of 54 ng/l, 40 ng/l and 27 ng/l. Cyclophosphamide is an antineoplastic drug frequently applied in cancer chemotherapy having a mutagenic action. It was found in 65 ng/l.

Triclosan is an antimicrobial agent found in many hand soaps (0.1 to 0.3%). In the Somes River triclosan was found in concentration of 38 ng/l. Acetylsalicylic

acid (Aspirin) is an analgesic and anti-inflammatory drug very frequently used in medical practice. It was sold in 2000 in quantities exceeding 1000 tonnes/ year in EU countries.

Our results, current and past research

The first detailed research of our group realized within NATO Project in wastewater and Danube surface water in the vicinity of Novi Sad. Within the NATO Project, based on determination of HEMS in the river Danube, we meet for the first time with NORMAN list of emerging substances [3], which was formed by NORMAN Project with the financial support of the European Commission within the 6th Framework EU Programme. According to NORMAN, emerging substances are defined as substances that have been detected in the environment, but which are currently not included in routine monitoring programmes at EU level and whose fate, behaviour and (eco)toxicological effects are not well understood. Emerging substances were divided in categories/ classes and sub-classes (Table 1). Examples from the NORMAN list of emerging substances are surfactants, flame retardants, pharmaceuticals and personal care products, gasoline additives and their degradation products, biocides, polar pesticides and their degradation products and various proven or suspected endocrine disrupting compounds (EDCs).

Table 1. *Emerging substances by NORMAN*

Category / class	Sub-class
Algal toxins	Cyanotoxins
Antifoaming agents	Antifoaming agents
Antioxidants	Antioxidants
Antifouling compounds	Antifouling compounds, Organotin compounds
Bio-terrorism/ sabotage agents	Bio-terrorism/ sabotage agents
Complexing agents	Complexing agents
Detergents	Aromatic sulphonates, Alcohol ethoxylates (AEs), ..., Ethoxylates/carboxylates of octyl/nonyl phenols
Disinfection by-products (drinking water)	Iodo-trihalomethanes, Bromoacids, ..., Other disinfection by-products
Plasticizers	Phthalates, Benzophenone derivatives
Flame retardants	Brominated flame retardants, Polybrominated diphenylethers, Organophosphates, Chlorinated paraffins
Fragrances	Fragrances, Nitro musks, Macroyclic musks, Polycyclic musks
Gasoline additives	Dialkyl ethers
Industrial chemicals	Industrial chemicals
Nanoparticles	Carbon fullerenes, Carbon nanotubes, Carbon black, Silicon-based, Titanium dioxide, Aluminium Oxide

Perfluoroalkylated substances and their transformation products	Perfluoroalkylated substances, Fluorotelomer alcohols, Perfluorosulfonamido alcohols
Personal care products	Sun-screen agents, Insect repellents, Carriers, Parabens (hydroxybenzoic acid esters)
Pesticides	Polar pesticides and their degradation products, Other pesticides, New pesticides, Degradation products of pesticides, Antimicrobial agents
Biocides	Biocides
Pharmaceuticals	Analgesic, Anorexic, ..., X-ray contrast media
Trace metals and their compounds	Trace metals and their compounds
Anticorrosives	Benzotriazoles, Methylbenzotriazoles (MBT), Tolyltriazoles (TT)
Wood preservatives	Phenols
Other	Drugs of abuse, Benzothiazoles (BT), Nicotine metabolite

In the Serbian language where the correct translation of EMS was requested, on the proposal of professor Milorad Miloradov and the members of our research group in accordance with the Serbian translation of priority and hazardous priority substances („prioritetne i hazardno prioritetne supstance“), emerging substances were translated as „emergentne supstance“. The first detailed description of HEMS as industrial emerging substances was published in Chemical Industry, Miloradov et al. [4].

The unique physicochemical characteristics of HEMS

The dominant physicochemical characteristics very specific and unique for HEMS are: stable structure, low/non degradability, lipophilicity and hydrophilicity with log Kow in the range of -4.76 to 10.6, bioconcentration/bioaccumulation, biomagnification and protein interaction, toxicity, eco/toxicity, and acute but rather chronic effect (Table 2). Most of the molecules of HEMS are endocrine disruptors, with suspected teratogenic, mutagenic and carcinogenic consequences in low and sub low doses. Low doses effect and non-monotonic response in relation to dose are observed in the picomolar to nanomolar range. HEMS are semivolatile, volatile and non-volatile compounds with different values of Henry constant, polar/nonpolar molecules, with short half-lives. In aquatic media HEMS could act as neutral, acidic or alkaline chemical species and exist in ionic or zwitter ionic states.

HEMS may cause negative environmental effects at very low concentrations. Mixtures of pharmaceutical compounds (chemical cocktails) may exert substantial effects even if individual compounds are present in

low level concentrations. Effects of such continuous and long-term exposure on aquatic organisms and humans are of particular importance, because they may remain undetected until their cumulative level induce and trigger irreversible negative changes.

The most of HEMS/Pharmaceuticals are polar compounds, with the high persistence and as the consequences of these characteristic, they can become widespread throughout the aquatic environment and could affect water quality distant from the primary source. After their release to surface waters, photolysis may be the dominant degradation process which influences the fate of EmS in the surface water.

EmS are generally polar if their $\log K_{ow}$ are <4.5 and non or semi volatile (Henry coefficient, $K_H < 10^{-3} \text{ Pa m}^3 \text{ mol}^{-1}$). EmS are also relatively stable towards most chemical reactions in the aqueous environment.

Physicochemical properties of EmS (solubility, ad/absorbability, biodegradability, beside others) vary greatly depending on their different molecular structures, number of asymmetric C-atoms, stereochemistry, size and shape, hydrophobicity, charge, degree of ionization and other. For the most EmS, there is currently insufficient amount of the information about their potential toxicological consequences on ecosystem, particularly from long-term and low-level environmental exposure. The fate and the transport of EmS in natural aquatic media are mostly unknown, especially in context of water/soil/sediment distribution and partitioning processes. These processes are in the intensive phase of research.

The main physical and chemical properties of EmS are characterized by some experimentally or mathematically derived constants of: protonation ($\log pK_a$) which are in range of $9.6 - 2.5$, octanol–water partition coefficient ($\log K_{ow}$) and solubility (S_w) with the values from 10^6 mg L^{-1} to 0.02 mg L^{-1} , sludge–water distribution coefficient $\log K_d$ and some others constants.

The unique and specific physicochemical characteristic of EmS are:

- Low doses occurrence and effects - ppm, ppb, and lower
- Non Monotonic Dose Response, NMDR
- Pseudo - persistency / persistency, short half live, $t_{1/2}$
- Stability low/non degradability
- Hydro/lipophilicity - ($\log K_{ow} = -4.76 - 10.6$)
- Bioconcentration/bioaccumulation/ biomagnification
- Irreversible binding and interaction with the proteins
- Toxicity with hazardous and chronic effects
- Endocrine modulating/disruption, with teratogenic and carcinogenic consequences within the low/sub low doses
- Volatile, non - or semi volatile compounds

- Water/lipid soluble molecules (0.06-3.1 10⁴ mg L⁻¹)
- Polar/nonpolar molecules
- Neutral, acidic or basic aquatic media
- Ionic-cationic, anionic or zwitter ionic charge status in the water system
- Chemical cocktails
- Size in nano scale range
- Poorly sorbed to solid phase (sediments, soil, adsorbents) depending on pH and type and class of EmS
- WWTP processes partially remove EmS from wastewater.

Table 2. Examples of some pharmaceutical constants

Examples	pKa	LogK _{ow}	S _w	logK _d
Aspirin	3.5	1.13	5295	n.d.
Diclofenac	4.15	4.51	4.52	1.2
Ibuprofen	4.51	3.90	41	0.9
Naproxen	4.2	3.18	144.9	1.1
Ciprofloxacin	6.38	0.4	1.2 *10 ⁴	4.3
Doxycycline	3.5/ 7.7/9.5	-0.02	312.9	nd
Penicillin V	-2.79	1.87	101.1	nd
Sulfamethoxazole	-5.7	0.89	3942	2.7
Tetracycline	3.3/7.7/9.7	-1.30	3877	3.9
Trimethoprim	-7.2	0.91	2334	2.3
Enalapril	nd	2.45	34.88	nd
Carbamazepine	-13.9	2.45	17.66	0.1

Our results gained within international projects

Some provocative results of the research of HEMS in wastewater and surface water in the literature resources were the challenges for exploring emerging substances focused on pharmaceuticals and PPCP in our research activities within international Projects, NATO and NETREL TEMPUS; and national project financed by Ministry of Education, Science and Technological Development, Provincial Government and city of Novi Sad.

The research activities were divided on screening and target analysis [5]. Four screening and two target analyses were performed. In screening analyses, more than 300 organic and inorganic substances were detected. Approximately 100 -150 compounds have been found in specific sampling points of wastewater and Danube River. In table 3, the results of the screening analysis of wastewater from the collector RP and Danube surface water, 100 m downstream of the discharge, are summarized. Compounds like Benzothiazole, 2-(methylthio)-, phthalates 1,2-benzenedicarboxylic acid, diethyl ester and 1,2-benzenedicarboxylic acid, dibutyl ester and Cholest-5-en-3-ol (3 beta)- are detected in both samples. Polycyclic aromatic hydrocarbon Anthracene,

fragrance Dihydro methyl jasmonate, personal care product 2-propenoic acid, 3-(4-methoxyphenyl)-, 2-ethylhexyl ester and β -Sitosterol are detected only in the Danube water.

Based on the results of screening analyses 69 compounds were selected for target analyses. Among 69 compounds selected for target analysis, 29 were above limit of detection (LOD) in surface water, wastewater and raw water samples collected on 11 sampling sites. PAHs, 8 PCBs, phthalates and organochlorine pesticides were measured above LOD and their concentrations varied from very low, about 1 ng/L for PCB congeners to 2170 ng/L for phthalate (di-(ethylhexyl)-phthalate).

Table 3. Results of screening analysis of wastewater from the collector RP and Danube water, 100 m downstream of the discharge

Phenol, 2-(1,1-dimethylethyl)-	Wastewater and Danube water
Phenol, 2,4-bis-(1,1-dimethylethyl)-	Wastewater and Danube water
Pentadecane	Wastewater and Danube water
Undecanoic acid, 10-methyl-, methyl ester	Danube water
1,2-benzenedicarboxylic acid, diethyl ester	Wastewater and Danube water NORMAN list
Benzothiazole, 2-(methylthio)-	Wastewater and Danube water NORMAN list
Hexadecane	Wastewater and Danube water
Dihydro methyl jasmonate	Danube water NORMAN list
Phenanthrene-D-10	Wastewater and Danube water
Anthracene	Danube water WFD hazardous priority substance
Heptadecane, 3-methyl-	Danube water
1-naphthalenol, 5,6,7,8-tetrahydro-2,5-dimethyl-8-(1-methylethyl)-	Wastewater
phenol, 4-(1-methyl-1-phenylethyl)-	Wastewater and Danube water
1,2-benzenedicarboxylic acid, bis(2-methylpropyl) ester	Wastewater
7-Acetyl-6-ethyl-1,1,4,4-tetramethyltetralin	Wastewater
3,7,11,15-Tetramethyl-2-hexadecen-1-ol	Wastewater
1,2-benzenedicarboxylic acid, dibutyl ester	Wastewater and Danube water NORMAN list
2-propenoic acid, 3-(4-methoxyphenyl)-, 2-ethylhexyl ester	Danube water NORMAN list
Cholest-5-en-3-ol (3 beta)-	Wastewater and Danube water NORMAN list
β-Sitosterol	Danube water NORMAN list

The most of the detected compounds (fluoranthene, anthracene, pentachlorobenzene, trifluralin, hexachlorocyclohexane, octylphenols, DDT, endosulfan, dieldrin and endrin are included in the list of Priority Substances and Certain Other Pollutants according to Annex II of Directive 2008/105/EC. Eight EPA PCB congeners, dieldrin and endrin belong to the Annex A of the Stockholm convention, DDT is included in Annex B of the Stockholm convention, hexachlorocyclohexane gamma (Lindane) belongs to the list of nine new chemicals of the Stockholm convention, while di-n-butyl phthalate was included as plasticizer in the list of NORMAN emerging substances, therefore special attention should be focused to those compounds.

Within the sampling campaigns of Danube river water and wastewater discharged directly into Danube, organochlorine pesticides were detected in the highest concentrations, especially in the wastewater, indicating pollution from agricultural activities, households and farms in the vicinity of the sampling point RO' (Table 4).

Table 4. Results of target analysis of wastewater from the collectors GC1, GC2, RO and RP in the vicinity of Novi Sad (in ng/L)

Compound	GC1'	GC2'	RO'	RP'
Dieldrin	<10	<10	70	<10
Endrin	<10	<10	20	<10
Chlorpyrifos (Chlorpyrifos-ethyl)	<30	<30	40	<30
Endosulfan alpha	<5	<5	60	<5
Endosulfan beta	<5	<5	80	<5
p,p'-DDD	230	240	620	220
p,p'-DDE	80	80	110	80
p,p'-DDT	260	<10	500	<10

These pesticides were determined in concentrations more than ten times higher than annual average values in European Union countries. Although DDT was banned in Serbia since 1972, determination of DDT in high concentrations could be the reason of concern. In the recent time, high concentrations of DDT in environmental samples were also mentioned in other literature, although in EU countries DDT concentrations showed decreasing trend. This could be the evidence of uncontrolled usage of DDT in European countries. p,p'-DDD (Rhothane), metabolite of DDT, the most lipophilic with the lowest value of K_{ow} of 4.73 within the metabolites of DDT, was detected in almost all samples with extremely high values at sampling sites RO' and GC1", which confirms historical contamination, but also recent contamination inputted upstream of the city of Novi Sad. According to the concentration ratio of p,p'-DDD and p,p'-DDT at sampling points with the highest concentrations, RO' and GC1", the values of 1.24 and 1.29 indicated historical contamination with these chemicals. Comparing results for DDT and

metabolites in surface water of Danube, we could conclude that they were in correspondence with the results of the quality of surface water of Serbian Environmental Agency in 2011.

p,p'-DDD is so similar to p,p'-DDT and is a metabolite of p,p'-DDT. p,p'-DDD is the solid substance and has been used as pesticide for agricultural use. Also, technical mixture of DDT which has been used in agricultural purposes, contains up to 30% of p,p'-DDD. Increased concentration of Rhothane could be the consequence of uncontrolled usage of this chemical as pesticide in East European countries.

Seasonal variations of caffeine and antibiotic concentrations were investigated along the selected sites of the Danube. The obtained results confirmed the presence of caffeine at four sampling points, near the wastewater discharges. The mean caffeine concentrations for summer, autumn, winter and spring were 24.78 ng/L, 26.83 ng/L, 24.61 ng/L, and 86.29 ng/L, respectively. The analysed antibiotics (sulfamethoxazole, chloramphenicol and tiamuline) were under the limit of detection in all tested samples taken from the Danube [6].

Seasonal variations of bisphenol A (BPA, IUPAC: 4,4'-(propane-2,2-diyl)diphenol) were investigated in the Danube River along the Novi Sad bank, Serbia. The obtained results confirmed the presence of BPA above the limit of quantification (6 ng L⁻¹) in 22 out of 32 the water samples at all eight sampling sites. The BPA concentration varied from <6 to 693 ng L⁻¹. The mean BPA concentration for summer (220 ng L⁻¹) significantly differed from those obtained for autumn (39 ng L⁻¹), winter (6 ng L⁻¹) and spring (41 ng L⁻¹) [7].

Three groups of POPs - DDT, HCH and PCBs were monitored in early human milk for 27 years (1982–2009), as a measure of environmental pollution in the same geographic region (South Bačka, Vojvodina, Serbia). Concentrations of DDT and HCH had general decreasing trend from 1982 to 2009. However, the concentrations of both groups of compounds showed small rises in 1994. Concentrations of PCBs had general decreasing trend from 1982 to 2009 — smooth and steep only till 1994 and with two small peaks in 2003 and 2009. The latest estimated daily intake of DDT and HCH was well below the EU upper limit for pesticides in food intended for infants and small children. Although the estimated daily intake of PCBs was far below the upper limit for daily milk products in Serbia, its increase in 2003 and 2009 is a clear indication of environmental influx of these compounds after the 1994 measurements. The likely explanation for such POP profiles in South Bačka could have been a series of negative environmental impacts escalating in 1999, after which four hot spots were identified in Serbia (Novi Sad, Pančevo, Bor and Kragujevac) by UNEP. The results of this monitoring showed that although a long standing environmental presence of POPs has a decreasing trend, their occasional output in

the environment may cause bioaccumulation and biomagnification in human organisms which already start in the neonatal age through mother–child transfer via human milk [8].

Table 5. Concentrations of pesticide residues and PCBs ($\mu\text{g/kg w.w.}$) in human milk samples. The values are mean, SD and range

Pollutants measured	Year of human milk collection (number of samples)		
	1982 (n=26)	1994 (n=14)	2006 (n=16)
Σ DDT	89.34 $\pm$	19.76 $\pm$	6.02 $\pm$
	45.54	15.01	14.22
	16.09 –	0.00 –	0.00 –
	207.43	61.20	64.57
p,p'-DDE	69.39 $\pm$	18.28 $\pm$	2.52 $\pm$
	33.79	14.51	1.42
	11.96 –	0.00 –	0.00 –
	139.24	57.70	3.53
p,p'-DDT	20.01 $\pm$	1.44 $\pm$	4.61 $\pm$
	15.94	1.15	10.37
	4.13 –	0.00 –	0.00 –
	68.19	3.50	46.60
DDE:DDT	3.5 : 1	13 : 1	0.5 : 1
Σ HCH	3.19 $\pm$	7.54 $\pm$	0.60 $\pm$
	3.42	5.08	0.23
	0.14 –	0.00 –	0.00 –
	16.01	22.70	0.79
α -HCH	0.46 $\pm$	1.51 $\pm$	0.35 $\pm$
	0.48	2.26	0.26
	0.00 –1.91	0.00 –	0.00 –
		8.10	0.79

The selected results presented in Table 5 evidently illustrate current and past research of persistent, hazardous emerging substances from 1982 to 2009 period in biological material – human milk.

For the risk evaluation the main task is to examine stressor-response relationship. Method for risk assessment is based on calculation of risk quotient (RQ) via MEC and PEC, measured environmental concentration and predicted environmental concentration, respectively, and PNEC values (predicted no-effect concentration) for every persistent and HEMS chemicals. The obtained results of the risk assessment calculation lead to the conclusion that the metal cations on three locations of Danube surface water pose a significant risk to the aquatic environment and human health, especially for cations of chromium, lead and cadmium.

The paper of Radonic et al. [9] presents the assessment of emission sources and health risk of 16 PAHs in the city of Novi Sad, Serbia, with developed oil, food, chemical and cement industry. The carcinogenic potency of studied PAHs, expressed as the sum BaP-eq, ranged from 0.25 ng/m³ for best-case scenario (i.e.

minimum exposure to PAHs) to 49.54 ng/m³ for worst-case scenario (maximum exposure). During the heating season, carcinogenic potency was over 8 times higher comparing to non-heating season.

Within indoor research activities the results of determination of carcinogenic emerging substance formaldehyde is abstracted in this study review. The presence of formaldehyde with concentration levels significantly higher than maximum allowed concentration (MAC) of formaldehyde in Serbia is 0.1 mg·m⁻³. The highest formaldehyde concentration value of 19.80 ppm in all three campaigns has been detected in the preparation room during the process of extraction of anatomical specimens from formalin as part of getting ready for the classes [10].

CONCLUSION

Hazardous emerging substances were recognized as old chemicals but new contaminants for the first time in wastewater and surface water, but later in air and soil. In this study review, the general state of art of HEMS based on selected literature references as well as of our original results were underlined with the dominant and unique physico-chemical characteristics of HEMS, exclusively pseudopersistency of HEMS, non-monotonic dose response, chemical cocktails, irreversible binding to proteins, following by constants of partitioning and distribution and different forms of HEMS species in the aquatic environment (molecules, ions, cation and anions, and zwitter ions). The concentration levels of HEMS were resulted from our international and national projects and scientific research papers. In this study, in outdoor and indoor environment, concentration levels of HEMS in waste water, surface water, indoor air and human milk were emphasised. A brief review of risk assessment and risk quotient of some selected HEMS is described and calculated.

REFERENCES

- [1] Florida Department of Environmental Protection. 2008. Emerging Substances of Concern: Division of Environmental Assessment and Restoration Tallahassee, Florida, USA.
- [2] Z. Moldovan: "Occurrences of pharmaceutical and personal care products as micropollutants in rivers from Romania", *Chemosphere*, Vol 64, 2006, pp. 1808-1817.
- [3] <https://www.norman-network.net/> Assessed:15.11.2018.
- [4] M. Vojinović Miloradov, M. Turk Sekulić, J. Radonić, N. Milić, N. Grujić Letić, I. Mihajlović, M. Milanović: "Industrial emerging chemicals in the environment", *Hemijska Industrija*, Vol 68(1), 2013, pp.51-62.
- [5] M. Vojinović Miloradov, I. Spanik, I. Mihajlović, M. Turk Sekulić, J. Radonjić: "Surprising the Residual High Concentrations of DDT and Metabolites in Water Samples", *Proceedings, 34. International Conference on Organizational Science Development" Internationalization and cooperation"*, University in Maribor, Portorož, Slovenia, 25-27 March, 2015, pp. 1273- 1277.
- [6] N. Grujić Letić, M. Milanović, N. Milić, M. Vojinović Miloradov, J. Radonić, I. Mihajlović, M. Turk Sekulić: "Determination of Emerging Substances in the Danube and Potential Risk Evaluation", *CLEAN – Soil, Air, Water*, Vol 43, 2015, pp. 731-738.
- [7] M. Milanović, J. Sudji, N. Grujić Letić, M. Vojinović Miloradov, J. Radonić, M. Turk Sekulić, N. Milić: "Seasonal variations of bisphenol A in the Danube River by the municipality of Novi Sad, Serbia", *Serb. Chem. Soc.*, Vol 80 (3), 2016, pp. 333–345.
- [8] D. Adamović, M. Vojinović-Miloradov, S. Adamović, J. Radonić, M. Turk Sekulić, B. Obrovski: "Exposure to formaldehyde in anatomy laboratory", *11. Savjetovanje hemičara i tehnologija Republike Srpske, Teslić: University in Banja luka, Faculty of Technology*, 18-19 Novembar, 2016, pp. 611-617.
- [9] J. Radonić, N. Jovčić Gavanski, M. Ilić, S. Popov, S. Batić Očovaj, M. Vojinović Miloradov, M. Turk Sekulić: "Emission sources and health risk assessment of polycyclic aromatic hydrocarbons in ambient air during heating and non-heating periods in the city of Novi Sad, Serbia", *Stochastic Environmental Research and Risk Assessment*, Vol 31, 2017, pp 2201–2213.
- [10] T. Vukavić, M. Vojinović-Miloradov, I. Mihajlović, A. Ristivojević: "Human milk POPs and neonatal risk trend from 1982 to 2009 in the same geographic region in Serbia", *Environment International*, Vol 54, 2013, pp. 45-49.

ACKNOWLEDGEMENTS

This paper is financially supported by NATO (ESP.EAP.SFP 984087), TEMPUS NETREL (530554-TEMPUS-1-2012-SK-JPHES), and Project of Ministry of Education, science and technological development, Republic of Serbia (III46009).

The authors want to acknowledge to the participants of the Projects and some research papers: Ivan Spanik, Jelena Radonic, Maja Turk Sekulic, Natasa Milic, Nevena Grujic Letic, Maja Milanovic, Maja Petrovic, Maja Sremacki, Dragan Adamovic, Srdjan Kovacevic.

BIOGRAPHY of the first author

Emeritus Mirjana Miloradov, is full professor with high experiences in the educational and research field of inorganic, bioorganic and environmental chemical engineering. The recent activities were focused on the applied physicochemical principles in environmental engineering on Bachelor, Master and Doctoral studies. Her scientific and research activities are focused on negative impact of environmental contamination by highly hazardous, toxic persistent and emerging substances on the quality of water, atmosphere, human material with the adverse consequences on climate changes. Prof. emeritus Mirjana Miloradov has published more than 900 scientific papers, more than 150 papers on the SCI list, with citations index higher than 850. She is the reviewer for 4 prestige peer-review scientific journals in continuum over an extensive period of time. Prof. Mirjana Miloradov was invited lecturer at numerous international and national conferences in Boston, Prague, Barcelona, Bratislava, Szeged, South Korea, Johannesburg, Belgrade, Vršac, Kruševac, Subotica, Zlatibor, Novi Sad, Bor, Kragujevac, Banja Luka and others.

She was Coordinator of the 11 international projects (FP5 APOPSBAL, MONET, NATO, bilateral projects of Slovak aid, TEMPUS, ERASMUS+) and over 12 national projects. Currently she is research leader and coordinator of 5 international projects. Professor Mirjana published 5 monographs, numerous textbook materials in Serbian and English languages with co-authors. She was a mentor for more than 50 MSc and 30 PhD theses. Prof. Emeritus Mirjana Miloradov was Director of Centre for Interdisciplinary Studies for Environmental Engineering at University of Novi Sad for more than 10 years, 6 years Director of Chemistry Institute on Faculty of Natural Sciences, Novi Sad, and long life the Chief of Chair of Medical Chemistry at the Faculty of Natural Sciences and Medical Faculty and the Chief of Chair of Environmental Engineering at the Faculty of Technical Sciences, University of Novi Sad.



EMERGENTNE HAZARDNE SUPSTANCE U ŽIVOTNOJ I RADNOJ SREDINI. STANJE U OBLASTI NAUKE. TEKUĆA I PRETHODNA ISTRAŽIVANJA.

Mirjana Vojinović Miloradov, Ivana Mihajlović

Rezime: U preglednom radu predstavljeno je stanje u oblasti kontaminacije hazardnim emergentnim supstancama (HEMS) u životnoj i radnoj sredini bazirano na originalnim rezultatima autora i ključnim literaturnim referencama. Opisan je istorijski prikaz novoprepoznate grupe HEMS-a. Ključne fizičko-hemijske karakteristike HEMS-a su istaknute, kao i pseudoperzistencija HEMS-a, ne-monotoni dozni odgovor, hemijski kokteli, ireverzibilno vezivanje HEMS za proteine, ilustrovano konstantama raspodele i distribucije u različitim hemijskim specijama HEMS u vodenoj sredini, kao što su molekulske, jonske, katjonske i anjonske, i zwitter jonske forme.

U prikazu istraživačkih aktivnosti kompilovani su reprezentativni originalni rezultati detektovanih HEMS-a u reci Dunav u okolini Novog Sada, otpadnoj vodi, vazduhu i humanom mleku realizovani u okviru brojnih međunarodnih i nacionalnih projekata i saopšteni u više od 30 radova objavljenih u časopisima SCI liste i 40 radova štampanih u celini na međunarodnim i nacionalnim konferencijama. Na osnovu određenih koncentracionih nivoa HEMS, za selektovane grupe HEMS-a urađene su analize procene rizika i izračunati RQ koeficijenti.

Ključne reči: emergentne supstance, otpadna voda, površinska voda Dunava, vazduh, humano mleko, procena rizika.

SANDRA KONSTANTINOVIĆ
VLADA VELJKOVIĆ

University of Niš,
Faculty of Technology in Leskovac

sakisandra12@yahoo.com
veljkovicvb@yahoo.com

HUMAN HEALTH RISK AND TOXICOLOGICAL ASPECTS OF BODIESEL PRODUCTION AND USE

Abstract: *Biodiesel, as well as other biofuels, is definitely one of the solutions for the world's growing energy needs. Its main advantage is the production from renewable resources. Less greenhouse gas emissions, better fuel economy, and a positive impact on the global economy are also the benefits achieved by the use of biodiesel. All efforts to explore, establish, and verify the advantages of biodiesel undoubtedly open the most important environmental protection issues. Unfortunately, current information does not permit a precise conclusion of the prospective influence on the environment and human health. Therefore, the inclusion of biodiesel into the fuel supply chain has to be done very carefully, regarding its potential disadvantages related to not only the technology and economy, but also the environment, society, and human health, which should be reduced or even completely eliminated. Therefore, this paper reviews the human health risk and toxicological aspects of biodiesel production and use.*

Key words: biodiesel, toxicological impact, human health risk, environment.

INTRODUCTION

Biofuels are naturally renewable alternatives for fossil fuels with many advantages, including those connected with the environment. Derived from biomass, biofuels include biodiesel, bioethanol, bio-oil, biomethane, biobutanol, biomass-to-liquid-diesel, and biohydrogen.

Biodiesel is a mixture of methyl or ethyl esters of long-chain fatty acids obtained from renewable sources like oils and fats. It is available as pure fuel (B100), or can be blended with petro-diesel (B2, B5, and B20, where the numbers represent the percent of biodiesel in blends, while the rest is petro-diesel).

It is known for its biodegradability, lack of sulfur and aromatic compounds, and excellent lubricity [1]. According to its origin, biodiesel can be divided into three generations. The first generation includes biodiesel obtained from traditional feedstocks (edible vegetable oils and animal fats) by using conventional technology based on transesterification reaction. The most commonly used feedstocks are soybean, rapeseed, sunflower, palm, and coconut oils. Although the vegetable oils are widely available, they are also the potential threat of the food chain and can enhance the carbon emissions when oily crops are cultivated outward the traditional agricultural settings. The second generation includes biodiesel produced from generally non-edible oily crops or used cooking oils, oily wastes from the oil production, waste animal fats (beef tallow, pork lard, poultry fat, fish oil). The non-edible oily crops are cheaper than the edible oily crops, since they breed on marginal land, with a minimum water and fertilizer use [2]. The third generation of biodiesel is produced from algal lipids. It is considered that fossil

fuels can be completely replaced by biodiesel produced from algal lipids [2,3] due to simple nutrient requirements, rapid growth rate, high biomass productivity, high oil content (up to 77% of dry biomass), as well as high photosynthetic and CO₂ fixation efficacy of algae [2,4,5]. Besides that, there is no need for arable land for cultivation and no competition with common food resources, while wastewater can be used for cultivation.

Comparing to petrol-diesel, biodiesel definitely produces less toxic pollutants and greenhouse emissions. Generally, the important action for the positive influence of biodiesel on human society and environment are considered to be lower greenhouse gas emissions and the optimization of the feedstock processing by using lower energy input. It makes them very important regarding its repressing effects on the global climate change in a manner of reducing greenhouse gas emission and pollution.

Such a potential positive impact serves as a stimulus for the creation of legal policy for the renewable energy promotion in the European Union and the United States of America and the increased global biodiesel production [6,7]. According to the Statistical World Review of World Energy, the biofuels production increased by 3.5% in 2017 [8]. Global biodiesel production is expected to reach 41.4 billion liters by 2025 corresponding to a 33% increase from the 2015. The European Union is expected to be the major producer of biodiesel, along with United States, Brazil, Argentina, and Indonesia (Fig.1) [9].

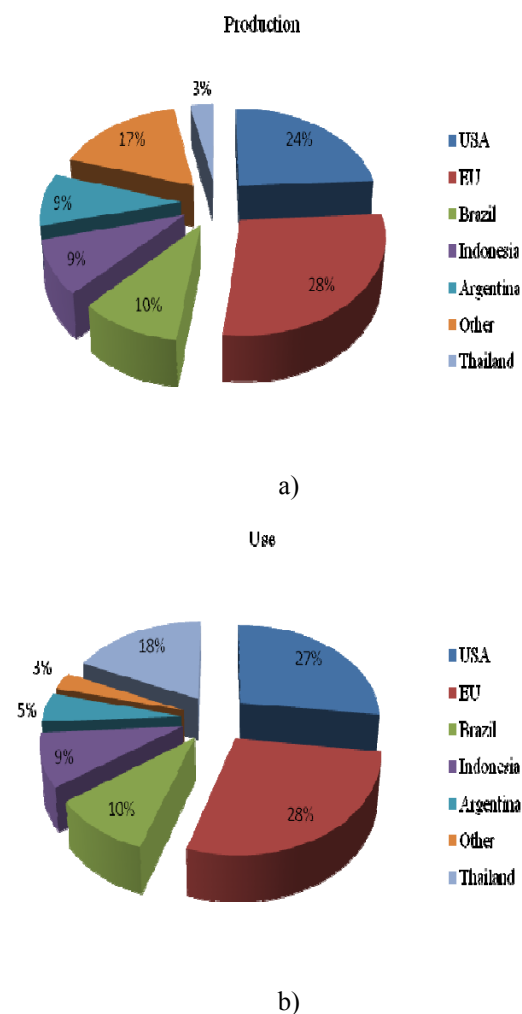


Figure 1. Predictions of regional distributions of world biodiesel (a) production and use (b) in 2025 [9]

However, the expansion of the biofuel industry develops a lot of questions about its potential impacts on the environment [10]. The environmental effects are also reflected through biodiversity, which may be affected by biofuels crops alteration of local habitats and resources, and sometimes impact the native species itself. These impacts are connected with types of crop and usual inputs, including chemicals and water. Anyway, the most of life cycle assessments show that the impact of biofuels includes resource depletion, eutrophication, acidification, and toxicity; thus, a further investigation of the potential risks of biofuels implementation should be focused on these issues [11].

Thus, the inclusion of biodiesel into the fuel supply chain must be done very carefully, regarding its potential disadvantages related to the technology, economy, environment, society, and human health that should be reduced or even completely eliminated. In this review paper, having a great influence on the human society and environment, the toxicological aspects and human health risk of biodiesel production and use are thoroughly considered.

TOXICOLOGICAL IMPACTS AND HUMAN HEALTH RISKS OF BIODIESEL

As a renewable, clean-burning fuel that can be used in existing diesel engines with minor or no modification, biodiesel is frequently seen as not only a “greener” but also healthier and safer option to petrol-diesel. Despite the evident benefits of biodiesel as an alternative fuel, the environmentalists are cautious about the potential short-term and extended effects that the biodiesel production and use may have on the human health. Since the main goal is the replacement of conventional fuels with biodiesel, a toxic capability of both fuel types is crucial, since it is directly connected with their production, distribution, transportation, and utilization. Therefore, the crucial question that arises is: Does biodiesel have toxicological influence on human health and environment, generally?

Toxicological impacts of biodiesel

The consideration of the biodiesel's toxicological effects is complicated by very complex procedures for overviewing every aspect of their impact. With respect to the toxicological impact of biodiesel, the greatest problem is the determination and explicit definition of the chemical composition of biodiesel and its emissions. Most of the researchers evaluate the biodiesel impact through the known hazardous substances, which can be released during the production and/or use. However, no definite bioassay results and achievements have been shown so far with regard to the toxicity of the (bio)fuels or their emissions [10].

Further, testing all organisms that may be exposed to biodiesel is impossible, and the reports based on testing the selected organisms are of limited importance. Concretely, the investigations of biodiesel show the reduced total emissions of hydrocarbons and the shift in the composition against a decrease of the unregulated hazardous air pollutants/total hydrocarbons mass ratio. This specific case demands synergism of the chemical and biochemical analyses since the first show only a certain part of the total emissions (regulated pollutants) while the second claims can diverge from the toxicity evaluation by the chemical analysis [10].

In addition, the relationship between fuel emission and human health can be generally very complicated, since it includes size and number of particles, concentrations of toxic compounds in fuel exhaust and type of engine [12].

Several results published in the last few years claim that biodiesel and its blends with petrol-diesel have an adverse toxicological impact. It can be expressed through mutagenic and genotoxic pollutants that are often connected with genotypic and phenotypic anomalies and carcinogenicity in the alive organisms [10,12].

Mutagenicity of biodiesel emissions is often conducted by the Ames or *Salmonella*/microsome bioassay. The Ames assay is a test of short-term bacterial reverse mutation that detects many chemicals producing a genetic damage that causes gene mutation. According to this bioassay, the particulate matter extracted from biodiesel and fossil fuels emissions, such as methyl esters of rapeseed and sunflower oil and low sulfur diesel fuel can slightly increase [13,14] or reduce [15] mutagenicity at the tested bacteria.

The ecotoxicological bioassay, implemented on the soil contaminated with diesel and biodiesel, showed that biodiesel was more toxic when it came to seed germination in tested plants (cucumber, kale, cress, arugula and lettuce seeds) [16,17].

A twofold influence of biodiesel on the dehydrogenase activity and the microbial biomass is connected to its concentration. At the concentration of 1%, biodiesel influences positively the dehydrogenases activity (60-300% higher than the control) and enhances the microbial biomass in the soil for 13%; at higher concentrations, biodiesel affect negatively both indicators after a longer time [18]. Also, the detected toxicity in some soil samples increases with increasing the concentration of biodiesel produced in the laboratory or purchased at a petrol station [18,19]. Furthermore, the fractions of biodiesel extracted by methanol and ethanol act as stressors for cells, as indicated by the changes in the production of reactive oxygen species, the glutathione S-transferase activation, and the disturbance in the DNA [20]. However, at any tested concentration, no fish mortality has been noticed so far [21].

Biodiesel exhaust and human health

The difference in pollutant emissions of fuels and biodiesel is obvious. Diesel emissions are “regulated emissions”, composed of pollutants such as particulate matter, carbon monoxide, nitrogen oxides, and hydrocarbons. Some “unregulated emissions” can significantly affect human health, such as sulfur dioxide, aldehydes, poly aromatic hydrocarbons (PAH), the soluble organic fraction of diesel particulate matters, nitrogen suboxide, nitrogen dioxide, metal oxides, and dioxins (Table 1). These substances are marked as potential mutagenic and carcinogenic agents for humans, which can even cause cellular effects [22].

Among the “unregulated emissions” chemical carcinogens, the PAH is a powerful carcinogen for humans. The exposed groups have enhanced risks of various cancers (skin, brain, lung, urinary tract). PAH emission from burning of biodiesel is considerably decreased compared to that from burning of diesel [22].

Also, biodiesel use can increase NO₂ emission, which can form even more carcinogenic nitro-PAH by the nitration of the available PAH. It can cause mutations in bacterial and mammalian cells as well as chromosomal aberrations in the cultured mammalian cells [23]. However, the opposite results about PAH

emissions have been reported for biodiesel employed as a fuel in vehicle engines. According to Bellesteros and coworkers [24], biodiesel reduces PAH emissions and stimulates the formation of the soluble organic fraction of diesel particulate matters [25].

Table 1. Air pollutants and their impact on human health [22]

Air polutants	Damage to human healths
CO	Decrease oxygen distribution through body; higher concentrations can lead to death.
NO_x	NO ₂ -provides formation of O ₃ ; induce inflammation in people; increases asthma symptoms.
SO_x	Related with bronchoconstriction in people; rises asthma symptoms.
O₃	Makes difficult to breath normally causing coughing and sore or scratchy throat, provokes asthma attacks, emphysema, and chronic bronchitis.
PM	Influence lungs and heart, induce death in people with heart or lung diseases, arrhythmia, and asthma.

On the other hand, it has been reported that particles produced by the burning of biodiesel can be harmful due to their large concentration and surface area [26,27]. Therefore, the type of fuel and the technology level of the used engine are equally important with respect to human health. With using biodiesel blends of different origin, both increases and decreases of PAH, nitro-PAH, and oxygenated PAH compounds are observed [28,29].

In comparison to fossil fuel, the well-to-wheel CO₂ use of biodiesel is about 50-80% [30]. Biodiesel can also reduce carbon monoxide, hydrocarbons, and particulate matter emissions because of higher cetane number, oxygen content, and the absence of sulfur and aromatic hydrocarbons [31,32]. Although rapeseed and soybean biodiesels produce more nitrogen oxides, they produce a lower emission than mineral diesel [30] and are harmless for human health.

The levels of carbonyl compounds, well-known carcinogens, can be an effective measure of local air pollution. Some studies showed an increase in formaldehyde and acrolein [33] in biodiesel emissions, which can induce pulmonary edema, respiratory disturbance, and asthma-like symptoms [34]. According to the Workshop held in Washington DC in 2014, the answer to the question if the exhaust from biodiesel-powered vehicles activates asthma to the same level as the exhaust from gasoline- and diesel-powered vehicles is yet unknown [35].

However, a significant reduction of the concentration of transition metals in biodiesel emission is noticed, compared to petroleum fuel combustion exhaust [36], which is very important since these metals can generate radicals harmful for human health.

CONCLUSION

Environmental and social problems have appeared because of the growing production and use of biodiesel. Although some investigations indicate a hazard potential of biodiesel, most of them are not comparable since different sources of biodiesel, selected organisms, various engine types, and extraction procedures have been applied. In general, a lower mutagenicity is detected for the exhaust produced from biodiesel than from petro-diesel. Also, cytotoxicity, the inflammatory potential, histopathological observations, biochemical effects, and the toxicity vary widely among the published studies.

Because of their toxic potential, the adverse influence of biodiesel and its exhaust on the human health and environment should not be ruled out. The emissions of regulated and non-regulated compounds from biodiesel burning are generally lower than or equal to those from fossil diesel, with the exception of nitrogen oxides emission. The amount of emission depends considerably on the type and configuration of the engine, the load condition, and the use of a catalyst. Modification of the standard engines is probably required for biodiesel use in order to reduce the emission of unwanted compounds, which is not accounted for or not mentioned in most investigations.

The results related to environmental and health impacts of the biodiesel use are rarely available and still difficult for understanding. The adverse impacts of both biodiesel and its emissions have been reported, but the available data are not enough for the concrete definition of human health risks.

Therefore, synergism between almost all scientific fields and additional experimental studies are imperative for the production and application of biodiesel with minimum environmental and human health risks.

REFERENCES

- [1] R.P.L. Camargo, A.J.I. Carim, N.R. Antoniosi Filho: "Study ecotoxicity of biodiesel from residual oils and fats and the effects of salinity aquatic ecosystems", *Ecotoxicology and Environmental Contamination*, Vol. 12, 2017, pp. 63-67.
- [2] S. B. Živković, M. V. Veljković, I.B. Banković-Ilić, I.M. Krstić, S. S. Konstantinović, S. B. Ilić, J. M. Avramović, O. S. Stamenković, V. B. Veljković: "Technological, technical, economic, environmental, social, human health risk, toxicological and policy considerations of biodiesel production and use", *Renewable and Sustainable Energy Reviews*, Vol. 79, 2017, pp. 222-247.
- [3] J. Milano, H.C. Ong, H.H. Masjuki, W.T. Chong, M.K. Lam, P. K. Loh, V. Vellayan: "Microalgae biofuels as an alternative to fossil fuel for power generation". *Renewable and Sustainable Energy Reviews*, Vol. 58, 2016, pp.180-197.
- [4] C.S. Jones, S. Mayfield: "Algae biofuels: versatility for the future of bioenergy", *Current Opinion in Biotechnology*, Vol.23, 2013, pp. 346-351.
- [5] G. Markou, E. Nerantzis: "Microalgae for high-value compounds and biofuels production: a review with focus on cultivation under stress conditions", *Biotechnology Advance*, Vol. 31, 2013, pp.1532-1542.
- [6] Commission of the European Communities, *Renewable Energy Road Map. Renewable Energies in the 21st Century: Building a More Sustainable Future*, COM (2006) 848, Brussels, 2007.
- [7] US-Government, *Energy Independence and Security Act of 2007*, Public Law 110-140, 2007.
- [8] *Statistical World Review of World Energy*, 67th Edition, June 2018, pp.45.
- [9] "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), 2016.
- [10] K. Bluhm, S. Heger, T.B. Seiler, A.V. Hallare, A. Schaffer, H. Hollert: "Toxicological and ecotoxicological potencies of biofuels used for the transport sector-a literature review", *Energy and Environmental Science*, Vol. 5, 2012, pp. 7381-7392.
- [11] R. Luque, J.A. Melero: "Advances in biodiesel production: processes and technologies, Woodhead Publishing Series in Energy: Number 39", Woodhead Publishing Limited, 2012, e-book.
- [12] A.N. Larcombe, A. Kicic, B.J. Mullins, G. Knothe: "Biodiesel exhaust: The need for a systematic approach to health effects research", *Asian Pacific Journal of Respiratory*, Vol. 20, 2015, pp.1034-1045.
- [13] J. Krahel, G. Knothe, A. Munack, Y. Ruschel, O. Schröder, E. Hallier, G. Westphal, J. Bünger: "Comparison of exhaust emissions and their mutagenicity from the combustion of biodiesel, vegetable oil, gas-to-liquid and petrodiesel fuels", *Fuel*, Vol. 88, 2009, pp.1064-1069.
- [14] M.L. Gagnon, P.A. White: "The mutagenicity and dioxin-like activity of biodiesel emissions", 39th Annual Meeting, Rio Grande, Puerto Rico, October 18-22, 2008, P62.
- [15] J. Bünger, J. Krahel, A. Munack, Y. Ruschel, O. Schröder, B. Emmert, G. Westphal, M. Müller, E. Hallier, T. Brüning: "Strong mutagenic effects of diesel engine emissions using vegetable oil as fuel", *Archives of Toxicology*, Vol. 81, 2007, pp. 599-603.

- [16] J.M. Cruz, P.R.M. Lopes, R.N. Montagnolli, I.S. Tamada, N.M.M.G. Silva, E.D. Bidoia: "Toxicity Assessment of Contaminated Soil Using Seeds as Bioindicators", *Journal of Applied Biotechnology*, Vol. 1, 2013, pp. 1-1.
- [17] I.S. Tamada, R.N. Montagnolli, P.R.M. Lopes, E.D. Bidoia: "Toxicological evaluation of vegetable oils and biodiesel in soil during the biodegradation process", *Brazilian Journal of Microbiology*, Vol. 43, 2012, pp. 1576-1581.
- [18] M. Hawrot-Paw, M. Izwikow: "Microbiome of soil contaminated by fuels", *Folia Pomeranae Universitatis Technologiae Stetinensis, Agricultura, Alimentari, Piscaria et Zootechnica*, Vol. 322, 2015, pp. 57-66.
- [19] M. Hawrot-Paw: "Biological activity of soils contaminated by biodiesel and the possibilities for their recultivation". Publisher: West Pomeranian University of Technology, 2011.
- [20] D.G.S.M. Cavalcante, N.D.G. da Silva, J.C. Marcarini, M.S. Mantovani, M. A. Marin-Morales, C.B.R. Martinez: "Cytotoxic, biochemical and genotoxic effects of biodiesel produced by different routes on ZFL cell line", *Toxicology in Vitro*, Vol. 28, 2014, pp. 1117-1125.
- [21] A.A. Felício, T.E.M. Parente, L.R. Maschio, L. Nogueira, L.P.R. Venancio, D. Rebelo, M.F. Schlenk, E.A. Almeida: "Biochemical responses, morphometrics, changes, genotoxic effects and CYP1A expression in the armored catfish *Pterygoplichthys anisitsia* after 15 days of exposure to mineral diesel and biodiesel", *Ecotoxicology and Environmental Safety*, Vol. 115, 2015, pp. 26-32.
- [22] L.L.N. Guarieiro, A.L.N. Guarieiro: "Vehicle emissions: what will change with use of biofuel?" *Biofuels* Zhen Fang, *IntechOpen*, 2013.
- [23] C.L.Song, Y.C. Zhou, R.-J. Huang, Y.Q. Wang, Q.F. Huang, G.Lü, K.M. Liu: "Influence of ethanol-diesel blended fuels on diesel exhaust emissions and mutagenic and genotoxic activities of particulate extracts", *Journal of Hazardous Materials*, Vol. 149, 2007, pp. 355-363.
- [24] R. Bellesteros, J.J. Hernandez, L.L. Lyons: "An experimental study of the influence of biofuel origin on particle-associated PAH emissions", *Atmospheric Environment*, Vol. 44, 2010, pp. 930-938.
- [25] N.C. Surawski, B. Miljevic, G.A. Ayoko, B.A. Roberts, S. Elbagir, K.E. Fairfull Smith, E. S. Bottle, Z.D. Ristovski: "Physicochemical Characterization of Particulate Emissions from a Compression Ignition Engine Employing Two Injection Technologies and Three Fuels", *Environmental Science and Technology*, Vol. 45, 2011, pp. 5498-5505.
- [26] B. Hawley, C. L'Orange, D.B. Olsen, A.J. Marchese, J. Volckens: "Oxidative stress and aromatic hydrocarbon response of human bronchial epithelial cells exposed to Petroor biodiesel exhaust treated with a diesel particulate filter.", *Toxicological Science*, Vol. 141, 2014, pp. 505-514.
- [27] B.J. Mullins, A. Kicic, K.M. Ling, R. Mead-Hunter, A.N. Larcombe: "Biodiesel exhaust-induced cytotoxicity and proinflammatory mediator production in human airway epithelial cells", *Environmental Toxicology*, Vol. 31, 2016, pp. 44-57.
- [28] E. Bakeas, G. Karavalakis, G. Fontaras, S. Stournas: "An experimental study on the impact of biodiesel origin on the regulated and PAH emissions from a Euro 4 light-duty vehicle", *Fuel*, Vol. 90, 2011, pp. 3200-3208.
- [29] G. Karavalakis, E. Bakeas, G. Fontaras, S. Stournas: "Effect of biodiesel origin on regulated and particle-bound PAH (polycyclic aromatic hydrocarbon) emissions from a Euro4 passenger car", *Energy*, Vol. 36, 2011, pp. 5328-5337.
- [30] M. Lapuerta, J. Rodriguez-Fernandez, J.R. Agudelo: "Diesel particulate emissions from used cooking oil biodiesel", *Bioresource Technology*, Vol. 99, 2008, pp. 731-740.
- [31] L.G. Lackey, S.E. Paulson: "Influence of feedstock: air pollution and climate-related emissions from a diesel generator operating on soybean, canola, and yellow grease biodiesel", *Energy and Fuels*, Vol. 26, 2011, pp. 686-700.
- [32] J. Xue, T.E. Grift, A.C. Hansen: "Effect of biodiesel on engine performances and emissions", *Renewable and Sustainable Energy Reviews*, Vol. 15, 2011, pp. 1098-1116.
- [33] L.L.N. Guarieiro, P.A.P. Pereira, E.A. Torres, G.O. da Rocha, J.B. de Andrade: "Carbonyl compounds emitted by a diesel engine filled with diesel and biodiesel-diesel blends: sampling optimization and emissions profile", *Atmospheric Environment*, Vol. 42, 2008, pp. 8211-8218.
- [34] C.A. McQueem: "Comprehensive Toxicology". Second Edition. 2010 Elsevier.
- [35] 10 Government Perspectives on Biofuels and Human Health. "Institute of Medicine. 2014. The Nexus of Biofuels, Climate Change, and Human Health: Workshop Summary. Washington, DC: The National Academies Press.
- [36] M.C. Madden, L. Bhavaraju, U.P. Lodavanti: "Toxicology of biodiesel combustion products. chapter biodiesel-quality, emissions and by-products" Copyright In tech., 2011.

ACKNOWLEDGEMENTS

This work has been funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Serbia (Project III 45001).

BIOGRAPHY of the first author

Sandra Konstantinović was born in Leskovac, Serbia. She finished PhD/MSc/BSc studies at the University of Nis, Faculty of Natural Science and Mathematics. Her main research areas include green synthesis, instrumental analysis, and application of biological active heterocyclic compounds and complexes, the chemical valorization of crude glycerol obtained by biodiesel production, etc. She is currently working as a full professor at the Faculty of Technology in Leskovac, University of Nis.



RIZIK PO LJUDSKO ZDRAVLJE I TOKSIKOLOŠKI UTICAJ PROIZVODNJE I KORIŠĆENJA BIODIZELA

Sandra Konstantinović, Vlada Veljković

Rezime: Biodizel, kao i sva ostala biogoriva, predstavlja jedno od mogućih rešenja problemu rastuće svetske potražnje za energijom. Mogućnost dobijanja iz bioobnovljivih sirovina, smanjena emisija gasova sa efektom staklene bašte, čistije rafinerije, poboljšana ekonomija goriva i ekonomija u celosti, olakšani transport i skladištenje su samo neke od prednosti postignute korišćenjem biodizela. Iako je do sada centralni fokus bio usmeren utvrđivanju prednosti koje ovo alternativno gorivo nosi sa sobom, pitanje uticaja na ljudsko zdravlje i životnu okolinu generalno, se nametnulo samo po sebi. Na žalost, na osnovu trenutno raspoloživih informacija nemoguće je doneti siguran i pouzdan zaključak o potencijalnom uticaju produkcije i korišćenja biodizela na životnu sredinu i ljudsko zdravlje. Stoga, uključivanje biodizela u lanac snabdevanja gorivom mora biti sprovedeno veoma pažljivo, kako bi se potencijalni rizici vezani za tehnologiju, ekonomiju, okolinu i društvo, ako ne potpuno, bar maksimalno redukovali. U ovom radu predstavljen je potencijalni toksikološki uticaj i eventualni rizici po ljudsko zdravlje produkcije i korišćenja biodizela.

Ključne reči: biodizel, toksikološki uticaj, ljudsko zdravlje, životna sredina.

JOVICA JOVANOVIĆ¹

¹University of Niš,
Faculty of Medicine,
Institute of Occupational Health

¹jovica.jovanovic@eunet.rs

SOCIAL - HUMANISTIC AND MEDICAL ASPECTS OF OCCUPATIONAL SAFETY

Abstract: *The number of occupational injuries and diseases are increasing in developing and industrialized countries. Occupational health and safety encompasses the social, mental and physical well-being of workers in all occupations. Effective workplace health and safety programmes can help to save the lives of workers by reducing occupational hazards and their consequences. Effective programmes can also have positive effects on both worker morale and productivity, and can save employers a great deal of money. The most effective accident and disease prevention begins when work processes are still in the design stage, which is the moment when safe conditions can be built into the work process.*

Key words: occupational health, occupational safety, psychosocial hazards, occupational stress.

INTRODUCTION

The prevention of injuries, illness, and unexpected death for workers is the basic definition of occupational safety. The discipline of safety is the systematic application of principles drawn from engineering, physics, education, psychology, health and hygiene, enforcement, and management to prevent harm to people, property, and the environment. Over the past decades many new issues have come to the fore, reflecting changes in the world of work, fragmentation, economic difficulties, demographic shifts, new technologies and, more generally, the impact of globalization. The workforce itself is also diversifying, with an increasing participation of women, migrants and older workers [1]. On April 28 The International Labour Organisation celebrates "World Day for Safety and Health" to raise awareness of safety in the workplace. Occurring annually since 2003, each year it focuses on a specific area and bases a campaign around the theme.

Occupational medicine is the branch of medicine which is concerned with the maintenance of health in the workplace, including prevention and treatment of diseases and injuries, with secondary objectives of maintaining and increasing productivity and social adjustment in the workplace. Occupational medicine aims to prevent diseases and promote wellness among workers. Occupational health physicians must have knowledge of potential hazards in the workplace including toxic properties of materials used, be able to evaluate employee fitness for work, be able to diagnose and treat occupational disease and injury, know about rehabilitation methods, health education, and government laws and regulations concerning workplace health, be able to manage health service delivery. Occupational health should aim to promote and maintain the highest degree of physical, mental and social well-being of workers in all occupations; to prevent amongst workers the departure from health caused by their working conditions; to protect workers

in their employment from risk resulting from factors adverse to health; to place and maintain workers in an occupational environment adapted to their physiological and psychological capabilities; in summary, to adapt work to the workers and each worker to his or her job.

CONTROL OF OCCUPATIONAL HAZARDS

Although work provides many economic and other benefits, a wide array of workplace hazards also present risks to the health and safety of people at work. These include but are not limited to, chemicals, biological agents, physical factors, adverse ergonomic conditions, allergens, a complex network of safety risks," and a broad range of psychosocial risk factors.

Psychosocial hazards include risks to the mental and emotional well-being of workers, such as feelings of job insecurity, long work hours, and poor work-life balance. Linked to psychosocial risks are issues such as occupational stress and workplace violence which are recognized internationally as major challenges to occupational health and safety. Occupational stress, anxiety, and depression can be directly correlated to psychosocial hazards in the workplace. Supported by strong evidence, a link has been indicated between the psychosocial work environment and consequences on employees' physical health. Increasing evidence indicates that four main physiological systems are effected: hypertension and heart disease, wound-healing, musculoskeletal disorders, gastro-intestinal disorders, and impaired immuno-competence. Additional disorders generally recognized as stress-induced include: bronchitis, coronary heart disease, mental illness, thyroid disorders, skin diseases, certain types of rheumatoid arthritis, obesity, tuberculosis, headaches and migraine, peptic ulcers and ulcerative colitis, and diabetes. Exposure to workplace psychosocial hazards has been strongly correlated with a wide spectrum of unhealthy behaviors such as physical inactivity, excessive alcohol and drug

consumption, nutritional imbalance and sleep disturbances.

Specific occupational hazard

Specific occupational safety and health risk factors vary depending on the specific sector and industry. Construction **workers** might be particularly at risk of falls, for instance, whereas fishermen might be particularly at risk of drowning. Similarly psychosocial risks such as workplace violence are more pronounced for certain occupational groups such as health care employees, police, correctional officers and teachers. **Agriculture workers** are often at risk of work-related injuries, lung disease, noise-induced hearing loss, skin disease, as well as certain cancers related to chemical use or prolonged sun exposure. Pesticides and other chemicals used in farming can also be hazardous to worker health, and workers exposed to pesticides may experience illnesses or birth defects. Agriculture is a common source of occupational injuries and illnesses among younger workers[2]. As the number of service sector **jobs** has risen in developed countries, more and more jobs have become sedentary, presenting a different array of health problems than those associated with manufacturing and the primary sector. Contemporary problems such as the growing rate of obesity and issues relating to occupational stress, workplace bullying, and overwork in many countries have further complicated the interaction between work and health. **Mining and oil and gas extraction industries** had high prevalence rates of exposure to potentially harmful work organization characteristics and hazardous chemicals. **Healthcare workers** are exposed to many hazards that can adversely affect their health and well-being. Long hours, changing shifts, physically demanding tasks, violence, and exposures to infectious diseases and harmful chemicals are examples of hazards that put these workers at risk for illness and injury.

Psychosocial hazards

There are psychosocial factors that have been identified in many studies and these include lack of variety or short work cycles, fragmented or meaningless work, under-use of skills, high uncertainty, continuous exposure to difficult clients, patients, pupils, work overload or too little work, machine pacing, high levels of time pressure, continually subject to deadlines, shift work, night shifts, inflexible work schedules, unpredictable hours, long or unsociable hours, low participation in decision-making, lack of control over workload, pacing, shift working, inadequate equipment availability, suitability or maintenance, poor environmental conditions such as lack of space, poor lighting, excessive noise, poor communication, low levels of support for problem solving and personal development, poor managerial support, lack of definition, organisational objectives, social or physical isolation, poor relationships with superiors, interpersonal conflict, lack of social support,

harassment, bullying, poor leadership style, violence, role ambiguity, role conflict, and responsibility for people, career stagnation and uncertainty, under-promotion or over-promotion, poor pay, job insecurity, low social value of work, conflicting demands of work and home, low support at home, problems relating to both partners being in the labour force (dual career). Shift work includes both long-term night shifts and work schedules in which employees change or rotate shifts. In medicine and epidemiology, night and shift work is considered a risk factor for some health problems in some individuals, as disruption to circadian rhythms may increase the probability of developing cardiovascular disease, cognitive impairment, diabetes, and obesity, among other conditions[3]. Shift work sleep disorder is a circadian rhythm sleep disorder characterized by insomnia, excessive sleepiness, or both. The risk of diabetes mellitus type 2 is increased in shift workers, especially men. People working rotating shifts are more vulnerable than others and have a increased risk of developing breast cancer, headaches, heart attacks, fatigue, stress, sexual dysfunction, depression, dementia, obesity, metabolic disorders, gastrointestinal disorders, musculoskeletal disorders, and reproductive disorders.

Stressful working conditions can lead to three types of strains: Behavioral (e.g., absenteeism or poor performance), physical (e.g., headaches or coronary heart disease), and psychological (e.g., anxiety or depressed mood)[4]. Physical symptoms that may occur because of occupational stress include fatigue, headache, upset stomach, muscular aches and pains, weight gain or loss, chronic mild illness, and sleep disturbances, anxiety, irritability, alcohol and drug use, feeling powerless and low morale. There is some evidence that stress plays a role in the development of several types of chronic health problems including cardiovascular disease, musculoskeletal disorders, and psychological disorders[5]. Other disorders that can be caused or exacerbated by occupational stress reaction include sleep disorders, headache, mood disorders, upset stomach, hypertension, high cholesterol, autoimmune disease, cardiovascular disease, depression, and anxiety. Stress at work can also increase the risk of acquiring an infection and the risk of accidents at work.

Mobbing, as a sociological term, means bullying of an individual by a group, in any context, such as a family, peer group, school, workplace, neighborhood, community, or online. When it occurs as emotional abuse in the workplace, such as "ganging up" by co-workers, subordinates or superiors, to force someone out of the workplace through rumor, innuendo, intimidation, humiliation, discrediting, and isolation, it is also referred to as malicious, nonsexual, nonracial, racial, general harassment. Victims of workplace mobbing frequently suffer from: adjustment disorders, somatic symptoms, psychological trauma, post-traumatic stress disorder, and major depression. Some patients may develop alcoholism or other substance

abuse disorders. Family relationships routinely suffer. Workplace targets and witnesses may even develop brief psychotic episodes occupational psychosis generally with paranoid symptoms.. Sociologists have created checklists and other tools to identify mobbing behavior [6].

SOCIAL ASPECTS OF OCCUPATIONAL SAFETY

There are a lot of social issues impacting workplace such as those who are dealing with alcohol/drug related problems can pose security threats to any workplace and in many cases, the business itself. If someone is exposed to domestic violence at home, can lead to depression and in worse case scenarios, violence in the workplace. An employee with a mental disorder can become a liability if a support system and a culture of acceptance is not fostered. When you have ageing people in your workforce, you have to consider various aspects including their safety and health, leaves, suitable work procedures, and more. Solving of these problems represents a significant measure of occupational safety.

Occupational health and safety of young workers

The Most temporary workers in EU were under 25 years. Young temporary workers have lower job demands and are less informed about risks at work. The 6% of them said that they had never been informed on dangers at work. These answers show that the state of knowledge of safety at work is not perfect and actions should be taken aiming at improving awareness of that field, not only, but especially among young people who start their professional career. Social media could be important for raising awareness, on hazards in the workplace and prevention in this area. The benefit resulting from the use of social media is easy access to information for a wide audience without creating additional costs. Apart from that, the form of the message is more attractive than the traditional one for younger generations who use social media in their everyday life.

Occupational health and safety of old workers

Workers approaching and past traditional retirement age (60-65 years) are now the fastest growing age group within the population. Research suggests that the brains of older adults may function differently from younger adults but not necessarily with reduced functioning. However, there remains some concern that increased work-related illness and accidents may occur in those working after age 60. Topics raised in association with workplace accidents include mobility, strength, dexterity and balance, sensory losses including hearing and vision, cognitive changes with slower information processing and delayed reaction times. These changes may increase the risk and severity of accidents. Research for those over age 60 reported higher rates of accident and injury, others presented lower rates when compared with younger workers. In

some, compensatory strategies linked with greater job experience or expertise, appeared as protective (e.g. maintaining driving safety). Job experience may therefore confound work injuries and fatalities that appear to be associated with age. On the other hand, job experience may be acting as a covariate with age.

Occupational health and safety of women

Much of women's work remains unrecognised, uncounted and unpaid: work in the home, in agriculture, food production and the marketing of home-made products, for example. Within the paid labour force, women are disproportionately concentrated in the informal sector, beyond the scope of industrial regulations, trade unions, insurance or even data collection. Women may undertake paid work at home, or combine part or full time paid work with household work and the care of children, the sick and the elderly. They are likely to move in and out of the paid labour force during different life stages; within the paid labour force they may have a variety of different occupations in succession. Research into women's and men's occupational health also requires a recognition of the extent of intra-sex variations and careful controls for biological and social characteristics which may affect health outcomes. Poor nutrition, for example, may be a more important factor in some types of occupational health impairment than simply being female.

The effects of potential occupational hazards on women's reproductive health have been, probably, the major focus of concern in the health of women workers. This concern has increased in recent years as more environmental hazards are identified and as more women enter the paid workforce. A range of occupational reproductive hazards has been documented but a large number of possible risks still require further examination.

Occupational health and safety of migrant workers

Many people were transnational migrants, approximately half of whom were workers, often engaged in jobs that are hazardous to their health. They work for less pay, for longer hours, and in worse conditions than do nonmigrants and are often subject to human rights violations, abuse, human trafficking, and violence. Worldwide, immigrant workers have higher rates of adverse occupational exposures and working conditions, which lead to poor health outcomes, workplace injuries, and occupational fatalities. Health disparities of immigrant workers are related to environmental and occupational exposures and are a result of language/cultural barriers, access to health care, documentation status, and the political climate of the host country. Recommendations on global and local scales are offered as potential solutions to improving the health of immigrant workers [7].

IMPORTANCE OF SOME PROTECTIVE MEASURES AT WORK

Importance of training

Workers often experience work-related health problems and do not realize that the problems are related to their work, particularly when an occupational disease, for example, is in the early stages. Besides the other more obvious benefits of training, such as skills development, hazard recognition, a comprehensive training programme in each workplace will help workers to recognize early signs/symptoms of any potential occupational diseases before they become permanent conditions; assess their work environment and insist that management make changes before hazardous conditions can develop.

Importance of Workplace health promotion

Health Promotion is defined as the process of enabling people to increase control over, and to improve, their health. For the successful development of workplace health promotion management, it is important to recognize the central role of the empowerment of employees, in terms of competency, level of autonomy, and sense of coherence, to ensure an appropriate balance between the processes of effectiveness increasing and the capacities of the workforce, to include a comprehensive understanding of health in company policies and in all procedures involved in a continuous improvement process, to identify factors contributing to development of health, to facilitate and strengthen impact of such factors conducive to health of all staff, to ensure the establishment of an enterprise-wide participatory infrastructure, and to enable all levels of employees to share their interests and expertise with the key players. An essential quality of health promotion is the direct involvement of people in maintaining or improving their own health.

Importance of Social Support at Work

Humans are social beings, and for many people it is true that they spend more time at work with their co-workers than with their spouse or family. A growing body of research has observed that social support is an important factor affecting health and well-being. Researchers agree that giving and receiving social support is an interactive process and must be regarded under the concept of reciprocity, which refers to giving support which is positively associated with receiving it. Typically viewed types of social support include, instrumental or practical support (e. g., practical help, assistance, or financial support), emotional support (e. g. comfort, sympathy, encouragement), and informational support (e. g. providing information which may help the respondent in problem solving, giving someone advice). In the working context, typical sources of social support are co-workers, supervisors, and the organisation in general. In the literature, these sources of social support are often termed as 'perceived co-worker support', 'perceived supervisor support' and

'perceived organisational support'. Support from non-work sources is usually provided informally by spouse or life partner, other family members, friends, neighbours, or formally by professionals outside the workplace (pastor, doctor, therapist).

CONCLUSION

Occupational health and safety encompasses the social, mental and physical well-being of workers, that is the "whole person". Successful occupational health and safety practice requires the collaboration and participation of both employers and workers in health and safety programmes, and involves the consideration of issues relating to occupational medicine, industrial hygiene, toxicology, education, engineering safety, ergonomics, psychology, etc.

REFERENCES

- [1] Caffaro F, Micheletti Cremasco M, Bagagiolo G, Vigoroso L, Cavallo. Effectiveness of occupational safety and health training for migrant farmworkers: a scoping review. *Public Health*. 2018; 160:10-17.
- [2] Kumaraveloo, K Sakthiaseelan; Lunner Kolstrup, Christina. Agriculture and musculoskeletal disorders in low- and middle-income countries". *Journal of Agromedicine*. 2018 ;23 (3): 227–248
- [3] Yuan X, Zhu C, Wang M, Mo F, Du W, Ma X. Night Shift Work Increases the Risks of Multiple Primary Cancers in Women: A Systematic Review and Meta-analysis of 61 Articles. *Cancer Epidemiol Biomarkers Prev*. 2018; 27(1):25-40
- [4] Burns, Richard A.; Butterworth, Peter; Anstey, Kaarin J. An examination of the long-term impact of job strain on mental health and wellbeing over a 12-year period. *Social Psychiatry and Psychiatric Epidemiology*. 2016; 51 (5): 725–733.
- [5] Kivimäki M, Steptoe A. Effects of stress on the development and progression of cardiovascular disease. *Nat Rev Cardiol*. 2018; 15(4):215-229.
- [6] Daniela AM, Silvia B, Antonella V. Mobbing (bullying at work) in Italy: characteristics of successful court cases. *J Inj Violence Res*. 2018; 10(1): 17–24
- [7] Moyce SC, Schenker M. Migrant Workers and Their Occupational Health and Safety. *Annu Rev Public Health*. 2018, 1;39:351-365.

ACKNOWLEDGEMENTS

This paper is part of the internal Project of the Faculty of Medicine in Niš under the title "Important Characteristics of the Personality and Nutrition of Workers in the Professional Stress Reaction".

BIOGRAPHY of the first author

Jovica Jovanović was born in 1957, in Niš, Serbia. He is currently working as full professor of Occupational Medicine at Medical Faculty and as Medical Director of the Institute of Occupational Health Medicine of Niš. He is the Member of the Serbian Expert Commission for Occupational Medicine, the Professional Supervisor in the field of Occupational Medicine in Serbia, the Member of the Scientific committee of a number Journals in the field of Occupational Medicine and Reviewer for the accreditation of higher education institutions in Serbia.



SOCIJALNO-HUMANISTIČKI I MEDICINSKI ASPEKTI ZAŠTITE NA RADU

Jovica Jovanović

Rezime: *Broj povreda na radu i profesionalnih bolesti raste kako u zemljama u razvoju tako i u visoko industrijalizovanim zemljama. Službe bezbednosti i zdravlja na radu pomažu u očuvanju socijalnog, mentalnog i fizičkog blagostanja radnika svih zanimanja. Efikasni programi bezbednosti i zdravlja na radu imaju pozitivne efekte na redukciju profesionalnih rizika i smanjenje njihovih posledica na zdravlje radnika. Oni takođe dovode i do značajnih finansijskih ušteda. Efikasna prevencija povreda i profesionalnih bolesti treba biti primenjena još u fazi projektovanja kada i daje najbolje rezultate.*

Ključne reči: zdravlje na radu, bezbednost, psihosocijalni rizici, profesionalni stres.

VESNA NIKOLIĆ¹
ALEKSANDRA
ILIĆ PETKOVIĆ²
MIRJANA GALJAK³
TAMARA VUKIĆ⁴

HIGHER EDUCATION IN THE FIELD OF OCCUPATIONAL SAFETY AND HEALTH IN NATIONAL AND INTERNATIONAL CONTEXT

¹ University of Niš,
Faculty of Occupational Safety

² University of Niš,
Faculty of Occupational Safety

³ Technical College of Applied
Sciences Leposavić, Serbia

⁴ University of Niš,
Faculty of Philosophy,
Department for Pedagogy

¹vesna.nikolic@znrfak.ni.ac.rs

²aleksandra.ilic@znrfak.ni.ac.rs

³marta7@ptt.rs

⁴tamaravukic93@gmail.com

Abstract: *Bearing in mind the crucial role of higher education in improving the system of occupational safety and health and in the development of occupational safety and health as a profession, there is an unacceptably low number of scientific articles in this field. Without discussing the reasons why this research question has not been deeply studied, we tried to present the current situation based on available resources, as well as the trends in the development of higher education in this field. In order to understand the current situation and determine the directions of development we need to reflect on the past. With reference to this, the first part of the paper provides a short historical overview of the development of higher education in the field of occupational safety and health while the second part elaborates on the existing situation on the basis of available sources in national and international context, which is a starting point for analysing the trends in the development of higher education in the light of legal and strategic documents in the future.*

Key words: higher education, occupational safety.

INTRODUCTION

Nowadays, occupational safety and health represents a complex scientific and professional field which deals with the analysis of work processes and conditions, their impact on the health of workers/their psychological and physical well-being, risk identification and possibility of their management, providing measures and solutions [1] for their minimisation and it also evaluates the effectiveness of protection. Experts in this field differ in terms of their educational qualification [2] and the tasks they perform (medical doctors, engineers, chemists, etc.). However, the difference among the professionals of occupational safety and health is most commonly made between occupational safety engineers and risk managers, that is, occupational safety managers. An occupational safety manager is in charge of giving advice, support and directions in terms of occupational policy to the managers and other employees in an organisation, while an occupational safety engineer is oriented towards technical aspects of protection. In some countries, the scope of duties and tasks performed by occupational safety professionals are defined by law and required education for each profile [3]. Apart from defining the tasks and roles of experts [4], [5] in the field of occupational safety and health, it is necessary to pay special attention to the issues of their professional/higher education in this field.

The paper analyses higher education in the field of occupational safety through the prism of the past, present and future. Any valid scientific analyses shall establish dialectical unity among them. The future, as a dimension of higher education, shall be observed

within the development of work, science and technology, social relations, globalisation, social and work changes, as well as a number of challenges to safety and factors of changeable work environment. The care for the future is not exhausted only in its prediction; what follows are concrete actions aimed at realising the concept of a safe and sustainable future. Higher education institutions are not always ready to accept changes. Novelty in this area includes the development of new or modernisation of existing study programs. Novelty should not be understood as a matter of time, but be accepted as a way of “life” and work of contemporary higher education institutions. New views on higher education pose a challenge to both science and occupational safety and health practices. Shaping the future depends on how these challenges are accepted. If the future is viewed from aspect of the changes brought about by the integration of man and technology (industry 4.0 and industry 5.0), the goals and outcomes of higher education in the field of occupational safety shall include the development of human resources/occupational safety professionals for the changing world, change management, innovation and pro-activity in the occupational safety and health system. This will only be possible if higher education is perceived as an active orientation and deliberate step into the future.

SHORT HISTORICAL OVERVIEW

Historically, occupational safety courses are mentioned in literature dating from the 19th century. In France, Germany and the Netherlands¹, safety museums have been first established with the aim of expanding the idea of safety and then implementing specific educational programs [6]. In the Netherlands, the Government initiated the introduction of a safety education program, while the Safety Museum organised and implemented programs for employers, employees and civil servants from the Labour Inspectorate². Until the Second World War, workplace safety and health were hardly found in university education, mainly in medical faculties, at the postgraduate level for doctors who specialised in dermatology or respiratory medicine, while technical schools incorporated only those aspects of safety related to the maintenance and safety of machines³. The Second World War led to the development of the military industry, but also a large number of work-related injuries and industrial accidents occurred, which prompted the need to educate experts on workplace safety and health issues⁴.

At that time, education, that is, training of experts, did not take place in higher education institutions [7], but it soon became evident that due to rapid technical, technological, social, economic, legal, cultural and other changes, experts in the field of occupational safety required academic knowledge and titles [8].

Throughout the second half of the 20th century, the development of higher education in the field of occupational safety took place in Europe and the United States. In the Netherlands, the first higher level occupational safety course was held in 1968, while in 1989 a postgraduate study program on safety, health and environment were created (MoSHE) on Delft University of Technology [7]. In addition to bachelor studies, the US government encouraged postgraduate studies in the field of occupational safety at several faculties in different states.

The Wuppertal University in 1974 was the first with pre- and post-bachelor program, followed by similar programs in Finland, and at Aston University in Birmingham in 1978. The course in Industrial Safety at the Imperial College London started a few years later, comparable to initiatives at the University of Leuven, at Stockholm and the safety officer course at the Federation Ballarat University in Australia in 1980 [7], [9].

The 1978 symposium *“University Education and Research in Safety”*, organized at TH Delft was exerting pressure to development academic education

in this field. The Symposium concluded with the statement that a separate and comprehensive course on safety at university level was necessary. “University level, because other experts in working conditions, like the occupational physician, and the occupational hygienist were academically trained. And comprehensive, because safety experts should cooperated with many disciplines, as he or she should be able discuss from a safety point of view arguments with other disciplines” [10].

In Central and Southern Europe, the process of accelerated transformation from agricultural to industrial production and urban way of life caused serious problems in work and living environment. In the Republic of Serbia and former SFRY, a large number of injuries, professional diseases and disabilities of workers, as well material loss and other damages, initiated the adoption of legal regulations on the basis of which many expert and scientific institutions were established with the aim of solving the emergent problems (institutes, colleges and faculties)⁵.

Bearing in mind the crucial role of higher education in improving the occupational health and safety system and the development of occupational safety as a professional field in general, there is an unacceptably low number of surveys and papers on this topic. Some authors [11] believe that education is not a very “popular” topic in the occupational safety and health system, which is the main reason why this research field is insufficiently examined. The resistance of universities against educating safety related topics was not only related to overcrowded programs, but also with the low quality of the academic safety research. Safety research was too descriptive and hardly analytical [12]. This changed in the 1980s, a time with a series of catastrophic major accidents in high-tech-high-hazard sectors.

The 90s of the last century showed a steady production of scientific papers on (post)academic safety education. Literature overview indicates that the majority of papers in this field deal with the problems of training workers for occupational safety [13], [14]. When it comes to higher education, the research is primarily based on the discussion regarding the introduction of occupational safety into the curriculum [15], [16], [17],

⁵ The initiative was introduced by the experts from the Institute of Occupational Safety in Niš, at the beginning of the second half of the 20th century. With years of experience in solving problems in industry, traffic and else, these experts recognised the need for educating professionals in the field of occupational safety. This idea was realised in 1965 by forming the Department for Occupational Safety at the Higher Technical School in Niš. Several years later, the competent authorities of the Community initiated the idea for establishing a separate higher education institution for educating professionals in the field of occupational safety. The idea was supported by the Technical Faculty at the University of Niš. The joint request of these institutions was considered by the National Assembly of Serbia. In June 1968, they reached the decision for establishing the Occupational Safety Department at the Technical Faculty in Niš. In 1972/73 this Department is transformed into an independent higher education institution – the Faculty of Occupational Safety.

¹ In the Netherlands, the Safety Museum was established in 1893.

² The first such course was organised in 1951.

³ ILO Encyclopedia, Geneva, 4th edition, Vol.1, chapter 18.

⁴ After the Second World War, such problems were especially present in those countries that gained independence as colonies of European countries and began to accelerate industrialization.

[18], [19], [20] or integration of safety into engineering education [21]. There are some papers dealing with the content analysis of occupational safety study programs on bachelor and postgraduate studies [4], [7], [22], [23], [24].

The analysis of relevant literature points to the plurality of programs, contents, names and, generally, the approach to higher education in the field of occupational safety. The reasons for this lie in national characteristics [11] and different legal regulations, higher education institutions and creators of study programs, that is, different cultural approach to the issue of occupational safety and health [4].

METHODOLOGY

The subject matter of this research is higher education in the field of occupational safety in national and international settings with the aim of analysing current conditions and creating strategic guidelines for its development in the future. The starting point of the research has been a general assumption that there are different approaches to higher education in occupational safety. Apart from the content analysis of study programs, the authors analysed the outcomes and competences of graduate students. Then, the competences in the light of existing legal regulations and strategic documents in the field of occupational safety and health were defined.

The contemporary trends and changes brought about by the Bologna Declaration point to an altered paradigm of learning. The subject position is assigned to the student, which changes the focus from teaching to the competences that students need to acquire after completing the study program. Therefore, the teaching process is relocated from the teacher to students, their needs, quality knowledge and skills they acquire. This approach is often called *an outcome-based approach*. Expressions such as *planned learning outcomes*, or *learning outcomes*, are used to show what is expected from students to know and be able to do at the end of the learning process.

Due to the subject of the research, the authors used the descriptive research method in which they utilised varied data collection techniques. Data collection was conducted through the internet/desktop survey, followed by interviews with available informants at engineering faculties. The interviews were carried out through face-to-face or telephone conversations. When processing the data and interpreting the results, the authors used comparative analysis of the results obtained by interviewed experts with official documents, study programs and other published and available sources.

RESULTS AND DISCUSSION

Higher education in the field of occupational safety in international context

We analysed the following European study programs: European University Cyprus⁶; Turin University⁷, Italy; Valencia University – Faculty of Social Sciences, Spain⁸; Keele University, Great Britain⁹; Technical University of Ostrava, Faculty of Safety Engineering – the Czech Republic¹⁰; Delft University in the Netherlands (DUT), but also the study programs offered by the Institute for Safety and Health¹¹, St. Petersburg, Russia; Institute for Occupational Safety and Health, Moscow¹², Russia, and Department for the Protection of Work and Living Environment, Kyiv¹³, Ukraine.

Apart from European, we also analysed the study programs of Johns Hopkins University¹⁴, Baltimore, Maryland, USA; Illinois University¹⁵, Chicago, USA; University of Central Missouri¹⁶, USA; Grand Valley State University¹⁷, Michigan, USA.

The analysis has shown that the largest number of faculties has master degree programs in occupational safety, while there are fewer faculties with the programs in this field on all three levels of education. Apart from specific objectives related to the issue of occupational safety and health and professional risk management, faculties promote safety culture and research and the development of occupational safety policy and strategy (Cyprus, Turin). Great attention is paid to the partnership with the International Training Centre (ITC) and International Labour Organisation (Turin). It is interesting to note that the Faculty of Social Sciences of Valencia University implements an accredited master study program in the field of occupational safety, which provides an opportunity to acquire wide interdisciplinary and multidisciplinary knowledge in this field. Keele University¹⁸ in Great Britain provides a PhD course in occupational safety, which shows a great dedication to the improvement of the occupational safety policy and strategy, and they

⁶http://www.euc.ac.cy/easyconsole.cfm/id/173/dep/162/program_id/109 (accessed on 10.09.2018)

⁷<http://www.mastersportal.eu/universities/1665/turin-school-of-development.html> (accessed on 01.09.2018)

⁸<http://www.uv.es/uvweb/college/en/university-valencia-1285845048380> (accessed on 02.09.2018)

⁹<http://www.abrostudy.com/sr/universities/united-kingdom/keele-university/> (accessed on 10.09.2018)

¹⁰<http://www.vsb.cz/en/about-us/http://www.studyin.cz/universities/> (accessed on 11.09.2018)

¹¹<http://niot.ru/default.htm> (accessed on 12.09.2018)

¹²<http://ohsi.ru/> (accessed on 14.09.2018)

¹³<http://sites.kpi.kharkov.ua/safetyofliving/Htm/internationalactivities.htm> (accessed on 15.09.2018)

¹⁴<http://www.jhu.edu/> (accessed on 18.09.2018)

¹⁵<http://www.uic.edu/uic/> (accessed on 11.09.2018)

¹⁶<http://www.ucmo.edu/undergrad/> (accessed on 10.09.2018)

¹⁷http://education-portal.com/directory/school/Grand_Valley_State_University.html (accessed on 10.09.2018)

¹⁸<http://www.abrostudy.com/sr/universities/united-kingdom/keele-university/> (accessed on 10.09.2018)

are also competent in fire protection, radiation protection, protection from biological hazard, hazardous waste etc. In the Czech Republic, at the Faculty of Safety Engineering within the Technical University of Ostrava, there are study programs on all three levels of study¹⁹. Those are: Workplace Safety, Emergency Response Management, Human and Property Protection Engineering, Fire Protection Engineering, with the content and objectives that involve developed competencies in these areas. In the Netherlands, at Delft University of Technology (DUT), a master program "Health, Safety and Environmental Management: Risk Assessment and Control" was introduced in 1989 [4]. The focus of the program is the management and policy where the problems of safety, health and well-being are observed together with other aspects of quality. In light of technological advances in solving technical problems of safety, health and the environment, the role of human factors in improving safety performance is particularly elaborated, therefore, the study program of this university favours managerial education in the field of occupational safety and health.

Kyiv University²⁰, at the Department for the Protection of Work and Living Environment, develops the programs of occupational safety and health which advance the competences in safety management, while the Institute for Safety and Health, St. Petersburg, and the Institute for Occupational Safety and Health, Moscow²¹ develop multidisciplinary training programs in the field of occupational safety and health, primarily related to the industry, ecology, civil protection and legal regulations in this area.

Considering wider international settings, Illinois University in Chicago (USA)²² educates occupational safety experts at the level of master and PhD studies. The University has developed active cooperation with a variety of universities, governmental agencies, professional organisations and companies which deal with this issue, with the aim of exchanging scientific and teaching knowledge, as well as providing students' internship in the area of industrial hygiene, education in occupational safety and health, labour medicine etc. (in the companies such as Abbott Laboratories, Ford Motor Co., Motorola, ArcelorMittal, the Cook County Department of Environmental Control, Fermi National Accelerator Laboratory etc.).

In Johns Hopkins University²³, Baltimore, Maryland, USA, the Johns Hopkins Education and Research Centre (ERC) for Occupational Safety and Health was established. The Centre implements a number of programs with the aim of educating engineers in the field of occupational safety at all levels of studies: bachelor, master and doctoral. Doctoral studies are

individually structured and include specific education and research of the conditions in one or more study disciplines which are of fundamental importance for industrial hygiene and safety.

University of Central Missouri²⁴ (USA) is a university with a long tradition in higher education, a great number of study programs and students who easily find a job after graduation. The University offers managerial master programs in the field of occupational safety. In addition to legal, ethical and other managerial responsibilities, students face some other issues in the national and local context regarding occupational safety; but they also provide technical solutions. The students have the opportunity to get a job even before graduation as safety analysts, occupational safety managers, corporate health officials, loss control managers, safety system analysts etc.

Grand Valley State University²⁵, Michigan, USA, offers a study program of occupational safety at technical colleges in the field of engineering, which can be civil, chemical, agricultural, mechanical, metallurgical, nuclear etc. This department belongs to manufacturing engineering. In addition to technical content, the curriculum contains legal regulations, fire protection, ergonomics and education in the field of occupational safety. Undergraduate students acquire knowledge related to risk assessment, professional risk management and other environmental risks, while master students learn how to design, evaluate and implement the programs promoting safe work and prevention on emergencies and accidents²⁶. PhD students prepare to become leaders and field researchers (in the occupational safety and health system, including toxicology, ergonomics etc.).

Higher education in the field of occupational safety in national context

Occupational safety and health is a field of study in numerous higher education institutions in Serbia. Within accredited higher education institutions, there are five faculties and eight higher vocational schools which implement some of the study programs in this area²⁷. Those are:

Faculty of Occupational Safety in Niš (bachelor academic studies – Occupational safety, master academic studies – Occupational safety engineering, doctoral academic studies – Occupational safety engineering),

²⁴ <http://www.ucmo.edu/undergrad/> (accessed on 15.09.2018)

²⁵ http://education-portal.com/directory/school/Grand_Valley_State_University.html (accessed on 10.09.2018)

²⁶ http://education-portal.com/directory/school/Grand_Valley_State_University.html

²⁷ Commission for Accreditation and Quality Assurance, A guide through accredited study higher education institutions and study programs in the Republic of Serbia, 2018. <https://drive.google.com/file/d/1jaaWTvUxZ9EtAAQxyVB1wvCmjOZ-bL60/view> (accessed on 5.8.2018)

¹⁹ <http://www.vsb.cz/en/about-us/http://www.studyin.cz/universities/> (accessed on 09.09.2018)

²⁰ <http://sites.kpi.kharkov.ua/safetyofliving/Htm/internationalactivities.htm> (accessed on 15.09.2018)

²¹ <http://niiot.ru/default.htm> (accessed on 10.09.2018)

²² <http://www.uic.edu/uic/> (accessed on 11.09.2018)

²³ <http://www.jhu.edu/> (accessed on 12.09.2018)

Faculty of Mining and Geology - Belgrade (bachelor academic studies – Environmental engineering and occupational safety, master academic studies – Environmental engineering and occupational safety),

Faculty of Technical Sciences - Novi Sad (bachelor academic studies – Occupational safety engineering in Serbian and English, master academic studies - Occupational safety engineering in Serbian and English, doctoral academic studies - Occupational safety engineering in Serbian and English),

Faculty of Engineering Kragujevac (master academic studies – Environmental engineering and occupational safety),

Faculty of Technical Sciences – Kosovska Mitrovica (bachelor academic studies - Environmental engineering and occupational safety, master academic studies - Environmental engineering and occupational safety),

College of Vocational Studies - Belgrade Polytechnic (bachelor vocational studies – Occupational safety and health, specialist vocational studies – Occupational safety),

Technical College of Vocational Studies– Zrenjanin (bachelor vocational studies – Occupational safety engineering),

Higher Education Technical School of Professional Studies in Novi Sad (bachelor vocational studies – Occupational safety, specialist vocational studies – Occupational safety),

Technical and Technological College of Vocational Studies in Kruševac (bachelor vocational studies – Environmental protection and occupational safety),

Technical College of Vocational Studies in Leposavić, Uroševac (specialist vocational studies - Occupational safety),

Business-Technical College of Vocational Studies - Užice (specialist vocational studies - Occupational safety and protection, specialist vocational studies – Occupational safety engineering and environmental protection, master vocational studies - Occupational safety and protection),

Engineering College of Vocational Studies “TehnikumTaurunum“ (bachelor vocational studies: Occupational safety and health, specialist vocational studies: Occupational safety and health),

Vocational College for Technology and Arts - Leskovac (bachelor vocational studies: Occupational and environmental safety).

As it can be seen, there are study programs in the field of occupational safety and health at all levels of studies. More precisely, there are three study programs at bachelor academic studies, five programs at master academic studies, two at doctoral academic studies, six at bachelor vocational studies, six at specialist vocational studies and one at master vocational studies. Bearing in mind these facts, it is evident that the Republic of Serbia pays much attention to higher

education of experts in occupational safety and health. Furthermore, the number of accredited study programs is increasing (ibid.).

CONCLUSION

Over the last decades there has been an intensive development of higher education in the field of occupational safety in various countries. Major accidents in high-tech/high-hazard sectors, together with legislation were major drivers for these course. The analysis of relevant sources, international documents especially, points to the consistency of attitudes regarding the need and importance of academic education in this field. Higher education in the field of occupational safety and health in national and international settings is being implemented at different levels of higher education - both in vocational colleges and faculties: at bachelor, master and doctoral academic studies. In Europe, there are evident differences in the program orientation, which are most often caused by national and cultural distinctions, but also legal and institutional approaches in the creation and implementation of these programs.

The paper offered the results of the research on available study programs in higher education institutions in national and international settings with the aim of identifying the present situation and creating strategic guidelines for the development of higher education in the field of occupational safety and health. One of the main conclusions is that there is a high variability among the analysed study programs. The results of the research show that the largest number of study programs in this field is implemented on master academic studies in engineering and management. However, it should be emphasised that these results are not representative as it was not possible to obtain the totality of study programs all over Europe. The harmonisation of occupational safety study programs will require a long period of time, bearing in mind the differences and complexity of study programs in all European countries. However, it is expected that there is some sort of compatibility behind the apparent diversity. As a result of existing differences in education, it is necessary to establish a set of standardised profiles to determine the different levels of qualifications of occupational safety professionals. This would allow them to be recognised in their work, but also to work in other countries and increase their professional mobility.

As a research field, occupational safety and health is studied within various sciences, ranging from technical and technological, through mathematical to social and humanistic disciplines. Considering the tendency of knowledge stratification and the development of complex jobs, there is an increased number of professionals dealing with occupational safety and health issues (engineers, doctors, lawyers, managers etc.). Furthermore, the need for their continuous improvement in this field is enhanced [25], which

ultimately implies the need to develop curricula that would meet these needs in various scientific fields and disciplines. In recent years, the concept of safety management and risk management has particularly evolved. Rooted in the technical and technological processes of high-risk industries, this concept has initiated the need for the development of study programs dedicated to risk management (occupational and environmental), i.e. creating experts in safety management and occupational safety managers (e.g. Delft University of Technology, the Netherlands). If we take into account the changes brought about by the Fourth Industrial Revolution (4.0) in artificial intelligence (AI), robotics, IoT (Internet of things), automotive industry, biotechnology, nanotechnology, the development of energy storage systems etc., it is necessary to consider higher education in the field of occupational safety from the aspect of globalisation, technical and technological processes and expected changes.

Numerous sources confirm the importance of occupational safety professionals in achieving and continuously improving the performance of occupational health and safety in each organisation. Unfortunately, in Serbian companies these issues are not discussed by the experts in this field, but by the staff which is not sufficiently motivated and equipped with knowledge to perceive the complexity of 'safety' issues. The existing legal regulations contribute to the current situation since they do not give priority to safety engineers in job application procedures. This calls into question the safety and quality of living and working environment, which, in the long run, causes higher material investments, but also the unemployment of experts professionally educated and prepared for this work field.

In national settings, the analysis of the effects of conducting the 2013-2017 Occupational Safety and Health Strategy²⁸ has pointed to several facts. One of the strategic goals of this document was to increase investment in the education system, with the effective use of existing resources, which should lead to the modernisation of teaching. This document does not have a strategic goal that relates to higher education exclusively, but primarily focuses on primary and secondary education, where it is necessary to work on raising awareness of the importance of one's own workplace safety and health from an early age. What is particularly important is that this strategy takes into account the need for continuous training of professionals in the field of occupational safety and health, but also other persons in this field. Thus, the Law on Changes and Amendments to the Law on Occupational Safety and Health²⁹ created a legal basis for the adoption of bylaws which will prescribe a

program of knowledge improvement of the professionals for occupational safety and health. On the basis of this, the adoption of the Rulebook on the knowledge improvement program and other issues related to the knowledge improvement of the person for occupational safety and health³⁰ is a significant step forward in the process of improving the knowledge of experts in this field, especially when considering lifelong learning as one of the objectives of the Strategy for Education Development³¹. However, it is necessary to pay more attention to determining the objectives of higher education development and clearly define the standardised educational attainment of occupational safety professionals in accordance with current requirements and changes that are expected in this area in the future.

REFERENCES

- [1] J. Saari: "Risk assessment and risk evaluation and the training of OHS professionals", *Safety Science*, Vol 20, 1995, pp. 183-189.
- [2] A. Garrigou, G. Peissel: "Reflexive approach to the activity of preventionists and their training needs: result of a French study", *Safety Science*, Vol 46, 2008, pp. 1271-1288.
- [3] R. Booth, A. Hale, S. Dawson: "Identifying and registering safety practitioners", *Safety Science*, Vol 14, 1991, 231-240.
- [4] P. Swuste, F. Arnoldy: "The safety adviser/manager as agent of organisational change: a new challenge to expert training", *Safety Science*, Vol 41, 2003, 15-27.
- [5] A. Hale, G. Bianchi, G. Dudka, W. Hameister, R. Jones, P. Perttula, I. Ytrehus: "Surveying the role of safety professionals objectives, methods and early results", *Safety Science Monitor*, Vol 9 (1), 2005.
- [6] P. Swuste, C. Gulijk, W. van Zwaard: "Safety metaphors and theories", *Safety Science*, Vol 48, 2010, pp. 1000-1018.
- [7] A. Hale, J. Kroes: "System in safety, 10 years of the chair in safety science at the Delft University of Technology", *Safety Science*, Vol 26 (1/2), 1997, pp. 3-19.
- [8] J. P. Brun, C. D. Loiselle: "The roles, functions and activities of safety practitioners: the current situation in Quebec", *Safety Science*, Vol 40, 2002, pp. 519-536.
- [9] P. Arezes, P. Swuste: "Occupational health and safety post-graduation courses in europe. A general overview", *Saf. Sci*, Vol 50, 2012, pp. 433-442.
- [10] Final report Symposium Academic Safety education ad research (in Dutch: Eindverslag Symposium Universitair Onderwijs en Onderzoek in Veiligheid), TH Delft, 1978
- [11] J. Verbeek, P. Kroon: "Editorial special issue on education and training on occupational health and safety", *Safety Science*, Vol 20 (3-4), 1995.

²⁸2013-2017 Occupational Safety and Health Strategy in the Republic of Serbia

²⁹Law on Changes and Amendments to the Law on Occupational Safety and Health, "Official Gazette RS", 91/2015

³⁰Rulebook on the knowledge improvement program and other issues related to the knowledge improvement of the person for occupational safety and health, "Official Gazette RS", No. 108/2017

³¹Strategy for Education Development in Serbia 2020.

- [12] D. Gute, A. Rossignol, N. Hanes, J. Tatly: „Factors affecting the permanence of occupational safety and health topics in engineering courses“, J. Eng. Educ, 1993, Vol 82 (2), 163-168.
 - [13] A.Seppala: Promoting safety by training supervisors and safety representatives for daily safety work. Safety Science 20 (2–3), 1995. pp. 317–322.
 - [14] R. Elangovan, K. Mohammed, S. Mohan: “Effectiveness of the designed safety education program modules by their implementation in selected industries”, Journal of Loss Prevention in the Process Industries, Vol 18, 2005, pp. 553-557.
 - [15] H. Heinrich: Recognition of safety as a profession, a challenge to colleges and universities. National Safety Council Transactions. In: Proceedings of the 44th National Safety Congress, October 22-26, Chicago, Ill, 1956, pp. 37-40.
 - [16] P. Nolan: “Safety and loss prevention training”, Journal of Loss Prevention in the Process Industry, Vol 2, 1989, pp.3-4
 - [17] S. Grossel: “Current status of process safety/prevention education in the US”, Journal of Loss Prevention in the Process Industry, Vol 5 (2), 1992.
 - [18] E. Senkbeil; “Laboratory safety course in the chemistry curriculum”, Journal of Hazardous Materials, Vol 36, 1994, pp. 159-164.
 - [19] W. Phoon: “Education and training in occupational and environmental health”, Environmental Management and Health, Vol 8 (5), 1997, pp. 158-161.
 - [20] R. Hill, D. Nelson: “Strengthen safety education of chemistry undergraduates”, Chemical Health and Safety, 2005 (Nov/Dec), pp. 19-23.
 - [21] J. Culvenor, D. Else: “Finding occupational injury solutions: the impact of training in creative thinking”, Safety Science, Vol 25 (1-2), 1997, pp. 187-205.
 - [22] J. Lundin, R. Jönsson: “Master of science in risk management and safety engineering, at Lund University, Sweden”, Journal of Loss Prevention in the Process Industry, Vol 15, 2002, pp. 111-117.
 - [23] Y. Toft, P. Howard, D. Jorgensen: “Changing paradigms for professional engineering practice towards safety design – an Australian perspective”, Safety Science, Vol 41, 2003, 263-276.
 - [24] H. Rouhof, P. Swuste, A. Lit, W van Lemmens, J. Devens, J. Prooi, J.: ”Ensuring minimum SHE competences: a case study for manufacturing employees in a multinational,”Journal of Applied., 2009.
 - [25] V. Nikolić: “Osnovi koncepcije kontinuiranog obrazovanja i usavršavanja za bezbednost i zdravlje na radu”, Conference proceeding, 15. International conference, Continuous education – the basis for improving occupational safety, SZNRS, Faculty of Technical Sciences in Novi Sad, 2018, pp.7-25.
 - [26] ILO Encyclopedia, Geneva, IV Edition, Vol. I, Chapter 18.
- ### Legal regulations
- [1] 2013-2017 Occupational Safety and Health Strategy.
 - [2] Strategy for Education Development in Serbia 2020.
 - [3] Law on Changes and Amendments to the Law on Occupational Safety and Health, “Official Gazette RS”, 91/2015
 - [4] Rulebook on the knowledge improvement program and other issues related to the knowledge improvement of the person for occupational safety and health,“Official Gazette RS”, No. 108/2017.
- ### Internet sources
- [1] http://www.euc.ac.cy/easyconsole.cfm/id/173/dep/162/program_id/109 (accessed on 10.09.2018)
 - [2] <http://www.mastersportal.eu/universities/1665/turin-school-of-development.html> (accessed on .01.09.2018)
 - [3] <http://www.uv.es/uvweb/college/en/university-valencia-1285845048380> (accessed on 02.09.2018)
 - [4] <http://www.abrostudy.com/sr/universities/united-kingdom/keele-university/> (accessed on 10.09.2018)
 - [5] <http://www.vsb.cz/en/about-us/http://www.studyin.cz/universities/>(accessed on 11.09.2018)
 - [6] <http://niiot.ru/default.htm>(accessed on 12.09.2018)
 - [7] <http://ohsi.ru/>(accessed on 14.09.2018)
 - [8] <http://sites.kpi.kharkov.ua/safetyofliving/Htm/internationalactivities.htm>(accessed on 15.09.2018)
 - [9] <http://www.jhu.edu/> (accessed on 18.09.2018)
 - [10] <http://www.uic.edu/uic/> (accessed on 11.09.2018)
 - [11] <http://www.ucmo.edu/undergrad/>(accessed on 10.09.2018)
 - [12] http://education-portal.com/directory/school/Grand_Valley_State_University.html(accessed on 10.09.2018)
 - [13] <http://www.uv.es/uvweb/college/en/university-valencia-1285845048380> (accessed on 10.09.2018)
 - [14] <http://www.abrostudy.com/sr/universities/united-kingdom/keele-university/> (accessed on 10.09.2018)
 - [15] http://education-portal.com/directory/school/Grand_Valley_State_University.html(accessed on 10.09.2018)
 - [16] Commission for Accreditation and Quality Assurance, A guide through accredited study higher education institutions and study programs in the Republic of Serbia, 2018.
<https://drive.google.com/file/d/1jaaWTvUxZ9EtAAQxyVB1wvCmjOZ-bL60/view> (accessed on 5.8.2018)
- ### ACKNOWLEDGEMENTS
- This paper is supported by Serbian Ministry of Education and Science (Project III 44006, III 42006 and III 43014).

BIOGRAPHY of the first author

Vesna Nikolić, PhD, is a full professor of the Faculty of Occupational Safety in Niš, Republic of Serbia. She is the Head of the Department for Social Development and Humanisation of Working and Living Environment.



She is the author or co-author of several monographs, textbooks and over 350 scientific papers published in scientific journals and proceedings of scientific conferences. She took part in the implementation of a number of national and international research projects and participated in the development of strategic and program documents in the Republic of Serbia. Her research interests include: education, training and learning, human resources management and development, knowledge management, organisational learning and behaviour (particularly in the system of safety – occupational safety, fire safety, protection of environment, sustainable development and emergency management) etc.

VISOKOŠKOLSKO OBRAZOVANJE ZA ZAŠTITU NA RADU U MEĐUNARODNIM I NACIONALNIM OKVIRIMA

Vesna Nikolić, Aleksandra Ilić Petković, Mirjana Galjak, Tamara Vukić

Rezime: *Imajući u vidu presudnu ulogu visokoškolskog obrazovanja u unapređenju sistema bezbednosti i zdravlja na radu i, uopšte, u razvoju profesionalnog domena zaštite na radu, neshvatljivo je mali broj istraživanja i radova dostupnih na ovu temu. Bez pretenzija da ulazimo u dublje sagledavanje razloga zbog kojih je nedovoljno pažnje posvećeno ovom istraživačkom pitanju, pokušali smo da na osnovu dostupnih izvora ukažemo na postojeće stanje, ali i trendove razvoja visokoškolskog obrazovanja u ovoj oblasti. Da bismo razumeli sadašnjost i utvrdili pravce razvoja u budućnosti, moramo se osvrnuti na prošlost. S tim u vezi, u prvom delu rada napravljen je kratak istorijski osvrt na razvoj visokoškolskog obrazovanja za zaštitu na radu, u drugom delu je izvršena elaboracija postojećeg stanja do kojeg se došlo analizom dostupnih izvora u međunarodnim i nacionalnim okvirima koja je zapravo poslužila kao polazište za razmatranje trendova razvoja visokoškolskog obrazovanja u svetlu zakonskih i strateških dokumenata u budućnosti.*

Ključne reči: visokoškolsko obrazovanje, zaštita na radu.



TECHNOLOGIES AND TECHNICAL SYSTEMS OF SAFETY



MILAN BLAGOJEVIĆ¹
RADOJE JEVTIĆ²
DEJAN RISTIĆ³

¹University of Niš,
Faculty of Occupational Safety
²School for electrical engineering
„Nikola Tesla“, Niš
³University of Niš,
Faculty of Occupational Safety

¹milan.blagojevic@znrfak.ni.ac.rs
²milan.jvtc@gmail.com
³dejan.ristic@znrfak.ni.ac.rs

COMPARATIVE ANALYSIS OF RULES FOR SMOKE DETECTORS PLACEMENT IN FIVE LEADING STANDARDS

Abstract: *The aim of this paper is a comparative analysis of rules for arrangement and distribution of smoke detectors in the world leading standards for fire detection systems design. There are several reasons for such analysis. Firstly, the rules for setting up the system components with the identical characteristics are not the same even for the simplest system components, such as for example manual fire detectors. Secondly, certain problems regarding the set-up of fire detectors are examined in detail in some standards, while in the others they are described in a couple of sentences or paragraphs. Finally, regardless of the fact that the national standards are mandatory, the designers should know how the identical problem is solved in an another standard. European standard 54-14 is mandatory, but in practice, some questions such as “Have all possible situations been examined”, and “Are there detailed explanations for all the situations that could possibly happen”? The main goal of this paper is to show the differences between the rules and the instructions for design and installation of fire detectors in five standards: EN 54-14, VDE 0833-2, BS 5839-1, НПБ 88, and NFPA 72. Also, the paper provides the best solution for particular situations in practice.*

Key words: fire detection system design, fire detectors, standards.

INTRODUCTION

The European standard EN 54 Fire detection and alarm systems *Part 14: Planning, design, installation, commissioning, use and maintenance* is mandatory for fire detection system designers, and in most countries it has the country's abbreviations in front of the EN. However, there are situations that this standard does not cover at all. For example, siting of linear fire detectors only is implicitly recommended in other parts of the EU standard, such as part 22.

German standard VDE 0833 Alarm systems for fire, intrusion and hold up *Part 2: Requirements for fire alarm system* generally gives the same recommendations as the European, but it is more detailed in some applications. The characteristic examples are rules for siting the detectors below the pitched roof or in racked warehouses. Therefore, it is used more in some countries than the European one - for example, in Croatia.

British standard BS 5839 Fire detection and fire alarm systems for buildings *Part 1: Code of practice for design, installation, commissioning and maintenance* has different solutions for different types of systems. Specifically, this standard is making a difference between types of system L (ife), P (roperty), etc., depending on what you are protecting. For purpose of this paper we chose some of the most interesting solutions.

Russian standard НПБ 88 *Нормы пожарной безопасности Установки пожаротушения и сигнализации. нормы и правила проектирования* has rules

that are largely restrictive compared to the other standards. For some applications there are no rules at all, but the standard refers to the manufacturer's documentation.

Finally, the US standard NFPA 72 *National Fire Alarm and Signaling Code* is the most detailed and most accurate one, but on the other hand requires a designer with a higher level of knowledge. Some of the solutions are largely different from the European rules, but regardless of that, some interesting solutions will be listed in the following text.

In this paper, some rules from European, German, British, Russian and American standards for point smoke detectors will be compared.

POINT SMOKE DETECTORS ARRANGEMENT AND DISTRIBUTION

Basic strategy of fire detection system designers is to obtain the number of point fire detectors in the room by dividing the area of the room with the area of coverage of individual detector. By doing that, three types of situations may occur, figure 1. The first one shows the situation when the number of detectors is not enough, which can lead to some unprotected parts of the room. Of course, we can always increase the number of detectors above the required ones, but the question is who will pay for it. The investor will certainly not be satisfied with our design.

Finally, the third situation is presented by perfect square arrangement of detectors which is achieved by overlapping of individual coverage areas and the

amount of 1/4 of individual coverage area. Thus, the three most important parameters that standards should define are: A - Area of coverage, r - radius and S - maximum distance between individual detectors.

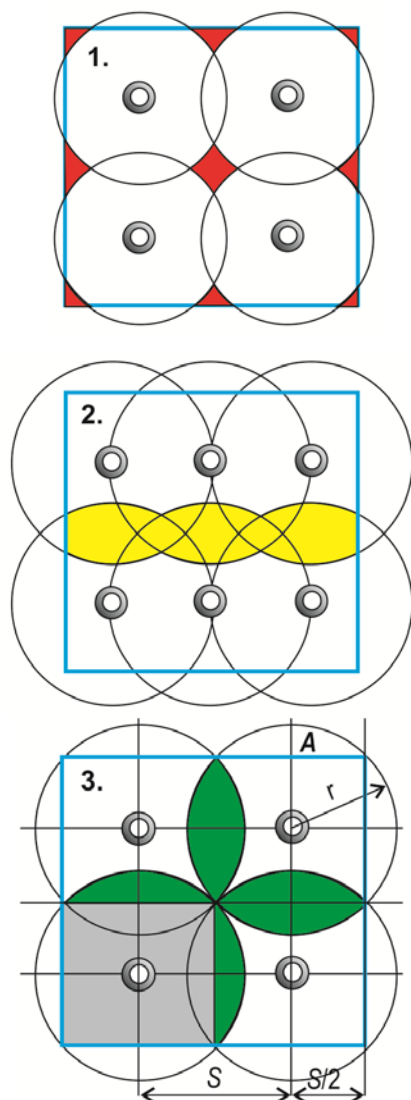


Figure 1. Siting and spacing of heat and smoke point detectors, 1-uncovered areas, 2-redundancy, 3-“ideal”

Point smoke detectors – basic rules for siting and spacing

European standard generally permits the use of these detectors to a height of 11 m, with a coverage radius of 7.5 m. In practice, area of coverage greater than 80 m² is rarely used, but this radius in essence, gives a coverage area of individual detectors even 112 m².

German standard, similar as for the point-type heat detectors, gives radius and coverage area through curves depending on the slope of the ceiling up to 20° and over 20°. For example, $r = 6.6$ m for $A = 80$ m², and $r = 7.4$ m for $A = 100$ m². It should be notice that there is a maximum permissible height of 12 m, and that for the same radius as in the EN 54-14, area of coverage is less - 100 m², not 112 m².

The rules in British standard are similar to the previous ones, $A = 100$ m² and $r = 7.5$ m, that is, individual coverage can be represented by a square measuring 7.5 x 7.5 m giving an actual area coverage of 112 m² per device.

Russian standard is the less flexible standard again, because it allows the maximum coverage area of 85 m². Instead of the radius of coverage, Russian standard gives the maximum distance between two detectors of 9 m, which is less than the European - this distance in accordance with EN 54-14 is 10.6 m.

American standard again has a different approach. In the circle that represents an area of covering of smoke detectors, rooms with the largest surface area of about 80 m² can be placed and a series of rectangles with a smaller surface area. This means that the standard radius is 9.1 m. Standard further recommends a virtual division of the room in the case of rooms with complex geometry. It is necessary to calculate the required number of detectors and the maximum allowable distance for each of the virtual area.

The basic rules for siting and spacing of point smoke detectors according to EN 54-14 are shown in table 1 and figure 2.

Table 1. EN 54-14 - Covering and radii of point smoke detector for smoke detector EN 54-7

Ceiling height [m]	≤4.5	>4.5≤6	>6≤8	>8≤11	>11≤25	>25
Radius [m]	7.5	7.5	7.5	7.5	NN	NS

Legend NN – Not normally used in the range, NS – Not suitable for use in the range

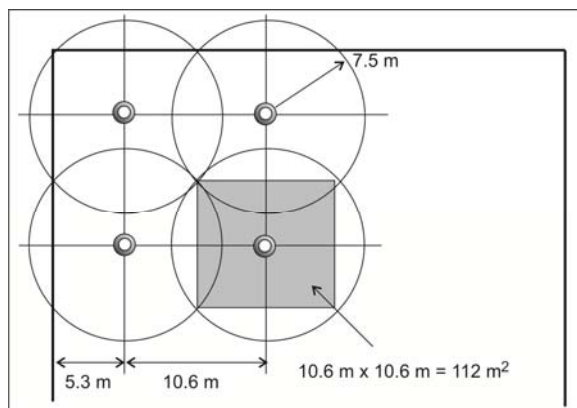


Figure 2. Area of coverage and radii for point detector according to EN 54-14

Because of the mentioned reasons, in this paper it is made simulations by means of PyroSim software package in order to find influence of various values on burner to detector response time. Firstly, we made simulations of rules from EN 54-14, and after that simulations for smoke detector placement rules in each standard.

Simulations

Dimensions of the compartment which was chosen for simulation are $25 \text{ m} \times 16 \text{ m}$, with total area for monitoring of 400 m^2 . The reason for such dimensions is very simple; with room height of 6 m coverage of point smoke detector becomes “discussable”, and therefore, 60 m^2 or 80 m^2 for individual coverage of detector should be chosen. Also, dividing area of the compartment of 400 m^2 by 60 m^2 or 80 m^2 coverage gives odd number of detectors for complete monitoring.

In this simulation, it is assumed that individual coverage of each point smoke detector is 80 m^2 . Obviously, coverage of 80 m^2 for individual detector leads to triangular placement of detectors in a compartment, which is not “ideal” placement having in mind that grid placement is recommended for arrangement of detectors. Because of that, simulations are carried for 4 smoke detectors with burners of 100 kW , 250 kW and 500 kW . If we assume for individual coverage of detector 80 m^2 , obviously, there are “blind spots” in compartment, so, the burner was located in “blind spot” of compartment (red square on the left side - Figure 3). Simulation results are shown on figures 4, 5 and 6.

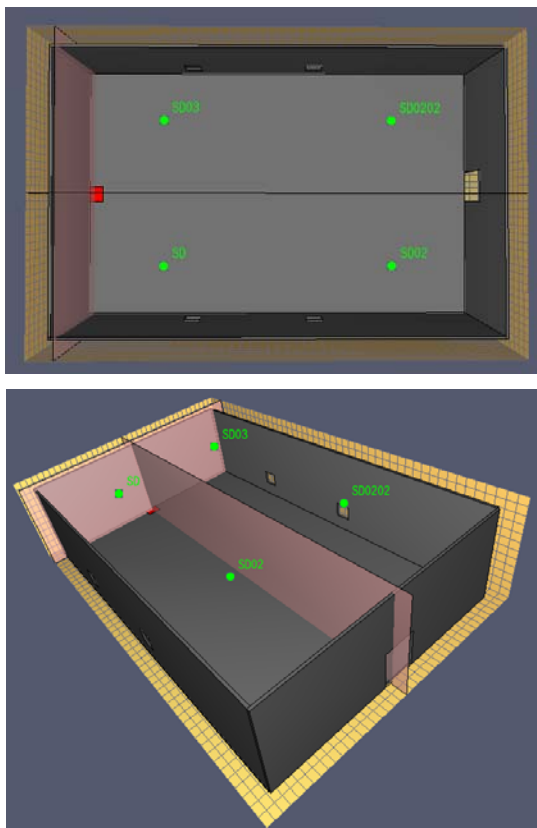


Figure 3. Arrangement of detectors and burner location

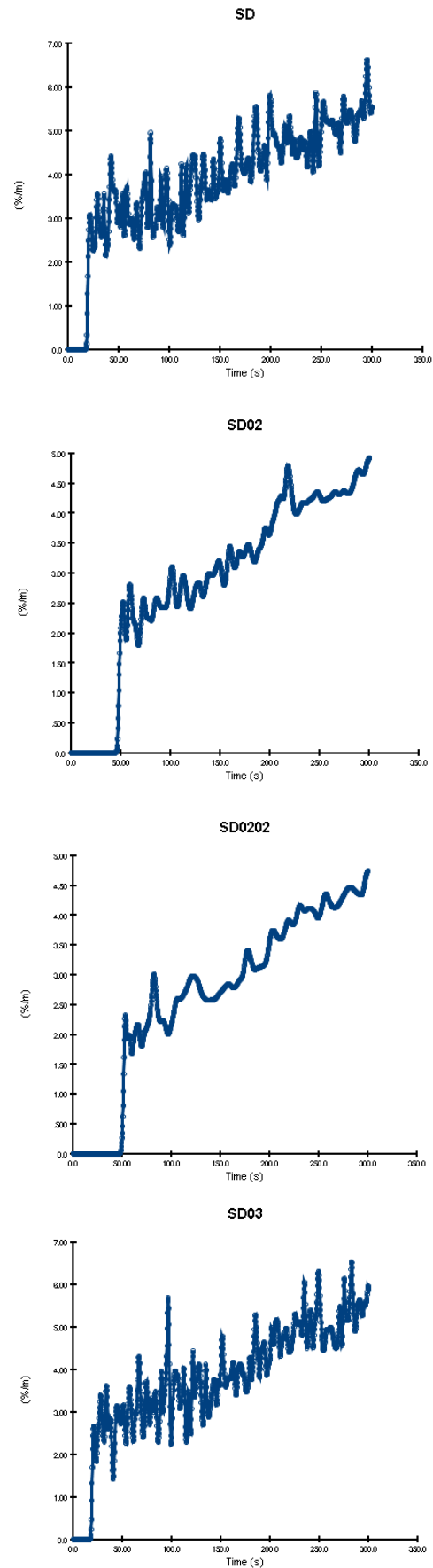


Figure 4. Obscuration vs. time - 100 kW burner

In the majority of applications, the threshold value for point smoke detectors (optical) is in range between 3.00 %/m and 5.00 %/m obscuration, depending on ambient conditions. In PyroSim software default threshold value is 3.3 %/m. It is obvious from previous figures for 100 kW burner that detectors which are closest to burner (SD and SD03) will have almost equal response time - about 25 s, while farthestmost detector (SD200) may respond after 80 s if is adjusted on 3.0 %/m obscuration as alarm value. For that reason, in the following examples, only simulation results for closest end farthestmost detectors will be presented.

In case of 500 kW burner response time on detector SD will not exceed ten seconds, independently of threshold values, whilst response time for SD202 will not be less than half minute.

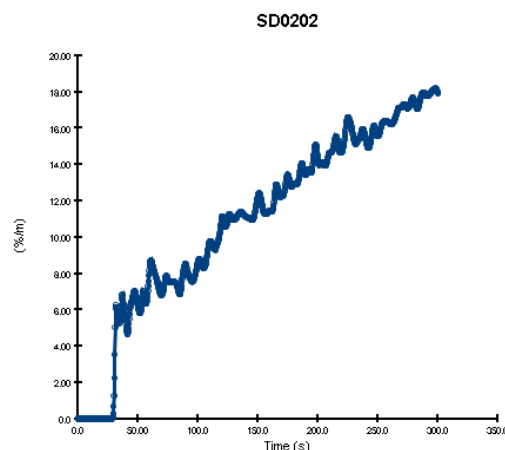
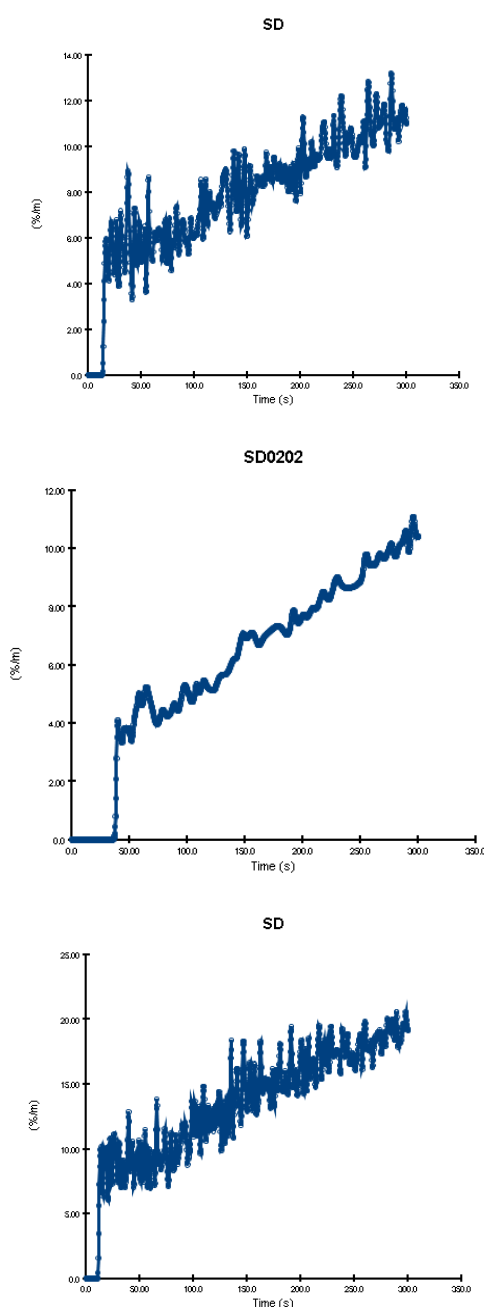


Figure 5. Obscuration vs. time - 500 kW burner

CORRIDORS AND NARROW ROOMS

In practice, fire alarm system designer can rarely meet with ideal situations as shown in figure 1. The interior of buildings depending on their purpose very often requires the application of special rules for siting. There are many special cases for siting of fire detectors, and the most often case refers to the narrow hallways and rooms. Here we already have the first problem, and that is the answer to the question “What is corridor”, or “Which is the maximum width of the room in order to be a corridor”? The European standard does not define the corridor, only states that if the room is narrower than 1.2 m, detector should be mounted within the middle third of the width.

Unlike the European, the German standard precisely defines that the corridor is the room of less than 3 m in width and gives rules for the distance between point-type smoke detectors. Smoke detectors can be located 15 m apart from each other, in case of coincidence detection type B up to 11 m or 7.5 m when triggering fire extinguishing systems.

According to the British standard, corridors are wider than the rest of European countries; a corridor is the room of less than 5 m in width. The standard does not provide specific rules, but only the formula for the calculation radius of detector, as follows: $(5 \text{ m} - w)/2 + 7.5 \text{ [m]}$. Based on the formula, it is obvious that if the corridor is 3 m wide, the radius will increase by 1 m. That is, we get 8.5 m for the smoke detector.

The Russian standard does not give specific recommendations, except that for smoke detectors mutual distance in the corridor can be increased 1.5 times, which is almost the same as in the German standard (maximum distance is $9 \text{ m} \times 1.5$ for room height up to 3.5 m).

NFPA 72 defines corridor as room of less than 15 ft. (4.6 m) without further recommendations for spacing spot-type detectors. In other words, a corridor 10 ft (3.0 m) wide and up to 82 ft (25.0 m) long can be covered with two 30 ft (9.1 m) spot-type detectors.

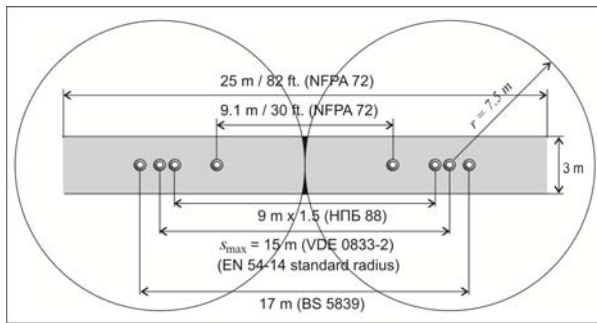


Figure 6. Distances between smoke point detectors in corridors

From fire detection system designer's point of view, it is interesting to find how these differences affect detectors response time. In order to investigate this problem, we made a simulation model for a corridor which is covered by point smoke detectors according to the previous rules in five standards. As we know, the response of the detectors subjected to fire is the most important factor which determines arrangement and distribution of fire detectors in order to detect fire in an early stage. For this reason, the simulation has been made for small initial mass and energy density, that is, for burners of 1 kW/m², 3 kW/m², 5 kW/m² and 35 kW/m², as the first parameter, and for ceiling height which is very significant and limiting factor for this type of consideration, as the second parameter. The main goal of the simulation is to investigate the differences between various standards rules, and consequently, the distance between detectors and site of fire, as well as the influence on detectors response times.

Simulations

For simulation model a corridor in shape T was chosen, which means that, independently of mentioned rules, one smoke detector will be located at intersection of corridor. According to this position, the location of other point smoke detectors was chosen. One section of corridor is 42 m long, the second one is 25 m long, the width of the corridor is 3 m and the height is 3.2 m. Positions of all detectors, i.e. s_{max} , are calculated according to the rules of standards measured from the detector located at intersection.



Figure 7. Simulation model with positions of burner and detectors

For each ceiling height and for each burner the simulation's time was set on 500 seconds. The ambient conditions in realized simulations were normal (temperature, humidity and pressure). The alarm threshold for every smoke detector was set to 3,28 %/m. The smoke detectors arrangement for was different for each standard. For the EN 54-14 and VDE 0832-2 standards the distance between smoke detectors was 15 m. For BS 5839-1 standard the distance between smoke detectors was 17 m. For HPIB 88 standard the distance between smoke detectors was 13.5 m whereas for NFPA 72 standard, the distance between smoke detectors was 9.1 m.

The simulations were made for ceiling heights of 4.5 m, 6 m and 8 m and burners of 1 kW/m², 3 kW/m², 5 kW/m² and 35 kW/m² for each ceiling height. Complete data for all simulations would take up a lot of space, so, here an example of simulation for 35 kW/m² burner and ceiling height of 4.5 m is shown.

The distance of a burner from a detector S1 was the same for all standards - on the edge of detector's area of coverage, so it is was interesting to evaluate the differences in standards taking into consideration the influence of the other detectors position on response time of detectors S2, S3 and S4.

Table 2. Response times of detector S1 in all standards

S1	1 kW/m ²	3 kW/m ²	5 kW/m ²	35 kW/m ²
h=4.5 m	438.38 s	86.66 s	73.33 s	40.20 s
h=6.0 m		86.56 s	73.33 s	43.10 s
h=8.0 m		93.37 s	80.29 s	44.45 s

Obviously, the height of the ceiling has a little influence on detector response time except for a burner of 1 kW. On the other hand, because of overlapping of detector S1 and S2 coverage areas, response times of detector S2 are a little shorter, and differentiate in mentioned standards.

Table 3. Response times of detector S2 for 4.5 m height

S2	1 kW/m ²	3 kW/m ²	5 kW/m ²	35 kW/m ²
EN, VDE	421.00 s	60.04 s	48.66 s	26.66 s
BS 5839-1	427.45 s	64.66 s	51.33 s	28.66 s
NPB 88	279.06 s	53.56 s	46.80 s	25.21 s
NFPA 72	165.50 s	41.30 s	33.56 s	19.33 s

Table 4. Response times of detector S2 for 6.0 m height

S2	1 kW/m ²	3 kW/m ²	5 kW/m ²	35 kW/m ²
EN, VDE		66.72 s	60.00 s	33.36 s
BS 5839-1		67.56 s	61.34 s	34.12 s
NPB 88	165.51 s	66.66 s	56.66 s	32.12 s
NFPA 72	140.89 s	40.10 s	34.20 s	20.10 s

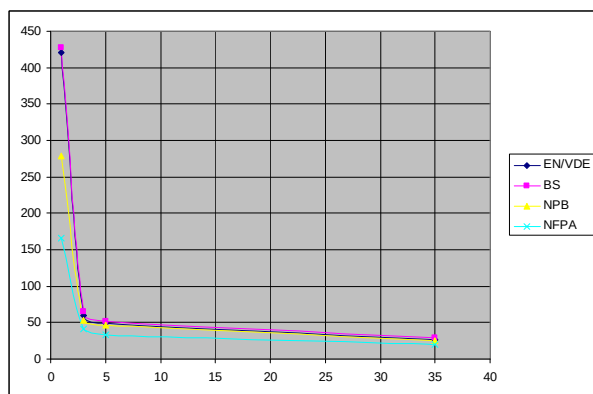


Figure 8. Response times of detector S2 for 4.5 m height

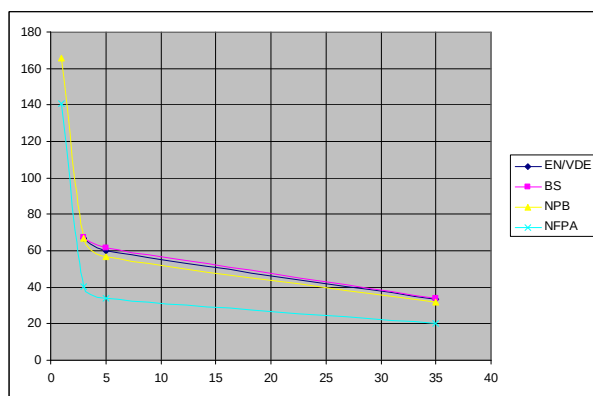


Figure 9. Response times of detector S2 for 6.0 m height

Table 5. Response times of detector S2 for 8.0 m height

S2	1 kW/m ²	3 kW/m ²	5 kW/m ²	35 kW/m ²
EN, VDE		70.32 s	61.21 s	32.98 s
BS 5839-1		81.23 s	72.81 s	40.67 s
NPB 88		67.10 s	53.56 s	30.11 s
NFPA 72		43.78 s	40.09 s	24.26 s

CONCLUSION

Regardless of the fact that described simulations present simplification of fire in the sense of fire burns at a steady state, there are two basic conclusions based on these simulations from point of view of fire detection system. The first one is crucial for an early warning: only the NFPA rules, as well as the rules from the Russian standard provide detection of fires which are characterized by small initial mass and energy density. This conclusion is especially valid for slow smoldering fires, such as test fires TF2 and TF3 with weak air flow. The second conclusion is that response times of nearest detectors for fire loads beyond 35 kW/m² are almost equal independently of the rules in various standards, especially for room heights up to 6 m.

REFERENCES

- [1] BS 5839-1:2002, "Fire detection and fire alarm systems for buildings", Code of practice for system design, installation, commissioning and maintenance, 2002.
- [2] DIN VDE 0833-2, "Alarm systems for fire, intrusion and hold up", 2009.
- [3] EN 54, "Fire detection and fire alarm systems", 1996. - 2015.
- [4] NFPA 72, "National fire alarm code", 2016 Edition, NFPA, 2016.
- [5] НПБ 88-2001, "Нормы пожарной безопасности - Установки пожаротушения и сигнализации". Нормы и правила проектирования, 2001.

BIOGRAPHY of the first author

Milan Blagojević was born in Niš, Serbia, in 1958. He received Ph.D. degree in fire protection from the University of Nis, Faculty of Occupational Safety. His main areas of research include alarm systems, fire detection systems, intruder detection systems, etc.



He is currently working as a full professor at the Faculty of Occupational Safety in Nis, University of Nis.

KOMPARATIVNA ANALIZA PRAVILA ZA POSTAVLJANJE DETEKTORA DIMA U PET VODEĆIH STANDARDA

Milan Blagojević, Radoje Jevtić, Dejan Ristić

Rezime: U radu je prikazana komparativna analiza pravila za postavljanje detektora dima u pet vodećih standarda u svetu. Postoji nekoliko razloga za ovakvu vrstu analize. Prvo, pravila za postavljanje pojedinih komponenta sistema sa identičnim karakteristikama se razlikuju čak i za najjednostavnije komponente, kao što su ručni javljači požara. Drugo, pravila za postavljanje detektora u pojedinim primenama su detaljno objašnjena u nekim standardima, dok su drugim data samo u nekoliko rečenica. Najзад, bez obzira na činjenicu da su nacionalni standardi obavezujući u smislu primene, za projektante je važno da znaju na koji način je identičan problem rešen u drugim standardima. U radu su prikazane razlike u osnovnim pravilima za postavljanje detektora dima koja su data u standardima EN 54-14, VDE 0833-2, BS 5839-1, НПБ 88 i NFPA 72.

Ključne reči: projektovanje sistema za dojavu požara, detektori dima, standardi.

DARKO ZIGAR¹
NIKOLA MIŠIĆ²
ACA BOŽILOV³
DUŠICA PEŠIĆ⁴

^{1,2,3,4}University of Niš,
Faculty of Occupational Safety in Niš

¹darko.zigar@znrfak.ni.ac.rs

²nikola.misic@znrfak.ni.ac.rs

³aca.bozilov@znrfak.ni.ac.rs

⁴dusica.pesic@znrfak.ni.ac.rs

THE ROLE OF FIRE BARRIERS IN FIRE SPREADING ACROSS BUILDING FACADE

Abstract: Nowadays the spread of fire across the facade is one of the fastest ways of spreading fire in buildings. In the world, 2-5% of residential buildings are damaged or destroyed in fires annually, and all this is accompanied by a huge number of human casualties. This number of victims comes not only directly from flame or smoke, but also from the demolition of constructions that were not prepared to withstand high temperatures that occur in fires. The paper presents an analysis of the spread of fire from the inside of a building to its facade. The analysis was carried out through an experimental numerical model of fire on the facade of the building, made of expanded polystyrene (EPS), and the development of fire spreading with and without the existence of stone wool barriers was investigated. The Fire Dynamics Simulator software package - FDS, which is based on the numerical fluid dynamics, was used for this purpose. The results of the simulation can be used in the assessment of the fire hazard depending on the spatial distribution of temperature and heat flux, for the design of thermal energy facades.

Key words: fire, facade, expanded polystyrene, fire barrier, numerical simulation.

INTRODUCTION

Today, due to the use of new building materials, and all with the aim of making the facades of the buildings more modern, bigger and more devastating fires occur. These facades are made from burning materials. One example is the fire that happened on the Grenfell Tower in London, which took 21 lives. In this case, burning materials were used as heat insulators.

When it comes to spreading fire through the window, it can be done both horizontally and vertically, but in real situations, there is much higher likelihood of vertical spread of the fire because the heated products of combustion go up and can affect the combustible and burning coatings on the facade of the building, Figure 1.

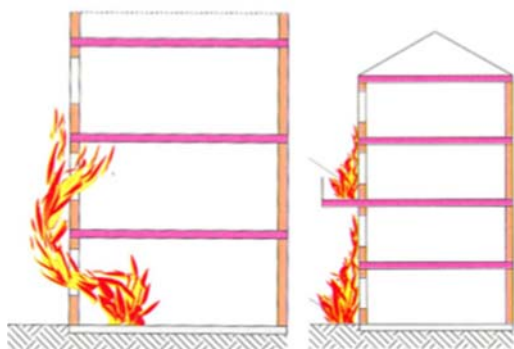


Figure 1. Vertical fire spreading through the window

Because of the high temperature and pressure inside the room, a crack appears on the windows that are above, and that leads to the ignition of combustible materials and further spread of fire. The vertical spread of fire across facade also can occur in the case of "ventilated facade", when there is a heat insulation underneath it

made of burning materials. High buildings increase the risk of this kind of fire spread, because the fire may spread to several floors above the point of fire origin, [1]. The risk of melted materials dripping or incandescent materials falling on the floors below the point of fire origin is also increased.

Wind flow also has a great influence on what is happening in front of the facade. If the wind flow can reach the room where the fire occurred, for example through the door, there is an increased release of heated combustion products and an increase in the flame length and the high temperature fields are present. Maximum temperatures occur on the upper edges of the opening. Maximum temperatures occur on the upper edges of the floor openings. This indicates that the openings on the floor above should be set further, that is, or that burning materials should not be used in close proximity.

In the horizontal direction, the flame expansion is somewhat slower, since heat energy is drain from non-flammable material. Fire spreading is faster on ceiling materials than spreading on flooring materials, because the ceiling materials are very often exposed to the ignition temperatures. A fire can be spread with a direct flame or from a heat transfer that is generated in a fire. Horizontal spreading of fire is the spreading of fire within one floor, through: fire resistant walls and doors, unprotected wall openings, windows, installations, through dropped ceilings, under double floors, etc.

When the flame exits through the window, it rises due to the large difference in temperature and threatens the upper floor, Figure 2, [2].

If the wind blows parallel to the facade, warm air and flame turns around and so they can pass to close windows.



Figure 2. Fire spreading to the floor above

The walls can be made of combustible or non-combustible materials. Only fire-resistant walls can prevent the spread of fire for a certain amount of time. Such walls must completely divide the room from floor to ceiling. The position of fire-resistant walls depends primarily on the type of facility or its purpose. In some buildings (residential, commercial, hotels, etc.) fire-resistant walls are placed at the places where it is functionally, although they can also be used as an obstacle for fire spreading, where there is a need for it.

The fire characteristics of expanded polystyrene and stone wool

Expanded polystyrene material made of polystyrene cells that are connected in a mutually homogeneous structure of thin, air-filled cavities.

The ignition temperature of this heat insulation material is 360-380°C (it is a heavily combustible, but burning material), while self-ignition temperature range from 460 to 480°C. In case of a fire of a building with this type of insulation where the temperature on the facade reaches over 900°C, ignition and burning of the material occurs, and this goes through several phases: at 85-90°C polystyrene starts to shrink; at 240-250°C polystyrene begins to melt; at 280-290°C thermal decomposition of polystyrene begins with the separation of gaseous products; at 360-380°C, polystyrene ignition occurs, at 460-480°C, polystyrene self-ignition occurs, without the presence of an open flame.

The main characteristics of stone wool are its non-combustibility and aging resistance. The essential property is the low value of the coefficient of thermal conductivity, $k=0,038\text{W/m}\cdot\text{K}$. Because of its structure and very high melting point (over 1000°C), stone mineral wool is ideal as a fire barrier in the function of fire protection, Figure 3.

Stone mineral wool does not develop flame (highest incombustibility class - A1), so it prevents the spread of fire and does not emit harmful gases that are causes of death in fires in 89% of cases.

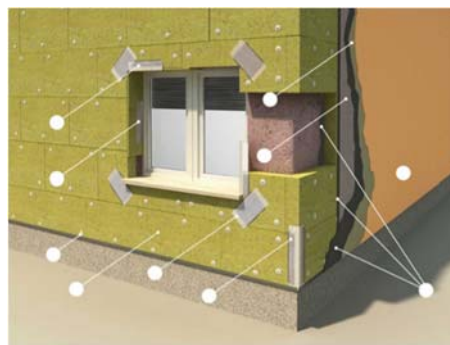


Figure 3. Elements of a facade system with stone wool

MATERIALS AND METHODS

Physical testing methods of fire spread across façade

In practice, there are many experiments involving burning of facade coatings, with the aim of understanding the difference in reaction to fire, or in fire spreading across the facade coating, [3]. These tests are performed on apparently identical samples, but with different types of thermal insulation materials.

- Sample 1 is a thermal insulation of expanded polystyrene (EPS) with a 15 cm of thickness, reaction to fire class B-s2, d0.
- Sample 2 is a thermal insulation of expanded polystyrene (EPS) with a 15 cm of thickness, reaction to fire class B-s2, d0, with a horizontal stone wool fire barrier with a 20 cm of thickness placed above the opening.
- Sample 3 is a non-combustible thermal insulation of stone wool with a 15 cm of thickness, reaction to fire class A2-s1, d0, Figure 4.



Figure 4. Samples before and after the beginning of the testing process

The testing showed that the facades constructed of expanded polystyrene (EPS) – sample 1, the most common facades made of inexpensive thermal insulation material, completely burned. Sample 2, with a horizontal barrier of non-combustible stone wool, slowed the spread of the fire; however, if firefighters need more than ten minutes for intervention and fire extinguishing, the flame will bypass the horizontal barrier and continue the vertical spread along the facade. The great dangers that can occur during the burning of samples 1 and 2 are burning droplets and black toxic smoke, which can lead to death and health damage, and also may impede evacuation and rescue. As for the sample 3 where stone wool was used, it remained undamaged. More precisely, only the final layer burnt, and after that, due to the non-combustible thermal insulation, there was not any further spreading of fire. After detailed analysis of the testing, the stability and compactness of stone wool was determined.

Mathematical models of fire spreading through openings

Flame projection through a windows opening

In order to calculate the amount of heat transfer from the flame of the fire along the external facade, it is necessary to determine the shape and size of the flame that comes out of the window and the temperature distribution within the flame. A flame, which leaves the room through a window, depends on a number of factors: the wall above the window itself, the shape and size of a window, and others effects that affect the temperature distribution. In case of a wide window, the flame projects along the facade and the fire attaches to the wall above the window, and in case of a narrow window it does not lean on the wall. The flame comes out of the neutral plane and strives to expand from the upper two thirds of the window, Figure 5, [4].

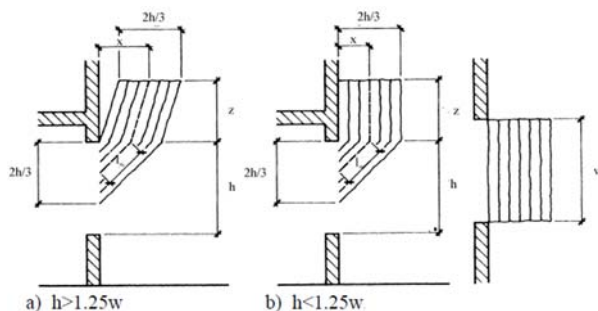


Figure 5. Flame projection depending on the window opening height h and width w ration, without forced air flow

The height of the flame, in case that there is no forced air flow, is calculated by the following equation:

$$Z = 12,8 \left(\frac{\dot{m}}{w} \right)^{\frac{2}{3}} - h \quad (1)$$

where, h is height of the window opening, $\dot{m}$ is combustion speed, a w is width of the window opening.

Heat spreading on the exterior facade walls

In the event of a fire in enclosed spaces, there is a gradual increase in temperature and heat in all objects in that area, as well as in all parts of the building such as walls, windows, floor, ceiling, etc. The temperature of the products of combustion is increasing over time, which leads to the increasing of pressure, cracking of window glass, walls and doors destruction and the vertical and horizontal spreading of fire. At the point of windows glass or door breaking, instantaneous combustion of present gases occurs in the form of flame, which exits the room under pressure and spreads to the external wall coatings. The total heat flux from the outer wall is defined as the sum of the intensities of both the convective and the radiation components to the exposed wall.

Figure 6 shows a summary heat transfer distribution by conduction, convection and radiation to the surface of the wall above the window opening.

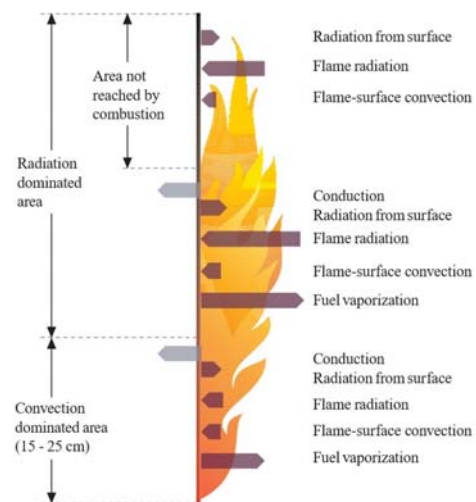


Figure 6. Heat transfer distribution by conduction, convection and radiation to the surface of the wall above the window opening

At the bottom, the dominant heat transfer is achieved by convection, while in the middle part, by radiation as a result of the upward flame spread. There is no combustion in the upper part of the wall (covering). The flame spread along the surface of the wall depends on: the thermal inertia of the material, the surface orientation, the surface geometry and the surrounding environment.

Flame projection transfers heat to the façade by convection, and so heat transfer by convection can be expressed as:

$$\dot{q}_c = \alpha(T_F - T_w) \quad (2)$$

where α Convective heat transfer coefficient ($\text{W}/\text{m}^2\cdot\text{K}$), T_F is flame temperature (which depends on the position above the window (K) and T_w is wall coating temperature (K). Convective heat transfer coefficient α depends on mass flow per unit surface $u\dot{m}$, hot gases, size and characteristics of the receiving surface.

Spreading heat by radiation

The thermal radiation of the flame through the window is a function of the geometry, temperature and emissivity of the flame. The expression for the net heat emitted by flame radiation, I , is:

$$I = \varepsilon_f \varepsilon_w \sigma (T_F^4 - T_w^4) \quad (3)$$

where ε_f is the emission of flame, ε_w the radiation emission of the wall, σ is the Stefan-Boltzman constant ($5,67 \times 10^{-11} \text{ kW/m}^2 \cdot \text{K}^4$). The outer wall emission, ε_w , will depend on the lining of the outside of the wall. The flame emission, ε_f , depends on the flame characteristics itself (flame thickness), λ :

$$\varepsilon_f = 1 - e^{-0,3\lambda} \quad (4)$$

Oleszkiewicz modified the shape of the flame and approximated it to the shape of a triangle, Figure 7, [4]. According to his assumption, the thickness of the flame near the top is two thirds of the height of the window.

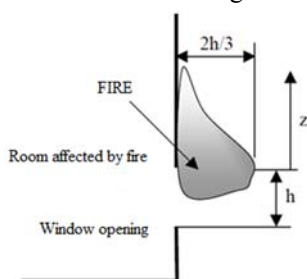


Figure 7. The assumed shape and thickness of the flame according to Oleszkiewicz

The variable thickness of the flame above the window will be calculated as:

$$\lambda = \frac{2}{3} h \left(\frac{z - h_w}{z} \right) \quad (5)$$

Numerical modeling of fire spreading across façade

Applying software package Fire Dynamics Simulator – FDS, which is based on numerical fluid dynamics, distribution of heat flux and surface temperature on façade was recorded.

Numerical model setup for simulating fire spreading across façade

Scenario applied in work, implies the spread of fire from room interior through a façade opening, size 1.2x1.2m. The building façade is isolated from outside with the ESP (10cm) and with 3mm plasteboard, Figure 8a. It is particularly simulated the case with the existence of a fire barrier of the stone wool, Figure 8b, which is placed along the upper edge of the window opening.

In the simulation of the fire is considered a single-storey building measuring 5,4x4,4x6,4m. The room where the fire is simulated is with closed door, one hole on the façade and without the presence of forced ventilation, Figure 8c. There is no upper floor terrace above the opening of the room affected by the fire. Dimensions of the room where the initial fire is 5x4x3m. The simulation

was carried out without the existence of wind, at normal ambient pressure and at a temperature of 20°C.

To initialize a fire, burner was used, size 0.4x0.4m with heat release rate of 880kW, placed on a couch. For simulation, an adequate resolution of the numerical mesh for calculation was used (0.1x0.1x0.1m), which is in line with the recommendations about validity for using FDS calculations. To record temperature and heat flux, sensors are placed above and to the side of the facade opening at every 0.2m, starting from the edge of the opening. The temperature and heat flux values are recorded up to 1.8m in height above the opening, while side-by-side values are recorded up to 1.0m from the edge of the window, as shown in Figure 8. Duration of the simulation is 20 minutes, which corresponds to the time that the fire is fully developed, i.e. when HRR (Heat Release Rate) reaches maximum and begins to decline.

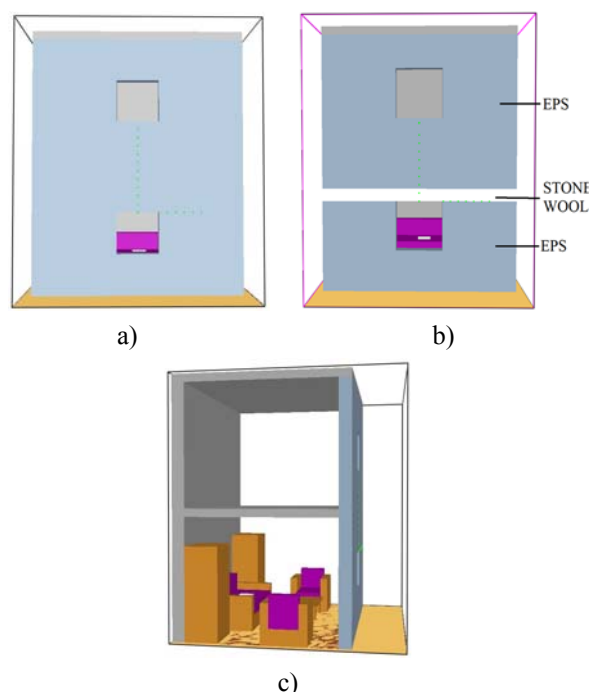


Figure 8. a) Simulation model without fire barrier; b) with fire barrier; c) arrangement of furniture inside the building

RESULTS AND DISCUSSION

The results of numerical simulations of fire spreading across the façade made from ESP, with and without fire barrier, for temperature and heat flux values, above and by side of the opening, are shown in Figure 9.

By analyzing the numerical simulation results, it is noted that as the distance from the opening increases, the temperature decreases, both in height and by side from the opening in both analyzed cases.

The temperature along the wall above the opening up to a height of 0.2m after the 100s duration of the fire is higher than 380°C, which is the ignition temperature

ESP. The value of heat flux increases as a function of the period of duration of a fire inside a room.

In case of a fire barrier, after 15s from beginning of fire, it can be seen that the temperature above the opening at 0.4m does not exceed 100°C, Figure 9. Right after 200s duration of fire temperature reaches 300°C which represents a potential risk of burning EPS. Similarly applies to the temperature by side of the opening, where fire barrier of stone wool also prevents the spread of fire in a short time interval, so for a height of 0.4 m the temperature will reach over 300°C after 400s.

The impact of heat flux on ignition of thermal insulation materials on the facade is in the function of the time exposure to this effect. If time exposure to the heat flux is longer, it is greater possibility of the occurrence and

fire spreading of fire on the facade. EPS can be ignited if the exposure level is 30kW/m² for about 15min, or 40kW/m² for about 4min. The risk of ignition EPS is more pronounced above the opening on the facade, rather than by side of the opening.

In case of a fire barrier, heat flux values at a height of 0.2m for 400s is 80.00kW/m², while the heat flux measured by sensors arranged by side from the opening, at a height of 0.2m is 35.00kW/m². Heat flux value increases as function of the time period during fire duration in the room, so it is necessary to reduce the influence of temperature and heat flux on the facade coatings for thermal insulation by fire fighting.

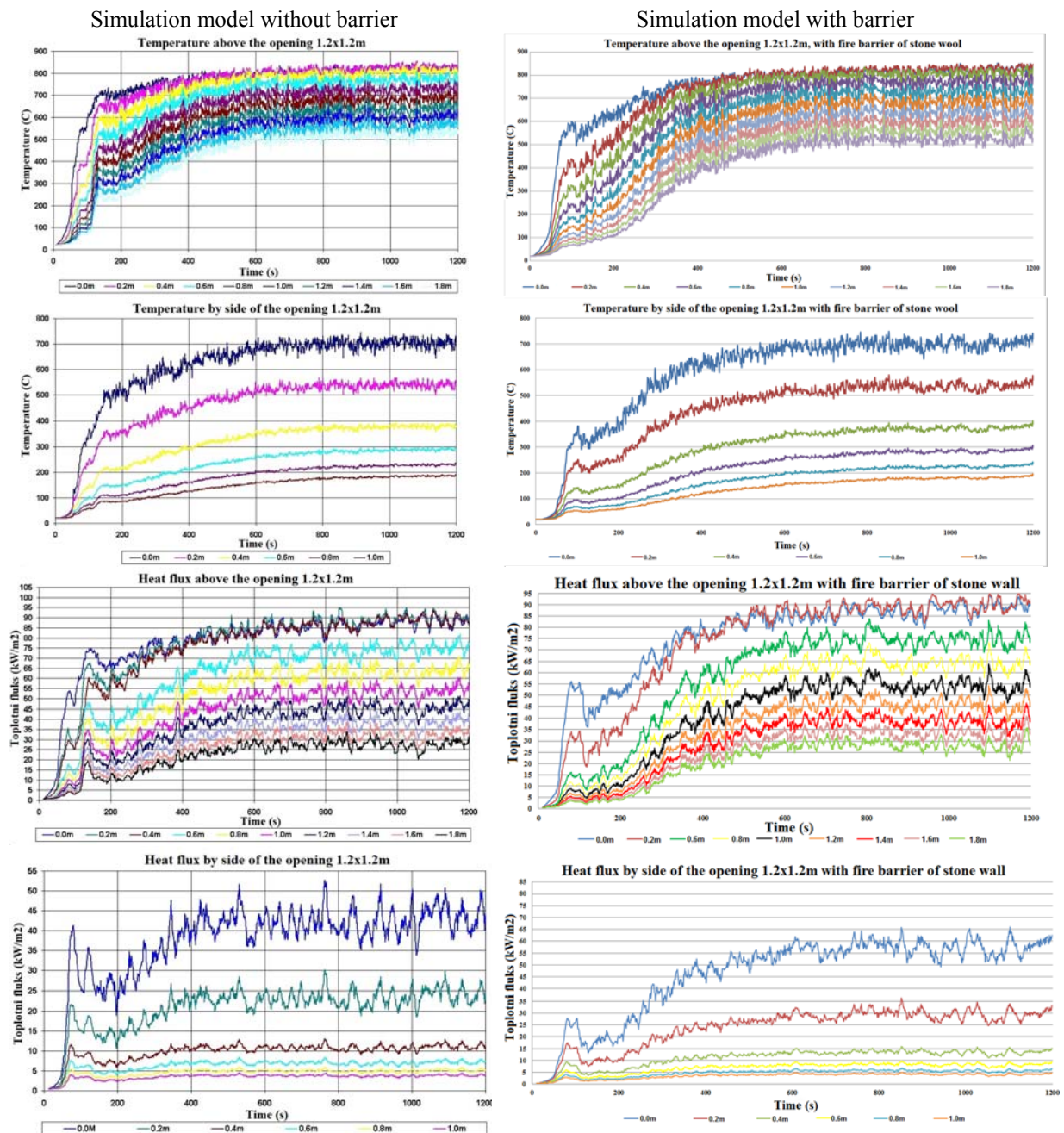


Figure 9. Numerical simulation results

CONCLUSION

The material composition of the facade has been identified as a key factor in the risk of fire. Materials for thermal insulation must satisfy the necessary fire resistance. The spread of fire along the facade of building can be limited if the EPS is coated on outside with material that is thermally resistant to fire for a certain period of exposure time to the heat flux.

Preventive construction measures are reflected in the installation of barriers from non-combustible materials around the holes on the building facade and between the building floors. In the case of fire over facades, if facade is made from flammable elements, very high temperatures would develop very quickly, which would result in the rapid spread of fire on the facade itself, whereas in the case of non-flammable facade elements or barriers constructed from stone wool, incubation would occur, and it would take much more time to reach such high temperatures, which would enable the prevention of fire spreading with the timely response of firefighters. These simulation results can be used in the fire hazard assessment in design phase of thermal energy facades, for the reason that they point to the spatial distribution of temperature and heat flux on the surface of the facade of a thermally insulated object.

REFERENCES

- [1] D. Rački, Gašenje viših objekata upotrebom visokog tlaka, završni rad, veleučilište u Karlovcu, odjel sigurnosti i zaštite stručni, studij zaštite od požara, 2015.
- [2] Ljerka Kopričanec-Matijevac, Mjere zaštite od širenja požara unutar građevine te prijenosa s građevine na građevinu. Zagreb, 2014.
- [3] M. A. Dubravka Bjegović, Ivana Banjad Pečur, Bojan Milovanović, Marija Jelčić Rukavina, "Ponašanje fasadnih sustava s različitim toplinsko izolacijskim materijalima u požaru," Infogr. - časopis studenata Građevinskog Fak., no. 9 (1334-5286), pp. 40-47, 2015.
- [4] Felix Nyuk Poh Bong, FIRE SPREAD ON EXTERIOR WALLS, no. February. Christchurch, 2000.

ACKNOWLEDGEMENTS

This paper was supported by projects III43011, III43012 and III43014 of the Ministry of Education and Science of Republic of Serbia.

BIOGRAPHY of the first author

Darko Zigar was born on April 16, 1973. in Pančevo, Serbia. He received B.Sc. degree in Environmental Protection and M.Sc. degree in Occupational Safety in 2002 and 2007 respectively, from University of Niš, Serbia. He has been with the Faculty of Occupational Safety, University of Niš, since 2008., where he is working as a researcher / assistant lecturer. In 2015, he received his doctorate and became an assistant professor at the same faculty. His areas of expertise include numerical fire simulations, as well as investigations of possible adverse effects of electromagnetic field irradiation from mobile phones and wireless systems.



ULOGA POŽARNIH BARIJERA U ŠIRENJU POŽARA PREKO FASADE OBJEKTA

Darko Zigar, Nikola Mišić, Aca Božilov, Dušica Pešić

Rezime: Širenje požara preko fasade danas predstavlja jedan od najbržih puteva širenja požara u objektima. U svetu u požarima godišnje bude oštećeno ili uništeno 2-5% stambenih zgrada, a sve to je praćeno ogromnim brojem ljudskih žrtava. Ovaj broj žrtava nastrada ne samo direktno od plamena ili dima, već i od rušenja konstrukcija koje nisu bile pripremljene da izdrže visoke temperature koje nastaju u požarima. U radu je prikazana analiza širenja požara sa unutrašnje strane na fasadu objekta. Analiza je sprovedena kroz eksperimentalni numerički model požara na fasadu objekta, izrađenu od ekspaniranog polistrena (EPS), pri čemu se istraživao razvoj širenja požara sa i bez postojanja požarne barijere od kamene vune. U tu svrhu koristio se softverski paket Fire Dynamics Simulator - FDS, zasnovan na numeričkoj dinamici fluida. Rezultati simulacije mogu se koristiti u proceni opasnosti od požara u zavisnosti od prostorno vremenske raspodele temperature i toplotnog fluksa, pri projektovanju termoenergetskih fasada.

Cljučne reči: požar, fasada objekta, ekspanirani polistren, požarna barijera, numerička simulacija.

IGOR APPOLINAREVICH
KAIBICHEV¹

¹Ural Institute of State Fire Service of
EMERCOM of Russia

kaibitchev@mail.ru

WORLD INDEX OF AVERAGE NUMBER OF INHABITANTS PER ONE CAREER FIREFIGHTER

Abstract: The world index of average number of inhabitants per one professional firefighter is presented. The calculation is largely similar to the method of calculating the Dow Jones index used in the stock market. 30 countries are included in the calculation of the average number of inhabitants per professional firefighter. The index value was calculated as the arithmetic mean. The calculation of the world index of the average number of inhabitants per one professional firefighter was made in 2015.

Key words: world fire statistics, average number of inhabitants per one career firefighter.

INTRODUCTION

Stock indices are used to assess the investment attractiveness of companies [1]. The companies included in the indices are chosen on a particular basis. Afterwards, based on the share prices, the index value is calculated according to a certain procedure. Changes in the index over time give grounds for determining the general direction of movement of stock prices. In the case of the index increase, the stocks of most companies included rise as well.

The most well-known stock market index is the industrial Dow Jones index [2]. The index includes the shares of 30 largest companies in the USA from various industries: finance, transport, consumer, food and industrial sectors.

Analogues to the Dow Jones index were developed in fire statistics for the number of fires [3], as well as the number of deaths from fires [4].

A world index of the number of professional firefighters was also proposed [5,6].

We consider it important to develop a global index of the average number of residents per professional firefighter.

INDEX CALCULATION

The calculation method in case of professional firefighters is similar to the Dow Jones index [2]. To calculate this index, share prices of the 30 largest companies in the USA are used. We replaced the industrial corporations with 30 countries. The value of the Dow Jones index is equal to the arithmetic mean of corporate stock prices. Therefore, we replaced the stock price of corporations with the average number of inhabitants per one professional firefighter.

In the Dow Jones method, the list of corporations is fixed. When calculating the index of the average number of inhabitants per one professional firefighter, the list of countries will be provisional. The listing of the index calculation (Tab. 1) includes 30 countries with the maximum number of inhabitants per one

professional firefighter. The value of the index is equal to the arithmetic mean. The statistics used for calculations is [7].

Table 1. The list of average number of inhabitants per one professional firefighter (index calculation)

N	Country	Average number of inhabitants per one career firefighter
1	Laos	26730
2	China	10168
3	Vietnam	8129
4	Switzerland	7279
5	Iran	6893
6	Albania	4974
7	Israel	4333
8	Singapore	3846
9	Netherlands	3471
10	Austria	3400
11	Ireland	3153
12	Finland	3120
13	Denmark	3045
14	Taiwan	2744
15	Portugal	2683
16	Malaysia	2666
17	Moldova	2573
18	New Zealand	2512
19	Slovenia	2428
20	Serbia	2268
21	Italy	2113
22	Sweden	2008
23	Belgium	1933
24	Germany	1845
25	South Korea	1633
26	France	1612
27	Great Britain	1530
28	Slovakia	1447
29	Cyprus	1388
30	Norway	1374
Average number of inhabitants per one career firefighter world index		4110

CONCLUSION

The situation with the countries referred to in the list of indices (Tab. 1) is troublesome. One professional fireman is assigned to rather large number of the inhabitants.

By means of index, it is possible to select the crisis group. Also, it is reasonable to include the country with the number of the inhabitants per one professional fireman with more or equal importance of the index.

The crisis group in 2015 included 7 countries: Laos, China, Vietnam, Switzerland, Iran, Albania, and Israel.

The paper developed a global index of the average number of inhabitants per one professional firefighter. The calculation of the world index of the average number of inhabitants per one professional fireman was done in 2015.

REFERENCES

- [1] Stock market index. - <http://en.wikipedia.org> – Stock market index - Wikipedia.
- [2] Dow Jones Industrial Average. - <http://en.wikipedia.org> - Dow Jones Industrial Average - Wikipedia.
- [3] Kaibichev I.A., Kaibicheva E.I. "Fire number index in rural terrain in Russian Federation for 2006-2010 years", Safety engineering in function of improvement of the working conditions, Proceedings, Ohrid, 10 – 12 of May, 2013, Republic of Makedonia, "St. Cyril and Methodius" University in Skopje, Faculty of Mechanical Engineering, Ohrid, 2013, pp. 136-140.
- [4] Kaibicheva E.I., Kaibichev I.A. "Index numbers of those killed in fires in rural areas of the Russian Federation in the 2006-2010 period", Facta Universitatis, 2013. Vol. 10, N 2, pp. 93-98.
- [5] Kaibichev I.A., Kaibicheva E.I. "Index of professional fireman number in world", Fire and explosion safety, 2015, Vol. 24, № 9, pp. 55-58. DOI: 10.18322/PVB.2015.24.09.55-58.
- [6] Kaibichev I.A., Kaibicheva E.I. "World index of professional firefighters' number in 2010-2014 years", Bulletin of Kokshetau technical Institute of CoES, the Ministry of Internal Affairs of the Republic of Kazakhstan, 2017, № 2 (26), pp. 45-50.
- [7] Brushlinsky N.N., Ahrens M., Sokolov S.V., Wafner P. "World Fire Statistics", CTIF, International association of fire and rescue services. Center of fire statistics, 2017, N 22, 56 p.

ACKNOWLEDGEMENTS

I thank the organizers of the 18th International Conference - Man & Working Environment - 50 Year of Higher Education, Science and Research in Occupational Safety Engineering for the invitation.

BIOGRAPHY of the first author

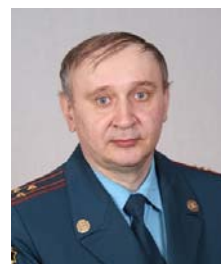
Igor Appolinarevich

Kaibichev was born in

Sverdlosk, Russia, in 1960.

He received the diploma in physics and the Candidate degree in physics and mathematics from the Ural State University named after A. M. Gorky.

He received the Doctor degree in physics and mathematics from the Institute of Radio Engineering and Electronics of RAS. His main areas of research include: surface elastic, magnetostatic and magnetoelastic waves in solids, interelectrode ion transport from metal melts, fire statistics, mathematical forecasting. He is currently working as an associated professor at the Ural Institute of State Fire Service of EMERCOM of Russia.



GLOBALNI INDEKS BROJA STANOVNIKA NA JEDNOG PROFESIONALNOG VATROGASCA

Kaibichev Appolinarevich Igor

Rezime: U radu je prikazan svetski indeks prosečnog broja stanovnika koji dolazi na jednog profesionalnog vatrogasca. Metoda proračuna je veoma slična metodi za izračunavanje Dau Džons indeksa koja se koristi na berzi. Dat je primer 30 zemalja za koje je izračunat prosečan broj stanovnika na jednog zaposlenog vatrogasca. Izračunata vrednost indeksa je aritmetička sredina. Kalkulacije globalnog indeksa prosečnog broja stanovnika na jednog profesionalnog vatrogasca su urađene 2015. godine.

Ključne reči: svetska statistika o požarima, prosečan broj stanovnika na jednog profesionalnog vatrogasca.

IVAN TODOROV¹
HRISTO PRODANOV²

¹Academy of the Ministry of Interior,
Faculty of Fire Safety and Civil
Protection, Sofia, Bulgaria

²Academy of the Ministry of Interior,
Faculty of Fire Safety and Civil
Protection, Sofia, Bulgaria

¹itodorovfpab@gmail.com
²hristoprodanov97@gmail.com

THEORETICAL STUDY OF THE POSSIBLE APPROACHES FOR EVALUATION OF THE FIRE RESISTANCE OF STEEL COLUMNS ACCORDING TO EN 1993-1-2

Abstract: *On the basis of literature study of the implementation of EN 1993-1-2 for the evaluation of the fire resistance of steel columns, four different approaches for the implementation have been highlighted. The theoretical study of these approaches is conducted on given example. Comparison of the obtained results has been performed.*

Key words: fire resistance, steel columns, simple calculation model, y tong®, gypsum fiber

INTRODUCTION

The strategy for evaluation of the fire resistance, set out in the Eurocodes, allows the use of one of the following three rules:

1. Time: $t_{fi,d} \geq t_{fi,requ}$
2. Load-bearing capacity: $R_{fi,d,t} \geq E_{fi,d,t}$
3. Temperature: $\theta_d \leq \theta_{cr,d}$

On the basis of the above mentioned rules (criteria), and based on the performed literature review of scientific works in this field [5], four different approaches for the evaluation of the fire resistance of steel columns can be highlighted, as follows:

First approach. Evaluation of the load-bearing capacity $R_{fi,d,t}$ of the steel column for the whole

period of heating in case of fire event $0 \leq t_d \leq t_{cr}$

Second approach. Evaluation of the load-bearing capacity $R_{fi,d,t}$ for given moment $t = t_{fi,requ}$

Third approach. Evaluation of the fire resistance t_{fi} using the critical temperature method θ_{cr}

Fourth approach. Evaluation of the fire resistance t_{fi} using the critical temperature method θ_{cr} through iterations.

PURPOSE

The purpose of the research is, for given example, to test the implementation of the different approaches for evaluation of the fire resistance of steel columns according to EN 1993-1-2.

EVALUATION OF THE FIRE RESISTANCE OF STEEL COLUMN, SUBJECTED TO AXIAL COMPRESSION

For the purpose of the article the following example has been used:

- steel columns, subjected to axial compression;
- the columns is attached to the foundation and, its head is articulated along the Y-Y axis, and stamped along the Z-Z axis;
- columns length - $H=8$ [m];
- axil load - $N_d=2000$ [kN];
- $E_a=210000$ [N/mm²];
- $f_y=235$ [N/mm²]; $\varepsilon = \sqrt{235 / f_y} = 1$.
- cross section type - HEB300;
- cross sectional area $A=149$ [cm²];
- dimensions - $h=300$ [mm], $t_w=11$ [mm], $b=300$ [mm], $t_f=19$ [mm], $I_y=25170$ [cm⁴], $i_y=13$ [cm], $i_z=7,58$ [cm];
- thermal properties of the steel – unit mass $\rho_a=7850$ [kg/m³]; specific heat $C_a=600$ [J/kg.°C].
- thermal properties of the insulation materials – gypsum fiber ($\rho_p=800$ [kg/m³], $C_p=1700$ [J/kg.°C], $\lambda_p=0,2$ [W/m.°C]) and YTONG ($\rho_p=500$ [kg/m³], $C_p=1050$ [J/kg.°C], $\lambda_p=0,16$ [W/m.°C]);

For the given example the methodology for the evaluation of the load-bearing capacity of insulated steel columns in case of fire, developed in [3,4], was implemented. All of the above mentioned approaches for the evaluation of the fire resistance require the evaluation of the development of the temperature field in the cross section of the columns. The results for the development of the temperature field in the steel column insulated by gypsum fiber and YTONG are presented on fig. 1.

All results were obtained using eq.1.

$$\Delta\theta_{a,t} = \frac{\lambda_p \cdot A_p / V \cdot (\theta_{g,t} - \theta_{a,t})}{d_p \cdot C_a \cdot \rho_a \cdot (1 + \phi/3)} \cdot \Delta t - (e^{\phi/10} - 1) \cdot \Delta\theta \quad (1)$$

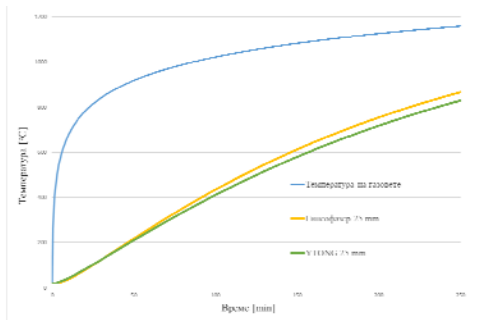


Figure 1. Development of the temperature field in the steel cross section, insulated by gypsum fiber and YTOG with thickness 25 mm.

FIRST APPROACH

After the calculations performed in the strength and deformation domain, using equations (2-5), the obtained results for the development of the load bearing capacity of the insulated steel column are presented on figure 2.

$$\alpha = 0,65 \sqrt{\frac{235}{f_y}} \quad (2)$$

$$\bar{\lambda}_\theta = \bar{\lambda} \left(\frac{k_{y,\theta}}{k_{E,\theta}} \right)^{0,5} \quad (3)$$

$$\varphi_\theta = 0,5 \left(1 + \alpha \bar{\lambda}_\theta + \bar{\lambda}_\theta^2 \right) \quad (4)$$

$$\chi_{fi} = \frac{1}{\varphi_\theta + \sqrt{\varphi_\theta^2 - \bar{\lambda}_\theta^2}} \quad (5)$$

$$N_{b,fi,Rd} = \frac{\chi_{fi} \cdot A \cdot k_{y,\theta} \cdot f_y}{\gamma_{M,fi}} \quad (6)$$

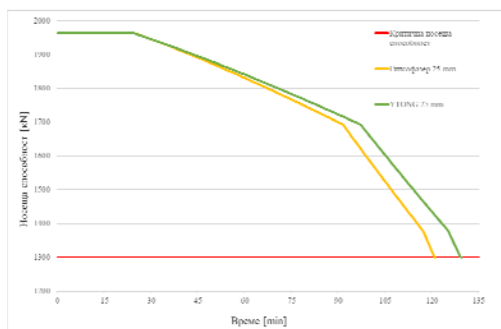


Figure 2. Comparison between the load bearing capacity in case of fire for steel columns, insulated by gypsum fiber and YTOG with thickness 25 mm.

The presented on figure 2 results show that the fire resistance of the column, insulated by gypsum fiber is 121 min for the value of the critical temperature of 513,9 °C, The fire resistance of the steel column, insulated by YTONG is 129,5 (critical temperature - 514,2 °C). The fire resistance of the non-protected column is 18,2 min (critical temperature - 513 °C), which means that the applied fire protection has increased the fire resistance more than six times for both protection materials.

SECOND APPROACH

Table 1. Values for the evaluation of the fire resistance of the insulated steel columns, using the second approach

	Fire protection	$\theta_{a,t}$ [°C]	$N_{b,fi,t,Rd}$ [kN]	$\Delta N_{b,fi,t,Rd}$ [%]
240	Gypsum fiber	845,65	165,44	91,57
	YTONG®	808,65	193,15	90,16
210	Gypsum fiber	778,64	233,57	88,10
	YTONG®	741,71	289,53	85,25
180	Gypsum fiber	728,35	309,18	84,25
	YTONG®	692,10	383,97	80,44
150	Gypsum fiber	612,36	721,44	63,25
	YTONG®	579,46	898,85	54,21
120	Gypsum fiber	510,23	1316,44	32,94
	YTONG®	482,08	1434,82	26,91
90	Gypsum fiber	393,93	1699,59	13,42
	YTONG®	372,90	1722,60	12,25
60	Gypsum fiber	263,67	1830,59	6,75
	YTONG®	252,32	1840,81	6,23
30	Gypsum fiber	124,02	1945,47	0,90
	YTONG®	124,06	1945,44	0,90

It can be stated from the implementation of the second approach for evaluation of the fire resistance of steel columns, that in both cases the steel columns can fulfill the requirements for R120.

THIRD APPROACH

Eurocode 3 gives permission as an alternative to the calculations in the strength and deformation domain to be implemented the critical temperature method. According to 4.2.4 (3) from [2], for elements with cross section of class 1, 2 and 3, the degree of utilization to be obtained by the following equation:

$$\theta_{a,cr} = 39,13 \ln \left[\frac{1}{0,9674 \cdot 0,66^{3,833}} - 1 \right] + 482 = 536,5 \text{ [°C]} \quad (7)$$

$$\mu_0 = \frac{N_{fi,d}}{N_{b,fi,0,Rd}} = \frac{1300}{1963,081} = 0,66 \quad (8)$$

Using the results, presented on figure 1, the fire resistance of the steel column is 127,5 min and 136,5 min, for the columns insulated by gypsum fiber and YTONG respectively.

FOURTH APPROACH

The main problem for the implementation of the critical temperature method (analysis in the temperature domain) for steel columns is that their load bearing capacity in case of fire is not directly proportional to their yield strength. In this case it depends on the reduction factor for flexural buckling, which is also temperature dependent, and is dependent on three more parameters - (α , $k_{y,\theta}$, $k_{E,\theta}$), which must be taken into

consideration when evaluating $\bar{\lambda}_\theta$ and φ_θ . The problem may be solved using iterative procedure. For the given example, using value for the degree of utilization $\mu_0 = 0,66$, according to table 4.1 from [2], we obtain that the value for the critical temperature of $\theta_{a,cr} = 536,33$ °C. The value of the reduction factor for flexural buckling is obtained for this critical temperature and the results from the iterative procedure are presented in table 2.

Table 2. Iterative procedure for the evaluation of the fire resistance of steel column, using the critical temperature method

θ_a [°C]	$k_{y,\theta}$	$k_{E,\theta}$	$\bar{\lambda}_\theta$	χ_{fi}
20	1	1	0,787	0,561
536,33	0,667	0,495	0,914	0,496
511,55	0,744	0,567	0,902	0,502
514,2	0,736	0,559	0,903	0,502

θ_a [°C]	$N_{b,fi,0,Rd} = \chi_{fi} \cdot A \cdot f_y$ [kN]	$\mu_0 = \frac{N_{fi,d}}{N_{b,fi,0,Rd}}$	$\theta_{a,cr}$ [°C]
20	1963,081	0,66	536,33
536,33	1737,57	0,75	511,55
511,55	1758,34	0,74	514,2
514,2	1756,35	0,74	513,95

After the last iteration the obtained value of the critical temperature is $\theta_{a,cr}$ of 514 °C, which according to figure 1 is reached after 121,5 minutes (for gypsum fiber) and 129,5 minutes (YTONG).

The results obtained using the different approaches are presented in table 3.

Table 3. Comparison of the results, obtained using the different approaches for the evaluation of the fire resistance of steel columns.

Approach	Fire protection	Critical temperature [°C]	Fire resistance [min]	$\Delta\theta_{cr}$ [%]	Δt [%]
1	Gypsum fiber	513,86	121	-	-
	YTONG	514,18	129,5	-	-
2	Gypsum fiber	513,05	120,83	-0,16	-0,14
	YTONG	506,58	127,55	-1,48	-1,51
3	Gypsum fiber	536,5	127,5	4,41	5,37
	YTONG	536,5	136,5	4,34	5,41
4	Gypsum fiber	514	121,5	0,03	0,41
	YTONG	514	129,5	-0,04	0,00

SUMMARY

The performed numerical study allows for the results, obtained from the implementation of the different approaches for the evaluation of the fire resistance of steel columns to be summarized as follows:

- although being most labor-intensive, the first approach gives the most complete picture of the temperature development and the decrease of the load bearing capacity of the steel columns for the full duration of the fire. That is why it can be considered as fundamental and serve as a basis for comparison with the results obtained using the other approaches;
- the closest results to the results obtained using the first approach gives approach 4, and in all cases examined the error is below 1%;
- after the fourth approach, the closest results to approach 1 gives approach 3, but they are not in favor of security, and in the examples examined, the error varies from 4-7%;
- the application of the second approach may receive wide-spread application in design practice, but there are limitations with respect to classifications for fire resistance of steel columns - must be greater than or equal to 30 min (specific requirement in the Bulgarian legislation).

CONCLUSION

The report presents a test of the different approaches for the evaluation of the fire resistance of steel column according to EN 1993-1-2. For a given example of protected steel column, subjected to axial compression, the results from the implementation of the different approaches have been obtained. The comparison of the results has been made.

The results from the study are successfully implemented in the discipline "Fire resistance and fire protection of building constructions", which is a part of the study curriculum in the BSc and MSc programs at the Faculty of Fire Safety and Civil Protection - Academy of the Ministry of Interior, Bulgaria.

REFERENCES

- [1] Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
- [2] БДС EN 1993-1-2:2005 Еврокод 3: Проектиране на стоманени конструкции. Част 1-2: Основни правила. Проектиране на конструкции срещу въздействие от пожар.
- [3] Тодоров Ив., Хр. Проданов, Узунова Д. Определяне границата на огнеустойчивост на стоманени колони, защитени с гипсофазер. С., Сборник доклади от Седмата научна конференция с международно участие „Гражданската безопасност 2014“, 2014
- [4] Тодоров Ив., Хр. Проданов. Опростен изчислителен метод за определяне на границата на огнеустойчивост на стоманени колони съгласно БДС EN 1993-1-2:2005, Сборник доклади от Седмата научна конференция с международно участие „Гражданската безопасност 2014“, С., 2014
- [5] Franssen J.M., Real P.V., Fire Design of Steel Structures, WILEY

BIOGRAPHY of the first author

Assoc. prof. Ivan Todorov, PhD was born in Chirpan, Bulgaria, in 1960.

He received the diploma in fire safety engineering and Ph.D. degree from the Academy of the Ministry of Interior, Faculty of Fire Safety and Civil Protection in Sofia, Bulgaria.

His main areas of research include fire resistance and fire protection of building constructions, etc.

His recent position is Dean of the Faculty of Fire Safety and Civil Protection at the Academy of the Ministry of Interior in Sofia, Bulgaria.



TEORIJSKA STUDIJA MOGUĆIH PRISTUPA ZA ODREĐIVANJE VATROOTPORNOSTI ČELIČNIH GREDA PREMA EN 1993-1-2

Ivan Todorov, Hristo Prodanov

Rezime: Pregledom dostupne literature o primeni standarda EN 1993-1-2 koji se odnosi na procenu otpornosti na požare čeličnih greda, izdvojena su četiri različita pristupa. U radu je prikazano teorijsko razmatranje različitih proračuna u slučaju primene ovog standarda na određenom primeru. Izvršeno je poređenje dobijenih rezultata.

Ključne reči: otpornost na požare, čelične grede, model kalkulacije, ytong®, gipsano vlakno.

MILE VAJKIĆ¹
BILJANA VRANJEŠ²
MLADEN TODIĆ³

IMPROVING PREVENTIVE MEASURES FOR FIRE FIGHTING IN INDUSTRIAL SYSTEMS IN B&H

¹ School of Mechanical Engineering
Prijevor,

² Faculty of Mechanical Engineering
University of Banja Luka,

³ Faculty of Mechanical Engineering
University of Banja Luka

¹m.vajkic@gmail.com

²biljana.vranjes@mf.unibl.org

³mladen.todic@mf.unibl.org

Abstract: *Fire protection measures in industrial systems are prescribed by law. Each industrial system is obliged to organize and apply the measures prescribed by the law, and to strive to improve the fire protection measures in order to reduce the degree of fire risk. Problems in the organization of fire protection in industrial systems arise from the poor implementation (non-compliance) of legal regulations, due to the inability to eliminate risks in the production process and the lack of legal definitions in fire protection system. Bearing in mind the annual number of industrial fires in Bosnia and Herzegovina (B&H), it is necessary to systematically improve fire protection measures in industrial processes. This can be achieved by: legislation, more frequent inspections, categorization of industrial systems, and cooperation with insurance companies.*

Key words: fire protection measures, industrial system, legislation, inspection

INTRODUCTION

Depending on type of technological process, industrial systems are, up to certain degree, prone to fire risk. Fires in industrial systems often occur but they are usually in low scale, easily localized, without larger material damage and danger for people. Higher scale fires with larger material damage and human i.e. fireman casualties are rare but not negligible. For that reason, prevention is required and it is necessary to make fire assessment risk in industrial systems which would increase safety level (better fire safety). After the fire assessment risk has been made, it is necessary to categorize the industrial system and determine measures which will decrease risk factors. At most times, the highest fire and explosion risk is the human factor together with technological work processes. The danger level is mostly influenced by physic-chemical material properties (inflammability and explosiveness) and treatment of material in applied process (temperature, pressure, etc.) and they are the basis for risk assessment. All other elements, adjoined facilities and installations of one industrial object are conditioned. Their construction, implementation, usage and maintenance must be subordinated to the technological processes. It is impossible to achieve and maintain security of one technological process at required level if all organizational and technical fire and explosion safety measures aren't met. In wider perspective, even the location, both micro and macro, of an object (technology) is in function of its safe use. Decreasing of fire risk in industrial systems comes from quality implemented preventive protection from fires within industrial systems. Fire risk degree would be decreased as well as the number of fires in industrial systems in B&H by constant fire safety and preventive measures improvement.

INDUSTRIAL SYSTEMS IN B&H

Technologically observed, industrial systems in B&H are represented through: heavy industry (metallurgy, metal, chemical and oil); light industry (textile, food and wood) and specific industry. Foreign investments and opening of the EU market lead to increased number of industrial systems in B&H. Industrial systems in B&H according to number of employees are set into three groups: small (up to 50 employees), medium (50-250 employees) and big systems (over 250 employees). Depending on assessed fire risk, industrial systems in B&H are set into four groups:

- systems with high level of fire risk
- systems with medium level of fire risk
- systems with low level of fire risk
- systems with no fire risk

ORGANIZATION AND IMPLEMENTATION OF FIRE SAFETY AND PREVENTIVE MEASURES IN INDUSTRIAL SYSTEMS IN B&H

Legislation

The scope of legislation in fire safety in B&H hasn't been adopted on state level yet (because of the B&H constitutional order) but instead every entity passes its individual regulations and by that, regulates the area. Both entities implemented fire safety laws harmonized with EU standards and they've also defined this area with adjoined regulations (subordinate legislation – Rulebooks). In some cases, subordinate legislations of Socialist Federal Republic of Yugoslavia (SFRY), The Republic of Serbia (SR), and Bosnia and Herzegovina B&H are used because of the absence of sublegal legislations in entities.

Fire safety and protective measures in industrial systems

Organization of preventive fire safety measures in industrial systems is defined and implemented in accordance with law regulation and categorization of the system in fire risk category within defined time lines. This organization must be coordinated with technological process in the system and follow all changes within the system. Organizing of fire safety and preventive measures in industrial systems is practiced by:

- projecting micro and macro location of the system;
- constant presence of the person responsible for fire protection;
- regular inspection done by servicing fire extinguishers and hydrant grid (once a year);
- lightening rod electrical installations inspection (once in three years);
- EX execution in electrical installations; installation and inspection of fire alarm system (once a year);
- installation and inspection of fixed fire extinguishing system for initial fire (once a year);
- regular inspection of smoke exhausting vents and ventilation systems;
- defining fire sectors.

Organizing and implementation of preventive fire safety measures is legally binding obligation for all systems. Monitoring and control of preventive fire safety measures in industrial system conducts the authorized inspection.

Implementation of fire safety and protective measures in industrial systems in B&H

The quality indicator of organization and implementation of preventive measures in industrial systems in B&H would be the number of industrial fires on annual level. Because there is no exact data about reported industrial fires on annual level, reports of authorized inspections can be used as an indicator. Inspection supervision over implementation of measures in industrial systems is organized on entity level. In the Federation of B&H this inspection supervision is complicated, jurisdiction overlapping is common (Cantonal Ministry of Internal Affairs fire safety inspection and Federal administration of civil protection) and there is no exact information about number of inspections. In RS-B&H there is an inspection of fire protection at the entity level. The existence of this inspection at the entity level has enabled control over implemented fire protection measures within industrial systems in the territory of the RS-B&H. Data (for the period 2011-2017) given by the RS-B&H Fire safety inspection department (jurisdiction over 49% of the B&H territory) have been used as demonstrators of implementation of preventive fire safety measures in industrial systems in B&H. These data are shown in table 1.

Table 1. *Inspection controls in period from 2011. to 2017. (1)*

Year	No. of controls in industrial systems	No. of nonconformities found	Percentage of nonconformities
2011	877	420	47%
2012	1160	562	48%
2013	1016	455	44%
2014	849	358	42%
2015	1040	426	40%
2016	930	349	37%
2017	997	294	29%

It is visible from the inspection data that the preventive fire safety and protection is on high level of organization in industrial systems in B&H. On the average, every third industrial system hasn't organized and implemented preventive fire safety measures. The most common imperfections are noticed in: lack of authorized fire safety and protection person; the inspection of lightening rod electric installations hasn't been done (once in three years); there is no EX execution in electric installations in EX zones; the fire alarm inspection hasn't been done; absence of fixed fire extinguishing system for initial fire; not defined fire sectors within the industrial system. On the basis of the inspection supervision data for period from 2011. to 2017., it is visible that the organization of preventive fire safety measures in industrial systems is left for the system management to run. It is also visible that industrial systems implement non expensive fire safety measures and avoid measures which imply costly investments. By perceiving the whole scope of situation regarding organization and implementation of preventive fire safety measures in industrial systems in B&H, it is reasonable to say that the problem is of systematic and not individual level. This systematic problem in implementation and organization of preventive fire safety measures in industrial systems is conditioned by great deficiency in implementation of legislation.

SYSTEMATIC DEFICIENCIES - A REASON OF BAD ORGANIZATION OF FIRE SAFETY AND PREVENTIVE MEASURES IN INDUSTRIAL SYSTEMS

The fact that deficiency in organization and implementation of fire safety and protection has been noticed in every third inspection in industrial systems shows that the problems are systematic and deeply rooted in the whole system organization. Within the system used in fire safety area today, faults which support bad organization and implementation of preventive fire safety measures are visible and have been used for presentation of implementation of preventive fire safety measures in industrial systems in B&H. These faults within the system are:

a) Educational system

There is no school subject in educational system in B&H schools which subject matter is to teach about fire prevention. By removing school subjects Civil defense and protection and Organization of work from school curriculums, students have been deprived of every possibility to learn what the fire safety means. This way, the basic culture of knowledge what the fire safety is has been lost.

b) Legislation in B&H

The fire protection legislation itself is good and well defined in both entities. The only, but huge in scope, problem for passing any legislation comes from the reason that B&H's constitutional order is very complicated but, from the expert's point of view, it is not clear why entities have separate fire protection legislations. Fire doesn't recognize borders, entities, regions, cantons and the only relevant thing for fire is the oxygen, source of ignition and fire material. In regulations which can be compared, the legislations in entities are well coordinated one to another but there are some differences in some rule books or one entity has got some rule books while the other one hasn't got them. Because of this, jurisdiction overlapping is common and that creates confusion in companies which have their business units in both entities. The biggest problem in current legislation in both entities the following can be accented: the rule book of categorization of subjects in fire danger ratings; the rule book of inspection of lightening rod electric installations; the law enforced act of Fire safety plan. The rulebook of categorization of subjects in fire risk ratings is good but its implementation is very difficult and slow. It is foreseen that categorization is done by authorized inspector who is not physically capable to do so (because of the huge number of subjects). Unaccomplished categorization in industrial system greatly slows down organization and implementation of preventive fire safety measures. The rulebook of inspection of lightening rod electric installations has a problem described as defining time lines for installation inspection. This rule book defines inspection of installations every three years regardless the age of installations and the facility. The act of Fire safety and protection in industrial system is passed by an expert and accredited organization (licensed by the authorized Ministry). After it has been made, this Act stipulates preventive and repressive fire safety measures, defines fire sectors within the system, regulates evacuation procedures, etc. The problem which appears afterwards is that once the Act has been passed it's been done by an external accredited company and as such that company is not capable of complete insight in specificity of some industrial system and that often results that stipulated preventive fire safety measures are inapplicable within the system. The second problem comes from the fact that administrative authority which controls the correctness of the Act hasn't been defined so this document is very often copied from one

industrial system to another (there is no defined control of approved organizations which use this fact and formally fulfill documentation for the industrial system but they leave out the essence).

c) Inspection supervision

The inspection supervision on the territory of RS B&H in 900 industrial systems per year is very low. The information that there are only 9 inspectors employed in the area of fire safety inspection department on the territory of RS and B&H shows the incapability of real control over implementation of preventive fire safety measures. Inspection supervision over implementation and organization of fire safety measures in industrial systems in the Federation of B&H is complicated, the jurisdiction of cantonal Ministry of Internal Affairs fire inspection overlaps with Federal civil protection department. In case when inspection supervision finds irregularity, the inspectors (according to Inspection laws and regulations) in 97% give a deadline for correction of irregularities. For very small number of found irregularities, 1-3%, the inspectors will fine systems (the responsible people) with money fines (5000 € max). This situation in Fire safety inspection department is skillfully used by management in industrial systems in order to avoid investments in fire safety measures.

d) The insurance

Insurance companies which provide insurance of facilities and machines in industrial systems make huge obstacle for improvement of general state in prevention of fire safety within industrial systems. Insurance companies according to their evaluation (they often observe economical but not the technical aspect as well) insure the facility to certain amount of money and by that the company management doesn't want to invest in preventive fire safety measures because they have already insured everything.

e) The cost of preventive fire safety measures

The company which creates fire safety documentation, provides services in fire safety area, installs fire alarm systems and fixed fire extinguishing systems, must have approval from appropriate ministry. There are about thirty companies in B&H registered and licensed by appropriate ministry department. Because of the small number of companies licensed for work in this scope, the market has become oligopolistic, i.e. these companies control price of services to gain profit as high as possible. For this situation on market, many industrial systems are not in real possibility to install adequate preventive fire safety system.

SUGGESTIONS FOR IMPROVEMENT OF FIRE SAFETY AND PREVENTIVE MEASURES IN INDUSTRIAL SYSTEMS

The improvement of fire safety and preventive measures in industrial systems can be implemented only by mutual cooperation of all subjects involved in this field. According to legislation, the organization of fire safety and preventive measures is obligatory for all industrial system managements but it is noticeable that industrial systems will not or are not able to organize and implement preventive fire safety measures adequately. Because the law defines (article 3. of Fire safety law RS B&H; section 4. of Fire safety law of the Federation of B&H) that Fire safety is the service of special interest it is required to act systematically in order to improve fire safety preventive measures. If system deficiencies shown in this writing are removed or decreased the preventive fire safety measures in industrial processes would automatically improve. Solving mentioned systematic deficiencies does not require investments but it requires the following:

a) It is necessary to enter one school subject which studies the safety aspect of life into professional high school curriculums (Safety and protection at work, Law on offences, Civil protection, Environment protection), two school classes in a school year when students are minimally burdened. It is necessary to organize workshops with this topic several times a year in other types of schools.

b) It is required to harmonize the existing legislation in both entities completely and to pass all missing Acts simultaneously in both entities (constitutional order in B&H does not allow uniformed system in this area). It is required to speed up the procedure of categorization of industrial systems or to change the way how it's done. For example, during the registration of scope of work a risk categorization should be done according to theoretical principle of categorization and further control the accuracy of categorization of industrial system and implementation of fire safety measures by inspection controls. It is also required to alter the rule book which regulates inspection of the lightning rod electric installations and to enter facility age categorization in it. Furthermore, it is necessary to simplify fire safety plan for industrial system and to make it applicable in everyday processes as well as to determine the way of control for the accuracy of this document (conformity with industrial system).

c) It is required to regulate jurisdiction of inspection departments (in both entities, to determine domain of work of Ministry of Internal Affairs' Fire safety inspection and entity inspection), to increase number of inspectors and supervisions per year, to decrease the number of supervisions with suggestions about correction of found irregularities and to increase the number of supervisions with money fines.

d) The insurance companies must have unified and technically correct criteria when insuring property of industrial system. The rule book which regulates the conditions for property insurance would help to avoid

situations where the property of industrial system could be insured without previous implementation of fire safety measures. That would set the conditions and scale of norms which would have to be obeyed prior to property insuring.

e) The current market state regarding investments in fire safety measures require monitoring of authorized institutions because it is obvious that price of these services are not realistic.

CONCLUSION

The number of industrial systems whose scope of work and production processes bring certain amount of fire risk is increasing in B&H. By accurate defining and implementation of fire safety and protective measures this risk can be decreased and reduced to acceptable level. Legislation in this area in B&H is good in essence but its practical implementation is not satisfactory. Information and facts gathered by occupation professionals. The improvement of these measures can incur only as a result of systematic work, firstly by more frequent supervision over implementation of these measures. Starting from the fact that fire safety is the service of special interest, it is necessary to remove all visible deficiencies which relate to fire safety scope from the entire system. It is required to prevent malversation in the implementation of legislation, increase the level of awareness with people regarding fire safety in the aim of improvement of preventive fire safety measures as well as to provide additional control of organization and implementation of preventive fire safety measures over property insurance. With precise legislation, better inspection supervision, appropriate price of services given by companies involved in fire safety business and higher demands (regarding organization of preventive fire safety measures) in property insurance would bring improvement of preventive fire safety measures in industrial systems. Education of young people about significance of fire safety within educational system in elementary and high schools as well as organizing meetings (seminars) about fire safety for industrial system managements would improve implementation of preventive fire safety measures.

REFERENCES

- [1] Department of inspection [*Inspektorat RS BiH: Inspection department annual report Godišnji izvještaji rada inspekcije*]
- [2] [Fire safety legislation] *Zakon o zaštiti od požara* ["Official gazette RS no.71/12"] "*Sl. glasnik RS*", br. 71/12
- [3] [Legislation on fire safety and fire service of F BiH] *Zakon o zaštiti od požara i vatrogastvu Federacije Bosne i Hercegovine* ["Official gazette FBiH no. 65/09"] ("*Službene novine Federacije BiH*", broj: 65/09)
- [4] [The rulebook on conditions, basics and standards for categorization of economic entities and other legal entities, administrative authorities and other republic authorities and entrepreneurs into corresponding fire risk categories (Official gazette RS no. 53/13)] *Pravilnik o uslovima, osnovima i mjerilima za razvrstavanje privrednih društava i drugih pravnih lica, republičkih organa uprave i drugih organa i preduzetnika u odgovarajuće kategorije stepena rizika ugroženosti od požara (sl. gl. RS. br. 53/13)*
- [5] [The rulebook on technical measures for lightning rod installation] *Pravilnik o tehničkim mjerama za izvođenje gromobranskih instalacija* ["Official gazette SFRJ no. 13/78"] ("*Sl. list SFRJ*", br. 13/78)

BIOGRAPHY of the first author

Mile Vajkić teaches the courses in the branch of mechanical engineering at the School of Mechanical Engineering Prijedor. He has many years of experience in the area of workplace protection and fire protection in industrial processes.



He has successfully passed the state qualifying exam and has a state licence to perform tasks of workplace safety and health. He is the author of three scientific papers published in the conference proceedings. He is one of the editors of collected legislation in the area of workplace protection in Republic of Srpska – Bosnia and Herzegovina. He is the founder and vice-president of the Association of Engineers of Workplace Protection of Republic of Srpska.

POBOLJŠANJE PREVENTIVNIH MERA ZA BORBU PROTIV POŽARA U INDUSTRIJSKIM SISTEMIMA U BIH

Mile Vajkić, Biljana Vranješ, Mladen Todić

Rezime: Mere zaštite od požara u industrijskim sistemima propisane su zakonom. Svaki industrijski sistem je obavezan da organizuje i primenjuje mere definisane zakonom, kao i da teži poboljšanju mera zaštite od požara u cilju smanjenja rizika od požara. Problemi organizacije zaštite od požara u industrijskim sistemima proističu iz lošeg sprovođenja (nepoštivanja) zakonskih propisa, nemogućnosti eliminisanja faktora rizika iz proizvodnog procesa i nedovoljno zakonski definisanih oblasti u okviru sistema zaštite od požara. Imajući u vidu broj industrijskih požara u BiH na godišnjem nivou, neophodno je sistematično poboljšanje mera zaštite od požara u industrijskim procesima. Mogući načini za poboljšanje ovih mera su: zakonodavstvo, česte inspekcije i kontrole, kategorizaciju industrijskih sistema i saradnju sa osiguravajućim društvima.

Ključne reči: mere zaštite od požara, industrijski sistem, zakonodavstvo, inspekcija.

SIMONA KARAMANOLOVA¹
RADOSLAV KARTOV²

^{1,2}Academy at The Ministry of the
Interior in Sofia,
Fire Safety and
Civil Protection Faculty

¹athletkata@abv.bg

²r_kurtov@abv.bg

FIRE HAZARDS OF PHOTOVOLTAIC SYSTEMS

Abstract: The paper analyzes the direct and indirect causes of fire in photovoltaic systems, and potential hazards which firefighters encounter during the extinguishment of PV systems. Also, some preventive measures against with fires in photovoltaic systems have been described in this paper.

Key words: photovoltaic systems, fire in photovoltaic systems, protection, fire measures.

INTRODUCTION

Global energy consumption shows that photovoltaic systems (PVS) can be very efficient and replace conventional energy sources. At the same time, they have a high level of fire hazard, as the main components that include photovoltaic installations can cause fires (fig.1). Fire extinguishing in photovoltaic systems is connected with serious challenges and a lot of danger for firefighters. Consider the myriad hazards that firefighters face in a PVS if they do not understand the technology.



Figure 1. Fire in building integrated photovoltaic systems

Direct and indirect reasons for fire in PVS

According to the analyzes, the reasons for the occurrence of fire are: direct and indirect.

Direct reasons are received from inappropriate power sizing of photovoltaic panels and electrical cables, the location of PVS elements on burning constructions and materials without the necessary safety, fire regulations and technical instructions.

It must be taken into account that the reason for fire also can be high transient resistances due to loose and poor connections, improper electrical connections, contact loosening and cable support. Other direct cause of fire in photovoltaic systems can be lack of necessary protection, leading to occurrence of an electrical arc.

Indirect reasons are related to the influence of atmospheric conditions (rain, snow, humidity, lightning, burning materials near photovoltaic systems

(grass, other vegetation and elements), rooftop or facade fire, caused by electrical installations, chimneys, negligens or animals chewing on wires.

In general, there are three cases of fires in photovoltaic installations and they are:

- fire begins from photovoltaic modules, which are usually located on the roof and the fire spreads down the building (fig.2);
- fire begins from inside of the building, whose roof is covered by photovoltaics and spreads and covers the roof installation (fig.3);
- fire begins from photovoltaic equipment – inverter, cables and wires, electrical boards, controllers and others (fig.4)



Figure 2. First case - fire begins from photovoltaic modules



Figure 3. Second case - fire begins from inside the building and covers the roof installation



Figure 4. Third case - fire begins from photovoltaic equipment

When investigating fire incidents that involve solar PV systems, there are a number of factors to take into consideration. The most basic of considerations is to look at the fire scene objectively, ruling out all other possible causes. Investigation efforts should be directed to all potential causes and sources of ignition, ruling each one out in a methodical and systematic approach.

Fires in PVS in Bulgaria

For the period from 2010 to 2016 on the territory of the Republic of Bulgaria Chief Directorate „Fire safety and civil protection”, Ministry of Interior has registered 30 fires with photovoltaic systems. The reason for this small number of accidents is that in Bulgaria, there are more ground photovoltaic parks.

The most common causes of these fires are:

- burning dry grasses and shrubs near photovoltaic parks – 27%;
- short circuit – 17%;
- negligence with fire – 13%;
- fire activities – 3%;
- technical malfunctions – 2%;
- poor repair – 2%;
- unspecified reason – 27%.

To deal with a fire, firefighters need to know very well every single component of photovoltaic system and potential hazards, which they hide. Depending on the nature of the incident, they can be:

- danger of electric shock and electric arc;
- the risk of fire in inverter or transformer inverter station;
- danger of toxins;
- danger of destruction and the construction of structures;
- the risk of slipping and falling for firefighters in building integrated photovoltaics.

The great danger to firefighters is electric shock in case of destruction the photovoltaic modules and the occurrence of electric arc. An electric arc can occur both in ground and building integrated photovoltaic systems. Permanent arcs can reach temperatures above 3000 degrees.

It is important to know that even small light photovoltaics are under voltage and produce electric

current. Firefighters need to know that even shutting down the photovoltaic elements, which are before the inverter such as modules, connecting wires and controllers, there are still current. The risk of damaging elements and insulation of conductor due to factory defects should not be underestimated too. Cutting wires can also lead to an electric arc. Due to the high DC voltages, long – lasting arc faults can occur which may cause serious fires. The output voltage of photovoltaic modules in building integrated PV systems is usually from 600V to 1000V.

Preventive measures to prevent a voltaic arc are:

- deployment DC protection of the cables at the output of the modules, not before the inverters;
- using separate cables to the inverter, which are at a distance at least 0,1m near burning constructions and materials and placing them in cable tunnels;
- doing research for use special isolation about animals chewing on wires;
- placing arc detection systems.

Fire protection distances for firefighting PVS.

Very important for fire safety in PV modules is keeping distance to the current – carrying parts depending on the electrical voltage in them. In this connection it can be used the experience of colleagues from Germany presented on a Table 1 and figure 5 [1,2].

Table 1.

Type of firefighter jet	Minimum distances at el. voltages AC < 1 kV or DC < 1, 5 kV	Maximum distances at el. voltages AC >1 kV or DC >1, 5 kV
Extinguishing with the spray jet	1	5
Extinguishing with a tight jet	5	10

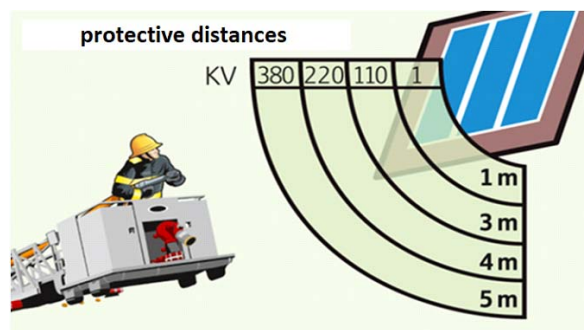


Figure 5. Minimum fire protection distances for firefighting PVS

Extinguishing photovoltaics

The extinguishing of photovoltaic systems and components damage by the fire is carried out at a distance (fig.6). Independent that the fire developed in a building with photovoltaics or in photovoltaic park for extinguishing is most used water or dry powder. It is best for firefighters to used dry powder.



Figure 6. *Extinguishing photovoltaics on a building from a distance*

It must be known that when fireman's use water for extinguishing the fire there is a real risk to their health. Removing these problems can be achieved by using an interrupted stream or using fire nozzle responsible of the requirements of DIN 14365 – CM (fig.7).



Figure 7. *Fire nozzle - standart DIN 14365 - CM*

These types of nozzles is used by German association of firefighters and they are specifically designed to work with electricity (fig.8). They are producing a broken jet, which protect fireman's from the occurrence of an electric arc or electric shock.

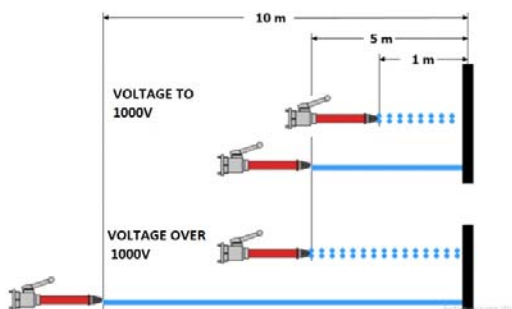


Figure 8. *Different between broken jet and normal jet*

Serious fire hazard are inverters in photovoltaic systems and their location in transformer inverter station (TIS) (fig.9). For that reason, it is necessary to ensure ventilation of the inverters, minimum safe distances from 0,3 m to burning materials and constructions and installing them over burning fundamentals.

Especially for TIS is very important to have gas protection, which turn off when the pressure of the vapor increase, when the transformer oil is heated.



Figure 9. *Fire in transformer inverter station*

Serious danger for firefighters are also toxins, which are separate from fires in photovoltaic systems. To protect themselves for this harmful toxins, fireman's must use self-contained breathing apparatus. In the case that fire is in the building with photovoltaics, it is absolutely necessary, firefighters to stop every ventilation or air-conditioning systems and evacuate all people and animals

CONCLUSION

The work of all firefighters, become more difficult, when the temperature in fire with photovoltaic is rises. If the construction is not enough secured and the necessary instructions have not been followed in the design of the installations PVS can very quickly fall apart under the fire.

As a result of heating it is possible destruction of a mounting frame and roof collapse with all photovoltaics modules, falling down inside the building. Firefighters should be careful with this and secure the area. They must wear their special clothing and the necessary safety equipment and focus their attention in every fire hazard connected with photovoltaic systems.

REFERENCES

- [1] Informationsschrift: „Einsatz an Photovoltaikanlagen” - z.B.DGUV – Information 205-018 (bisher BGI/GUV –I 8675).
- [2] Einsatz an stationären Lithium – Solarstromspeichern, Hinweise für die Brandbekämpfung und technische Hilfeleistung Bundesverband Solarwirtschaft e.v.Dezember 2014

BIOGRAPHY of the first author

Simona Karamanolova was born in Yambol, Bulgaria in 1994. She has graduated from the Academy of The Ministry of Interior in Sofia, Bulgaria and holds a Bachelor's degree in Fire Safety and Civil protection. She is engineer of Fire Safety and Civil protection.



Simona is currently working in Regional fire department – Opan, to the Regional Directorate of Stara Zagora. Right now she is studying master's degree in the Academy of The Ministry of Interior in Sofia, Faculty of Fire Safety and Civil Protection.

OPASNOSTI OD POŽARA FOTONAPONSKIH SISTEMA

Simona Karamanolova, Radoslav Kartov

Rezime: *U radu su analizirani direktni i indirektni uzroci požara fotonaponskih sistema i potencijalne opasnosti za vatrogasce tokom gašenja požara. Takođe, prezentovane su preventivne mere zaštite od požara fotonaponskih sistema.*

Ključne reči: fotonaponski sistemi, požar na fotonaponskim sistemima, zaštita, preventivne mere.

MILAN PROTIĆ¹
MILENA MANČIĆ¹
MIOMIR RAOS¹
MILAN BLAGOJEVIĆ¹
PREDRAG STANKOVIĆ¹

¹University of Niš,
Faculty of Occupational Safety in Niš

¹milan.protic@znrfak.ni.ac.rs

IGNITABILITY STUDIES OF COMMON FOREST FUELS

Abstract: In this paper we examined the ignitability of common forest fuel samples. Tests were performed on mass loss calorimeter for heat fluxes in the range from 5 to 40 kW/m². The results of our experiments revealed that the critical flux for the ignition of all tested forest fuel samples was 15 kW/m². Additionally, we found that the effect of a type of species tested becomes relatively insignificant as the incident heat flux increases. It was shown that this effect becomes the most pronounced for heat flux in the range between 20 and 25 kW/m².

Key words: forest fires, forest fuels, ignitability, mass loss calorimetry

INTRODUCTION

Forest fires pose a great threat to the environment, property and humans. Regions with long summer seasons and extreme summer temperatures are particularly affected. Climate change, due to global warming, is another issue. It can be designated as a notable indirect trigger for devastating wildfires. One of the most damaging wildfires in recent history occurred in Australia in 2009. The Black Saturday bushfires (as they were called) were a series of wildfires that engulfed vast regions of the Australian state of Victoria [1]. During these fires a total of 180 people were confirmed to have died as a result of the fires [2]. Another big wildfire hit the Attica in Greece in July 2018. The death toll rose to 99 people with almost 200 injured [3]. According to a database maintained by the Centre for the Research on the Epidemiology of Disasters in Brussels, this wildfire was the deadliest wildfire in Europe since 1900 [4]. The most recent California wildfire in Paradise County in November 2018 devastated the area of more than 117,000 acres, killing at least 42 people (with 200 still missing), becoming the deadliest wildfire in modern California history [5]. As regards Serbia, the figures of the official data from the European Forest Fire Information System regarding the number of forest fires are presented in Table 1 [6]. The data only cover a time frame of three years, due to the lack of official information.

Table 1. Statistical data regarding wildfires in Serbia [6]

Year	Total area (ha)	Engulfed forest land (ha)
2017	8170.02	3005.37
2016	771.9	549.48
2015	1011.18	596.02

It is obvious from the figures listed above that forest fires pose a great threat and that a scientific approach to solving problems related to forest fires is required.

Forest fires generally originate from forest fuel bed ignition. The phase that precedes ignition is pre-

ignition. In this phase, forest fuel particles dehydrate and devolatilize. The moment when the first, low mass, volatiles start to emerge is referred to as pyrolysis. In the pyrolysis phase, complex forest fuels are decomposed. This particularly pertains to cellulose, hemicellulose and lignin, the main constituents of biomass. Cellulose and hemicellulose decompose relatively easily as opposed to lignin, which is much more thermally stable.

In the process of pyrolysis combustible gases are created. Direct or indirect source of ignition is sufficient for the onset of fire. After that, if favourable conditions are met, fire is sustained. Different forms of fire can be distinguished: flaming combustion, diffusion and premixed flames, smouldering and spontaneous combustion [7]. In the context of forest fires, flaming combustion and smouldering prevail. In forest fires, flames are the main source of heat by means of which most wildfires spread [8]. Smouldering is a relatively slow combustion process that involves oxygen from the air and a solid fuel [7]. The reaction proceeds on the surface of the solid particle and is characterized by glowing and charring. Flaming is the transition from the pre-ignition to the combustion phase, when sustained combustion is possible and when external sources of ignition are not needed.

Flammability and ignitability research of forest vegetation material is widely covered in open-access literature. Anderson et al. performed field experiments with stands of gorse (*Ulex europaeus* L.) in New Zealand to determine the conditions under which fires would both ignite and spread [9]. The authors concluded that thresholds for gorse ignition and fire spread differ, which corresponds well with other observations. Additionally, they discovered that the single most important variable for ignition and spread of gorse is the moisture content. This observation corroborates the conclusions from similar forest fuel ignitability studies. Flammability study of European gorse was performed by Madrigal et al. [10]. The authors reached the following conclusions: ignitability highly depends on the type of ignition source. Combustibility was more dependent on the dead fraction than on the live plant part characteristics and

fire sustainability was mainly related to physical characteristics, such as air flow interaction with fuel compactness [10]. Ganteaume et al. conducted a series of tests in laboratory conditions to assess the potentials of firebrands to ignite and sustain fire in different forest fuel beds [11]. In their studies, an epiradiator was used for creating firebrands, which were afterwards used for igniting fires in artificially created forest fuelbeds. The authors indicate that grasses have the greatest ignition and flammability potential, followed by *Pinus* litter. A similar study, assessing the ignition potential of firebrands, was performed by Guijarro et al. [12]. The authors assessed flammability potentials of 8 different woody species and grasses. Their conclusions were similar to the previously mentioned study. Grasses have the greatest potential for initiating and spreading fires. According to the authors, the tested grass species have lower times to ignition, higher rates of initial fire spread and combustion, as well as higher flame heights than litters of woody species [12]. As for the woody species litter, according to the authors, litters belonging to the species of the genus *Pinus* and the *Ulex europaeus* were designated as the most flammable.

Even though literature studies covering ignition and flammability of forest fuel are available, most of them are confined to Mediterranean regions and vegetation species native to Mediterranean flora. The aim of the present study is to assess the ignitability and flammability of some of the forest species indigenous to Serbia, especially its south-eastern parts.

MATERIALS AND METHODS

Forest fuel samples used in this study were selected so as to represent as much as possible some of the typical forest fuelbeds in Serbian forests. Samples were collected during the summer season and conditioned in the laboratory before the experiments were conducted. While some authors propose convective drying of samples before the experiments, in this study the samples were analysed in their as-received state. The following species were analysed: needles of *Pinus sylvestris*, cones of *Pinus sylvestris* and leaves of *Fagus sylvatica*.

Gross heating values (GHV) of the samples were determined using the IKA C200 calorimeter. Prior to testing, the samples were milled. Specimens were burned in a ceramic crucible inside a decomposition vessel. Experiments were performed according to ISO 18125 [13].

Ignitability studies were conducted using a mass loss calorimeter (Fire testing technology, UK). A mass loss calorimeter is a standalone instrument used for determining mass loss rate. If it is used in an assembly with a chimney with thermopile and heat flux meter, and is properly calibrated with methane sand burner, the instrument can be used for assessment of heat release rate of fuel samples. The instrument contains the same fire model as a cone calorimeter according to ISO 5660-1[14]. A crucial element of the instrument is

the truncated conical radiant heater, which can provide heat fluxes in range from 0 to 100 kW/m². This assembly had already been used for ignitability assessment [15]. In this study, the original instrument or, more precisely, the sample holder was somewhat modified. Namely, as opposed to enclosure fires, in forest fire scenarios fuels are almost constantly exposed to over-ventilated conditions. In order to mimic the real forest fire scenarios as much as possible, a special perforated sample holder was manufactured. The layout of the sample holder used in this study is presented in Figure 1.

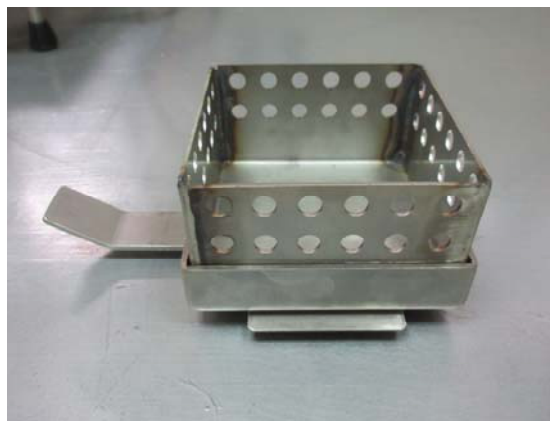


Figure 1. Sample holder for forest fuels

This special design with perforations accelerates the diffusion of air into the sample and replicates a real forest fire scenario.

Proper calibration of the instrument is necessary, since direct readings of heat flux do not exist. Only the readings of cone surface temperature are available on the control unit of the instrument. For heat flux measurement during the test, a water-cooled Schmidt-Boelter thermopile type heat flux meter (Medtherm, USA) was used. The heat flux meter was positioned at a distance of 25 mm from the conical heater, which closely corresponds to the position of the surface of forest fuel specimen (Figure 2).



Figure 2. Instrument with a heat flux meter during the calibration phase

Temperature readings of the cone surface were recorded for predefined heat fluxes. For this study, fluxes from 5 to 40 kW/m² with a step of 5 kW/m² were used. A relation between the temperature readings of the conical heater and the measured heat flux was established. The corresponding values are presented in Table 2.

Table 2. Relation between the temperature readings of the conical heater and the measured heat flux

Temperature of conical heater [°C]	Measured heat flux [kW/m ²]
675	40
645	35
607	30
558	25
502	20
440	15
360	10
245	5

RESULTS AND DISCUSSION

The obtained results for gross heating value of forest fuel samples are presented in Table 3.

Table 3. Gross heating values of forest fuel samples

Species	GHV [MJ/kg]
<i>Pinus sylvestris</i> (needles)	22.57
<i>Pinus sylvestris</i> (cones)	18.52
<i>Fagus sylvatica</i> (leaves)	19.26

The results represent the averaged means of three measurements per each tested material. A relatively high heating value for *Pinus sylvestris* needles arises from the chemical composition and low moisture content.

Ignitability studies were performed in a mass loss calorimeter. The experiments started with the heat flux of 40 kW/m². The flaming combustion of *Pinus sylvestris* cones while exposed to a heat flux of 40 kW/m² is presented in Figure 3.



Figure 3. Flaming combustion of *Pinus sylvestris* cones

The heat flux was incrementally reduced up to the value of 5 kW/m² and the time to ignition was measured for each heat flux. The experiment was to be designated as unsuccessful if no visible flame was observed after 10 min of heat flux exposure to fuel sample.

The instrument was placed under the ventilation hood with a volumetric flow of 50 l/s. A hood for collecting exhaust gases was placed immediately above the chimney of the mass loss calorimeter. *Pinus* needles and *Fagus* leaves were tested separately, while *Pinus* cones were mixed with *Pinus* needles to better represent the forest fuelbed. All the experiments were performed with piloted spark ignition. The obtained results for all tested samples are shown in Figure 4.

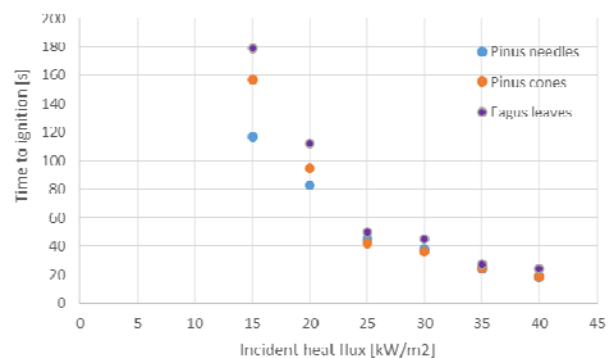


Figure 4. Measured times to ignition for tested fuel samples

The first observation from Figure 4 is that there was no ignition when the incident heat flux dropped below 15 kW/m² for all tested samples. This finding corresponds closely with the results of some similar studies found in the literature [16]. Figure 4 shows that for the heat fluxes greater than 20 kW/m² times to ignition are relatively independent of the type of the sample. This effect is especially pronounced for the heat flux of 35 kW/m². The effect of species type on time to ignition rises as the heat flux decreases and it is most pronounced for the heat flux of 15 kW/m². The biggest change in time to ignition happens in the interval between 20 and 25 kW/m².

CONCLUSION

In this paper we performed an ignitability study of forest fuel samples. Our experiments revealed that the critical heat flux for ignition of forest fuel samples was 15 kW/m². Additionally, we found that time to ignition becomes relatively independent of the forest fuel type as the heat flux becomes higher. However, this study was limited to only three species and further investigation is required.

REFERENCES

- [1] https://en.wikipedia.org/wiki/Black_Saturday_bus_hfires
- [2] https://en.wikipedia.org/wiki/Black_Saturday_bus_bushfi
- [3] https://en.wikipedia.org/wiki/2018_Attica_wildfires
- [4] <https://www.cbsnews.com/news/death-toll-rises-deadly-greece-wildfires-today-2018-07-29>
- [5] <https://www.nytimes.com/2018/11/12/us/california-fires-camp-fire.html>
- [6] <http://effis.jrc.ec.europa.eu/about-effis/>
- [7] Quintiere, J.G., 2016. Principles of fire behavior. CRC Press
- [8] Johnson EA, Miyanishi K. Forest fires: behavior and ecological effects. 2001
- [9] Anderson SA, Anderson WR. Ignition and fire spread thresholds in gorse (*Ulex europaeus*). International Journal of Wildland Fire. 2010 Aug 30;19(5):589-98
- [10] Madrigal J, Marino E, Guijarro M, Hernando C, Díez C. Evaluation of the flammability of gorse (*Ulex europaeus* L.) managed by prescribed burning. Annals of Forest Science. 2012 Apr 1;69(3):387-97
- [11] Ganteaume A, Lampin-Maillet C, Guijarro M, Hernando C, Jappiot M, Fonturbel T, Pérez-Gorostiaga P, Vega JA. Spot fires: fuel bed flammability and capability of firebrands to ignite fuel beds. International Journal of Wildland Fire. 2010 Jan 6;18(8):951-69
- [12] Guijarro M, Hernando C, Díez C, Martínez E, Madrigal J, Lampin-Cabaret C, Blanc L, Colin PY, Pérez-Gorostiaga P, Vega JA, Fonturbel MT. Flammability of some fuel beds common in the South-European ecosystems. In IV International Conference Forest Fire Research 2002 Nov
- [13] ISO 18125:2017 Solid biofuels - Determination of calorific value
- [14] ISO 5660-1:2015 Reaction-to-fire tests - Heat release, smoke production and mass loss rate - Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)
- [15] Madrigal J, Guijarro M, Hernando C, Díez C, Marino E. Effective heat of combustion for flaming combustion of Mediterranean forest fuels. Fire technology. 2011 Apr 1;47(2):461-74
- [16] Mindykowski P, Fuentes A, Consalvi JL, Porterie B. Piloted ignition of wildland fuels. Fire Safety Journal. 2011 Jan 1;46(1-2):34-40

ACKNOWLEDGEMENTS

The instrument used in this study, the mass loss calorimeter, was purchased under the project: "Joint Training Programme for Forest Fire Prevention and Management". The project is co-funded by EU through the Interreg-IPA CBC Bulgaria-Serbia Programme.

BIOGRAPHY of the first author

Milan Protić was born in Niš, Serbia, in 1979. He received the diploma in mechanical engineering and the Ph.D. degree from the University of Niš, Faculty of Occupational Safety in Niš. His main areas of research include renewable energy sources, district heating systems, combustion and fire research. He works as an assistant professor at the Faculty of Occupational Safety in Niš, University of Niš.



ISPITIVANJE UPALJIVOSTI TIPIČNIH ŠUMSKIH GORIVIH MATERIJALA

Milan Protić, Milena Mančić, Miomir Raos, Milan Blagojević, Predrag Stanković

Rezime: U ovom radu izvršeno je ispitivanje upaljivosti uzoraka šumske biomase. Ispitivanja su rađena na kalorimetru sa termoparovima za merenje toplotne snage za toplotne flukseve u rasponu od 5 - 40 kW/m². Dobijeni rezultati ukazuju da je toplotni fluk od 15 kW/m² bio dovoljan za paljenje za sve uzorke šumske biomase. Takođe, utvrđeno je da sa porastom vrednosti toplotnog fluksa potrebno vreme do paljenja ne zavisi od vrste testirane šumske biomase. Pokazano je da je ovaj efekat najizraženiji za toplotne flukseve u rasponu od 20 do 25 kW/m²

Ključne reči: šumski požari, šumska biomasa, upaljivost, kalorimetar za merenje toplotne snage

MARTIN NACHOV¹
RADOSLAV KARTOV²

^{1,2}Academy at The Ministry of the
Interior in Sofia,
Fire Safety and Civil
Protection Faculty

¹m.nachov@abv.bg
²r_kurtov@abv.bg

DEVELOPING OF LIGHTNING PROTECTION SYSTEM FOR FIRE ALARMING SYSTEMS OPERATING AT A HIGHER RISK OF LIGHTNING STRIKES

Abstract: *The phenomenon of the lightning and its striking factors have been considered. The problems in the exploitation of fire alarming systems caused by overvoltage due to lightning strikes have also been analysed. The paper suggests an innovative method for protection in fire alarm systems in case of lightning strike danger.*

Key words: lightning, fire alarming system, C systems, fire.

INTRODUCTION

Lightning is a natural phenomenon which could cause death, fire, destruction of buildings, damage to electrical and fire alarm systems, etc. The geographical features of Bulgaria put the country in the way of lightning. Looking at the map, Bulgaria is located on the 43rd parallel. The European countries around this parallel accumulate an average of 1,300,000 lightning strikes in June and 1,500,000 in July. The last two cases of fire caused by lightning strikes also support these statistics. On July 4, 2018 at 02.43 AM a fire brigade from the department in Montana responded to a call for fire at a house in the village of Dolna Riksa. At 11:44 PM fire fighters from the station in the village of Gavril Genovo and the department in Montana visited a fire scene in an agricultural building in the village of Kamenna Riksa. The probable cause of both fires is lightning. In neighboring Greece, 93,850 lightning strikes were registered in June. There have been more than 64,000 thunders only for the period from 15th to 19th June [1]. At the same latitude, in the northern and eastern part of India, there have been 46 casualties of thunderstorms and lightning strikes only for a period of two days. In Bangladesh, during the first 10 days of May lightning strikes have taken the lives of 112 people. The pre-monsoon thunderstorms have caused chaos in the country, and in May 2016 82 people died just for a day. On an average, the casualties are 350 to 400 per year. In most of the cases, along with the casualties, fires also cause significant material damage. It has been proven that Bulgaria is a country with a high thunder activity. According to official data six people on average die in Bulgaria each year as a result of lightning. The summer thunderstorms which hit our country are causing damage evaluated to around BGN 60 million [2], while the damage to fire alarm systems is estimated at over BGN 12 million. While the problem concerning the protection of buildings against direct strikes by lightning has been addressed in the Regulation on Lightning Protection of Buildings, External Facilities and Open Spaces [3], this is not the

case with the lightning protection of electrical installations. The lack of a regulatory framework for lightning protection of electrical installations leads to the necessity of searching for alternative ways to protect these systems from lightning.

REASONS FOR THE FORMATION OF LIGHTNING

Despite the fact that lightning is one of the most common natural phenomena, we know too little about it. Lightning is a powerful electrostatic discharge which tears the the atmosphere at a speed of 96,000,000 km/h. An electric charge of 1 billion volts flows through the air, while the electric current measures to around 2000 amperes. [4] This current creates waves of light. A bright streak of light flashes in the sky. The air at its center is heated to over 27,000 °C causing it to expand so quickly that it explodes. A deafening thunder follows. This thunder and the flash occur simultaneously. However, the thunder is heard later due to the fact that the speed of light (299,338 km/s) is much higher than the speed of sound (about 1,126 km/h depending on the temperature, humidity and atmospheric pressure). All this occurs for a fraction of a second and about 8 million times a day in the world. Lightning is formed by processes where small droplets of water move updrafts in the inside of a cloud, freeze and fall downdrafts in the form of ice. Due to the strong turbulence caused by the updraft movement of air the water droplets and the ice crystals collide. This collision and the friction between the water droplets and the ice crystals causes them to become positively or negatively charged. The electrons from the lighter particles (the ice crystals) are ejected, which makes them positively charged. The heavier particles (the water droplets) capture the free electrons and therefore become negatively charged. Due to the gravity, the heavy negative particles move toward the base of the cloud, while the light positive particles remain at the top of the cloud as a result of the updraft movement of

the air flows. The strong collision between the two types of particles leads to disbalance between the electric charges in the cloud. The difference in the potential of the upper and the lower part of the cloud measures to tens of millions of volts. The particles of different charge are separated from each other, and when they reassemble this causes the lightning to occur. (fig. 1)

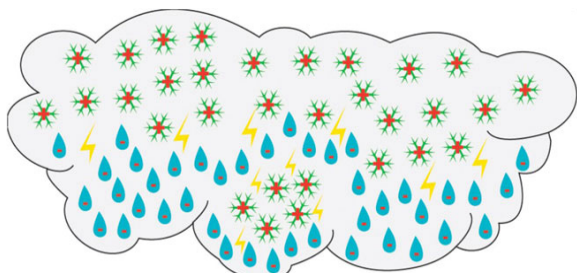


Figure 1. *An electrically charged cloud*

TYPES OF LIGHTNING

There are two types of lightning – a flash and a ball lightning. The average length of a flash is about 2.5 km (it can reach up to 20 km) and its width is 2-3 cm. Its speed can reach up to 220,000 km/h (61 km/s). The temperature within the lightning can reach about 30,000 °C and its electric current is about 300 kA [5]. The color of the lightning is bright (white, yellow). (fig. 2)



Figure 2. *Flash lightning*

On the other hand, the ball lightning is an atmospheric phenomenon the nature of which is not yet studied well enough. It is an extremely rare phenomenon and it could be described as a large electric charge with a spherical shape. It occurs mostly at the end of a thunderstorm. Its diameter varies from 20 - 30 cm to a few meters and it has unclear borders. It sometimes has a bluish halo and could be accompanied by a hissing sound. It usually lasts between 5 seconds and 2-3 hours. It travels at a speed of about 10 m/s, usually a meter above the ground. The color of the ball lightning can be red, yellow, orange, blue, violet, green, gold, white or silver (fig. 3)



Figure 3. *Ball lightning*

SECONDARY EFFECTS OF THE LIGHTNING

The damage to fire alarm systems and other electrical installations is caused by the so-called secondary effects of the lightning. When a lightning strikes the lightning rod of a building a very powerful electrical current reaching up to 100,000 – 200,000 A flows through the lightning conductor in the direction to ground, even though this occurs for a short period of time. If we assume that the current of the lightning which has struck the lightning rod is in around 100 kA and the resistance of the earthing (grounding) system is 1 Ω, this means that the electrical voltage at the earthing point will be around 100 kV [6]. However, the electrical installation of the building is also grounded (connected to the Earth's conductive surface) either through an electrical panel or a transformer station. When the grounding of the electrical installation is located near the grounding of the lightning rod (as it is in the general case), those 100 kV received at the earthing point of the lightning rod could move through the earthing of the electrical installation directly to the TV, computer or other electronic devices. No electronic device could resist such a powerful electrical shock. This is the so-called galvanic secondary effect of the lightning. It is extremely dangerous because the earth's surface is electrified with an extremely high voltage which spreads through the ground and it is only reduced to safe values at a distance not less than 1 ÷ 1,5 km from the point of the lightning strike. This factor is extremely dangerous for both electronics and humans or animals because the so-called "pinch" tension is formed. (fig. 4)

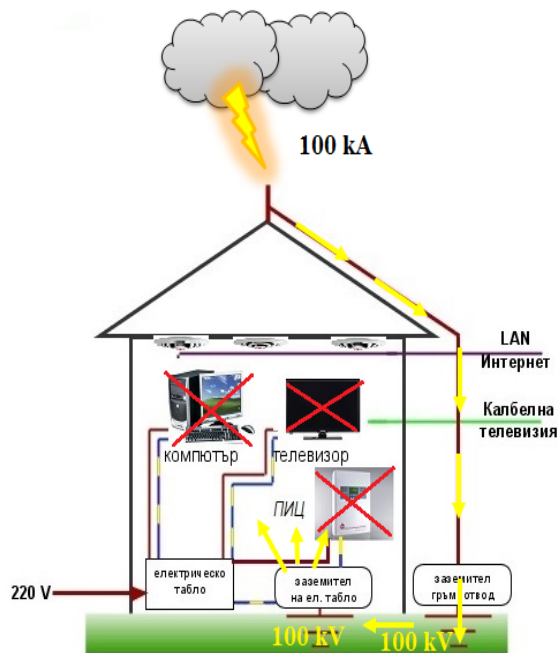


Figure 4. Galvanic secondary effect of the lightning

The electromagnetic effect is another dangerous secondary factor of the lightning. When a lightning occurs (either cloud to ground or cloud to cloud) a powerful electromagnetic impulse emerges and the so-called "Transformer principle" is manifested. The primary coil is the lightning itself, while all the metal objects on the ground are secondary coils in which electricity is induced. The cables of fire alarm systems, TV, Internet or telephone are also secondary coils. Thus, the electronic devices receive an electric shock through their external cables. The electromagnetic secondary striking effect of the lightning is less powerful than the galvanic effect, but it is powerful enough to damage the fire alarm system, the TV, the computer, the Internet connection or the telephone. (fig 5).

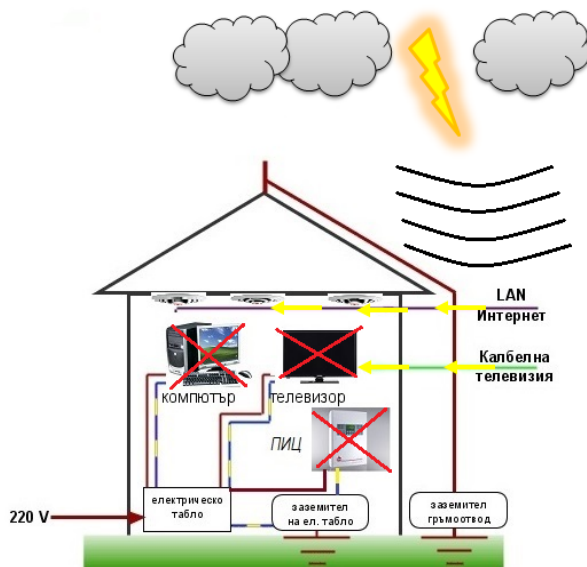


Figure 5. Electromagnetic secondary effect

The capacitive effect is the third secondary striking factor of the lightning. It is manifested even before the lightning itself is formed. The thunder cloud and the earth form a huge air condenser. The cloud and the ground are its two opposite poles. The voltage between the two poles is extremely high – between 100 ÷ 200MV (fig. 6)

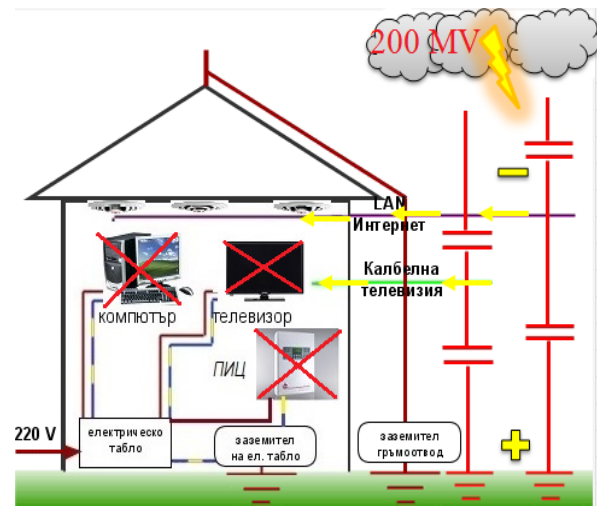


Figure 6. Capacitive secondary effect

If the cables of the television, the Internet, the phone, etc. are airborne instead of underground, they divide this huge air condenser into two connected condensers. Thus, the air cables receive a part of the potential of the thunder condenser which reaches the TV, computer, modem, etc. It is important to know that the secondary effects of the lightning do not occur one after the other but at the same time and that they can cause damage to the electrical installation and the fire alarm system.

TECHNICAL SOLUTION TO PREVENT LIGHTNING DAMAGE TO FIRE ALARMING SYSTEMS

The two-zone fire alarm system operates in a different way depending on the zone. The fire alarm sensors in Zone 1 are wireless and the information is transmitted to the fire alarm station directly via radio addresses. A new element, a so-called zone monitor, is introduced in Zone 2. It is connected to the conventional zone via cables. The information which is transmitted from the sensors to the zone monitor is received by the monitor and then transmitted wirelessly to the fire alarm station. The implementation of this type of a fire alarm system would ensure its efficient and reliable operation regardless of the weather conditions.

The risk of damage due to overvoltage caused by different types of lightning and their effects could be managed and the reliable operation of the fire alarm systems could be ensured by galvanically separating areas of the panel by carrying out the the following actions:

- Removing the cable connection between the separate areas and the fire alarm panel.
- Introducing radio addresses / messages and autonomous power supply for the fire detectors by removing the cable installation for the fire alarm zone (s).
- Introducing a zone monitor for a wireless communication with the panel.

The implementation of a fire alarm system which would operate reliably and with no failures during lightning is presented at the diagram in Figure 7.



Figure 7. Fire alarm installation

CONCLUSION

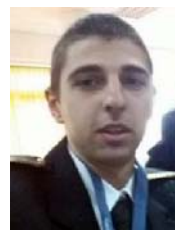
Following the thorough analysis of the current issue with the losses on the Fire alarming systems following the secondary effects of a lightning, it proposes innovative protection of fire detection centres through combining of a zone monitor with conventional sensor systems. This monitor could be used for avoidance of cabling in the system between the central and the zones. The possible development and potential kick-off of the device would prevent damages for thousands of levs.

REFERENCES

- [1] https://www.actualno.com/balkani/blizo-93-850-mylinii-registriraha-v-gyrcija-prez-uni-news_683035.html
- [2] http://disasters.comeze.com/index_files/HTML/prirodni%20bedstvia/malnii%20i%20gramotevici/Malniite%20v%20Bulgaria.htm
- [3] Regulation № 4 /22.12.2010 on Lightning Protection of Buildings, External Facilities and Open Spaces
- [4] <http://megavselenia.bg/igrte-na-atmosferata-kak-se-razhdad-burite/>
- [5] <https://bg.wikipedia.org/wiki/%D0%9C%D1%8A%D0%BB%D0%BD%D0%B8%D1%8F>
- [6] <https://euroengineering.bg>

BIOGRAPHY of the first author

Martin Nachov was born in Kula, Bulgaria. He has graduated from the Academy of the Ministry of Interior in Sofia, Bulgaria, and holds a Bachelor's degree in Fire Safety and Civil Protection. He is currently working in the 7th regional department of the Capital Directorate for Fire Safety and Civil Protection.



RAZVOJ SISTEMA GROMOBRANSKE ZAŠTITE U USLOVIMA VISOKOG RIZIKA OD UDARA GROMA

Martin Nachov, Radoslav Kartov

Rezime: U radu je razmotren fenomen munje i njenih udarnih faktora. Analizirani su problemi u radu alarmnih sistema izazvani prenaponima zbog udara groma. Predložen je inovativni metod zaštite sistema za zaštitu od požara od opasnosti izazvanih udarom groma

Ključne reči: munja, alarmni sistem, C sistemi, požar.

MARKO NIKOLIĆ¹
STEFANA JANKOVIĆ¹
JELENA
MALENOVIĆ-NIKOLIĆ²

^{1,3}ITVI DOO
²University of Niš,
Faculty of Occupational Safety

¹first@eunet.rs
²second@gmail.com
³third@ptt.rs

ACCIDENT VENTILATION AND A DOOR FAN TEST AT THE WORKSPACE

Abstract: *The electronic equipment room contains designed ventilation, which aims to extract combustion products and a fire extinguisher after bleeding the gas from the automatic extinguisher system in an accident mode. Before installing fire extinguishing equipment, a door fan test in the room must be carried out to maintain a constant gas concentration as a fire extinguishing agent.*

Key words: accident ventilation, fan door test.

INTRODUCTION

In the room with electronic equipment, there is ventilation after gas exhaustion for the automatic fire extinguishing system. The ventilation operates in the following way - the extinguishing agent is extracted, as well as the products of combustion in the room where electronic equipment is placed. The room should be hermetically sealed to maintain the required gas concentration in the room.

PSYISICAL CHARACTERISTICS OF NOVEC 1230

In the room where electronic equipment is located, an automatic fire extinguishing system has been designed (Novec 1230). The power of extinction of Novec1230 is high and the minimum concentration for the ISO 14520 test for class A fires is 3,4 % for class B 4,4 %. Minimum concentration projects should be concentration for Class A fires in the amount of 5,3% for Class B 5,9% and for electronic devices 5,6%. According to this, it can be concluded that the required volumetric concentrations for typical flammable substances for safety adopt a volume concentration of 6% indicated in the following table, obtained experimentally. [1]

Table 1. *Required volumetric concentration [1]*

The name of the flammable substance	Optimal min. concn.	Min. necessary concn.
Acetone	4,5	5,9
Ethanol	5,5	7,2
Diesel for marine engines	4,5	5,9
Methanol	6,5	8,5
Methyl ethyl ketone	4,5	5,9
Methane	8,8	9,7
Propan	8,1	8,9

Depending on the type of combustible material, concentration up to 9% are used, which is determined as the standard for the calculation of the required quantities for extinguishing. The Novec 1230 fire

extinguishing mechanism is, in addition to the chemical congestion, an effect that occurs as a result of the decomposition of this molecule into 18 smaller molecules, in contrast to other means where it is physically disruptive effect by reduction of heat due to absorption, and indirectly by reduction of oxygen form fire [1]. One of basic features of Novec is that it can be used within the indicated values in the table in normality spaces

Table 2. *Toxity of Novec 1230 [1]*

Type of occupation	Maximum concentration % of air volume concentration.
Acetone	5,9
Ethanol	7,2

Maximum recommended concentration Novec for premises where people are present, provided the automatic switch-on of the system is 9%. For Novec, NOAEL (No observed adverse effect level) is defined highest concentration at which they are not perceived psychic and toxic damage to 10% and LOAEL (Lowest observable adverse effect level) the lowest concentration at which psychological and toxic damage were observed to 10,5%. People can be exposed to Novecs low-concentration, for a short time, without serious impact on health and safety. Exposure to higher concentrations over a longer period can cause dizziness, coordination disorder and cardiac arrhythmia.

VENTILATION IN CASE OF AN ACCIDENT

A bottle of 51 litre filled with 40 kg of gas Novec 1230 was installed in the room. The bottle through steel pipes distributes Novec 1230 to the protected area. The working space was adopted as one fire zone and in the event of fire, a bottle of 51 litre filled with 40 kg of gas Novec 1230 is activated.



Figure 1. Bottle with gas Novec 1230

In the event of a fire, the gas will burst in the room, the amount of gas Novec 1230 must be maintained for at least 30 minutes and the estimated time is 5 to 10 seconds. Due to the occurrence of pressure in the room, collapse of the suspended ceiling and damage to property.



Figure 2. Colapse of the suspended ceiling

In order to prevent unwanted events, it is foreseen to install a pressure relief damper DUX 300 which is positioned at 25 cm from the floor of the room.



Figure 3. Pressure relief damper AFP-DUX 300

Accident ventilation is designed so that it starts operating 30 minutes after the start of the extinguishing process. Accident ventilation consists of fans, galvanized channels, fire dampers and external weather

louvers. In the normal operation, the fan does not work and the fire damper is closed.



Figure 4. Fire damper

In the event of fire, there are executive commands for activating and discharging gas into the endangered sector where the extinguishing takes place. Upon completion of the shutdown, the voltage is applied to fire damper to open and the fan voltage to switch on. Gas and combustion products from the room exit onto the facade wall trough an external weather louver. Just start the fan by turning in manually only after 30 minutes from the beginning of the extinguishing.



Figure 5. Fan Vent 125L

The airflow is ensured by opening the front door room where is electronic equipment is located. The number of air changes in the room is 5 h^{-1} .

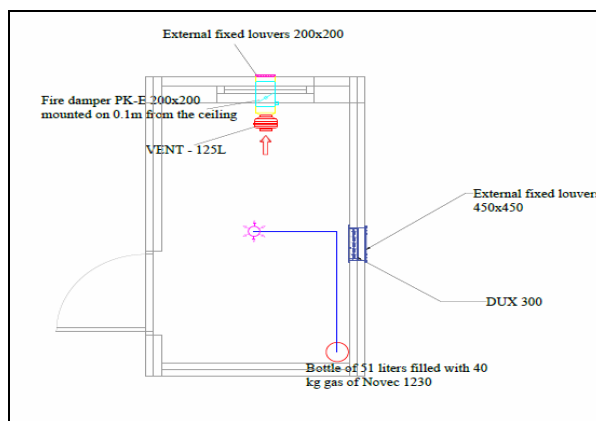


Figure 6. Built-in system in the room

In order to maintain the desired gas concentration in the room a fan door test must be performed.

A DOOR FAN TEST

Before installation of automatic fire extinguishing equipment Novec 1230 it is necessary to do the fan door test of protected space. Fan door test become standard procedure of standard SRPS EN 15004-01 Annex E. The equipment required for testing is a plate on the door, a micrometer and a fan.



Figure 7. Plate on the door



Figure 8. Air fan

There are 2 criteria on which fan door test is based. The application of the first criterion is based on maintaining a constant gas concentration over an interval of 10 minutes.



Figure 9. Micrometer

In case of insufficient space tightness, gas concentration may be reduced. In order for the second criterion to be met, the concentration should not fall below the target concentration by the designer for a time interval of at least 10 minutes. Testing is done depressurization and pressurization.

CONCLUSION

Before installing the equipment, it is necessary to perform a fan door test in order to fulfil the condition of keeping constant concentration in the subject room. After firing the fire extinguisher, it is necessary to discharge the gas and combustion products. For this, it is necessary to install the system of accident ventilation. It is also necessary to install a pressure relief damper so as not to increase the pressure in the room.

REFERENCES

- [1] Z. Sekulović, M. Damjanović, M Bogner, Instalacije za gašenje požara, ETA, Beograd 2014
- [2] SRPS EN 15004-1:2009 Gas extinguishing systems – Design, installation and maintenance
- [3] SRPS EN 15004-2:2009 Gas extinguishing systems – Physical properties and system design of gas extinguishing for FK-5-1-12 extinguishant
- [4] Zakon o zaštiti požara ("Sl. glasnik RS", br 111/09, 20/15 i 87/18)
- [5] <http://www.infiltec.com/inf-ha.htm#Introduction>

BIOGRAPHY of the first author

Marko Nikolić was born in Knjaževac, Serbia, in 1989. He received a degree in environmental protection engineering at Faculty of Occupational Safety in Niš. He also received master degree in energetic and process engineering at Faculty of Mechanical Engineering in Niš. He works at TVI Belgrade d.o.o. as an automatic fire suppression system designer assistant.



HAVARIJSKA VENTILACIJA I FAN DOOR TEST RADNOG PROSTORA

Marko Nikolić, Stefana Janković, Jelena Malenović-Nikolić

Rezime: *Prostorija sa elektronskom opremom sadrži projektovanu ventilaciju koja ima svrhu da posle ispucavanja gasa iz sistema automatskog gašenja za havarijski režim izvlači produkte sagorevanja i sredstvo za gašenje požara. Pre ugradnje opreme za gašenje požara potrebno je izvršiti fan door test prostorije kako bi se održala konstantna koncentracija gasa kao sredstva za gašenje požara.*

Ključne reči: havarijska ventilacija, fan door test.

RADOJE JEVTIĆ¹
MILAN BLAGOJEVIĆ²

¹School for electrical engineering
“Nikola Tesla” Niš,
²University of Niš,
Fakulty of occupational safety

¹milan.jvtc@gmail.rs

²milan.blagojevic@znrfak.ni.ac.rs

SPECIAL CASES IN POINT FIRE DETECTORS ARRANGEMENT - ROOFS WITH MORE SLOPES

Abstract: The right number of fire detectors and their optimal arrangement in an object enable right time fire detection and appropriate actions in order to stop and eliminate fire progress. Fire detectors arrangement was defined by several valid standards. Although those standards deal with the same problems, there are differences between their references for fire detectors arrangement. Those differences can cause diverse reaction times for fire detectors, which is particularly emphasized in certain cases, such as for example an object with a roof with multiple slopes. This paper has been written to show the simulation results for smoke detectors arrangement according to VDE 0833-2 standard.

Key words: smoke detector, roof, slope, standard, simulation.

INTRODUCTION

The importance of a well-designed fire protection system is huge and invaluable in protection of human lives and property from fire. But, what does a well-designed fire protection system exactly mean? The answer to this question is the fact that optimal relationship between system's performances and prices must be achieved. It is not always simple to realize this task. The example can be the case with needed number of fire detectors - with increased number of fire detectors over number that is regulated by proper standards, the complete speed response will not be much increased. So, it is obvious that the most accurate way is, for engineers and designers, to strictly apply rules defined by standards. The most famous standards are EN 54 (European norms), BS (British Standard), NFPA 72 (National Fire Protection Association), НПБ 88-2001 (Нормы пожарной безопасности), VDE 088-2 (Verband der Elektrotechnik- originally- Association of German Electrical Engineers, now- Association for Electrical, Electronic & Information Technologies) and other. The next question is: Do all valid standards “cover” all potential situations that can occur in real life? It is obvious that the answer is negative. Furthermore, for the same situations, different standards can give different references and different solutions. Also, there are lot of illogical statements (for example, the reserve power supply according to Russian standard should be 3 hours after the alarm; however, the doubt remains - what was the purpose of the whole system if a fire could not be extinguished after 3 hours?) [1-3].

The designer should decide what to do for some particular problem according to his own experience and knowledge, but without significant deviation from the rules defined by valid standards. This is specially emphasized in some “special” cases, such as slope roofs, duplicate roofs and narrow hallways, stairs, no typical geometry objects, grids, galleries and similar.

ROOF WITH MULTIPLE SLOPES ACCORDING TO VDE 0833-2 STANDARD

The task to arrange fire detectors in object with one or more slopes at roofs is very often; several standards also deal with this problem with different solutions. German standard VDE 0833-2 defines rules for roofs with one slope, for roofs with slopes that have angle bigger than 20 degrees and for roofs with more slopes. As an example, the distance of point smoke detectors at slope roof in dependence of slope angle is presented in table 1. An arrangement of fire detectors in case for roofs with several slopes is presented on figure 1.

Table 1. Distance of point smoke detectors at slope roof (table source: Fire detection system design, Blagojević M., AGM Book, Belgrade, 2018. Pp. 170)

R_H	Slope of the roof α	
	$\alpha < 20^\circ$	$\alpha > 20^\circ$
	D_L	D_L
up to 6 m	14	0 pt
6 m to 12 m	11	0 pt
(12 m to 16 m)*	10	6 pt

*- in dependence from ambient characteristics. i.e. the way of smoke development and spreading

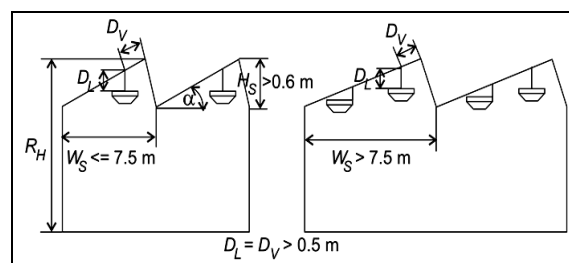


Figure 1. An arrangement of fire detectors in case for roofs with several slopes (figure source: Fire detection system design, Blagojević M., AGM Book, Belgrade, 2018, pp.171)

According to this standard, for roofs with more slopes, it is important to note the height of slope, defined as H_s on the figure 1. For height that is bigger than 0.6 m, every "slope" should have one row of fire detectors. These fire detectors should be installed at the roof, with the lower slope on distance D_v from the slope at the height D_L (defined in table 1). It is important to note that the distance D_v should be at least 0.5 m. In the case when the width of slope (defined as W_s on figure 1) is bigger than 7.5 m and more than the additional detectors are needed, in order with basic rules for fire detectors arrangement.

Particularly interested case is the case for roofs with curved bows. For this roofs, for angle α (defined in table 1), the average slope is calculated on the next way: for the relationship when $G_H/G_B \leq 0.2$, it is considered that the angle $\alpha \leq 20^\circ$; for the relationship when $G_H/G_B > 0.2$, it is considered that the angle $\alpha > 20^\circ$ ($G_H = R_H - V_H$ presents the height of the arc, while the G_B presents the width of the arc, as it is presented on figure 2).

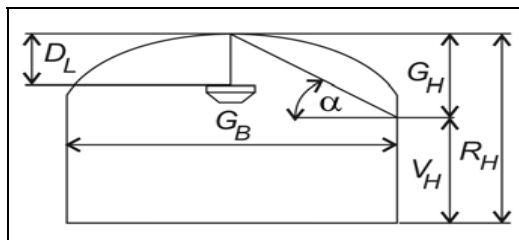


Figure 2. Fire detectors arrangement for roof with curved bows according to the VDE 0833-2 (figure source: Fire protection systems designing, Milan Blagojević, AGM Book, Belgrade, ISBN 978-86-86363-89-3, 2018, pp.170)

The aim of this paper is to show smoke propagation and adequate smoke detectors reaction for both cases of roofs with more slopes, when the width of slope (defined as W_s on figure 1) is bigger than 7.5 m and when the width of slope is smaller than 7.5 m [1,4, 5].

SIMULATION MODEL

Simulation models were realized in FDS-Fire Dynamic Simulator (version 6.6). This software is used for prediction of fire, smoke, carbon monoxide and other fire consequences. Usage of this and similar software present great improvement in observing and investigation of fire. FDS is free software, developed by the National Institute of Standards and Technology (NIST) of the United States Department of Commerce. FDS, the first version, was published in 2000 and since then, there were several versions of this software that came in public.

Simulation models used for this paper were objects with dimensions 25 m x 25 m x 6 m, with three and five slopes. For the object with dimensions 25 m x 25 m x 6 m and three slopes, the slope width marked as W_s on figure 1 was 8.24 m. For the object with dimensions 25 m x 25 m x 6 m and five slopes, the

slope width marked as W_s on figure 1 was about 4.6 m. For both cases, the distance from the top of the roof (marked as D_L on figures 1 and 2) was set to be 0.4 m and 0.6 m. This was done with purpose, because according to the standard, the distance from the top of the roof (marked as D_L on figures 1 and 2) should be bigger than 0.5 m and the value of 0.4 m was taken to be in opposition with standard. It was considered that object was closed with no smoke or ventilation communication with outer air and space.

The fire source was modeled as burner with dimensions of 0.9 m x 0.9 m and HRR (Heat release rate per area) of burner 1500 kW/m². The burner's positions were at the left corner for every simulated object and in the middle of every simulated object. The activation threshold of smoke detectors was 3.35 %/m of obscuration. The examples of simulated objects with three slopes and with five slopes, with proper smoke detectors arrangement are presented on figures 3 and 4. On figure 3, the middle slope is hidden in order to have a view in smoke detectors arrangement below the roof [6, 7].

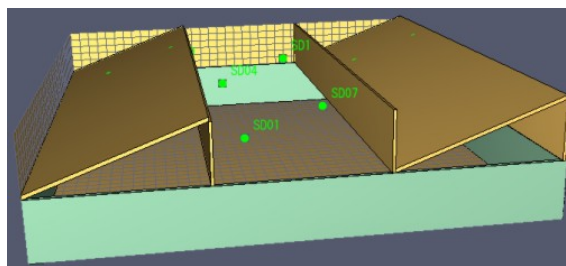


Figure 3. Fire detectors arrangement in case of object with three slopes

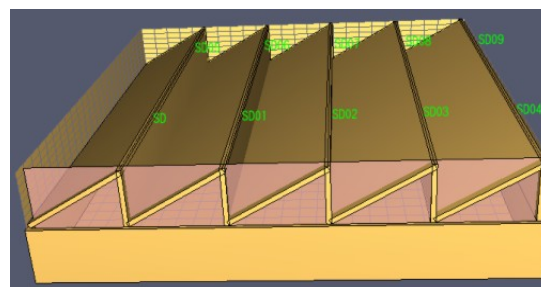


Figure 4. Fire detectors arrangement in case of object with five slopes

SIMULATION RESULTS

The computer used for simulations realized in this paper was laptop LENOVO IdeaPad 320-15IAP - 80XR00B5YA with processor Intel® Pentium® N4200 up to 2.50GHz, screen diagonal from 15.6", 500GB HDD and 4GB of RAM memory. The simulation time was set on 300 seconds for every simulation. This and similar simulation software demand usage of very strong hardware computer configuration and can take a lot of time for simulations realization. Simulation moments for object with three slopes and with burner position at the left corner of the object are presented on figures from 5 to 7.



Figure 5. Smoke propagation in object with 3 slopes after 11.9 s after start with burner position at the left corner of the object



Figure 6. Smoke propagation in object with 3 slopes after 59.7 s after start with burner position at the left corner of the object



Figure 7. Smoke propagation in object with 3 slopes after 178.5 s after start with burner position at the left corner of the object

Simulation moments for object with three slopes and with burner position in the middle of the object are presented on figures from 8 to 10. Simulation moments for object with five slopes and with burner position at the left corner of the object are presented on figures from 11 to 13.



Figure 8. Smoke propagation in object with 3 slopes after 28.9 s after start with burner position in the middle of the object

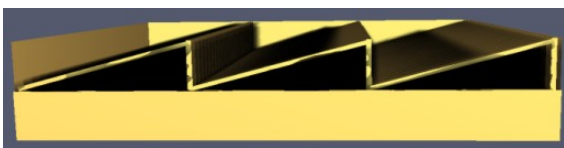


Figure 9. Smoke propagation in object with 3 slopes after 131.4 s after start with burner position in the middle of the object

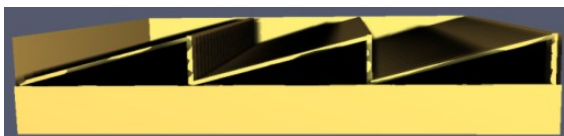


Figure 10. Smoke propagation in object with 3 slopes after 232.0 s after start with burner position in the middle of the object



Figure 11. Smoke propagation in object with 5 slopes after 11.9 s after start with burner position at the left corner of the object



Figure 12. Smoke propagation in object with 5 slopes after 45.6 s after start with burner position at the left corner of the object

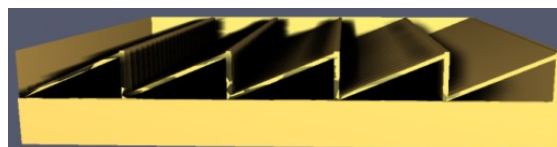


Figure 13. Smoke propagation in object with 5 slopes after 104.7 s after start with burner position at the left corner of the object



Simulation moments for object with five slopes and with burner position in the middle of the object are presented on figures from 14 to 16.

Figure 14. Smoke propagation in object with 5 slopes after 17.3 s after start with burner position in the middle of the object

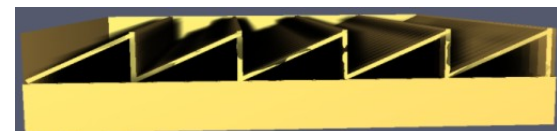


Figure 15. Smoke propagation in object with 5 slopes after 71.3 s after start with burner position in the middle of the object



Figure 16. Smoke propagation in object with five slopes after 163.1 seconds after start with burner position in the middle of the object

The complete results of simulation are presented on figure 17.

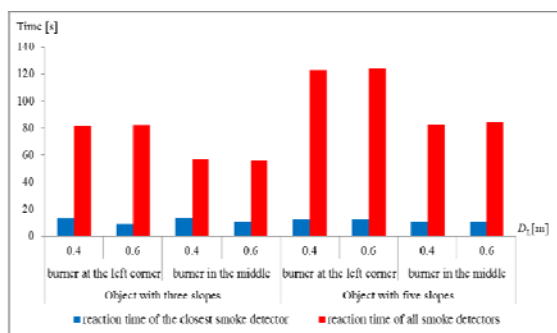
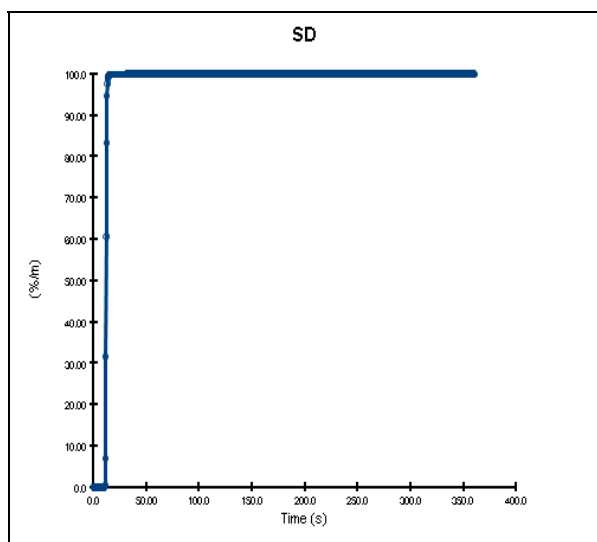


Figure 17. The complete simulation results for both cases and for both burner's positions

RESULTS ANALYSIS

Simulation results showed that all smoke detectors for both cases and for both burner's position reacted. Although the distance from the roof (marked as D_L on figures 1 and 2) should be bigger than 0.5 m according to the standard, simulation results showed that all detectors would react even and for $D_L = 0.4$ m. According to the realized results, the first detectors reactions were noted for only 9 to 15 seconds, what can be seen on figure 18 (a and b) for object with five slopes but different burner's position- at the corner of the object and in the middle of the object.



The closest smoke detectors reacted for similar time for both cases in both objects, but, time needed for reaction of all smoke detectors was shorter for object with three slopes than object with five slopes, what can be seen on figure 17.

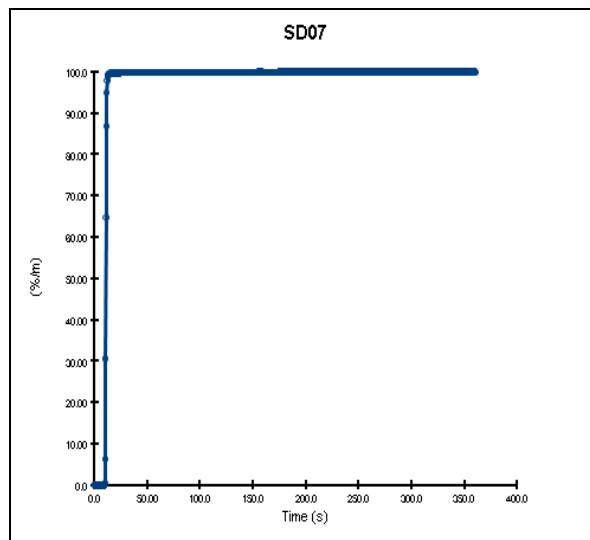


Figure 18. Reaction times of the closest smoke detectors for object with five slopes, when the burner's position was at the corner of the object (a) and when the burner's position was in the middle of the object

DISCUSSION

Simulation results showed that in both cases, when the smoke detectors were arranged according to **VDE 0833-2** standard and with little digression related to this standard, the results are similar and valid. For the same situation or case different standards, there can be similar or different suggestions; however, designers are obliged to introduce every valid standard and, relying on their experience and knowledge, choose and find the best solution.

The usage of simulation software is a very good, safe and economic way for different standards check and for comparative analysis of several different standards for the same situation or for the same scenario. However, this will be the subject of future investigations [8-14].

REFERENCES

- [1] Blagojević, Đ. M.: *Alarm systems*, Faculty of occupational safety in Niš, ISBN 978-86-6093-025-7, Niš, 2015, pp. 66-67, 220-236.
- [2] Blagojević, Đ. M.: *Fire detection system design*, AGM Book, Belgrade, ISBN 978-86-86363-89-3, 2018, pp. V-VII, 75, 162-171.
- [3] Jevtić, B. R.: *Fire Detectors Arrangement in Objects with Slope Roof*, Tehnika Elektrotehnika, Vol 5., ISSN 0040-2176, Beograd, Serbia, 2016, pp. 774-782.
- [4] Jevtić, B. R., Blagojević, Đ. M.: *Point Fire Detectors Arrangement in Special Cases-The slope Roofs case*, Int. Journal of Engineering Research and Application, ISSN 2248-9622, Vol. 8, Issue 3, (Part-3) March 2018, pp.21-27.
- [5] Blagojević, M., Jevtić, R. and Ristić, D.: *On the correct number and arrangement of point smoke detectors*, XXIV. ročník mezinárodní konference Požární ochrana 2015, Ostrava, Czech Republic, 2015.
- [6] Baum, H.R., Ezekoye, O.A., McGrattan, K.B. and Rehm, R.G.: *Mathematical Modeling and Computer Simulation of Fire Phenomenon*, Theoretical and Computational Fluid Dynamics, 1994, pp. 125-139.
- [7] McGrattan, K., Hostikka, S., McDermott, R., Floyd, J. and Vanella, M.: *Fire Dynamics Simulator User's Guide*, NIST Special Publication 1019 Sixth Edition, June 2018, National Institute of Standards and Technology.
- [8] Jevtić, B. R.: *Smoke spreading simulation in double (perforated) ceilings*, Vatrogaštvo i upravljanje požarima, Vol 7., 2017/1. pp. 31-40, ISSN 1848-347X, Zagreb, Croatia, 2017.
- [9] Jevtić, B. R.: *Comparative Simulation Results for EN-54, HITE 88 and NFPA 72 Standards-the Hallway Case*, Int. Journal of Engineering Research and Application, ISSN 2248-9622, Vol. 7, Issue 12, (Part-2) December 2017, pp.62-70.
- [10] Jevtić, B. R.: *The Factors that Have Influence on Fire Detectors Selection-room's Height*, Tehnika Elektrotehnika, Vol 6., pp. 919-927, ISSN 0040-2176, Belgrade, Serbia, 2017.
- [11] Jevtić, B. R., Blagojević, M.: *Smoke and Heat Detectors Arrangement in Hallways*, Safety Engineering, Vol 7. , No. 2., pp. 21-26, ISSN-2217-7124, Niš, Serbia, 2017.
- [12] Blagojević, M., Jevtić, R. and Ristić, D.: *Point Smoke Detectors Siting in the Presence of a Ceiling Irregularity in Form of "Honeycomb"*, XXVI. ročník mezinárodní konference Požární ochrana 2017, Ostrava, Czech Republic, 6. - 7. září 2017.
- [13] Blagojević, M., Jevtić, R. and Ristić, D.: *Comparative analysis of rules for smoke detectors arrangement in corridors*, Facta Universitatis, Working and Environmental Protection, Vol 14, N° 2, pp. 149-158, ISSN 0354-804X, Niš, Serbia, 2017.
- [14] Blagojević, M., Jevtić, R. and Ristić, D.: *Comparative analysis of rules in five leading standards for smoke detectors siting in the presence of a ceiling irregularity*, Transactions of the VSB - Technical university of Ostrava, DOI 10.1515/tvsbses-2017-0011 , Vol. XII, No. 2, , pp. 23-29, 2017.

BIOGRAPHY of the first author

Radoje Jevtić was born in Aleksinac, Serbia, in 1973. He received the diploma in electrical engineering for automatics and electronics from Faculty of Electronic Engineering, University of Niš, the Magister of Science degree and



PhD in technical sciences from Faculty of Occupational Safety at University of Niš. His main areas of research include fire and burglary protection systems, simulations, fire and burglary sensors, etc. He is currently working as a professor of vocational subjects at Electrotechnical School Nikola Tesla in Niš

SPECIJALNI SLUČAJEVI POSTAVLJANJA DETEKTORA POŽARA - VIŠESTRUKI KROVOVI

Radoje Jevtić, Milan Blagojević

Rezime: *Pravilan raspored detektora požara u objektu omogućava otkrivanje požara i najranijoj fazi pravovremenu reakciju za zaustavljanje širenja požara. Postavljanje detektora požara je regulisano evropskim i nacionalnim standardima pojedinih zemalja. Međutim, za pojedine specijalne slučajeve, pravila za postavljanje se razlikuju u pojedinim standardima što ima za posledicu različito vreme odziva detektora i samim tim kasnije otkrivanje požara. U radu je analizirana situacija otkrivanja požara u objektima sa višestrukim krovovima.*

Ključne reči: detektor dima, krov, nagib, standardi, simulacija požara

MARTINA PETKOVIĆ¹
UROŠ JAKŠIĆ¹
SANJA MARKOVIĆ¹
BILJANA NIKOLIĆ¹
MARIJOLA BOŽOVIĆ¹
LIDIJA MILOŠEVIĆ²
DRAGAN KNEŽEVIĆ³

¹Higher Technical Professional
School in Zvečan

²Faculty of occupational safety in Nis

³LOGOS Centar, Mostar

¹*martinaeco@yahoo.com*

²*lidija.milosevic@znrfak.ni.ac.rs*

³*draganlknezevic@hotmail.com*

INFORMATION TECHNOLOGIES IN SAFETY

Abstract: *Information technologies and information systems used in the area of safety (fire protection, environmental protection and occupational safety) are constantly developing and improving in line with the modern trends in information technologies related to protection. The overall aim is to preserve the balance and healthy and good working and living environment. The study reviews the development of information systems and the use of IT in safety.*

Key words: information system, information technologies, protection, monitoring.

INFORMATION SYSTEMS

Informatics is a scientific discipline used to study ways of storing, transfer, register, processing, and utilization of information in various forms (numerical, textual, logical, and visual forms – images and video records). The origin of informatics is related to the emergence of computers – devices with the ability to store, register, process or use certain data for getting new solutions. Computers perform data operations using the universal computer language in its basic form, called machine language. It is made up of a series of impulses with electronic components with or without voltage (1,0). Such a way of data entry, processing, or any other operations is very complex and difficult to apply. This was the reason to develop different programming artificial languages that use human-based languages commands, thus making the programme development faster and easier in comparison to machine code.

Generally speaking, writing a computer programme for the purpose of information processing would be done in vain if there were no pre-designed, planned steps to guide a programmer (a person who writes computer programmes) to reach the goal – solutions of information-based task. A designed set of steps and plans for the realization of programme writing is called an ALGORITHM.

The processes taking place from the initial idea on solving a problem to realization and final solution include:

- Algorithm writing - a method for solving problems
- Writing a computer programme - in an artificial language
- Translation of programming language to machine code – automatic translation
- The continuous control and checking of each process for error correction

Such an overall process from the starting task to final computer-derived solution is known as a cycle. When the cycle is completed, it can be positively said that a task is ready to be implemented into computer processing, including its advantages, such as speed, simplicity, accessibility, simple parameter input, simply

displayed exit data, stored database for a new assignment etc.

A modern approach in the utilization of computers implies computer networking for faster and more effective processing of different pieces of information and the amount of information, thus multiplying the number of operations and significantly shortening data processing time.

Such a computer networking and global networking as well, intranet (interlinked network within an enterprise or institution), internet (network of all networks, the most advanced computer data processing globally) have led to unimaginable information exchange at all levels and forms among different users, thus enriching overall knowledge of the mankind.

The expression 'information systems' denotes all computer networks in the range from scientific and technological aspects (complex mathematical calculations), information systems for business function (data processing, informing, banking data processing, etc.), to management systems that are more involved in the field of decision making, advising and counseling, analytics, and spatially oriented fields, thus having common names, such as: Geographic Information System, or Hydro-Meteorological Information System etc. but they may be modelled as Expert Systems for different purposes.

TYPES OF INFORMATION SYSTEMS

There is a wide variety of information systems, depending on their practical application. An information system should have all the pieces of information necessary for users. There are different kinds of information systems and their classification includes the following criteria:

- 1) Orientation – data processing, management;
- 2) Function or working processes encompassed in the production, purchase, sales, accounting etc;
- 3) The level in decision-making – operational, tactical, and strategic;
- 4) Technical foundation – integrated, non-integrated;
- 5) System of data processing – sequential, off-line, on-line. Modern information system is not oriented to data

gathering and processing, but to the process of decision-making.

While designing and creating a modern information system it is necessary to define the full extent covered by an information system. The crucial factor in designing and selecting a sub-system is data integrity that ensures logical connection between business process and functions. Information systems cannot exist beyond subsystems that are oriented towards the performance of certain categories of assignments and tasks. Business processes include information modules, and the application is the lowest completed information entity aiming at solving a business process. Application components are programmes written in one of the programming languages.

INFORMATION SYSTEMS MANAGEMENT

The problem of system management emerges with the introduction of data processing. The methodological basis for assessing the quality of information system management is a profit function. The functioning and expenses of information systems at each management level must be taken into account. Expenses can be related both to hardware and software. Hardware costs include investments for purchase and installation of information technology equipment, its maintenance, including the loss due to outdated equipment. Software costs include investment regarding its design, purchase and maintenance. The structure of information system management is comprised of a set of activities within the system and communication with other parts of the system. There are two basic models of information system management in practice nowadays, centralized and decentralized models. A centralized management model is characterized by defining the amount of information content, maximum utilization of resources and provision of service in one particular central unit. A decentralized management model is characterized by management decomposition into separate parts of the information system, along with mandatory connections with the centralized management. Regardless the model used, it is necessary to maintain dynamics and balance between information and obtained results.

A NEED FOR THE DEVELOPMENT OF AN INTEGRATED INFORMATION SYSTEM

Once recorded information requests may be used to build up only one level of information system. Each subsequent information request results in extensive development of an information system, since each new management problem requires introduction of new applications, causing multiple storage of the same data. This problem could be solved by introducing a new method into the development of information systems, that is by using systemic approach and the concept of integration. The concept of an integrated information system means that:

1) information system is based on a unified concept and acts as a whole;

2) data needs to be entered only once and from one place;

3) centralized data control is provided;

4) more economical and efficient use of the database is provided;

5) provides the best relationship between the information system benefits and expenses;

6) provides better data maintenance updates;

7) data within the database used as a source for unlimited number of different information requests;

8) a unique database is not the final line of data usage;

9) data utilization is achieved by appropriate application software solutions.

For an integrated information system, the importance lies in the following:

Unified content – each user is required to define their needs for information in a more precise way.

Unified identification – it means that codes for one issue can be applied in all applications. Unified communication system – a requirement for the installed equipment to meet the net connection standards.

Information system integrity – it requires a unified management of defined data processing within the net, proper management regarding the design and function of an information system, unified human resources policy and its organization unification.

An integrated approach may be realized in two ways: as centralized –meaning that this model is based on a unified database, and as a distributed system – database is distributed or made up of different independent databases. The role of an integrated information system is to give relevant pieces of information on a complete situation within an organization or institution in order to achieve more effective and high-quality work and high-quality decision-making as well.

The modern development of human life and health protection, as well as environmental protection against various threats requires a need for undertaking extensive prevention measures and introduction of multifunctional protection systems. The most important prerequisite for proper planning, organization and management is the access to necessary information that can be achieved only by a well-developed information system for managing environmental threats. Such an information system (IS) is a set of organized pieces of information about phenomena and facts aiming at better understanding of that very environment (Čvorović, 2005). It is especially important for identifying and clearly defining problems, for planning intervention procedures, adequate decision-making, for monitoring changes and for outcomes evaluation. Actually, it is the system aiding in efficient threats management in the Republic of Serbia.

Many authors assessed the information systems in our country, so we are mentioning certain information systems in our country related to humans and environment protection.

- System of monitoring and notification, the basic function of the defense system is to note and

identify vital problems and to use effective protection. In order to timely reveal different kinds of threats, a system of monitoring and notification has been designed to enable successful interventions that mitigate or eliminate threats regarding the state security. This system consists of monitoring and notification services, companies and other organizations and bodies engaged in observing certain phenomena in the fields of hydrometeorology, seismology, transportation, health, agriculture, electricity, etc. within their scope of activities.

- Implementation of the system within the Centers for Notifications and Alerts, will greatly improve the quality and speed of information transfer from the moment of the onset of emergency situation to full remedy of the consequences.
 - Health information system – application of information technology in health-care system in Serbia started in 1970s, but a significant improvement has been achieved only in certain fields. Most of health-care facilities in Serbia use personal computers, but the information systems are mostly used at the levels of departments, services and institutions, not at the level of the Republic of Serbia. The development program of an integrated health system should result in more efficient health-care protection, fulfilment of standard requirements, interoperability and implementation of the newest technologies (Microsoft technology).
 - Information system of the Ministry of Internal Affairs – the existing information system deals with performance of duties within the scope of the Ministry of Internal Affairs of the Republic of Serbia. It provides timely reports and information on all relevant issues within this area (performance in fighting crime, disturbance of public order and peace, firearm use, traffic safety, fire protection, etc.), legally conducted and used criminal-operational records and issuing certificates and reports to citizens and other users.
 - Geographic information system (GIS) is one of the most complex information systems which includes all the elements of the geosphere, elements and components of the environment used for analyzing and displaying geographical and spatial phenomena that are present on the Earth, or that may happen in future. It is based on a combination of statistical data with indicators used for monitoring the environment. Geographic information system is used to cover all environmental issues, planning and traffic management, population mapping, development of hazard maps and plans of action in case of emergency situations. Basically, the GIS contains all the pieces of information about air, water, soil, anthropogenic element of space, which can greatly facilitate a timely reaction in cases of natural disasters or technical-technological hazards.
 - Environmental information system is a set of information on environment aiming to establish proper environmental behaviour. On the basis of this IS it is possible to predict future environmental changes, create prognosis and dynamic models. It is important for establishing environmental legislation and monitoring of environmental status, since a situation can be controlled only if the information of the situation is available, and the management can be performed only if the subject of management is familiar.
 - Hydro-meteorological information system is composed of an observation system, a data transfer system and an analytical-prognostic system for data processing. The complete system for observation and measurements is divided into hydrological and meteorological observation system. Certain networks of stations are defined within the system according to the observation and measurement programme (Informator o radu RHMZ, 2011).
 - Other information systems – besides aforementioned information systems, there are other significant systems in our country for efficient and quality environmental threats management. They include: – Seismic information system; – Serbian Army information system; – Information system of Auto-moto association of Serbia; – Information system of the National Poison Control, Military Medical Academy; – Information system of the Red Cross in Serbia; – Information system of the Directorate for air-traffic control; – Information system of 'Elektroprivreda' Serbia and others.
 - Of course, a significant role in this area belongs to global data networks as well, and the most important among them are: – Global Environmental Monitoring System (GEMS) – it enables organized monitoring of environmental status by operating 25 global information and monitoring networks, each having their own database, and the data are comparable; – International Environmental Information System (INFOTERRA) serves as the main channel for international exchange of environmental information, supported by a global network of government and non-government participants; – International Register of Potentially Toxic Chemicals (IRPTC) is a system that includes a database, enables international exchange of chemical substances information, and helps countries that are included in the national registry systems on potentially toxic substances; – Global resource information database (GRID) is a global network for geo-referenced environmental data used for archiving, gathering and transfer of digital information taken from the maps, satellite records, statistic tables, and other sources within and outside the UN system. All the data are connected by a computerized GIS and image processing systems (<http://www.grid.umep.ch>, 25. 12. 2011).
- The development of information technologies has a growing tendency and follows modern trends in protection technologies. Some systems are widely applied: from small to big ones and from standardized

to sophisticated. Some protection systems obtain a fast and full review of all systemic messages. They are easy to use and they also provide a remote access as well. They can be installed independently or they can be a part of a big and complex network by using LAN technology. Detectors in systems fulfill all the requirements both in normal and rigorous environment. Fire safety information systems provide the best level of fire protection. All products and materials may adapt to all types of buildings and fulfill the requirements – from standard to demanding ones, and from compact to large applications. The application of integrated fire safety modular systems enables users to expand or adapt to changing requirements. Some characteristics of modern technologies and fire protection systems help in designing Intelligent system suitable for object protection, the system based on the newest technological platform for all the functions, all types of buildings and all forms of applications in future. TV cameras – in fighting wildfires fire and rescue units should be given modern technology equipment besides the standard one, such as thermographic cameras, drones, and telemetry equipment. The utilization of this equipment is supposed to facilitate localization and fire-fighting, as well as assistance to wildfire and accidents survivors. Thermo-graphic cameras help in early detection of fires. For example, when firefighters extinguish a fire in an object, they slide the camera over the walls and check for possible electrical wiring fire. These cameras can be used for finding persons in burning rooms, since persons who need help, who are injured or unconscious cannot be seen during the fire because of the thick smoke. Cameras can also be used in traffic accidents, for example, when firefighters have to intervene at night it is difficult to detect how many people are in danger, or accidentally fallen out of a car. Drones may help in forest fires in facilitating the detection of fire locations more quickly, in estimating their size, and in detecting persons at risk in open spaces.

CONCLUSION

Current development of protection technologies (fire protection, environmental protection) provides preventive measures in eliminating negative impact of certain factors that may cause process termination or impairment of system stability. From the economic

point of view, the return on each economic indicator investment made in prevention is manifold. Advanced technologies in environmental protection are useful not only at micro-, but also at macro-planning, since networking and continuous monitoring provide monitoring at the state, regional and global levels, which results in the protection of the environment and working environment quality.

REFERENCES

- [1] Mandić, G.: Osnovni principi infracrvene termografije. *INTEGRITET I VEK KONSTRUKCIJA*, Vol 6, br 1-2 (2006), str. 15-23
- [2] Kolečki, J., Iwsczuk, D., Stilla, U. : Calibration of an IR camera system for automatic texturing of 3D building models by direct geo-referenced images Volker Schatz: Synchronised Data Acquisition for Sensor Data Fusion in Airborne Surveying, FGAN-FOM Research Institute for Optronics and Pattern Recognition, Ettlingen, Germany
- [3] Šumarac, D., Ninkov, T., Todorović, M., Bulatović, V.: Review of a methodology for determination of energy loss in civil construction buildings, International conference on district energy, Potorož, Slovenija, 2011.
- [4] Milica Tepšić, Rade Tanjga, ZAŠTITA INFORMACIONIH SISTEMA, Banja Luka College i BESJEDA, Banja Luka 2011

BIOGRAPHY of the first author

Martina Petković was born in Kruševac, Serbia, in 1979.

She received the diploma in environmental protection and the Magister degree in fire protection from the University of Nis, Faculty of Occupational safety in Nis. Her main areas of research include fire prevention, fire protection, environmental safety, occupational safety, etc. She is currently working as an Instructor, Higher Technical Professional School in Zvečan.



INFORMACIONE TEHOLOGIJE U ZAŠTITI

Martina Petković, Uroš Jakšić, Sanja Marković, Biljana Nikolić, Marijola Božović, Lidija Milošević, Dragan Knežević

Rezime: *Informacione tehnologije i informacioni sistemi koji se koriste u oblasti zaštite (zaštite od požara, zaštite radne i životne sredine) se konstantno razvijaju i inoviraju prateći savremene trendove u tehnologijama zaštite, a sve u funkciji očuvanja stabilnosti funkcionalne ravnoteže zdrave i kvalitetne radne i životne sredine. U radu je dat osvrt na razvoj informacionih sistema, kao i pregled korišćenja ovih sistema u našoj zemlji u oblasti zaštite.*

Ključne reči: informacioni sistem, informacione tehnologije, zaštita, monitoring.

VELJKO RADOSAVLJEVIĆ¹
MILE MITIĆ²

¹Elektromehanika DOO, Niš

¹veljko.radosavljevic994@gmail.com

²miticmile@yahoo.com

MEASURES FOR PROTECTION AGAINST DEMOLITION OF MINE ROOMS IN UNDERGROUND MINING

Abstract: *Underground coal mining is one of the most dangerous branches of industry. Given that more than 70% of jobs are in manufacturing industry with increased risk, our goal is to investigate one of the most common risks for workers. It is about the structures of the subframe, the way of construction, installation, replacement, installation of a permanent (steel) subframe, and removal of the wooden (temporary) subframes. The expenses that arise from investments in occupational safety and health can bring a great surplus for the overall system of occupational safety in underground exploitation.*

Key words: subframe, temporary subframe, permanent subframe, tunnel, mining room, mine, risk.

INTRODUCTION

The production of coal in underground exploitation brings various risks, the most frequent being the risk of proper building up of rooms, tunnels and work sites. It is vitally important to incorporate the construction of the subframe correctly, and in this way to reduce the percentage of risk that can eventually cause a disaster. Causes of disasters or occupational accidents, in addition to the human factor, may also be rock bursts as well as earthquakes. In the follow-up, we have described in more detail the support in the underground exploitation which is the basis for safety and health at work in the mines.

MEASURES FOR PROTECTION AGAINST MINING ROOM COLLAPSE AND MEASURES FOR PREVENTION

The opening of the deposit is the first phase in the development of mines with underground exploitation. In the framework of the opening of the deposit, mine rooms are being constructed, the initial stage of construction is the construction with a wooden subframe which is later changed by a permanent or steel subframe. These rooms connect the bearing and its parts to the surface and make it permanently accessible in the safest, most expedient and most economical way. The purpose of the opening room is the transport of coal, bringing fresh air, draining exhausted air, draining water, supplying raw materials and passing people. For the upgrading of mining rooms, a steel circular loose subframe is generally adopted $\varnothing 3,5$ bright surfaces of the cross section $S = 8,2 \text{ m}^2$ ($9,6 \text{ m}^2$ full profile), made of steel profile weight 21 and 24 kg/m (**Figure 1**) and a steel arch loose subframe 3,2-3 m bright surfaces of cross section $S = 8.6 \text{ m}^2$ made of steel profile weight 21 and 24 kg/m.

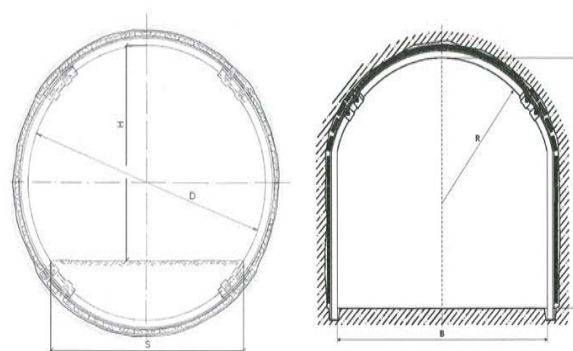


Figure 1. Steel circular yielding subframe and steel semicircular yielding subframe

For the upgrading of mining premises before the steel subframe is installed, a wooden trapezoidal subframe, bright surfaces, of cross section $S = 7,5 \text{ m}^2$ is used. All of these dimensions are variable in relation to the rock pressure in the ground.

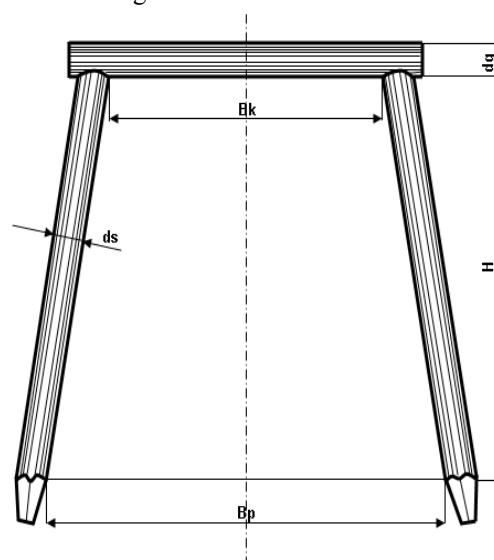


Figure 2. Cross-section of the room, built with a wooden trapezoidal subframe of bright surface

Rocks in the Earth's crust are in a stressed equilibrium state. This condition is disturbed after the production of cave rooms. As a result, there is a redistribution of the tension, that can be seen in the pressure and deformation of the surrounding walls. Increasing the cross-section of the rooms and the depth at which they are located, increases the pressure. The deformation of the mine, wall cracking, and the falling of the walls of the ceiling and the sides of the room occur. If the tension in the mass of a rock is higher than it can withstand. The main causes of deformation of the mining rooms and employee injuries are:

- the collapse of hanging pieces of the wall
- untimely or inadequate subcontracting,
- the application of a low-quality wooden subframe that does not correspond to pressures in the room,
- failure to maintain the prescribed dimensions of rooms and pillars,
- non-use of personal protective equipment.

Statistics show that from 30% to 35% of all injuries in the mines are caused by falling the pieces of the walls from the ceilings or from the sides of the rooms.

Besides this, demolition of rooms leads to other hazards and mining disasters, which are reflected in the following:

- demolition in blind cave rooms may cause closing the only exit for workers working in. Lack of air or the occurrence of toxic gases, and in some cases water, may cause massive problems for trapped workers,
- demolition in the main mining facilities that are used for the passage of people and the ventilation of the mines, may violate the regime of ventilation of the mine, resulting in the danger of gases and water for all employees in the mine.

Appropriate protection measures should be applied to avoid these hazards.

In the production of mine rooms, there are also dangers of sudden demolitions of the rooms and they mostly dominate, but besides them, there are other dangers related to the way of making underground mining rooms and to the type of rooms being built. In particular, we can observe the dangers that occur in the production of mines and digging, as follows:

- horizontal underground mining rooms,
- vertical underground mining rooms.

Depending on the method used, the excavation of the deposit carries with it certain dangers that should also be known.

Horizontal cave rooms are those rooms with a slight slope (up to 5%) or horizontal. Horizontal rooms include underpasses, main corridors, warehouses, etc. The technology of making these rooms can be very different, depending on the type of rock in which it is made and the machinery used. Cross sections and shapes of cave rooms must match the purpose for which the room will serve. Cave openings that will be used for incoming air current, must be built on the length of the first 10 m with the flame-resistant and

high-temperature resistant material. This measure is necessary in order to keep these rooms safe from any possible fire on the surface. Possible sources of injuries and accidents in these rooms are:

- falling off the walls of the ceiling and the side of the room,
- injuries on machines and tools,
- poisoning by blasting products in blind areas when ventilation is not well organized,
- non-use of protective agents,
- noise, poor lighting, vibration, etc.

Demolitions at the end of the corridors are the result of making the corridors in soft rocks. In these corridors the appropriate subframe is necessary. A wooden subframe is still being used in corridors because it is combined with a steel structure, it is easy to install and it is safe thanks to the steel subframe. However, the cons are that it's not permanent and it's expensive. Now different types of supporting parts are being used, which are better and more economical in terms of protection at work. These are concrete, steel arched and other. Some of these substructures require the implementation of a temporary subframe in the construction of a corridor, and then the installation of a permanent subframe. There is a risk of removing the temporary subframe because of the placing of the permanent subframe. This is why the approach to this operation must be careful with the opening of the space as much as the characteristics of the rocks allow. Permanent subframe in these rocks are installed without removing the temporary subframe. If there is demolition at the end of a corridor or any other part, an empty space is formed above the corridor, which presents a potential danger for further collapse in the corridor and injuries of the workers. This space must be well supported by the mining winch and when installing, the concrete subframe must be filled with clay. In the dense rocks where the demolition of the material would continue, the ruins are supported by the use of a permeable subframe. When making a permanent subframe, the temporary subframe remains above the permanent.

TECHNICAL MEASURES FOR CONSTRUCTION

- The subframe must correspond to the conditions at the site, purpose, and time for which the underground mining premises will be used,
- The manner and types of substructures must correspond to the strength and direction of the pressure, cross-section and slope of mining works and the properties of the rocks,
- Sub-building must be done directly with the progress of the front of the work site,
- In the vicinity of old works, disturbed zones, when changing the subframe, and before constructing a permanent subframe, the workplace is provided with a temporary or auxiliary subframe,
- Apply dense subframe especially in pressurized rocks,

- In a soft and insecure ground, the supports should be placed on pedals or fences,
- The cavities above the subframe must be provided with a additional subframe and, if necessary cavities must be filled,
- The site must be inspected and results typed at the beginning of each shift, after each mine and downtime, and, if necessary site must be secured,
- Underground mining works, especially those approaching safety pillars, old water or gas works, must be carried out on the basis of accurate measurements,
- Underground mining works, especially those approaching safety pillars or old works filled with water or gas, must be carried out on the basis of accurate measurements. Free cross sections and the margins of the underground mining premises must correspond to their purpose and show the greatest static resistance. In insufficiently rigid rocks, in which due to the mine of the site a permanent subframe can not be provided immediately, a temporary subframe must be provided.

The temporary subframe should be replaced as soon as possible with permanent one. If the wooden subframe can not withstand the existing pressure for a long time, it should reduce the distance between the frames, or replace the construction style. In appropriate rock, the walls and ceiling can be provided with anchor, if such a possibility is determined by previous tests. The number of anchors on the unit of the open surface on ceiling or walls, as well as their depth and layout, are regulated by technical instructions.



Figure 3. Collapsed ventilation hall of the mine pit

The angle of the underground mining room is 30 degrees. In the construction of these rooms, the same protection measures should be undertaken as for horizontal ones, but with the addition of the special ones to avoid different hazards. In the process of building up rooms downhill or rooms that go up using wooden subframe, there is the danger of demolishing the subframe of the room that goes down if it is made in soft rocks. Subframes sets are therefore placed straight positioned on the axis of the hall and are well-stretched among the spans. In steep rooms that go

downwards in every 8 m, there should be built a special support for the subframe. The base of this support construction is made of horizontal beams that are deeply relying on the walls. There is also a risk of rolling rocks and other objects. At the end of the down room, a barrier should be foreseen to protect people from accidentally unhooked wagons. The barrier is constructed at 10 m from the front of the work site and has to withstand the impact of a full wagon. The same barrier is also made on the top of the room that goes down. This barrier is placed at a distance of one length of the wagon and it opens only after the wagon has tightened the rope. The production of vertical room in the mines is very common and at the same time the most dangerous. Vertical rooms can be made by digging from top to bottom or from bottom to top. The way of making these rooms today is very different, depending on the depth of the mine shaft. Appropriate technical documentation is required for the design of the mine shaft. Work in main or blind mine shaft may be performed, as a rule, only in one level. The most common injuries can be:

- because of the collapse of the rocks from the sides of the mine shaft due to the failure to establish a temporary subframe or a permanent subframe.
- due to the falling of pieces of rocks and various objects caused by poor maintenance of the subframe, etc.
- Falling people into the shaft due to malfunction of the passing section, and disregard of the regulations.
- Due to the rupture of pipelines or ropes on export cables
- Due to the non-use of personal protective equipment.

The protection from the collapse of the mine shaft is carried out by performing a temporary subframe. The temporary timber should not be at a distance greater than 3 m from the front of the work site. At the entrance of the mine shaft must be a strong main dam. The openings on the defense are closed with solid lids that can exert strong punches. At the bottom of the mine shaft, there is also an outbreak to protect the workers from falling parts of the rocks and other objects. At the time of export, no one should stay at the bottom of the shaft where the vessels are lowered. Vessels are accepted by hooks. After blasting and ventilating the shaft, all the pieces of the rocks that were eventually held on the temporary subframe should be cleaned.

Shafts are made from the bottom upwards only in the rocks where it is possible in a safe way.

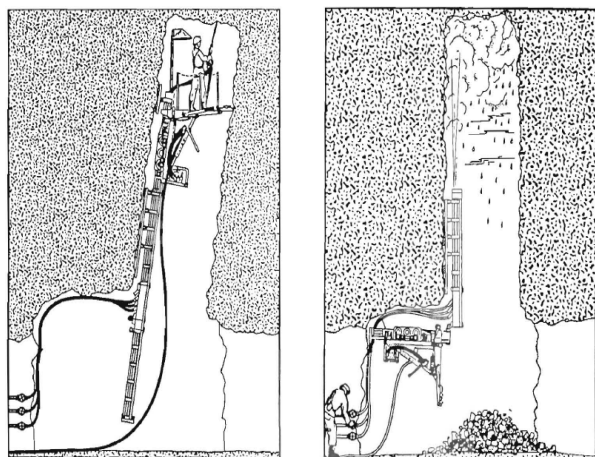


Figure 4. Platform for breaking the mine pite roof

It is very important to mention earthquakes and rock burst. The earthquake occurs due to the movement of tectonic plates and the consequence is the shake of the Earth's crust due to the release of great energy. Tectonic plates annually move from 2 to 3 cm. Contrary to the widespread belief that these are rare, they occur very often, but their greatest number is of low intensity and occurs on relatively small surface areas of the land or the ocean floor. As a result of the earthquake, there can be a rock burst, which is, by definition: a sudden uncontrolled collapse of large amounts of surrounding rock and earth in the underground mines caused by the excavation of the ore and is often the cause of mining accidents.

More precisely, the rock burst is the result of tectonic disorders in the earth's crust. According to the opinion of the mining engineers and the directors, a rock burst is the biggest disaster that can hit one mine. In their opinion, there isn't a protection from the rock burst. There are measures such as reinforcement of a wooden subframe with concrete one, concrete pillars and so on. But these are just measures that can alleviate the consequences and extend the evacuation time.

CONCLUSION

Properly designed subframe construction may be a big expense for mines, but it carries a surplus of workers protection with them, which is a more than sufficient reason to invest in technical advancement and overall upgrading. The system of subframes and the rest of the occupational safety system is of vital importance for the life of miners in risky situations.

REFERENCES

- [1] V. Radosavljević: "Analiza sistema zaštite na radu u rudniku JP PEU RMU REMBAS Resavica", diplomski rad, fakultet zaštite na radu, univerzitet u Nišu, 2017, Niš.
- [2] Dokumentacija JP PEU RMU REMBAS Resavica.
- [3] Akt o proceni rizika JP PEU RMU REMBAS Resavica.
- [4] Z. Aksentijević: "Čeono obaranje zakrovine uglja u jami Ravna Reka IV blok", Tehnički fakultet, 2012, Bor.
- [5] V. Jovičić, M. Miljković, J. Nuić: "Sigurnost i tehnička zaštita u rudarstvu", Rudarsko-geološki fakultet, 1987, Tuzla.

BIOGRAPHY of the first author

Veljko Radosavljević was born in Čuprija, Serbia, in 1994.

He received the Bachelor with Honours diploma in occupational safety engineering from the University of Niš, Faculty of Occupational Safety in Niš

His main areas of research include occupational safety in mines, risk assessment and environmental protection.



MERE ZAŠTITE OD ZARUŠAVANJA JAMA U RUDNICIMA SA PODZEMNOM EKSPLOATACIJOM

Veljko Radosavljević, Mile Mitić

Rezime: Podzemna eksploatacija uglja jeste jedna od najopasnijih grana idustrije. S obzirom da je vise od 70% radnih mesta u proizvodnji sa povećanim rizikom, naš cilj jeste da kroz ovaj rad obradimo jedan od najčešćih rizika po radnike. Reč je o samim konstrukcijama podgrade, načinu izrade, postavljanja, zamene, ugradnje stalne-čelične podgrade, uklanjanje drvene-privremene podgrade. Rashodi koji se javljaju kao posledica ulaganja u bezbednost i zdravlje na radu donosi veliki suficit za celokupan sistem zaštite na radu u podzemnoj eksploataciji.

Ključne reči: podgrada, privremena podgrada, stalna podgrada, tunel, prostorija, rudnik, rizik.

PHYSICAL AND CHEMICAL ASPECTS OF WORKING AND LIVING ENVIRONMENT



ZVONKO NJEŽIĆ¹
IVANA BANKOVIĆ-ILIĆ²
OLIVERA STAMENKOVIĆ³
VLADA VELJKOVIĆ⁴

¹University of Novi Sad,
Institute of Food Technology in
Novi Sad, Serbia
^{2,3,4}University of Niš,
Faculty of Technology in Leskovac,
Serbia

¹zvonko.njezic@fins.uns.ac.rs
²ivanabank@yahoo.com
³oliverastam@yahoo.com
⁴veljkovicvb@yahoo.com

ENVIRONMENTAL ASPECTS OF THE PRODUCTION AND USE OF CORN OIL BIODIESEL

Abstract: *The present paper reviews the environmental aspects of the production and use of corn oil-based biodiesel. The environmental aspects are analyzed by considering the used-corn oily feedstocks and production technology. Besides that, the possibilities for the improvement of the biodiesel production process are emphasized. The most valuable corn-oil feedstocks are waste corn oil and corn distillers oil obtained primarily from dried distillers grains with solubles (DDGS). The use of DDGS, a by-product of ethanol production, for biodiesel production and glycerol, a by-product of biodiesel production, as a substrate for ethanol production, allows the development of an integrated ethanol/biodiesel production and contributes to the elimination or minimization of wastes and the production of the added-value products. Biodiesel is a degradable, less-toxic, safe, and generally, clean-burning fuel with exception of NO_x emission that can be reduced by the appropriate methods but further investigations are desirable.*

Key words: corn oil, biodiesel, environmental aspect, ghg emission, pollution.

INTRODUCTION

The industrial growth, demographic expansion, increased transportation, and higher living standard cause the continued increase in energy demand. The most important energy sources, particularly in the transportation sector, are the fossil fuels, so the modern world is confronted with the fossil fuel depletion that leads to the increase of their price and the environmental problems connected with their consumption, such as significant greenhouse gases (GHG) emission, global warming, and climate changes. Consequently, particular attention is dedicated to the development of renewable energy sources and among them to biodiesel a very perspective fuel.

The biodiesel is a mixture of fatty acid alkyl esters (FAAE), usually methyl or ethyl esters, which is obtained from oily feedstocks rich in triacylglycerols or free fatty acids by alcoholysis and esterification reaction, respectively. The FAAE synthesis is performed in the presence of a catalyst, which can be a base or an acid. On the basis of the catalyst's solubility in the reaction mixture, this synthesis can be homogeneous (soluble) or heterogeneous (insoluble). The catalyst of the FAAE synthesis can also be an enzyme – lipase, usually used in the immobilized form. In addition, at the reaction temperature and pressure over the alcohol critical values, the alcoholysis reaction can be performed with no catalyst i.e. as a supercritical reaction. The physicochemical properties of biodiesel are prescribed by the biodiesel quality standard specifications EN14214 or ASTM D6751 in EU and USA, respectively. The various feedstocks are used for

biodiesel production, such as edible vegetable oils and animal fats (first generation biodiesel), non-edible oils, used edible oils, waste oily streams and animal fats from different production processes (second generation biodiesel), and algal oils (third generation biodiesel).

A promising oil crop for biodiesel production may be corn or maize (*Zea mays* L.) that is widely cultivated, especially in the USA and China, followed by Brazil, Mexico, Argentina, India, and France [1]. It was discovered about 9,000 years ago in Central America, from where it was spread all over the world, with the generation of a large number of types and varieties adaptable to different growing conditions [2]. Today's corn is the result of long-term spontaneous and continuous mutation through cultivated breeding during the development of civilization and the application of different selection methods. By the natural selection, a number of varieties have also been created for different purposes. Corn is grown in different climatic conditions, from moderate to tropical. It does not tolerate frost and thrives best when the mean daily temperature is about 15 to 25 °C. Performance of corn cultivation depends significantly on the proper selection of varieties and timely applied agricultural measures.

Corn is primarily used as a fodder, raw material in the food and alcoholic beverage industries, for the bioethanol fuel production, and since recently for the paper, packaging, and plywood production. Generally, large corn quantities are used in the production of starch and ethanol wherein a by-product is the corn oil that is "fastest expanding oily feedstock for biodiesel production" [3].

The present paper deals with the environmental assessment of corn oil-based biodiesel production and use from the technological point of view. The aim of the work was to analyze the ecological impacts of corn oil-based biodiesel production in terms of the used oily feedstocks and the production technology. Furthermore, the possibilities for the improvement of the current biodiesel production processes are discussed.

CORN OIL BIODIESEL PRODUCTION

Oily feedstocks

Various corn oil-based feedstocks can be used for biodiesel production, such as corn oils originated from different plant parts (neat corn oil), waste frying corn oil (WFCO), and corn distillers oil (CDO). Neat corn oil can be extracted from whole ground kernels and germs. Kernels are rarely used for the oil recovery due to the low oil content (3-5%) [4]. The most often used methods are the extraction with ethanol [5]. The germ or embryo is part of the corn kernel, rich in the oil (35-56%) [6], which is used for the commercial production of corn oil. Germs can be obtained by a wet- or dry-degerming milling process. The former process, primarily used for starch production, is more effective since 50% more germs is separated, compared to the latter process [7]. However, this process is environmentally unfavorable due to the requirement of a large amount of water, the presence of other kernels portions in the output stream, and the need of an appropriate pretreatment for the oil release [8]. The germs obtained by the wet-milling process are used for producing edible corn oil. The corn germ oil for biodiesel production is usually obtained from germs obtained by the dry-degerming milling process, which is applied in the most ethanol facilities because of its high ethanol yield, low capital, energy and water investment, and simplicity [7].

Several approaches have been used for recovery of corn germ oil, such as pressing, extrusion, as well as various solvents extraction. Traditionally, corn germ oil is recovered by *n*-hexane extraction and pressing followed by *n*-hexane extraction of the obtained cake. Due to the environmental, health, and safety risk, *n*-hexane extraction is needed to be replaced with the environment friendly methods. Accordingly, the U.S. Environmental Protection Agency issued rigorous instructions for hexane emissions by plants for vegetable oil extraction in 2001 [9]. For minimizing the environmental impact of the corn oil extraction, the substitution of hexane as extracting agent is required. Alcohols, supercritical (SC) fluids (especially SC-CO₂) and water are promising, environmentally-friendly solvents; the enzyme-assisted aqueous extraction has also attracted an attention for the same reasons [10].

Waste cooking oils are advantageous feedstocks for biodiesel production due to their environmental desirability. Namely, their disposal onto landfills can cause certain environmental problems, such as water and soil pollution. Their valorization helps to reduce

waste, to minimize the footprint of the technology and to add value through the production of valuable products. Up to date, WFCO has rarely investigated for biodiesel production [11] but the increased use of corn oil in food processing will certainly contribute to its significance in the future biodiesel production.

The most interesting corn oily feedstock for biodiesel production is CDO. It is obtained from the by-products of the ethanol production process. One of them, called whole stillage (WS), is obtained after fermentation and ethanol separation. Although the various fraction of whole stillage can be used as a feedstock for oil recovery, the most often is used distiller dried grain with solubles (DDGS or distiller dried grain DDG). Considering the composition and annual production of DDGS, its importance is underestimated and it is mainly used in the preparation of animal feed [12]. Bearing in mind that DDGS contains 8-10% of the oil (based on dry mass), which is higher than the amount needed for animal feed, it can be a valuable feedstock for the biodiesel production. The investigations of the oil recovery from DDGS have started at the end of the XX century, and hence, no many literature data are presently available. The most often used methods for oil recovery are the extraction with SC-CO₂ [13,14] and ethanol [15] while the use of *n*-hexane is limited to WS fractions with a lower oil content. Regarding the environmental and economic aspects, these fractions are not considered as biodiesel feedstocks because of *n*-hexane flammability and toxicity and low oil content.

It is obvious that the environmental impact of oily feedstocks for corn biodiesel production could be minimized by using WFCO and DDGS as raw materials as well as environmentally favorable solvents for the oil extraction. The use of DDGS allows the development of a new integrated process that has a positive both ecological and economic effects.

Production technology

The present commercial biodiesel production is generally based on the homogeneous base-catalyzed alcoholysis. However, this process is environmentally unfavorable because of the need for a complex purification of crude biodiesel that involved a number of washing steps generating a large amount of wastewater [16,17].

A lower environmental impact on biodiesel production can be achieved by developing new and improving current production processes. The biodiesel perspectives generally include the development of emerging technologies based on the process intensification concept aiming at overcoming the drawbacks of the conventional processes. Emerging technologies are based on the catalyst selection, new reactor type design, lower energy inputs, easy process control, and reduced "footprint" requirements.

The use of heterogeneous catalysts and enzymes and the conduction of the biodiesel synthesis at supercritical conditions of alcohol without catalyst are environmentally more acceptable. Among them, the heterogeneous processes are promising, which can be

further improved by the development of high-active, easily available, stable, and eco-friendly catalysts, prepared either from waste materials (shells of oyster, cockle, sea snail, and mollusc, and waste eggshell) or from biomass [18]. Their use not only adds a value to these wastes but also enables the development of a sustainable process. Furthermore, the development of continuous processing technologies based on the heterogeneous catalysis minimizes or eliminates the numerous downstream separation and purification steps. It is expected that these technologies gain a wider acceptance in the near future [19]

An encouraging approach from environmental and economic aspects is the development of integrated and *in situ* processes that have numerous advantages.

Integration of biodiesel production into the existing ethanol production facilities is an advanced method that allows adding value to the by-products from the ethanol production. The schematic presentation of the biodiesel production process from DDGS as mostly oily feedstock is shown in Figure 1.

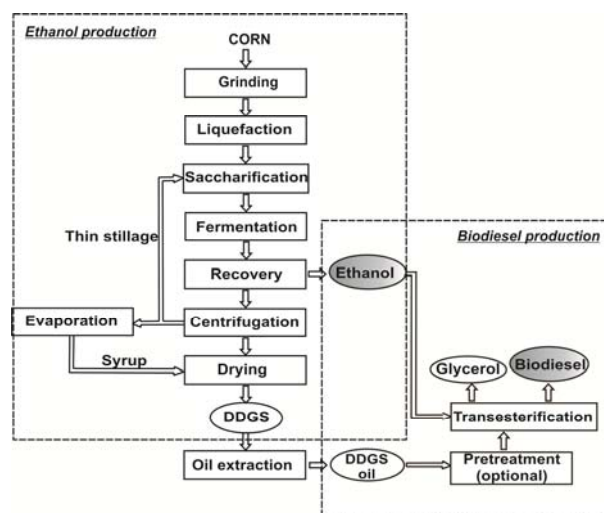


Figure 1. Integrated production of corn based ethanol and biodiesel

Corn oil from DDGS is already recovered in some ethanol plants and used for biodiesel production [20]. The incorporation of the necessary equipment does not affect ethanol production and has many environmental and economic advantages. Among them, the most significant is the exploitation of by-products streams, the use of existing infrastructure, the reduced transportation, the energy savings, as well as the obtaining of a fully agricultural biodiesel fuel. In this way, this approach reduces the negative environmental impact related to land use for new plant building, transportation of raw materials, lower use of non-renewable energy sources, and replacement of highly toxic methanol with ethanol. Furthermore, the overall process results in significant capital savings and higher cost efficiencies compared to conventional biodiesel processes.

Another approach for the improvement of corn-based biodiesel production is the development of the

integrated process where glycerol, a by-product of biodiesel production, is used as a substrate for ethanol production, which is schematically presented in Figure 2 [21]. The use of heterogeneous catalysts or immobilized enzymes with high stability is desirable for the biodiesel synthesis in order to develop a continuous process or enable their multiple uses with/without an appropriate treatment. The fermentation residue can be used for the production of biofertilizers that can be used in corn cultivation.

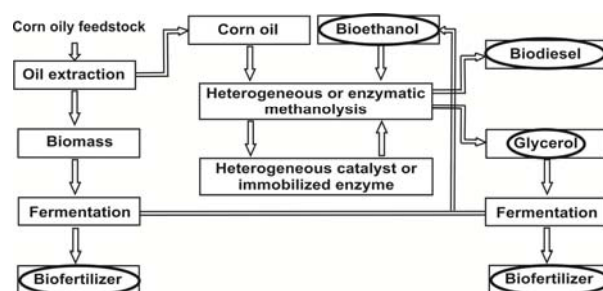


Figure 2. Integrated process of heterogeneous or enzymatic biodiesel production

The *in situ* transesterification is a novel technology for producing biodiesel from corn oil, which is designed with the aim of avoiding the use of a large solvent amount for the oil extraction from corn germs, thus reducing the environmental impact and the overall cost. As a feedstock in the *in situ* biodiesel production from corn, the germ separated in the processing of the whole corn kernels or milled and treated whole kernels are used [22]. Besides the positive environmental impact of this process, the obtained esters yield is higher compared to the conventional two-step extraction/alcoholysis process.

THE USE OF CORN OIL BIODIESEL

The environmental impact of the corn oil biodiesel use has rarely been investigated. However, many researches have been aimed at the assessment of these implications for biodiesel obtained from other feedstocks [23]. Since the biodiesel physicochemical characteristics are prescribed by the standard specifications, it is expected that the environmental impacts of corn oil biodiesel are similar or even the same with those of biodiesel originated from other oily feedstock. The use of corn oil biodiesel reduces the emission of GHG, sulfur, particulate matters, and hydrocarbons [24], consequently lowering the negative impacts on air, water, land, biodiversity, and climate changes. Based on different approaches taking into account the emissions of the six climate gases defined in the Kyoto Protocol, it was estimated that biodiesel reduces the GHG emissions by 22-59 %, compared to fossil diesel [25]

The use of biodiesel reduces life-cycle CO₂ emissions by 50–75% or net CO₂ emissions by 78.45% compared to fossil diesel [26]. Therefore, biodiesel is considered as a carbon neutral fuel, as plant during photosynthesis

captured nearly overall CO₂ released during biodiesel production and use. Biodiesel has no sulfur (< 0.0024 ppm) and no emission of the sulfur oxides during its combustion, so the risk of the acid rain formation is significantly lowered. Also, the biodiesel burns with a significantly lower CO emission (up to 20%) compared to fossil diesel due to higher oxygen content and improved biodiesel combustion. Although the importance of biodiesel on the reduction of life-cycle CH₄ emissions is low (the most 2.57%), it is significant because CH₄ is a particularly harmful GHG [26]. Compared to fossil diesel, NO_x emissions from the biodiesel burning are higher and generally influenced by the engine performances. The environmental concern has resulted in the development of the methods for the reduction of NO_x emissions, such as increasing the injection fuel pressure and postponing the injection timing and adding certain additives such as alcohol or emulsifiers [27]. So far, only Wang et al. [28] have indicated the co-product treatment approach in GHG emission evaluations. The presented results indicated that the calculated GHG emissions depend on the used methodology. Based on the three developed methods, named marginal, hybrid allocation, and process-level energy allocation, the GHG emissions were estimated to be 14, 59, and 45 g CO₂e/MJ, respectively, while the fourth method designated as displacement, showed that corn-oil biodiesel is burden-free.

The environmental advantages of biodiesel are its degradability and safety. The degradation degree of biodiesel is 80.4–91.2% in 30 days, which is 3.3–3.7 times higher compared to fossil diesel under the same conditions [29]. The high biodiesel flash point (above 120 °C) indicates its easier and safer storage and transport and lower fire hazard compared to fossil fuel. The valuable method for capturing all the environmental influences of the products during their life cycle is the life cycle assessment (LCA). LCA studies of biofuels generally include the stages from the production of feedstocks to biofuel end-of-life. However, the LCA analysis depends on the availability and quality of the data and simulation methodologies and frequently does not comprehend feedstock variations and processes differences which are important for the analysis. Therefore, a further improvement and the addition of other analysis to LCA are needed to obtain more specific LCA results [30].

CONCLUSION

Corn is a promising crop as it is produced worldwide in large quantities for use as the main ingredient in livestock feed and processing into many industrial products and biofuels, such as bioethanol and biodiesel. Corn-oil biodiesel is attractive biofuel due to its environmental and economic advantages that can be considered in terms of corn-oil feedstock and production process. The use of WFCO and DDGS as a raw material for the biodiesel production and environmentally favorable solvents for the corn germ oil extraction minimizes the environmental impact of

biodiesel production. The development of the new, emerging technologies aiming at lowering the environmental impact and improving the process economy allows sustainable development. The integrated bioethanol/biodiesel production process based on the use of DDGS from ethanol plant as a biodiesel feedstock, glycerol from fatty ester synthesis as the substrate in bioethanol production, and *in situ* processes have the numerous environmental advantages. The use of corn-oil biodiesel significantly contributes to the reduction of exhaust emission, especially GHG, particulate matter, sulfur oxides, and hydrocarbons. The NO_x emission from biodiesel combustion should be further investigated in order to reflect the environmental impact of the biodiesel use.

REFERENCES

- [1] V.B. Veljković, M.O. Biberdžić, I.B. Banković-Ilić, I.G. Djalović, M.B. Tasić, Z.B. Nježić, O.S. Stamenković: "Biodiesel production from corn oil: a review", *Renewable and Sustainable Energy Reviews*, Vol. 91, 2018, pp. 531–548.
- [2] Y. Matsuoka, Y. Vigouroux, M.M. Goodman, J. Sanchez Garcia, E. Buckler, J. Doebley: "A single domestication for maize shown by multilocus microsatellite genotyping", *Proceedings of the National Academy of Science, USA*, Vol. 99, 2002, pp. 6080–6084.
- [3] L. Grooms: "Biodiesel industry turns Corn oil, Farm Industry News 2014" (<http://www.farmindustrynews.com/biofuel/biodiesel-industry-turns-corn-oil>) [Accessed 25 October 2018].
- [4] J.M. Marchetti: "A summary of the available technologies for biodiesel production based on a comparison of different feedstock's properties", *Process Safety and Environmental Protection*, Vol. 90, 2012, pp. 157–163.
- [5] J.R. Kwiatkowski, M. Cheryan: "Extraction of oil from ground corn using ethanol", *Journal of the American Oil Chemists' Society*, Vol. 79, 2002, pp. 825–830.
- [6] S. Ni, W. Zhao, Y. Zhang, M.A.A. Gasmalla, R. Yang: "Efficient and eco-friendly extraction of corn germ oil using aqueous ethanol solution assisted by steam explosion", *Journal of Food Science and Technology*, Vol. 53, 2016, pp. 2108–2116.
- [7] G.S. Murthy, E.D. Sall, S.G. Metz, G.F. Foster, Singh V. Foster: "Evaluation of a dry corn fractionation process for ethanol production with different hybrids", *Industrial Crops and Products*, Vol. 19, 2009, pp. 67–72.
- [8] P. Blanchard: "Wet milling". In: *Technology of corn wet milling and associated processes*, Elsevier Science, Amsterdam, 1992, pp. 92–3.
- [9] EPA (Environmental Protection Agency) (2001). National emissions standards for hazardous air pollutants: Solvent extraction for vegetable oil production; 40 CFR Part 63. Final Rule, *Federal Register*, 66 19005–19026.
- [10] D. Shende, G.K. Sidhu "Methods used for extraction of maize (*Zea mays*, L.) Germ oil-a review", *Indian*

- Journal of Scientific Research and Technology, Vol. 2(4), 2014, pp.48-54.
- [11] N.S. El-Gendy, S.F. Deriase, A. Hamdy: "The optimization of biodiesel production from waste frying corn oil using snails shells as a catalyst", *Energy Source A*, Vol. 36, 2014, pp. 623–37.
- [12] Y. Lu, K.A. Rosentrater: "Physical and chemical properties of whole stillage, thin stillage and syrup" *American Society of Agricultural and Biological Engineers* 2015, Paper Number: 152184612, July 26 – 29, 2015, New Orleans, Louisiana.
- [13] O.N. Ciftci, J. Calderon, F. Temelli: "Supercritical carbon dioxide extraction of corn distiller's dried grains with solubles: experiments and mathematical modelling", *Journal of Agricultural and Food Chemistry*, Vol. 60(51), 2012, pp. 12482-1290.
- [14] J.K. Winkler, K.A. Rennick, F.J. Eller, S.F. Vaughn: "Phytosterol and tocopherol components in extracts of corn distiller's dried grain", *Journal of Agricultural and Food Chemistry*, Vol. 55, 2007, pp. 6482–6486.
- [15] N. Singh, M. Cheryan: "Extraction of oil from corn distillers dried grains with solubles", *Transactions of the ASAE*, Vol. 41(6), 1998, pp. 1775-1777.
- [16] I.J. Stojković, O.S. Stamenković, D.S. Povrenović, V.B. Veljković: "Purification technologies for crude biodiesel obtained by alkali-catalyzed transesterification", *Renewable and Sustainable Energy Reviews*, Vol. 32, 2014, pp. 1–15.
- [17] V.B. Veljković, O.S. Stamenković, M.B. Tasić: „The wastewater treatment in the biodiesel production with alkali-catalyzed transesterification“, *Renewable and Sustainable Energy Reviews*, Vol. 32, 2014, pp. 40–60.
- [18] B. Sanjay: "Heterogeneous Catalyst derived from Natural Resources for Biodiesel Production: A Review", *Research Journal of Chemical Sciences*, Vol. 3(6), 2013, pp. 95-101.
- [19] Z. Helwani, M.R. Othman, N. Aziz, J. Kim, W.J.N. Fernando: "Solid heterogeneous catalysts for transesterification of triglycerides with methanol: A review", *Applied Catalysis A: General*, Vol. 363, 2009, 1–10.
- [20] B.R. Moser, S.F. Vaughn: "Biodiesel from corn distillers dried grains with solubles: preparation, evaluation, and properties", *Bioenergy Resource*, Vol. 5, 2012, pp. 439–49.
- [21] K.R. Jegannathan, E.-S. Chan, P. Ravindra: "Harnessing biofuels: A global Renaissance in energy production?", *Renewable and Sustainable Energy Reviews*, Vol. 13, 2009, pp. 2163–2168.
- [22] A. Shi, Z. Du, X. Ma, Y. Cheng, M. Min, S. Deng, P. Chen, D. Li, R. Ruan: "Production and evaluation of biodiesel and bioethanol from high oil corn using three processing routes", *Bioresource Technology*, Vol. 128, 2013, pp.100–106.
- [23] S.B. Živković, M.V. Veljković, I.B. Banković-Ilić, I.M. Krstić, S.S. Konstantinović, S.B. Ilić, J.M. Avramović, O.S. Stamenković, V/B. Veljković: "Technological, technical, economic, environmental, social, human health risk, toxicological and policy considerations of biodiesel production and use", *Renewable and Sustainable Energy Reviews*, Vol. 79, 2017, pp. 222–247.
- [24] S. Gowthaman, K. Velmurugan: "Performance and emission characteristics of direct injection diesel engine using bio-diesel with SCR technology", *International Journal of Engineering Science*, Vol. 2, 2012, pp.1083–9.
- [25] M. Frondel, J. Peters: "Biodiesel: A new Oildorado?", *Energy Policy* Vol. 35, 2007, pp. 1675-1684.
- [26] S. Živković, M. Veljković: "Environmental impacts the of production and use of biodiesel", *Environmental Science and Pollution Research*, Vol. 25(1), 2017, pp. 191-199.
- [27] S.E. Hosseini, M.A. Wahid: "Necessity of biodiesel utilization as a source of 423 renewable energy in Malaysia" *Renewable and Sustainable Energy Reviews*, Vol. 16, 2012, pp. 5732.
- [28] Z. Wang, J.B. Dunn, J. Han, M.Q. Wang: "Influence of corn oil recovery on life-cycle greenhouse gas emissions of corn ethanol and corn oil biodiesel", *Biotechnology for Biofuels*, Vol. 8, 2015, pp. 178-188.
- [29] A. Demirbaş: "Biodegradability of biodiesel and petrodiesel fuels", *Energy Sources –A*, Vol. 31, 2008, pp. 169–174.
- [30] J. Lin, C.W. Babbitt, T.A. Trabold: "Life cycle assessment integrated with thermodynamic analysis of bio-fuel options for solid oxide fuel cells" *Bioresource Technology*, Vol. 128, 2013, pp. 495-504.

ACKNOWLEDGEMENTS

This work has been funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Project III 45001). It is also a part of the Project 0-14-18 of the SASA Branch in Niš, Serbia.

BIOGRAPHY of the first author

Zvonko Nježić was born in Sremska Mitrovica, Serbia, in 1966. He received the B.Sc. diploma in mechanical engineering, as well as the M.Sc. and Ph.D. degrees in environmental engineering from the University of Novi Sad, the Faculty of Technical Sciences.

His research areas belong to sustainable development and waste management. Since 2018, he is a Research Associate Professor.



EKOLOŠKI ASPEKTI PROIZVODNJE I PRIMENA BIODIZELA IZ ULJA KUKURUZA

Zvonko Nježić, Ivna Banković-Ilić, Olivera Stamenković, Vlada Veljković

Rezime: U radu su prikazani ekološki aspekte proizvodnje i primene biodizela iz ulja kukuruza na osnovu pregleda i analiza dosadašnjih istraživanja i dostupnih podataka. Ekološki aspekti su povezani sa korišćenim uljnim sirovinama i tehnologijama proizvodnje biodizela. Takođe, razmotrene su mogućnosti za unapređenje postupaka proizvodnje biodizela. Ekološki najpovoljnije sirovine za sintezu biodizela su otpadno kukuruzno ulje i ulje nus-proizvoda prerade kukuruza, u prvom redu suve džibre iz postupka dobijanja etanola (DDGS). Upotreba DDGS-a, nus-proizvoda u proizvodnji etanola za proizvodnju biodizela i glicerola, nus-proizvoda u proizvodnji biodizela, kao supstrata za proizvodnju etanola, omogućava razvoj integrisane proizvodnje etanola i biodizela i doprinose eliminisanju ili minimiziranju otpada i dobijanje vrednih proizvoda. Biodizel je razgradivo i manje toksično, bez posebnih zahteva prilikom transposrta i skladištenja, i generalno predstavlja "čisto" gorivo sa izuzetkom emisije azotovih oksida. Smanjenje emisije oksida azota je moguće primenom odgovarajućih metoda, ali su za njihovu primenu neophodna dalja istraživanja.

Ključne reči: biodizel, ekološki aspekti, emisija gasova sa efektom staklene bašte, kukuruzno ulje, zagađenje.

MILICA STOJANOVIĆ¹
DANICA ĆIRIĆ¹
RAQUEL NIETO¹
ANITA DRUMOND¹
EVICA STOJILJKOVIĆ²
LUIS GIMENO¹

¹University of Vigo, EphysLab,
Facultade de Ciencias in Ourense,
Spain

²University of Niš, Faculty of
Occupational Safety in Niš, Serbia

¹mstojanovic@uvigo.es

²evica.stojiljkovic@znrfaq.ni.ac.rs

TRACKING THE ORIGIN OF MOISTURE OVER SERBIA USING THE LAGRANGIAN METHOD

Abstract: *In this study, we investigate the sources of moisture over Serbia using a Lagrangian method based on the FLEXPART V9.0 particle dispersion model combined with ERA-Interim reanalysis data, to track changes in atmospheric moisture. This approach computes the budget of evaporation-minus-precipitation by calculating changes in specific humidity along forward and backward trajectories. We considered a time period of 34 years, from 1980 to 2014, which allowed the identification of climatological moisture sources and moisture transport towards the country. The results showed that Serbia receive moisture mainly from two sources: the Mediterranean Sea which is the dominant source during the winter (October-March) and the own region which predominate during the summer (April-September).*

Key words: moisture sources; flexpart; lagrangian method; serbia.

INTRODUCTION

The study area covers the territory of Serbia, which is located between Central and Southern Europe. It comprises around 18% (88,361 km²) of the Balkan Peninsula and almost entire territory (92%) is drained by Danube River while the rest of the territory belongs to Adriatic and Aegean drainage basin [1]. The northern part of the country is located within the Pannonian Plain and the rest covers the mountainous regions: the Dinaric Alps which stretching through the west and southwestern regions, the Carpathian, Balkan, and Rhodope Mountains occupying the eastern and southeastern areas [2].

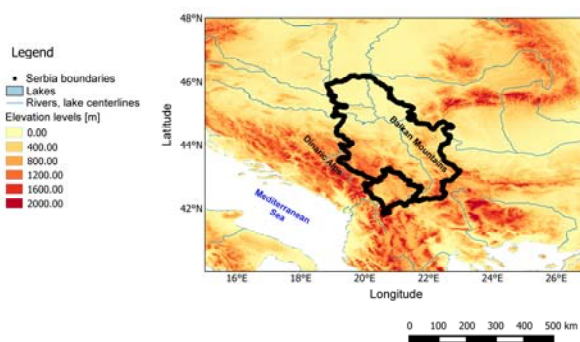


Figure 1. *The black line indicates the boundaries of Serbia. The elevation levels of the region are indicated in colors (meters, m). Data were taken from the HydroSHEDS project available online at <https://hydrosheds.cr.usgs.gov>*

The average altitude of Serbia is 473 m and varies in elevation from 29 m in eastern parts of the country, near to the borders between Bulgaria and Romania and rises up to 2,656 m on Prokletije Mountain in the south part of the country [3]. The climate of the Serbia is

very diverse, with the Mediterranean influence in the south and southwestern parts, while the north part of the country has characteristics of typical continental climate with air masses predominantly originating from Northern Europe [4].

Precipitation over Serbia varies extensively, and increases with altitude as well as from the north toward the south of the country. Average annual precipitation for the Northern part is estimated below 600 mm while southern regions receive around 1000 mm per year, with except of mountain summits in the southwest which receive over 1000 mm per year. Most of the country has a continental precipitation regime with maximum precipitation occurring during June and May and minimum precipitation occurring during February and October [1].

Many previous studies using the observational data, have analysed the spatial pattern of the temperature and precipitation trends in Serbia and the possible changes in the natural drivers with impacts on water resources, water availability, and extreme hydrological events [2, 4]. The transport of moisture over the region of interest represents the link between the water evaporation from the moisture source regions and the continental precipitation. Knowing that the precipitation is one of the most important element of the water cycle [5] it is really important to detect and understand the origin of atmospheric moisture over the Serbia. Knowledge of the main moisture sources for specific region is crucial to justify physically the changes in precipitation both for current and future climates [6]. Given the importance of moisture transport the main objective of this study is to identify main climatological moisture sources for precipitation over the Serbia and to analyze their variability comparing the moisture sources variation month by month. Study covers the 34-year time period from 1980 to 2014 and it is performed using the Lagrangian method FLEXPART V9.0 in its

backward mode, tracking the air masses that ultimately reach the region of Serbia. Moreover, wet and dry conditions were detected over Serbia during the analysed period using the Standardised Precipitation Evapotranspiration Index (SPEI). Wet and dry conditions represent important elements for the studies connected with climate changes impact, supporting the investigation, monitoring and prediction of extreme hydrological events such as occurrence of drought and floods.

METHODOLOGY

Lagrangian model FLEXPART

The Lagrangian FLEXible PARTicle dispersion model (FLEXPART) developed by Stohl and James [7, 8] was used for the identification of the climatological moisture sources for Serbia during the analyzed period from 1980 to 2014. The model uses global ERA-Interim reanalysis database from the European Centre for Medium-Range Weather Forecasts (ECMWF) which has a horizontal resolution of 1° on 61 vertical levels, ranging from 1000 to 0.1 hPa [9]. FLEXPART model divides the atmosphere into a great number of virtual air particles (approximately 2.0 million) and the mass (m) of each particle is considered to be constant. The particles were transported by a 3-dimensional wind field, and the specific humidity (q), and position of the particles were recorded for each air parcel at each 6 hours' time period (00, 06, 12 and 18 UTC). The transport time of the particle is limited to 10 days, which represent the average water vapor lifetime in the global atmosphere [10].

Recorded changes in the variations of the specific humidity of each air parcel along the time could be calculated and expressed by following equation (1):

$$(e - p) = m \left(\frac{dq}{dt} \right) \quad (1)$$

where, m represents the mass of a particle and $(e - p)$ represents evaporation minus precipitation, which is the freshwater flux of the particle. Changes in specific humidity permit us to identify where the particles lose moisture through precipitation (p) or gain moisture through evaporation (e). The summ of the freshwater flux $(e - p)$ of all particles presented in the atmospheric column over an area A , represents the total freshwater flux $(E - P)$ expressed by equation (2):

$$(E - P) \approx \frac{\sum_{k=1}^K (e - p)}{A} \quad (2)$$

Where, E represents the total evaporation, P represents the total precipitation, and K represents the number of particles over the area A .

The trajectory of the particles can be followed using backward-in-time analysis with the aim to determinate the main sources of moisture for the target region ($E - P > 0$) or forward-in-time analysis to investigate the

moisture sinks regions after being transported by particles ($E - P < 0$).

Recently, the Lagrangian method was used for detection of the main moisture and sinks regions near Serbia, for instance over the Mediterranean Sea [11], the Alps region [12], the Danube River basin [13], etc. Also, the method was successfully applied for investigation of the extreme hydrological events of drought [14] and intense precipitation [15] in the surrounding areas of Serbia.

More detailed information about the functionalities of FLEXPART can be founded in the studies of Stohl and James [7, 8] and Gimeno et al. [6].

Detection of wet and dry conditions over the region

To identify dry and wet conditions in Serbia, the Standardised Precipitation Evapotranspiration Index (SPEI) developed by Vicente-Serrano et al. [16] was used. The SPEI follows the same conceptual approach as the Standardised Precipitation Index (SPI), but rather than concentrating on precipitation alone it is based on a climatic water balance (precipitation minus potential evapotranspiration), which is computed on different timescales. The data of precipitation and potential evapotranspiration were obtained from Climate Research Unit (CRU) Time-Series (TS) v.3.24.01 [17]. We identified wet and dry conditions over Serbia during 1980–2014 through the SPEI-1, SPEI-3, SPEI-6, SPEI-12, SPEI-24 time scales. McKee et al. [18] suggested a classification system to define the intensity of dry and wet categories as shown in Table 1.

Table 1. Dryness/wetness categories based on the SPEI values, according to the categories given by McKee et al. [12], which were applied to the SPI

Range	Category
$2 \leq \text{SPI}$	Extremely wet
$1.5 \leq \text{SPI} < 2.0$	Severely wet
$1.0 \leq \text{SPI} < 1.5$	Moderate wet
$0 < \text{SPI} < 1$	Mild wet
$-1.0 < \text{SPI} < 0$	Mild drought
$-1.5 < \text{SPI} \leq -1.0$	Moderate drought
$-2.0 < \text{SPI} \leq -1.5$	Severe drought
$\text{SPI} \leq -2.0$	Extreme drought

RESULTS

The Lagrangian method FLEXPART V9.0 [7, 8] was used to track the air masses over the Serbia backward in time with purpose to identify the main moisture source regions. The annual values of 10-day integrated atmospheric moisture budget obtained via backward experiment for Serbia for the 34-year period 1980-2014 are shown on Figure 2. The areas characterized by the reddish colors (Figure 2) represent regions where $(E-P) > 0$, meaning that evaporation exceeds precipitation in the net moisture budget, and on this way the main moisture source regions were identified.

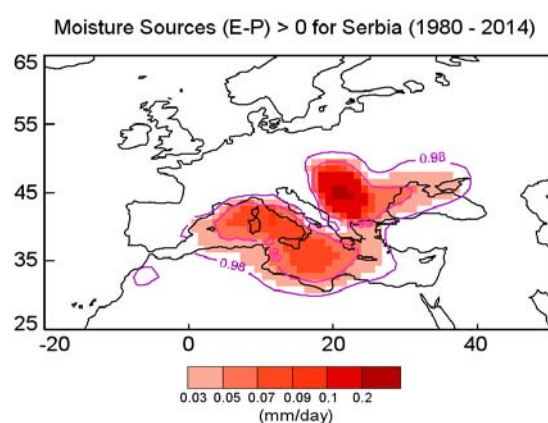


Figure 2. Climatological annual 10-day integrated $(E-P)$ obtained for the backward experiment for Serbia during the period 1980-2014. The pink contour line delimits the source areas selected using the 98 and 99 percentile of the $(E-P) > 0$ values (i.e., 0.0220 and 0.0525 mm/day, respectively).

According to the applied thresholds for identification the water source regions, pink contour line of 0.0220 mm/day corresponds to the 98% percentile of the annual averages of $(E-P) > 0$ and value of 0.0525 mm/day indicates the 99% percentile obtained by the backward experiment from the methodology described above. Obtained result suggests that Serbia mainly receives moisture from two main source regions: the Mediterranean Sea and from the local evaporative processes as a moisture source for the region throughout the year, indicating the area of Serbia itself as moisture for precipitation. Observing the annual variation, looking the changes in moisture sources month by month, we obtained plotted maps shown in the Figure 3 revealing that during the winter season (October-March) the dominant source of moisture for Serbia is the Mediterranean Sea while during the summer season (April-September) the main source is its own region (Figure 3). This results are confirmed by findings of other authors [13] that highlighted that the Mediterranean Sea is the predominant moisture source for winter precipitation over the Danube River Basin, taking in consideration that area of Serbia represents a part of the countries which constitute the catchment of the Danube River Basin.

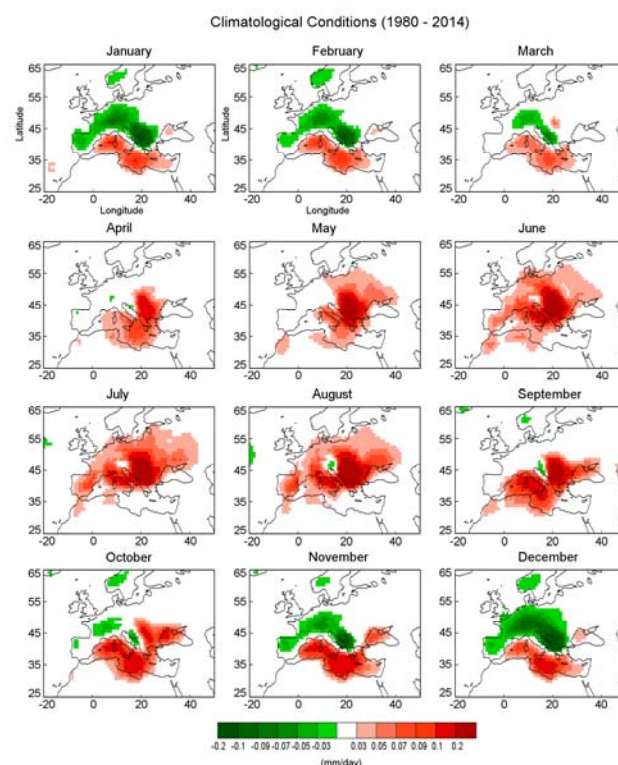


Figure 3. Climatological monthly 10-day integrated $(E-P)$ values observed for the period January 1980–December 2014, for all the particles bound for Serbia, determined from backward tracking. Red (green) colours represent regions acting as moisture sources (sinks) for the tracked particles.

As we mentioned above, the identification of wet and dry conditions for a region is important for many aspects linked with climate changes over the region and a detailed study of related hydrological phenomena such as drought and extreme precipitation of floods. Figure 4 shows the SPEI-1,-3,-6,-12,-24 time series for Serbia during the period 1980–2014, in which the negative values (red bars) represent dry conditions and the positive ones (blue bars) represent wet conditions. Looking at the Figure 4 we can see that on the shorter time scale (SPEI-1) for wet conditions the peak value was found in 1980 year while for the dry conditions the peak values is observed in 2000. For longer time scale for instance SPEI-24 which represents the water balance of 24 months, the highest value during the wet period is recorded in 1981 on contrast during the dry period the peak value is observed in 2012 year.

Future analysis and investigation of precipitation and drought events over Serbia based on identified wet and dry conditions may be useful for prevention, adaptation and protection of natural environment and human lives in the region.

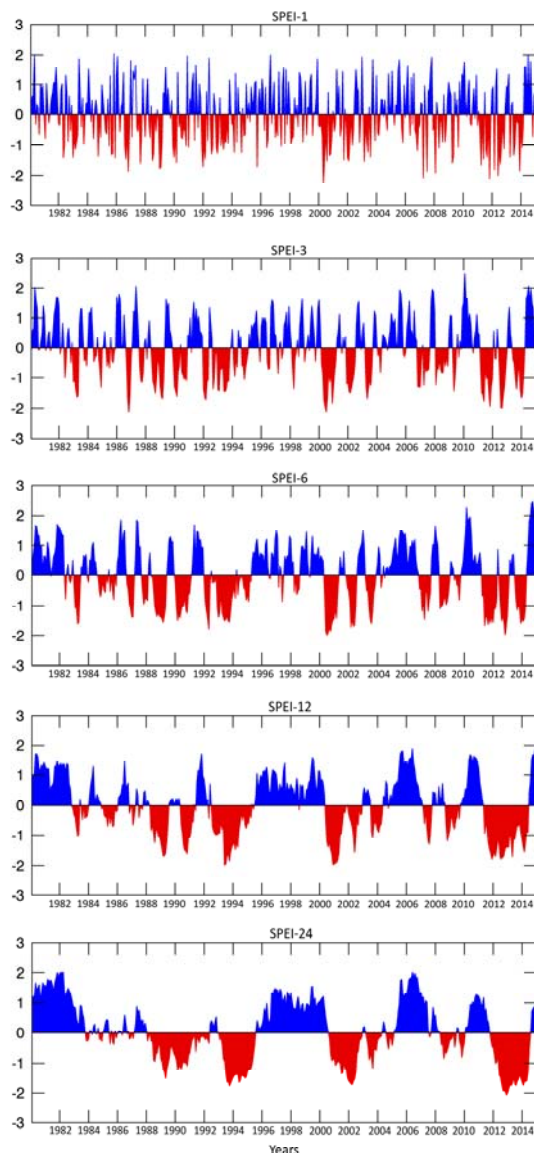


Figure 4. Time series of Standardized Precipitation Evapotranspiration Index for the region of Serbia during 1980–2014. Red and blue bars represent positive and negative values, respectively.

CONCLUSION

Obtained result suggests that Serbia mainly receives moisture from two main source regions: the Mediterranean Sea and the local evaporative processes (as a moisture source for the region throughout the year). During the winter season (October–March) the dominant source of moisture for Serbia is the Mediterranean Sea, while during the summer season (April–September) the main source is its own region. Those results are confirmed by findings of other research revealing that the Mediterranean Sea is the predominant moisture source for winter precipitation over the Danube River Basin.

REFERENCES

- [1] J. Luković, D. Blagojević, M. Kilibarda, B. Bajat: "Spatial pattern of North Atlantic oscillation impact on rainfall in Serbia", *Spatial Statistics*, 14, 2015, pp. 39–52.
- [2] B. Bajat, D. Blagojević, M. Kilibarda, J. Luković, I. Tošić: "Spatial analysis of the temperature trends in Serbia during the period 1961–2010", *Theoretical and Applied Climatology*, 121, 2015, pp. 289–301.
- [3] L. Luković, B. Bajat, M. Kilibarda, D. Filipović: "High resolution grid of potential incoming solar radiation for Serbia", 19, 2015, pp. S427–S435.
- [4] M. Unkašević, Đ. Radinović: "Statistical analysis of daily maximum and monthly precipitation at Belgrade", *Theoretical and Applied Climatology*, 66, 2000, pp. 241–249.
- [5] K.E. Trenberth, A. Dai, R.M. Rasmussen, D.B. Parsons, "The changing character of precipitation", *Bulletin of the American Meteorological Society*, 2003, 84 (9), 1205 – 1217.
- [6] L. Gimeno, A. Stohl, R.M. Trigo, F. Dominguez, K. Yoshimura, L. Yu, A. Drumond, A.M. Duran-Quesada, R. Nieto: "Oceanic and terrestrial sources of continental precipitation", *Reviews of Geophysics*, 2012, 50, pp. 1–41.
- [7] A. Stohl, P.A. James, "Lagrangian Analysis of the Atmospheric Branch of the Global Water Cycle. Part I: Method Description, Validation, and Demonstration for the August 2002 Flooding in Central Europe", *Journal of Hydrometeorology*, 2004, 5, pp. 656–678.
- [8] A. Stohl, P.A. James, "Lagrangian analysis of the atmospheric branch of the global water cycle: Part II: Moisture Transports between Earth's Ocean Basins and River Catchments", *Journal of Hydrometeorology*, 2005, 6, pp. 961–984.
- [9] D.P. Dee, S.M. Uppala, A.J. Simmons, P. Berrisford, P. Poli, S. Kobayashi, U. Andrae, M.A. Balmaseda, P. Bauer, et al., "Configuration and performance of the data assimilation system", *Quarterly Journal of the Royal Meteorological Society*, 2001, 137, pp. 553–597.
- [10] A. Numaguti, "Origin and recycling processes of precipitating water over the Eurasian continent: Experiments using an atmospheric general circulation model", *Journal of Geophysical Research Atmospheres*, 1999, 104, pp. 1957–1972.
- [11] R. Nieto, L. Gimeno, A. Drumond, E. Hernandez, "A Lagrangian identification of the main moisture sources and sinks affecting the Mediterranean area" *WSEAS Transactions on Environment and Development*, 2010, 5, 365–374.
- [12] H. Sodemann, E. Zubler, "Seasonal and inter-annual variability of the moisture sources for Alpine precipitation during 1995–2002", *International Journal of Climatology*, 2010, 30, 947–961.
- [13] D. Ciric, M. Stojanovic, A. Drumond, R. Nieto, L. Gimeno, "Tracking the Origin of Moisture over the Danube River Basin Using a Lagrangian Approach", *Atmosphere*, 2016, 7, 162.
- [14] M. Stojanovic, A. Drumond, R. Nieto, L. Gimeno, "Moisture Transport Anomalies over the Danube River Basin during Two Drought Events: A Lagrangian Analysis", *Atmosphere* 2017, 8, 193.
- [15] D. Ciric, R. Nieto, A.M. Ramos, A. Drumond, L. Gimeno, "Wet Spells and Associated Moisture Sources Anomalies across Danube River Basin", *Water*, 2017, 9, 615.

- [16] S.M. Vicente-Serrano, S. Begueria, A.J. Lopez-Moreno, "A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index", *Journal of Climatology*, 2010, 23, 1696–1718.
- [17] I. Harris, P.D. Jones, T.J. Osborn, D.H. Lister, "Updated high-resolution grids of monthly climatic observations—The CRU TS3.10 Dataset", *International Journal of Climatology*, 2014, 34, 623–642.
- [18] T.B. McKee, N.J. Doesken, J. Kleist, "The relationship of drought frequency and duration to time scales", In *Proceedings of the Eighth Conference on Applied Climatology*, Boston, MA, USA, 17–22 January 1993; pp. 179–184.

ACKNOWLEDGEMENTS

Fellowship of Milica Stojanovic and Danica Ciric come from a subsidy for residences awarded at the University of Vigo. This work was supported by Xunta de Galicia under Project ED431C 2017/64-GRC "Programa de Consolidación e Estruturación de Unidades de Investigación Competitivas (Grupos de Referencia Competitiva)". We would also like to thank the

IMDROFLOOD project financed by the Water Works 2014 co-funded call of the European Commission.

BIOGRAPHY of the first author

Milica Stojanović was born in Leskovac, Serbia, in 1990. She holds master diploma in Environmental engineering, from University of Nis, Faculty of Occupational Safety, Nis, Serbia. The main areas of her research include environmental science, the global water cycle and the impact of climate change on hydrology. Currently, she is a PhD student at University of Vigo, Spain.



PRIMENA LAGRANŽOVOG METODA ZA PRAĆENJE POREKLA ATMOSFERSKE VLAŽE ZA SRBIJU

*Milica Stojanović, Danica Ćirić, Raquel Nieto, Anita Drumond,
Evica Stojiljković, Luis Gimeno*

Rezime: U ovoj studiji istraženi su izvori vlage za Srbiju primenom Lagranžovog disperzionog modela FLEXPART V9.0, koji koristi ERA-Interim podatke za pracenje promena atmosferske vlage. Ovaj model izračunava razliku između isparavanja i precipitacije računajući promene u specifičnoj vlažnosti duž trajektorija čestica nazad (backward) i napred (forward) u vremenu. Za studiju se koristio vremenski period od 34 godine, od 1980 do 2014. Koristeći model trajektorija unazad, moguće je identifikovati klimatološke izvore vlage i pratiti transport te vlage ka Srbiji. Rezultati pokazuju da Srbija dobija vlagu uglavnom iz dva izvora: Sredozemnog mora (koje je dominantni izvor tokom zimskog perioda (oktobar-mart)) i sopstvenog regiona (koji prevladava tokom leta (april-septembar)).

Ključne reči: izvori vlage, flexpart, lagranžov metod, Srbija.

MAJA STANKOVIĆ¹
MARIJA CVETKOVIĆ²
NENAD KRSTIĆ³
DRAGAN ĐORĐEVIĆ⁴
MIODRAG
STANISAVLJEVIĆ⁵
ANA STOJKOVIĆ⁶
IVAN KRSTIĆ⁷

^{1,2,3,4} University of Niš,
Faculty of Sciences and Mathematics

⁵ High Technical School of
Professional Studies, Požarevac

^{6,7} University of Niš,
Faculty of Occupational Safety

¹ majastan@gmail.com

² marija-maki89@hotmail.com

³ nenad.krstic84@yahoo.com

⁴ dragance73@yahoo.com

⁵ vode@ptt.rs

⁶ ana.stojkovic@znrfak.ni.ac.rs

⁷ ivan.krstic@znrfak.ni.ac.rs

CHEMICAL CHARACTERIZATION OF SOLID INDUSTRIAL WASTE

Abstract: Hot-dip galvanizing process is usually used for corrosion protection of iron and steel. It is performed under conditions of electrolysis. Carbon-graphite electrodes are used in the process. The waste material is potentially environmentally contaminant, and, in this paper, mineralogical and chemical analysis of electrode sludge was done. The results show that the sample is made mainly from carbon, silicon, iron. The investigated metals are mainly incorporated within soluble oxide and silicate fraction that represents the immobile phase

Key words: electrode sludge, hot dip galvanization, heavy metals

INTRODUCTION

Early hot-dip galvanizing processes of corrosion protection of iron and steel products were used in 16th and 17th centuries when first trading with zinc have been traced in China and North India. It was when the term "corrosion" was used for the first time. In 1742. the Frenchman Malouin discovered a procedure of dipping iron into melted zinc protecting it with a coat of zinc. The procedure of hot-dipping galvanization was patented by Sorel in 1837.

After 1840. zinc plants started emerging in France, England and Germany. During the process of hot-dipping galvanization leaned surface of steel element is dipped into melted zinc and this how galvanized coat is produced having extremely anticorrosion characteristics [1]. Taking into consideration the loss due to corrosion of unprotected iron and steel, appliance of hot-dipping galvanization in the process of surface protection provides saving energy and natural resources. Metal zinc has got numerous characteristics that make it excellent to be used as a coating, not to mention its ecology suitability when protecting different products. Zinc coatings surfaced by hot-dipping procedure posses very good adhesion with basic material, they are quite ductile, and influenced by atmosphere thick layer of corrosion products on the surface of zinc is made protecting it from any other influence [2]. Most important field of application of zinc are protection from corrosion and production of brass, bronze and other zinc alloys. Taking into account extensive researches of new technologies of

exploitation of less suitable mineral resources, recycling metals from waste material present not only economically justified necessity but also inevitable obligation in order to affirm declared Principle of sustainable development [3].

Waste generated from realization of surface protection by a procedure of hot-dipping galvanization includes by-products created in the process. Comprehensively, waste from production plants comprise a group of industrial waste from the process and waste from resolving waste water, packing waste from raw materials used in the process, as well as waste from auxiliary material used during realization of the technological process. Sludge management, given the technological process that takes place in production plants, requires a way of implementation providing the least risk to endangering lives and health of people and environment by conducting control and taking measures of monitoring the pollution of water, air and soil.

Zinc ash and zinc slag have considerable commercial value and enter into a recycling stream allowing retreat of metal zinc and zinc oxide. Regarding recommendation how to treat hazardous waste generators of this type of sludge, plants for hot-dipping galvanization it is emphasised that that these sludge are: zinc slag and zinc ash registered as waste to be recycled. Major producers of zinc-oxide recycle the waste from the procedure of hot-dipping galvanization in the form of slag from the bottom not fro the ash or sludge solutions of dezincification.

According to the results of researches made on waste from different plants for hot-dipping galvanization the waste has got high concentration of metal, particularly zinc and iron providing good ground for recycling and regeneration [4]. Apart from zinc ash and zinc dross sludge also appears during the process of hot-dipping galvanization. Water from flow flushing reach in fewer amounts to the neutralization propulsion. Acid-alkaline flushing waste water is processed either continuously or not in neutralization pools. Taking into consideration both the content of the degreasing solution and chemical reactions taking place in this solution, flushing alkaline water mainly contain: sodium carbonate, sodium hydroxide, sodium phosphate, surface active substances and suspended substances. Considering the content of the solution for etching and chemical reactions going on in the solution acid flushing water consists of: hydrochloric acid, iron chloride, iron oxides, iron hydroxide, elementary iron. Acid and alkaline flushing water are collected in a joint line being mixed and partially neutralized where the degree of neutralization mainly depends on the quantity and concentration of this water.

Technological procedure of the treatment of waste water implies removing rough particles, removing grease substances followed by neutralization, deposition and filtrating of the sludge. The process of neutralization embraces two processes: neutralization of free acids and bases and deposition of heavy metals in the form of metal hydroxides acting with limewater. The quantity and content of the sludge produced by work of plant for hot-dipping galvanization depends mainly whether the process is run continuously or discontinuously, from the capacity of working pools, from the performance and monitoring of the technological process from the point of concentration of basic components in the solution and rinsing water. Managing both other types of waste and the sludge in the plant comprises monitoring from the moment of occurring till the disposal presenting it as a primary objective in the interest of environmental protection.

The process of hot-dipping galvanization is followed by rinsing waste water. Waste water may contain metal ions (Cu^{2+} , Ni^{2+} , Cr^{6+} , Cr^{3+} , Zn^{2+} , Cd^{2+} , Pb^{2+} , Fe^{2+} , Al^{3+}), cyanides, phosphates, acids, bases, fat and oil, organic solvents, surface active substances and a whole range of other pollutants. Heavy metals found in surface water do not decompose biologically but they accumulate in flora and fauna world of the rivers thus falling due to a food chain indirectly affecting people's health. Waste water is processed either by conventional or unconventional methods in the neutralization pools. Conventional methods are chemical oxidation and reduction, neutralization, coagulation, flocculation, precipitation. Unconventional methods used in the process of treating waste water from the process of hot-dipping galvanization allow regeneration of toxic metals, mineral oils and colour with high quality of effluent which can be circulated again in the technological process of galvanization [5].

This paper analyses chemical characterization of electrode waste from the process of hot-dipping galvanization in the pre-plant EI "Čegar" Niš. The point of the survey is influence of these components on the environment and waste disposal following the process of hot-dipping galvanization.

METHODS

Fourier transformation infrared (FTIR) spectroscopy

The FTIR spectra were recorded on a Michelson Bomen MB-series spectrophotometer, using the KBr pellet (1.5 mg/150 mg) technique (area of 4000-400 cm^{-1}) on the room temperature.

Inductive coupled plasma-optical emission of spectroscopy (ICP-OES)

Concentrations of metal ions from the soluble rest were determined by ICP- Optical emission of spectroscopy, series iCAP 6000, Thermo-scientific, Cambridge, United Kingdom. The analyses were done in Laboratory for analytic and physical chemistry (Faculty of Science and Mathematics, Nis)

Stereo zoom microscopy

Stereo-microscopy images magnified 180x were taken by Krüss KSW5600 stereo-microscope in the Laboratory of general and inorganic chemistry (Faculty of Science and Mathematics, Nis)

Sample

The sample was taken from the tailings storage of the pre-plant EI "Čegar" Niš, Bulevar Svetog cara Konstantina 80-86, Niš. Approximately 1kg of material was sampled. Sampling was conducted from the top, the middle and the bottom. The sample itself is made of granules, average size of the granule is 2-5 mm

Chemical processing of the sample - Fractional analyses

A fractional analysis consists of selective resolving minerals in appropriate mineral acids. It is an excellent way to obtain information about mineral content of the sample. [6]

In order to extract different fractions of OM from the sample a method of selective resolving in organic solvents of different polarity is implemented.

RESULTS AND DISCUSSION

On the basis of selective resolving and chemical analysis of the sample of electrode waste from the process of hot-dipping galvanization a detailed quantitative image of the metals present in the whole sample as well as in particular fractions can be obtained.

Table 1. Content of macroelements (%) in the sample

Oxides	Al_2O_3	CaO	K_2O	MgO	Na_2O	P_2O_5	SiO_2	Total C
%	11.10	2.75	1.04	0.67	10.49	3.55	15.84	54.55

Regarding the results in Table 1, it is evident on the basis of the sample of electrode waste from the process of hot-dipping galvanization there is a total of C (54.55%), then SiO₂ (15.84%), Al₂O₃ (11.10%) and Na₂O (10.49%). Other oxides are present in total of the content <5%.

Organic substance has not resolved in the methanol (CH₃OH), n-hexane (n-C₆H₁₄) and benzene (C₆H₆), and due to this there is no polar fraction, resin and asfalten. The insoluble substance is finally removed by annealing. The solution obtained by this process presents soluble fraction out of which a content of the elements was tested and incorporated into an organic material.

Table 2. Content of macroelements (ppm) in fractions
* in the sample

Elements		Total content	Oxidant fraction	Silicate fraction	Organic fraction
B	ppm	13160	118.5	12414.5	627
	%	100	<1	94	5
Ba	ppm	300	54	160	86
	%	100	18	53	29
Li	ppm	133	20.5	101.5	11
	%	100	15.70	76	8.30
Sb	ppm	28216.50	260	27379.5	577
	%	100	<1	97	2
Sr	ppm	241.5	83.5	77	81
	%	100	35.5	30.5	34

*Dissolved fractions expressed in percentages: oxidant fraction 1.57%, silicate fraction 1.21% and organic fraction 97.22%.

There are absorbed elements on the surface and connected with slightly soluble oxide minerals in the oxide fraction. Metals from the oxide fraction can easily be washed since they are not firmly connected with the surface that is they can be easily washed from the waste material by the influence of rain water and/or organic acids present in the soil. They present a mobile phase while silicate and organic fractions make un-mobile phase due to the fact that if any present toxic and heavy metals can only be removed by treating heavy acids by warming (warm HCl/HF) or burning. Organic fraction is then decomposes and becomes available to leaching. Elements present in oxide fraction ie. In mobile phase easily reach the water course and pollute the eco system. On the basis of Table 2 it can be observed that most of the tested elements in the sample are in a silicate fraction (B, Sb), which presents a fraction with the highest proportion in total concentration (12417.5 ppm). There is also in the organic fracture most of B (627 ppm) and Sb (577 ppm). High concentration of B most likely originates from the fact that galvanization is executed on alloyed boron where the process of anticorrosion protection of hot-dipping galvanization is obligatory. The content of the element in the oxide fraction goes from 20.8 ppm (Li) to 260 ppm (Sb). By sample. The content of the metal in this fraction goes

from 77 ppm (Sr) to 27379.5 ppm (Sb). Apart from Sb there is B in significant concentration (12417.5 ppm). There is also in organic fraction large quantity of B (627 ppm) and Sb (577 ppm). High concentration of B mostly results from the fact that galvanization is performed on steel legated by boron requiring the process of anticorrosive protection by hot-dipping galvanization. In the oxide fraction the content of the elements goes from 20.8 ppm (Li) to 260 ppm (Sb).

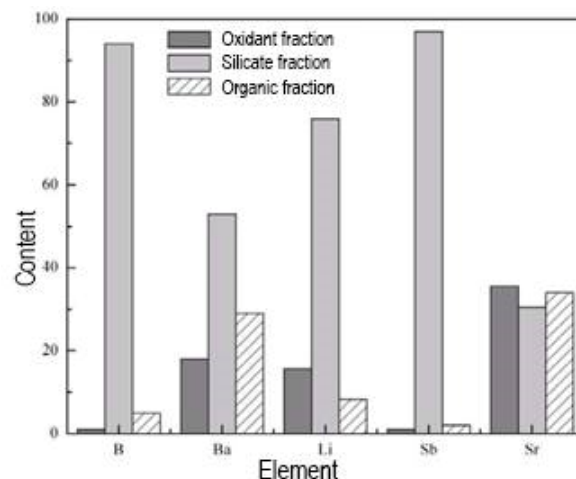


Figure 1. Graphic presentation of microelements according to fractions in the sample

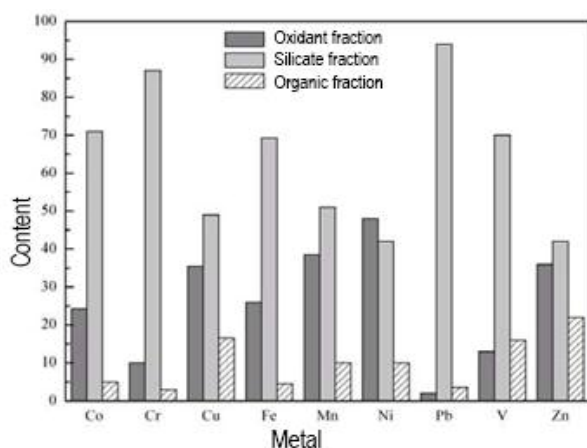
The results show the presence of absorbed metals on the surface in the oxide fraction and that they are bound to easily soluble oxide minerals. Metals from oxide fraction can easily be washed due to their weak bounds to the surface that is they can be washed from waste material under the influence of rainwater and/or organic acids present in the soil. They present a mobile phase while silicate and organic fractions present immobile phase since present toxic and heavy metals if any can only be treated by strong means (warm HCl/HF) or by burning. It is when organic fraction decomposes and becomes available to rinsing. Metals present in oxide fraction ie. In mobile phase easily reach the watercourse and pollute the ecosystem.

Table 3. Content of heavy metals (ppm) by fractions*in the sample

Elements		Total content	Oxidant fraction	Silicate fraction	Organic fraction
Co	ppm	28	6.50	20	1.50
	%	100	24	71	5
Cr	ppm	256	26.50	222	7.50
	%	100	10	87	3
Cu	ppm	218	76	106	36
	%	100	34.50	49	16.50
Fe	ppm	33590	8800	23265	1525
	%	100	26	69.50	4.50
Mn	ppm	568	218	291	59
	%	100	39	51	10
Ni	ppm	72	34	31	7
	%	100	48	42	10
Pb	ppm	205	5	193	7
	%	100	3	94	3
V	ppm	229	31	161	37
	%	100	14	70	16
Zn	ppm	190	58	121	11
	%	100	30	64	6

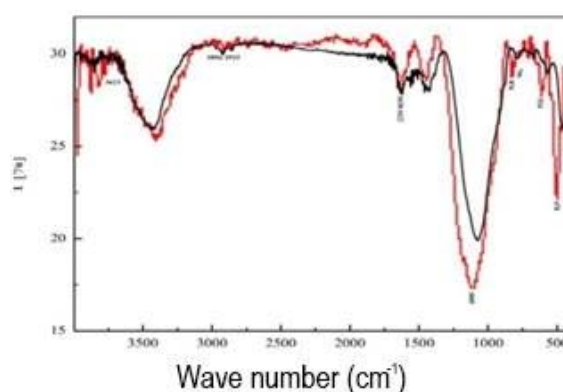
*Dissolved fractions illustrated as percentages: oxide fraction 1.57%, silicate fraction 1.21% and organic fraction 97.22%.

The Table 3 clearly indicates that most of the researched metals in the sample are found in a silicate fraction (Fe, Pb, Mn, Cr, V), presenting a fraction with greatest concentration in the whole sample. Concentration of Fe is (23265 ppm), Mn (291 ppm), Cr (222 ppm), Pb (193 ppm), V (161.5 ppm), Zn (121 ppm). Fe (1525 ppm) is mostly present in the organic fraction whereas the concentration of Cu and V are equal (36 ppm) and the concentration of other metals is <10 ppm. Fe (8800 ppm) is mostly present in oxide fraction whereas Ni and V are equally present (31 ppm), the content of Cu is 63 ppm, and the least concentration is one of Co (6.5 ppm).

**Figure 2.** Graphic presentation of distribution of heavy metals by fractions in the sample

The process of hot-dipping galvanization is used as a method of corrosion protection of alloying steel where Fe most likely originates from the matrix being due to the whole process. Mn is one of the basic alloying elements in the process of steel production so it is obvious that high amount of this metal probably originates from steel corrosion protection was executed on.

FTIR spectrum of untreated sample were recorded and after removing the mineral fraction in order to determine strips typical for particular chemical groups of present mineral phases.

**Figure 3.** FTIR spectrum of the sample

The presence of organic matter in the sample is characterized in the field 2856-2922 cm^{-1} , which corresponds to aliphatic stretching vibrations of $-\text{CH}_2$ and $-\text{CH}_3$ groups. Wide absorption maximum concentrated around 1620-1622 cm^{-1} originates from $\text{C}=\text{C}$ vibrations of olefins or aromati. Strips occurring at 794 cm^{-1} originate from (Al, Mg)-OH deformation vibrations. Furthermore, strips occurring at 874 and 876 cm^{-1} originate from carbonates (CO_3^{2-}). A wide strip with a bend at 1089 cm^{-1} originates from Si-O valent vibrations. Strips at 524 and 470 cm^{-1} present deformation vibrations, δ (Si-O-Al) ie. δ (Si-O-Mg). Absorption strip at 3433 cm^{-1} originates from valent vibrations O-H. Other strips (2514 cm^{-1} , 1794 cm^{-1} , 1429 cm^{-1}) originate from stretching CO_3^{2-} .

Table 4. Identified strips in FTIR spectrum of the sample

Wave number (cm^{-1})	Asignation of the tape	Intensity
2856-2922	ν (aliphatic $-\text{CH}_2$ i $-\text{CH}_3$)	poor
1620-1622	ν ($\text{C}=\text{C}$ olefin or aromatic)	medium
794	(Al, Mg) -OH	medium
1089	ν (Si-O)	strong
524	δ (Si-O-Al)	strong
470	δ (Si-O-Mg)	strong
3623	ν (O-H)	medium
874	ν (CO_3^{2-})	medium

Figure 4 presents stereo-microscopic records of tested sample.



Figure 4. Stereomicroscopic photos of the sample

It is obvious that the sample is heterogenic. Matrix of the sample presents carbon, which can be seen as a black mass in the figure. Red colour probably indicates the presence of iron oxide. Tiny bright particles are also observed probably originating from quartz which is also present.

CONCLUSION

By selective dissolution in various acids and organic dissolvers, extracted organic matters it was determined that 1.57% is dissolved in cold HCl, this fraction consists of absorbed elements and easily soluble metal oxides. 1.21% of total sample is dissolved in the mixture of warm HCl/HF, presenting a group of heavily soluble metal oxides and a group of silicate minerals. Extraction of organic matter by methanol, n-hexane and benzene confirmed that organic fraction of the sample was not built from polar fraction, resin and asfaltena. The analysis of obtained results led to these conclusions:

- On the basis of electrode waste from the process of hot-dipping galvanization the total of C-graphite form is (54.55%), and then SiO₂ (15.84%), Al₂O₃ (11.10%) and Na₂O (10.49%). Other oxides are present in the total content of <5%. It indicates that graphite electrode is used as electrode.
- The largest share of tested microelements in the sample is found in oxide fraction. Oxide fraction consists of microelements absorbed on the surface which are bound to easily soluble oxide minerals where they present a mobile phase. Silicate and organic fractions make immobile phase since toxic and heavy metals if present can only be removed by a treatment with strong means (warm HCl/HF) or by burning. The largest share of tested microelements in the sample is found in silicate fraction 27379.5 ppm (Sb), 12417.5 ppm (B). High concentration of B most likely comes from the steel alloyed by Boron, which requires to be protected by all means from corrosion by the process of hot-dipping galvanization.

- The largest share of tested heavy metals in the sample is found in a silicate fraction (Fe, Pb, Mn, Cr, V), which presents a fraction with the largest share in the whole sample. Fe (1525 ppm) is in the organic fraction also mostly present. The process of hot-dipping galvanization is used as a method of corrosion protection of alloying steel where Fe most probably originates from the matrix, the subject to the whole process.

REFERENCES

- [1] Bastii, S., Pečar, M., Description of hot-dipping galvanization procedure, Maksim d.o.o. Celje, Slovenija, 50- 54, 2010.
- [2] Nikolić, R., Đorđević, D., Krstić, N., Transitional metal chemistry, Faculty of Sciences and Mathematics, Niš, 2018.
- [3] Frost R.S., Klopogge, J.T., Ding, Y. The Garfield and Uley nontronites-an infrared spectroscopic comparison. Spectrochimica Acta. Part A, 1881-1894, 2002.
- [4] Gardić, V., Pektrović, B., Development of the technology of recycling metals from hazardous waste from the plants for hot-dipping galvanization, Institute for mining and metalurgy, Bor, 35-42, 2010.
- [5] Stanisavljevic M., Krstic I., Zec S., Eco-technological process of glass-ceramic production from galvanic sludge and aluminium slag, Science of sintering, International Institute for the Science of Sintering (IISS), ITN SANU, p.p. 125-130, 2010.
- [6] Đorđević D., Stankovic M., Đorđević M., Krstic N., Pavlovic M., Radivojevic A., Ftir spectroscopic characterization of bituminous limestone: Maganik mountain (Montenegro), Studia UBB Chemia, LVII, 4, 39-54, 2012.

BIOGRAPHY of the first author

Maja Stanković born in 1981 in Niš. She received the diploma in chemistry at the Faculty of Science and Mathematics in Niš in 2000. She finished her PhD studies in 2010 and defended PhD thesis in Science of Chemistry in the field of inorganic chemistry entitled

“Comparative geo-chemical testing of smectite of volcanic origin from Arizona (USA) and smectite of limited sediment Cretaceous-paleogen from Denmark”. She currently works at the Faculty of Science and Mathematics in Niš as an associate professor.



HEMIJSKA KARAKTERIZACIJA ČVRSTOG INDUSTRIJSKOG OTPADA

*Maja Stanković, Marija Cvetković, Nenad Krstić, Dragan Đorđević,
Miodrag Stanisavljević, Ana Stojković, Ivan Krstić*

Rezime: Toplo cinkovanje je proces koji se koristi za antikorozivnu zaštitu proizvoda od gvožđa i čelika. Radi se pod uslovima elektrolize. Kao elektroda koristi se ugljenično grafitna elektroda. Otpadni materijal predstavlja potencionalni ekološki kontaminant pri čemu je vršena mineraloška i hemijska analiza. Dobijani rezultati pokazuju da je najveći % ugljenika, silicijuma, gvožđa. Najveći udeo ispitivanih metala se nalazi u frakciji teško-rastvornih oksida i silikatnih minerala koja predstavlja ne mobilnu fazu.

Ključne reči: elektrodni otpad, toplo cinkovanje, teški metali.

NENAD KRSTIĆ¹
MAJA STANKOVIĆ¹
DRAGAN ĐORĐEVIĆ¹
VLADIMIR DIMITRIJEVIĆ¹
MARIJA MILIVOJEVIĆ²
DEJAN KRSTIĆ³
ALEKSANDAR BOJIĆ¹

¹University of Niš, Faculty of
Science and Mathematics,
Department of Chemistry,
Višegradska 33, 18000 Niš, Serbia
²The Mining and Metallurgy Institute
Bor, Zeleni bulevar 35, 19210 Bor,
Serbia
³University of Niš,
Faculty of Occupational Safety,
Čarnojevića 10a, 18000 Niš, Serbia

¹nenad.krstic84@yahoo.com

ACTIVATED NATURAL ZEOLITE AS A POTENTIAL SORBENT FOR COPPER(II) ION FROM WASTE WATERS – PRELIMINARY STUDY

Abstract: *Natural zeolites are the most environmentally friendly and cost-effective materials for inorganic and organic pollutants removal from waste water. In this study, we investigated activated natural zeolit from Zlatokop locality as a potential sorbent for copper(II) ion removal from water system. Natural zeolit was activated with sodium chloride and sodium hydroxide. Activated zeolites showed good removal efficiency for copper(II) ion under the investigated conditions. Since these were preliminary tests, investigated zeolites will be further examined under different experimental conditions.*

Key words: natural zeolite, activation, copper, sorption.

INTRODUCTION

Because of a constant increase in industrial and other sources of pollution, water resources are endangered globally. Therefore, the protection and improvement of water resources have received increased attention from all the community.

Over the years, various materials in native form or chemically modified, have been studied for their ability to remove heavy metals and pesticides from wastewaters. Studied materials should be low cost, widely available and environmentally friendly. [1]

Heavy metals (lead, cadmium, cooper, zinc etc.) represent a serious ecological problem due to their soluble nature, their mobility and ability to accumulate in the soil. Exposure to these heavy metals can originate from different sources (drinking water, food and air), and they can enter the human body through the respiratory and digestive systems. Through accumulation in the internal organs, they manifest different toxic effects. [2]

Natural zeolites are used in many industrial applications, such as for the purification of water, soil improvement, animal production, food supplements and additives, radioprotection, etc. [3] The possibilities of using zeolites for the heavy metal removal from wastewaters have been extensively studied. Their use is also stimulated by the availability and low cost, in addition to excellent physicochemical properties, like selective sorption of different metals and non-toxic nature. Clinoptilolite is the most abundant natural zeolite. Its tabular morphology shows an open reticular structure of easy access exhibited by (eight- and ten-membered ring) channels [4].

In this study were investigated activated natural and activated zeolite from Zlatokop locality as a potential sorbent for heavy metal removing from water systems.

Natural nonactivated zeolite was designated further in the manuscript as „zVB“.

Zlatokop is a locality in south-east Serbia near Vranjska Banja and represents one of the largest zeolite deposits in Serbia (Figure 1).

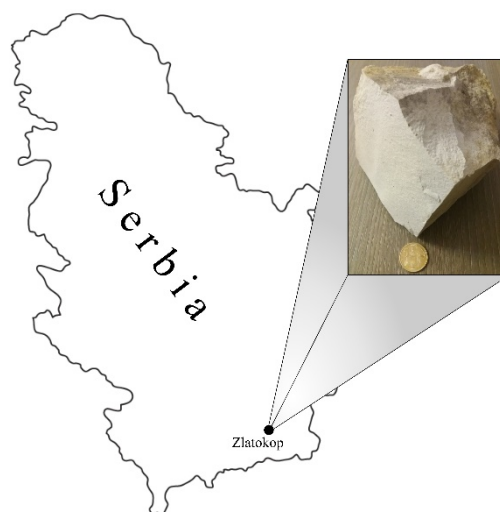


Figure 1. Geographical location of zVB origin

EXPERIMENTAL

Sample preparation and activation

Natural zeolite sample was crushed in an agate mortar and sieved in order to obtained fractions different particle size. Particle size fraction of 0.8 – 1.25 mm was washed with distilled water to remove the surface dust, and then dried in the oven at 100-105 °C. Prepared material was then activated with 2M NaOH and 2M NaCl. The mixtures were stirred for 12 h using a magnetic stirrer at room temperature, separated by decantation, thoroughly washed with deionized water

until chloride ions were eliminated for part treated with NaCl (zVB_{NaCl}), and until neutral pH for zeolite treated with NaOH (zVB_{NaOH}). After that zeolite samples were dried in the oven at 100-105 °C.

The batch adsorption experiments

The adsorption equilibrium experiments were conducted in 250 cm³ Erlenmeyer flasks, containing 125 cm³ of the copper contaminated model solution (concentration 50 mg dm⁻³) during 60 min. Aliquots of solutions (4.0 cm³) were withdrawn at preset time intervals, the biomaterial was removed by filtration through a 0.45 µm membrane filter and the filtrates were analyzed for metal ions. All experiments were conducted at ambient temperature (20.0±0.5 °C), at initial pH 5.0±0.1 and carried out in triplicates, using 4 g of zeolite as sorbent. The experiments were performed using magnetic stirrer on 200 rpm.

X-ray diffraction (XRD) analysis

X-ray diffraction (XRD) analysis of native zVB sample was performed on the GNR Explorer diffractometer in the 2θ range of 4-70°, with a step of 0.02° and an exposition of 2s (The Mining and Metallurgy Institute Bor).

Atomic Absorption Spectrophotometry (AAS)

The concentrations of Cu(II) ions in the solution before and after adsorption were determined by using an atomic absorption spectrophotometer (AASAnalyst 300, Perkin-Elmer, USA) at a wavelength of 324.8 nm. The spectrophotometer was calibrated by a series of standard solutions.

The adsorption capacity of the biosorbent, q_e (mg g⁻¹), at equilibrium was calculated as:

$$q_e = \frac{(C_0 - C_e)V}{m} \quad (1)$$

where q_e is the amount of M(II) ion adsorbed per unit weight of the adsorbent, V is the volume of solution, C₀ is the initial concentration of metal ion (mg dm⁻³), C_e is the equilibrium metal ion concentration (mg dm⁻³), and m is the mass of the adsorbent (g).

The metal removal efficiency, RE (%), of the adsorbent was estimated according to the following equation:

$$RE = \frac{C_0 - C_e}{C_0} \times 100 \quad (2)$$

Where C₀ and C_e are the initial and equilibrium concentrations (mg dm⁻³) of Cu(II) ions in solution, respectively.

RESULTS AND DISCUSSION

XRD diffractogram of zVB sample is shown on Figure 2. According to the data from Figure 2, the dominant zeolite's mineral is hydrated sodium clinoptilolite (c.a. 80%), while as follow minerals in the samples are present quartz (c.a. 2%) and anorthite (c.a. 18%).

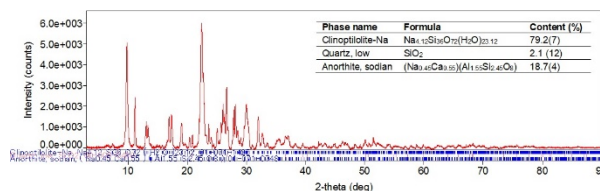


Figure 2. XRD diffractogram of zVB sample

Clinoptilolite is a porous crystal material, which adsorption properties are strongly related to the framework structure, which has performance for the physical adsorption and ion exchange. [5]

The effect of contact time on the residual concentration of Cu(II) ions in aqueous solution with zVB, zVB_{NaCl} and zVB_{NaOH} is shown at Fig. 3. Experiments were performed with model wastewaters containing Cu(II) ions at an initial concentration of 50.0 mg dm⁻³, a biosorbent dose of 4.0 g dm⁻³, at 20±0.5°C and pH 5.0. These results indicate that unmodified (zVB) zeolite (particle size 0.8 – 1.25 mm) is not efficient biosorbent, but after modification with sodium- chloride and hydroxide it became a very efficient biosorbent for removal Cu(II) ions from wastewater. The concentration of copper declined sharply with contact time in the first 15 minutes, and continued this trend in the range of investigated contact time.

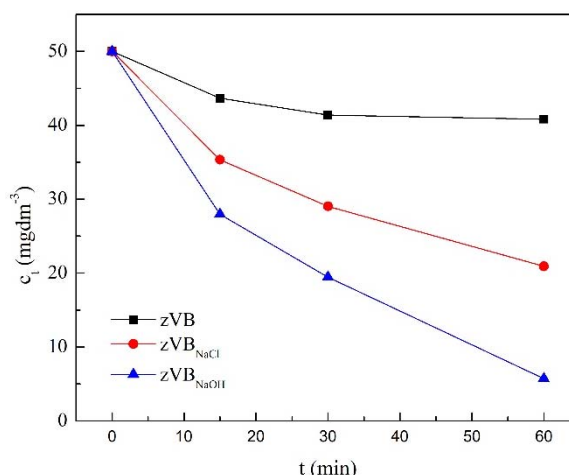


Figure 3. Effect of contact time on removal Cu(II) by zeolite

The adsorption capacity of the zeolite, q_e (mg g⁻¹), at investigation equilibrium increased after activation with NaCl and NaOH (from 0.2863 mg Cu g⁻¹ for zVB to 0.9088 for zVB_{NaCl} and 1.3836 for zVB_{NaOH}). Also, the copper removal efficiency, RE (%), showed increased trend after activation. RE for zeolite activated with sodium hydroxide is c.a. 88%, after sodium chloride activation is c.a. 58%, and c.a. 18% for natural zeolite. The literature data showed that ion exchange and to less extent the chemisorption on zeolites govern the immobilization of metal cations in natural zeolites. According to the ion exchange mechanism, ions present in the pores of zeolite crystalline lattices are substituted by toxic metal ions from the solution. The ion exchange process is reversible, and the zeolite may be recovered

for a further use. The chemisorption results in the irreversible formation of stable complexes, where functional groups on the zeolite framework, like OH, form strong chemical bonds with metal ions.[6]

Obtaining preliminary results show good sorption characteristics of activated natural zeolite. Further tests will be done in different experimental conditions (longer contact time, different particle size of zeolite, temperature, dose of sorbent etc.) such as potential application for other inorganic and organic water pollutants.

CONCLUSION

Activated zeolites zVB_{NaCl} and zVB_{NaOH} from Zlatokop locality showed good removal efficiency for copper(II) ion under the investigated conditions (c.a. 58% and 88% respectively). Since these were preliminary tests, activated zeolites will be further examined under different experimental conditions (longer contact time, different particle size of zeolite, temperature, dose of sorbent etc.) for other inorganic and organic water pollutants.

REFERENCES

- [1] M. N. Stankovic, N. S. Krstic, J.Z. Mitrovic, S. M. Najdanovic, M. M. Petrovic, D. V. Bojic, V. D. Dimitrijevic, A. Lj. Bojic: "Biosorption of copper(II) ions by methyl-sulfonated Lagenaria vulgaris shell: kinetic, thermodynamic and desorption studies", New Journal of Chemistry, Vol. 40, 2016, pp. 2126-2134.
- [2] R. S. Nikolić, J. M. Jovanović, G. M. Kocić, N. S. Krstić, Glutathione and Lipoic Acid Benefit Effects on Liver, Kidney, Brain and Pancreatic Tissue from Cd-, Pb- and Cu- Provoked Lipid Peroxidation Monitoring via MDA Content among Wistar Rats. doi: 978-1-63482-793-5, pages: 55-83. In: Malondialdehyde (MDA): Structure, Biochemistry and Role in Disease, Edition: Biochemistry Research Trends, Editor: Jackson Campbell, Nova Science Publisher, ISSN/ISBN: 978-1-63482-807-9 (2015).
- [3] M. Tomasevic-Canovic: "Purification of natural zeolite-clinoptilolite for medical application- Extraction of lead", Journal of Serbian Chemical Society, Vol. 70, 2005, 1335-1345.
- [4] N. Rajic, Dj. Stojakovic, S. Jevtic, N. Zabukovec Logar, J. Kovac, V. Kaucic: "Removal of aqueous manganese using the natural zeolitic tuff from the Vranjska Banja deposit in Serbia", Journal of Hazardous Materials, Vol. 172, 2009, 1450-1457.
- [5] X. Li, C. Lin, Y. Wang, M. Zhao, Y. Hou: "Clinoptilolite Adsorption Capability of Ammonia in Pig Farm", Procedia Environmental Sciences, Vol. 2, 2010, 1598-1612.
- [6] S. Cerjan Stefanovic, N. Zabukovec Logar, K. Margeta, N. Novak Tusar, I. Arcon, K. Maver, J. Kovac, V. Kaucic: "Structural investigation of Zn^{2+} sorption on clinoptilolite tuff from the Vranjska Banja deposit in Serbia", Microporous and Mesoporous Materials, Vol. 105, 2007, 251-259

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia under the Project TR34008.

BIOGRAPHY of the first author

Dr Nenad S. Krstić was born in Vranje, Serbia, in 1984.

He received the Diploma in Chemistry in 2007 and the Ph.D. degree in Chemistry (2013) from the University of Niš, Faculty of Sciences and Mathematics, Department of Chemistry.

His main areas of research include inorganic, coordination, bioinorganic and heavy metal chemistry, such as material chemistry.

He is currently working as Assistant Professor on Department of Chemistry, Faculty of Sciences and Mathematics, University of Niš.



AKTIVIRANI PRIRODNI ZEOLIT KAO POTENCIJALNI SORBENT ZA TEŠKE METALE - PRELIMINARNA ISPITIVANJA

Nenad Krstić, Maja Stanković, Dragan Đorđević, Vladimir Dimitrijević, Marija Milivojević, Dejan Krstić, Aleksandar Bojić

Rezime: Prirodni zeoliti su pogodni materijali za životnu sredinu, oni su jeftini i dobri materijali za uklanjanje neorganskih i organskih polutanata iz otpadnih voda. U ovom radu ispitivani su aktivirani prirodni zeoliti sa lokaliteta Zlatokop u blizini Vranjske Banje (jugoistočna Srbija) kao potencijalni sorbenti za uklanjanje bakar(II) jona iz vodenih sistema. Prirodni zeoliti su aktivirani natrijum hloridom i natrijum hidroksidom. Aktivirani zeoliti su pokazali dobru efikasnost u uklanjanju bakar(II) jona pod ispitivanim uslovima. Pošto su ovo bila preliminarne ispitivanja, ovako aktivirani zeoliti će dalje biti ispitivani pod različitim eksperimentalnim uslovima.

Ključne reči: prirodni zeolit, aktivacija, bakar, sorpcija.

TATJANA GOLUBOVIĆ¹
ANA MILTOJEVIĆ²
SLOBODAN GOLUBOVIĆ³
SRETEN ILIĆ⁴

^{1,2}University of Niš,
Faculty of Occupational Safety in Niš
³Institute for Quality of Working and
Living Environment "1 May", LLC
Niš

⁴Military Technical Institute,
Belgrade

¹tatjana.golubovic@znrfak.ni.ac.rs

²ana.miltojevic@znrfak.ni.ac.rs

³slobodan.golubovic69@gmail.com

⁴ilicsreten@sbb.rs

ASBESTOS-RELATED OCCUPATIONAL RISKS

Abstract: *Despite the common knowledge of its harmful effects, asbestos is still used worldwide. It is estimated that about 125 million workers around the globe are exposed to asbestos in the workplace, while at least 90,000 people die annually from asbestos-related diseases. Asbestos dust is generated during mining, during separation of fibres from the serpentine part, and during processing in various industry branches. Employees involved in these production processes are especially at risk. Chronic exposure to asbestos can increase the risk of asbestosis, lung cancer, and mesothelioma. Asbestos exposure is usually reduced through replacement of asbestos with materials with similar properties and through the use of personal protective equipment. Disease prevention requires the implementation of strict asbestos removal procedures, ban on further use, and registering of persons exposed to asbestos, including their follow-up or preventive medical check-ups.*

Key words: asbestos, occupational risks.

INTRODUCTION

Asbestos is a natural silicate mineral of fibrous and crystalline structure. It is naturally occurring in two forms: serpentine and amphibole. Serpentine asbestos includes the mineral chrysotile, which has the widest commercial application. Amphibole asbestos includes the minerals actinolite, tremolite, anthophyllite, crocidolite, and amosite.

Asbestos is widely used owing to its unique physicochemical properties. Due to their convenient properties, asbestos and materials containing asbestos are still widespread in the occupational and natural environment, even though they have been banned in the European legislation. Asbestos is most commonly used in the manufacture of insulating materials, asbestos paper and filters, brakes and clutches, and protective firefighting clothes against radiation and heat, as well as a construction material, for shipbuilding, for steam boiler insulation, and for a variety of household applications.

Despite the existing legislation, which limits and prohibits the use of asbestos-containing products, its use and the related exposure to asbestos in both the occupational and the natural environment are still prominent. In most products, asbestos is not pure but is bound to form other composite materials. Over time the materials wear out, which disintegrates the composite material matrix and leads to asbestos fibre emissions.

Potential health risk to workers exposed to asbestos depends on the concentration of asbestos fibres, the duration of exposure, the frequency of exposure, and the size, shape, and chemical composition of the fibres. Risk prevention and reduction measures are established according to a risk assessment for asbestos exposure. Risk assessment is mandatory before any work with potential risk of asbestos exposure can begin.

USE OF ASBESTOS

It is estimated that there are currently over 3,000 different products containing asbestos on the market. Despite the knowledge of its harmful effects, it is still widely used throughout the world. The largest consumption of asbestos and asbestos-containing products was registered in China (ca. 30%), India (15%), Russia (13%), Kazakhstan (5%), and Brazil (5%) [1].

Even though there are laws and measures in place that prohibit the use of asbestos, it is still a health and environmental hazard in Serbia, because it is widespread, especially in construction materials, in water distribution pipes, and brake systems in cars and vessels. In addition to a ban on use in construction, asbestos-containing products are no longer manufactured in Serbia.

Serbia was home to two asbestos mines – Stragari and Korlaće. Asbestos extracted from these mines was used in Serbian companies "Jugoazbest", in asbestos-based construction products, and "Fiaz", Kruševac, for brake disc manufacture.

According to the data from 2011, an estimated 30% to 70% of the water supply network was made of asbestos. The report on the environmental impact of the activities of the Electric Power Industry of Serbia from 2006 showed that the insulation material in thermal power stations "Nikola Tesla" A and B contained around three tonnes of asbestos, while the construction material in thermal power station Kostolac contained around five tonnes [2].

In the occupational environment, asbestos fibres can be found during mining, manufacture of asbestos-based products, or after the destruction of asbestos-containing materials (insulation material, asbestos paper, brakes and clutches, asbestos powder, flour, talc-mortar, and others).

ASBESTOS EXPOSURE

Exposure to asbestos is not hazardous until its fibres are dispersed from the composite materials of which they are a part. Over time the materials wear out, which causes disintegration of the composite material matrix and leads to the dispersal of asbestos fibres [2].

Asbestos dust is generated during mining, during separation of fibres from the serpentine part, and during processing in various industry branches, which puts employees involved in these production processes at risk. Workplace atmospheres can contain particles with a length of 1-5 microns as well as longer particles, from 10 to 30 microns long.

WHO studies have shown that asbestos dust is more likely to cause cancer than the asbestos ingested orally.

There is no limit value for asbestos exposure that is considered to be completely safe. Thus, any exposure is treated as hazardous and the more a person is exposed, the higher the risk of disease becomes [2].

According to the Rules on Preventive Measures for Safe and Healthy Work during Asbestos Exposure, the limit value of exposure is 0.1 asbestos fibres per 1 cm³ of air during an eight-hour workday.

Potential human risk factors include the following: asbestos fibre concentration; duration of exposure; the frequency of exposure – how often a person was exposed over a given period; and size, shape, and chemical composition of asbestos fibres.

During asbestos exposure, when long and thin fibres are inhaled, they reach the lower parts of the respiratory system and the alveolar space. There they are retained in the lungs for prolonged periods and are more toxic than shorter and thicker fibres. For instance, fibres of amphibole asbestos, such as tremolite, actinolite, and crocidolite are retained longer in the lower respiratory tract than the fibres of chrysotile, which are similar in size. Thicker fibres reach the upper respiratory tract, but not the lungs, which are the location of their induced toxicity. Short and thin fibres also play a role in the pathogenesis of asbestos-related diseases [2].

HEALTH EFFECTS OF ASBESTOS

According to the classification of toxic substances, asbestos belongs in a special group of toxic substances (dusts).

Dusts are usually defined as aerosols, solid toxic particulates, and their mixtures in workplace atmospheres. Dusts are divided into organic and inorganic. Inorganic dusts are of metallic and mineral origin, whereas organic dusts can be artificial (plastic and synthetic materials) or of plant or animal origin.

Dusts can also be classified according to the intensity of pulmonary tissue reaction, manifested as pulmonary fibrosis, into fibrogenic dusts, which cause an intensive pulmonary tissue reaction and destroy the alveoli and alveolar blood vessels, and non-fibrogenic dusts, which cause a minimal lung tissue reaction.

Asbestos is not harmful because of its chemical composition but because of its needle-like structure, which easily puncture the pulmonary membranes and lead to chronic inflammation, the body's reaction to the presence of a foreign body.

Asbestos fibres float in the air and if they are inhaled into the lungs, they can easily bypass natural filtration, deeply penetrate the pulmonary tissue, and cause serious health effects. Research has shown that the inhalation of longer, more stable fibres, such as tremolite or other amphibole fibres, contributes to certain diseases [2].

Chronic asbestos exposure can increase the risk of lung cancer, mesothelioma, as well as pleural disorders. Diseases due to asbestos exposure take longer to develop.

Asbestos exposure is more likely to result in a disease if the asbestos concentration is higher, if the exposure lasts longer, and/or if the exposure is more frequent.

The operating mechanism of asbestos fibres is still unknown, but they are believed to irritate tissues in which they are nested over time and to cause changes that ultimately lead to a disease.

Pleural changes, such as thickening, calcification, and plural effusion, are early markers of asbestos exposure. Diseases due to asbestos exposure have been diagnosed in workers handling asbestos and in the general population living in the vicinity of asbestos mines or processing plants.

As a mineral with diverse biological effects, asbestos can cause pulmonary fibrosis, better known as asbestosis, lung cancer, pleural thickening and calcification, and asbestos warts on the skin.

The WHO lists the following diseases as being directly associated with asbestos inhalation: asbestosis, mesothelioma, and lung cancer following asbestosis (malignant lung disease).

Of all the aforementioned diseases, only asbestosis is non-malignant, whereas mesothelioma and lung cancer are malignant lung diseases. Most cases of lung cancer or asbestosis in workers occurred only 15 or more years after the initial exposure. The occurrence of malignant lung diseases, such as lung cancer or pleural cancer, depends on the duration and intensity of asbestos exposure, as shown in Table 1.

The symptoms indicating some of the possible diseases due to asbestos exposure include: fatigue and dyspnoea; dry cough; asbestos warts; chronic obstructive bronchitis; and emphysema.

If any of the listed symptoms are detected, the diseases caused by asbestos can be confirmed by means of X-rays, computed tomography (CT) scans, or lung tissue biopsy.

Table 1. Diseases caused by asbestos

FACTORS	LATENCY PERIOD	DISEASES
Fibre type	10-40 years	Acute and chronic bronchitis
Fibre size	10-40 years	Asbestosis
Fibre dose	10-40 years	Bronchial carcinoma
Industrial process	10-40 years	Gastrointestinal carcinoma
Concentration	10-40 years	Laryngeal carcinoma
Duration of exposure	10-40 years	Mesothelioma
Exposure type (work, home, environment)	10-40 years	Pericardial thickening
Smoking	10-40 years	Pleural effusion, pleural thickening
Pre-existing lung disease	10-40 years	

Asbestosis is a lung disease characterized by scar tissue reproduction, destruction of pulmonary tissue, and reduced lung distensibility, which results in reduced inflow of oxygen [3,4].

Asbestosis is a serious, progressive, and long-lasting lung disease, which is not a cancerous, i.e. it is non-malignant. [3].

Asbestosis is a non-malignant lung disease caused by inhalation of asbestos fibres, which are then nested in small bronchi, bronchioles, and alveoli.

Inhalation of asbestos fibres can irritate pulmonary tissue, causing scar tissue and subsequently asbestosis. The scars make breathing very difficult. Asbestosis develops slowly and can vary from asymptomatic, through debilitating, to potentially fatal.

Due to slow disease progression and the late onset of symptoms, asbestosis takes about 20 years of asbestos exposure to develop. There is no 'threshold' dose or a 'safe' dose that would not lead to asbestosis.

Since the operative mechanism of asbestos fibres is still unknown, it is assumed that the body tries to dissolve the microfibers by increasing acidity. However, acidity has little effect on the fibres but instead destroys the surrounding tissue. Increase in acidity inside the body causes an inflammatory process, which in turn leads to pleural inflammation, inducing pleural thickening over time, with granulation tissue, while fibrosis develops in the lungs. The pathogenesis of asbestosis is still unknown, but there are several theories: the mechanistic theory – asbestos fibres similar to needles traumatize the pulmonary tissue and cause microhaemorrhages; theory of fibrosis induction with silicic acid – it is released slowly from asbestos and has a toxic effect on the pulmonary parenchyma; theory of immunological reaction – asbestos corpuscles in the

organism are coated with proteins, thus acquiring antigenic properties. The entire process unfolds over several stages: initial damage; alveolitis; fibroblast proliferation; alveolar collapse; and collagen production and deposition into the pulmonary interstitium. The first symptoms occur after 15 to 20 years of exposure. Shortness of breath, or dyspnea, is the main symptom of asbestosis. In time, chronic pulmonary insufficiency can develop [5,6].

**Figure 1.** X-ray image of lungs with asbestosis [3]

Mesothelioma is a malignant disease of the pleura and/or the peritoneum. This type of malignant disease is highly specific and, according to what is known thus far, it is directly associated with asbestos inhalation. In nearly 50% of the cases, the mesothelioma metastasizes and spreads locally, ultimately leading to death. Pleural effusion is an early marker of mesothelioma.

The time required for the diagnosis of mesothelioma is 30 or more years after initial asbestos exposure. The precise cause of this tumour is unknown, but it is assumed that professional exposure to asbestos is a significant risk factor. Scientists list amphibole asbestos as one of the causes of mesothelioma, owing to long periods of their retention in the lungs.

Statistical data of the affected show that as many as 75% of persons with pleural mesothelioma have been exposed to asbestos to a certain extent.

Cases of mesothelioma were most often registered among miners, persons working with grinding machines, persons transporting asbestos, persons manufacturing friction materials, textile, asbestos cement pipes, and roofing materials, and persons involved in shipbuilding. Common high-risk jobs also include construction workers, plumbers, welders, and electricians.

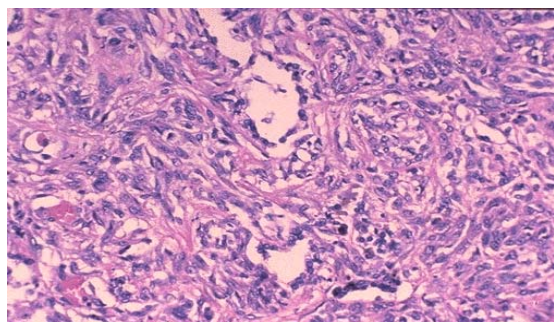


Figure 2. Tissue affected by mesothelioma [3]

Lung cancer is a malignant disease resulting from asbestosis.

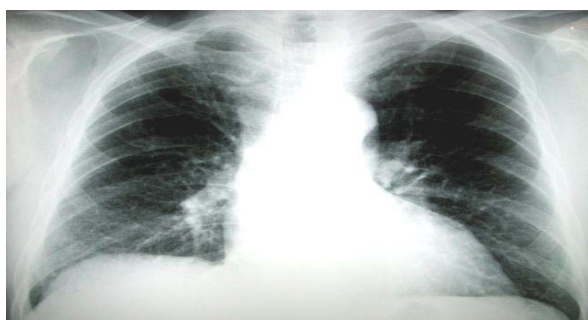


Figure 3. X-ray image of lung cancer [3]

Smokers are at greater risk of lung cancer due to synergetic effects of cigarette smoke and asbestos. High risk populations for lung cancer also include workers in mines, amphibole and crocidolite mills, textile plants, workers handling cement, and workers in construction and shipbuilding. The risk of disease for these workers occurs only 15 to 19 years after the initial exposure to asbestos.

ASBESTOS EXPOSURE LEGISLATION

Short descriptions of the most significant legal and sub-legal acts on asbestos exposure control are given below.

Regulation on Preventive Measures for Safe and Healthy Work during Asbestos Exposure [7]

The Regulation prescribes the requirements the employer has to meet by ensuring the implementation of preventive measures for the purpose of eliminating or minimizing the risk of harmful health effects on employees due to occupational exposure to asbestos. The regulation also establishes the limit value of asbestos exposure and other specific requirements.

Rules on Handling Waste Containing Asbestos [8]

The Rules prescribe the manner of packaging, criteria, conditions, and manner of the final disposal of waste containing asbestos, as well as other measures of prevention of asbestos fibres and dust dispersion in the

environment. The provisions of the Regulation pertain to waste raw asbestos and to asbestos-containing waste.

Rules on Limits and Bans on Production, Sale and Use of Chemicals That Pose Unacceptable Risk to Human Health and the Environment [9]

The Rules prescribe limits and bans on production, sale, and use of chemicals, banned and permitted ways of use, as well as other requirements for production, sale, and use of substances, mixtures, and products that pose unacceptable risk to human health and the environment.

Rules on Preventive Measures for Safe and Healthy Work during Asbestos Exposure [10]

The Rules prescribe minimum requirements the employer has to meet by ensuring the implementation of preventive measures for the purpose of eliminating or minimizing the risk of injury or damaged health of employees due to occupational exposure to asbestos; requirements imposed on legal entities licensed to preventively and periodically; limit values of asbestos exposure.

Regulation on the Manner and Procedures for Managing Asbestos-containing Waste [11]

The Regulation prescribes the manner of managing waste asbestos and asbestos-containing waste, as well as procedures of preventing environmental pollution from asbestos. The goal of the Regulation is to ensure the implementation of measures aimed at preventing and reducing asbestos pollution and to establish an asbestos-containing waste management system in accordance with the legislation governing human and environmental health protection.

CONCLUSION

Asbestos poses a health risk only when it is dispersed. In most products containing asbestos, it is not present in its pure form but is bound to form a composite material. Over time, the material wears out, leading to composite matrix disintegration and dispersal of asbestos fibres in the air. Occupational exposure to asbestos poses a great risk to human health and it can have serious consequences, such as professional respiratory diseases, because dispersed asbestos fibres easily reach the lungs due to their specific structure. The three most common diseases associated with asbestos exposure are asbestosis, a chronic obstructive lung disease, which can even be fatal, mesothelioma, and lung cancer. The level of exposure can be reduced by replacing asbestos materials with other materials with similar properties. Exposure can also be reduced through the use of personal protective equipment. Disease prevention requires the adherence to strict procedures of asbestos removal, a ban on any further use of asbestos, and creation of a registry of all buildings containing asbestos and of all persons exposed to asbestos, including their periodical and preventive medical examinations.

REFERENCES

- [1] M. Bernsteinl M: "Review of the differences between chrysotile and amphibole asbestos", 2009.
- [2] V. Petrović, B. Simendić: "Azbest, karakteristike i principi smanjenja izloženosti" [Asbestos – Properties and Principles of Exposure Reduction], Visoka tehnička škola strukovnih studija u Novom Sadu, 2013, Novi Sad.
- [3] M. Arandelović, J. Jovanović: "Medicina rada" [Occupational Medicine], Medicinski fakultet u Nišu, 2009, Niš.
- [4] P. Bulat: "Zdravstveni efekti izloženosti azbestu u radnoj i životnoj sredini" [Health Effects of Occupational and Environmental Asbestos Exposure], Medicinski fakultet u Beogradu, 2010, Beograd.
- [5] NCI-National Cancer Institute Factsheet: *Asbestos Exposure: Question and Answers*, USA, 2007.
- [6] Agency for Toxic Substances and Disease Registry, *Asbestos: Health Effects*, 2009.
- [7] Regulation on Preventive Measures for Safe and Healthy Work during Asbestos Exposure, "Official Gazette of the Republic of Serbia", No. 108/2015.
- [8] Rules on Handling Waste Containing Asbestos, "Official Gazette of the Republic of Serbia", No. 75/2010.
- [9] Rules on Limits and Bans on Production, Sale and Use of Chemicals That Pose Unacceptable Risk to Human Health and the Environment, "Official Gazette of the Republic of Serbia", No. 89/2010.
- [10] Rules on Preventive Measures for Safe and Healthy Work during Asbestos Exposure, "Official Gazette of the Republic of Serbia", No. 106/2009.
- [11] Regulation on the Manner and Procedures for Managing Asbestos-containing Waste, "Official Gazette of the Republic of Serbia", 2008.

BIOGRAPHY of the first author

Tatjana Golubović is an associate professor at the Faculty of Occupational Safety in Niš, University of Niš, Serbia. She graduated from the Faculty of Science and Mathematics, University of Niš, where she also obtained her Ph.D. degree. Her main areas of research include



chemistry, environmental chemistry, soil protection, toxicology, and eco-toxicology. She has published a number of scientific papers on these topics and participated in five scientific research projects funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia. She is a member of the Serbian Chemical Society.

RIZICI USLED IZLOŽENOSTI AZBESTU U RADNOJ SREDINI

Tatjana Golubović, Ana Miltojević, Slobodan Golubović, Sreten Ilić

Rezime: Uprkos saznanju o štetnim efektima, azbest se i dalje koristi širom sveta. Procenjuje se da je oko 125 miliona radnika u svetu izloženo azbestu na radnom mestu, a najmanje 90.000 ljudi godišnje umire od bolesti koje su povezane sa azbestom. Prašina azbesta javlja se prilikom dobijanja rude, separacije vlakana od serpentinskog dela, kao i prilikom obrade u različitim granama industrije. Radnici zaposleni u ovim proizvodnim procesima posebno su izloženi riziku. Hronična ekspozicija azbestu može povećati rizik nastanka azbestoze, raka pluća i mezotelioma. Smanjenje izloženosti azbestu postiže se zamenom azbestnih materijala, materijalima sličnih karakteristika, ali i primenom ličnih zaštitnih sredstava. U cilju prevencije oboljenja neophodno je sprovođenje strogih procedura uklanjanja azbesta, zabrane dalje upotrebe azbesta, registrovanja osoba koje su bile izložene azbestu i njihovih periodičnih i preventivnih lekarskih pregleda.

Ključne reči: azbest, rizici, radna sredina.

MAJA BRBORIĆ¹
MIRJANA VOJINOVIĆ-
MILORADOV¹
JELENA RADONIĆ¹
BOJANA ZORAJA¹
MAJA TURK- SEKULIĆ¹

OCCURRENCE OF POLYCYCLIC AROMATIC HYDROCARBONS AND POTENTIAL ECOTOXICOLOGICAL RISK IN FRESHWATER ECOSYSTEM OF THE DANUBE RIVER, SERBIA

¹University of Novi Sad, Faculty of Technical Sciences

¹majastupavski@uns.ac.rs

³jelenaradonic@uns.ac.rs

⁴bojanaberonja@uns.ac.rs

⁵majatürk@uns.ac.rs

Abstract: The top layer of riverbed sediments from 10 sites along the Danube River flow in Serbia were analyzed for the presence of polycyclic aromatic hydrocarbons (PAHs). Total concentrations of 16 US-EPA in sediment samples ranged from 99.48 µg/kg to 520.48 µg/kg. PAH molecular diagnostic ratios suggest that PAH loading in the river were mostly of pyrolytic origin. Comparison of contaminant levels prescribed by the international Sediment Quality Guidelines and calculation of total toxic Benzo[a]pyrene equivalent suggest that sediments of the Danube River do not pose an elevated ecotoxicological risk for benthic organisms.

Key words: PAHs, The Danube, sediment, risk assessment.

INTRODUCTION

The observation of contaminant levels in aquatic sediments is of crucial importance because it can provide important information about fate, effects and transport mechanisms of various environmental pollutants, especially hydrophobic organic pollutants such as polycyclic aromatic hydrocarbons [1, 2, 3]. Once released to the environment, during anthropogenic as well as natural processes, this toxic and carcinogenic pollutants can significantly endanger the environment depend on their physicochemical properties and the properties of the environmental compartments they are mostly associated with [4, 5, 6].

PAHs are characterized by persistence, toxicity, long-range environmental transport ability as well as a propensity to accumulate in plant and animal tissues [7]. Owing to their mutagenic and carcinogenic nature, sixteen PAHs are considered as priority pollutants by the United States Environmental Protection Agency (US-EPA). To date, the growing public and environmental health concerns regarding PAHs in the environment have led many countries to implement various programs and regulations to monitor, control, or restrict their release into the environment.

Due to rapid industrialization and urbanization, huge amounts of PAHs are discharged into aquatic systems and accumulated in river sediment [8]. Low molecular weight PAHs (LMW), which are usually dominant in water, are considered acutely toxic to aquatic organisms, and the carcinogenicity of PAHs increases with increasing molecular weight [7]. High molecular weight PAHs (HMW) that predominate in sediments have been linked with liver neoplasm and other abnormalities in bottom-dwelling fish [9].

Previous investigations of PAHs in Danube River have focused on their distribution in water, sediment and biota [10, 11]. However, there is a paucity of

information regarding the identification and quantitative evaluations of sources as well as the ecological risks posed by PAHs in the river sediment. Such information is essential for the formulation of effective pollution mitigation strategies. Furthermore, there is no recent comprehensive study on the distribution of PAHs in the sediments of the river, especially after the NATO "Allied force" operation in 1999. Therefore, the purpose of this research is to provide a detailed overview of the spatial distribution, patterns, and origins of PAHs in the Danube River sediment. Finally, the potential risk for aquatic organisms was also estimated. The study outcomes have important implications for the management of the catchment and will be valuable in identifying and implementing pollution prevention strategies and source control opportunities.

MATERIALS AND METHODS

Study area and sampling

The sampling was performed in October 2012. For this investigation, 10 samples of bottom sediment from different sites of the Danube River through Serbia (Apatin- D1 (1401 km), Labudnjača- D2 (1367 km), Neštin- D3 (1264 km), Begeč- D4 (1275 km), Ratno Ostrvo- D5 (1257 km), Šangaj- D6 (1250 km), Knićanin- D7 (1214 km), Belegiš- D8 (1199 km), Ritopek- D9 (1141 km), Dubravica- D10 (1103 km)) were collected using a grab sampler (Fig. 1). The sampling sites were chosen in order to cover the whole Danube area through Serbia and the results correspond to a network of ten representative sampling sites. Samples were taken to the laboratory in an ice cooler, where they were weighed and sealed to avoid contamination. All sediment samples were analyzed in the laboratory of Research Centre for Toxic Compounds in the Environment - RECETOX (Brno,

Czech Republic) after two days. Before analysis, wet sediment samples were sieved through 2 mm sieve to remove leaves, stones and roots.

Sample preparation and instrument analysis for PAHs

The target PAHs in this study were the 16 US-EPA priority AHs: Nap, naphthalene; Acy, acenaphthylene; Ace, acenaphthene; Fl, fluorene; Phe, phenanthrene; Ant, anthracene; Flu, fluoranthene; Pyr, pyrene; B[a]A, benzo[a]anthracene; Chr, chrysene; B[b]Flu, benzo[b]fluoranthene; B[k]Flu, benzo[k]fluoranthene; B[a]P, benzo[a]pyrene; IP, indeno[1,2,3-cd]pyrene; DB[ah]A, dibenzo[ah]anthracene; B[ghi]P, benzo[ghi]perylene. Spiked samples were extracted with dichloromethane (DCM) using hot solvent automated Soxhlet extraction. PAHs were determined using a GC-MS instrument (GC 7890/MS-MS Triple Quadrupole 7000B; Agilent) supplied with a J&W Scientific fused silica column DB-5MS (60m x 0,25 mm x 0,25 μ m). Terphenyl was used as internal standards for polyaromatic hydrocarbon (PAH).

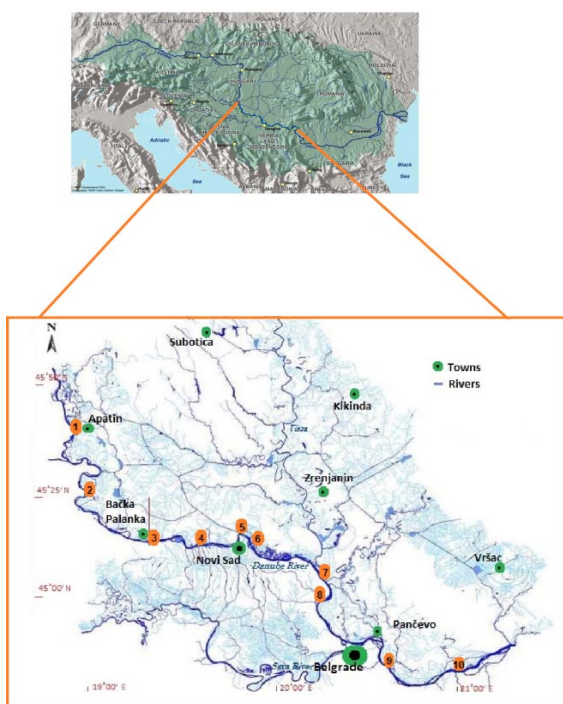


Figure 1. Danube River sampling sites

RESULTS AND DISCUSSION

The total content of 16 PAHs ranged from 99.48 to 520.48 ng/g with arithmetic mean value of 271.86 ng/g and median of 235.37 ng/g dw represented PAHs level in the Danube sediment. Value of total PAHs content obtained in bank sediment sample along the Danube River through Serbia was 2718.59 ng/g.

Source identification

The diagnostic ratios were used for source identification of PAHs in our study. Diagnostic ratios offer the opportunity to distinguish between PAHs originating from petrogenic (liquid fuels spills) and pyrogenic (combustion of fuels) sources, as well as burning biomass, coal, or fossil fuels [5].

Flu/Pyr and Phe/Ant ratios are considered as a method for assessing the contamination sources. It is generally agreed that low Phe/Ant values (< 10) and high Flu/Pyr values (> 1) are characteristic of a pyrolytic pollution [12]. Fig. 2 shows the distribution of Phe/Ant and Flu/Pyr ratios for the studied sampling points. The results from diagnostic ratios indicated that the PAHs in the sediment from the sampling area mainly came from pyrogenic sources. The activities of the local population, farming operations, and water transportation all affected PAHs pollution in the area.

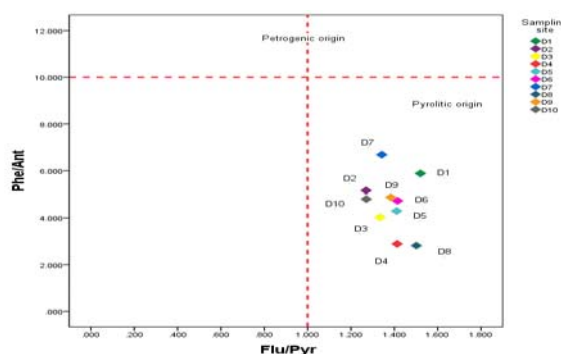


Figure 2 Plot of the Phe/Ant values compared with the Flu/Pyr values for the analyzed sediments

Ecological risk of PAHs

Biological effects

The concentrations of effects range low (ERL), effects range-medium (ERM), threshold effect level (TEL) and mERMQ have been widely used to characterize the ecological risk of PAHs freshwater sediment [13,14]. Table 1. presents the concentration ranges of PAHs proposed by international Sediment Quality Guidelines (SQGs) (ERL-ERM) and the number of stations amongst ranges of international SQGs at the Danube River. SQG values showed that PAHs no exceeded the ERL for total PAHs and ERM for individual PAHs. Fluorene concentrations in riverbed sediment at D5 (88 μ g/kg) were in the intermediate range (ERL/TEL and ERM/PEL) and were below ERL/TEL at the remaining nine sites. Considering that the site D5 is characterized by high contamination and low content of TOC, this finding is expected. Only light PAHs were recorded at elevated levels (i.e., the value of Fl was exceeded and no adverse biological effects are anticipated at this site.

Table 1. SQGs values for PAHs and relative percentage of samples for Danube stations

Compound	SQG ^a ERL ^b – ERM ^c (ng/g d.w.)	No. of stations			SQG ^a TEL ^d – PEL ^e (ng/g d.w.)	No. of stations		
		<ERL	ERL– ERM	>ERM		<TEL	TEL – PEL	> PEL
Nap	340–2100	D3	-	-	35–391	D3	-	-
Acy	44–640	D9	-	-	6–128	D9	-	-
Ace	16–500	D5	-	-	7–89	D5	-	-
Fl	35–640	D1	D5	-	21–144	D1	D5	-
Phe	225–1380	D9	-	-	42–515	D9	-	-
Ant	85–960	D9	-	-	47–245	D9	-	-
Flu	600–3600	D9	-	-	111– 2355	D9	-	-
Pyr	350–2200	D9	-	-	53–875	D9	-	-
B[a]A	230–1600	D9	-	-	75–693	D9	-	-
Chr	400–2800	D9	-	-	57–862	D9	-	-
B[b+k]Fl	-	-	-	-	-	-	-	-
B[a]P	400–2500	D9	-	-	32–782	D9	-	-
IP	-	-	-	-	-	-	-	-
DB[ah]A	63–260	D9	-	-	6–135	D9	-	-
B[ghi]P	-	-	-	-	-	-	-	-
Σ ₁₆ PAHs	4000– 35000	D9	-	-	655– 6676	D2	D9	-
LMW PAHs ^f	552–3160	D9	-	-	-	-	-	-
HMW PAHs ^g	1700– 9600	D9	-	-	-	-	-	-

^a SQG values taken from MacDonald et al. (2000) and MacDonald et al. (1996).^b ERL = effects range-low value^c ERM = effects range-median value^d TEL = threshold effects level^e PEL = probable effects level^f LMW PAHs = the sum of the concentrations of low-molecular-weight PAHs, i.e., naphthalene and fluoranthene^g HMW PAHs = the sum of the concentrations of high-molecular-weight PAHs, i.e., pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenzo[a,h]anthracene, and benzo[ghi]perylene (Keshavarzifard et al., 2014)^h Sampling point that has the highest value, i.e. value that is closest to prescribed values of SQG sets.

Potential toxic risk

Considering all potentially carcinogenic PAHs, B[a]P is the only determined polycyclic aromatic hydrocarbon for which sufficient published toxicological data exist to allow the calculation of carcinogenic potency factor. Therefore, the potential toxicity of sediments was assessed by calculating the total toxic Benzo[a]pyrene equivalent (TEQ^{carc}) for all PAHs^{carc}, using the toxicity equivalent (TEF^{carc}) for each PAH (TEFs for B[a]A, Chr, B[b]Flu, B[k]Flu, B[a]P, DB[ah]A and IP are 0.1, 0.001, 0.1, 0.01, 1, 1 and 0.1, respectively) and using the following equation:

$$TotalTEQ^{carc} = \sum C_i \cdot TEF_i^{carc} \quad (1)$$

where:

C_i is the concentration of an individual PAHs^{carc} (μg/kg) and

TEF_i^{carc} (toxic equivalency factor) is the toxic factor of PAHs^{carc} relative to BaP.

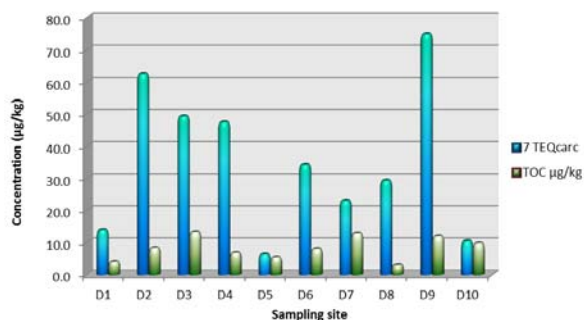


Figure 3 Total TEQ^{carc} values for 7PAHs detected in Danube sediment

Total TEQ^{carc} in Danube River ranged from 6.49 to 74.94 ngTEQ/g, with a mean concentration of 35.20 ngTEQ/g (Fig.3). The low TEQ^{carc} concentrations indicate potentially low carcinogenicity. The contribution of each carcinogenic PAH to the total TEQ^{carc} in Danube River varied according to the following order: B[a]P (67.66%), IP (11.29%), B[b]Flu (19.6%), DB[ah]A (5.9%), B[a]A (4.40%), B[k]Flu (2.84%), and Chr (0.47%). In addition, sediments from D9 contained slightly higher levels of TEQ^{carc} than those at other sites, while the sediment collected at the site D5 had the lowest value.

CONCLUSION

In the current study, we determined the levels of 16 PAHs in the Danube bottom sediment at 10 locations along the whole flow of the Danube through Serbia. The highest level of PAHs was recorded at the locality Ritopek, while the lowest was recorded at the locality Dubravica. PAH origins, as determined by the diagnostic ratios method, revealed a prevalence of PAHs of pyrolytic origin at all studied sites.

The ecotoxicological evaluation, based on international Sediment Quality Guidelines, showed low ecological risks for the freshwater organisms, especially for benthic species. The results of potential toxicity and biological effect evaluations show that riverbed sediments from Danube River have a relatively low level of hazardous pollution. The only exception is the site D9, with a medium level of toxic pollution. The results of this study add new data to the international database of the river Danube producing comparable and reliable information of sediment and water quality.

REFERENCES

- [1] C.A. Alves, A.M.P. Vicente, J. Gomes, T. Nunes, M. Duarte, B.A.M. Bando: "Polycyclic aromatic hydrocarbons (PAHs) and their derivatives (oxygenated-PAHs, nitrated-PAHs and azaarenes) in size-fractionated particles emitted in an urban road tunnel", Atmos. Res., 180, 2016, pp. 128-137.
- [2] C.F.J. Franco, M.F. de Resende, L.A. Furtado, T.F. Brasil, M.N. Eberlin, A.D.P. Netto: "Polycyclic aromatic hydrocarbons (PAHs) in street dust of Rio de Janeiro and Niterói, Brazil: particle size distribution, sources and cancer risk assessment", Sci. Total Environ., 599–600, 2017, pp. 305-313.
- [3] L.J. Heintzman, T.A. Anderson, D.L. Carr, N.E. McIntyre: "Local and landscape influences on PAH contamination in urban storm water", Landsc. Urban Plann., 142, 2015, pp. 29-37.
- [4] H.O. Kwon, S.D. Choi: "Polycyclic aromatic hydrocarbons (PAHs) in soils from a multi-industrial city, South Korea", Sci. Total Environ., 470–471, 2014, pp. 1494-1501.
- [5] G.O. Duodu, K.N. Ogogo, S. Mummullage, F. Harden, A. Goonetilleke, G.A. Ayoko: "Source apportionment and risk assessment of PAHs in Brisbane River sediment, Australia", Ecol. Indic., 73, 2017, pp. 784-799.
- [6] I. Tongo, L. Ezemonye, K. Akpeh: "Levels, distribution, and characterization of polycyclic aromatic

hydrocarbons (PAHs) in Ovia river, Southern Nigeria", J. Environ. Chem. Eng., 5, 2017, pp. 504-512.

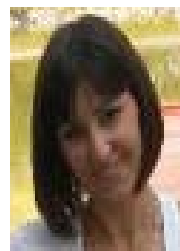
- [7] K.H. Kim, S.A. Jahan, E. Kabir, R.J.C. Brown: "A review of airborne polycyclic aromatic hydrocarbons (PAHs) and their human health effects", Environ. Int., 60, 2013, pp. 71-80.
- [8] S. Liu, X.R. Liu, M. Liu, B. Yang, L. Cheng, Y. Li, A. Qadeer: "Levels, sources and risk assessment of PAHs in multi-phases from urbanized river network system in Shanghai", Environ. Pollut., 219, 2016, pp. 555-567.
- [9] M. Tiwari, S.K. Sahu, G.G. Pandit: "Distribution of PAHs in different compartment of creek ecosystem: ecotoxicological concern and human health risk", Environ. Toxicol. Pharmacol., 50, 2017, pp. 58-66.
- [10] D.M. Crnković, N.S. Crnković, A.J. Filipović, L.V. Rajaković, A.A. Perić-Grujić, M.D. Ristić: "Danube and Sava river sediment monitoring in Belgrade and its surroundings", J. Environ. Sci. Health 43, 2008, pp. 1353-1360.
- [11] S. Sakan, B. Ostojić, D. Dordević: "Persistent organic pollutants (POPs) in sediments from river and artificial lakes in Serbia", Journal of Geochemical Exploration, 180, 2017, pp. 91-100.
- [12] G. Perra, K. Pozo, C. Guerranti, D. Lazzeri, V. Volpi, S. Corsolini, S. Focardi: "Levels and spatial distribution of polycyclic aromatic hydrocarbons (PAHs) in superficial sediment from 15 Italian marine protected areas (MPA)", Marine Pollution Bulletin, 62, 2011, pp. 874-877.
- [13] E. Long, D. MacDonald, S. Smith, F. Calder: "Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments", Environ. Manage. Vol. 19, 1995, pp. 81-97.
- [14] D. MacDonald, R. Carr, F. Calder, E. Long, C. Ingersoll: "Development and evaluation of sediment quality guidelines for Florida coastal waters", Ecotoxicology vol. 5, 1996, pp. 253-278.

ACKNOWLEDGEMENTS

This research was supported by the Ministry of Education, Science and Technological Development, Republic of Serbia (III46009 and TR34014), the Czech Ministry of Education, Youth and Sports (LM2015051) and the European Structural and Investment Funds, Operational Programme Research, Development, Education (CZ.02.1.01/0.0/0.0/16_013/0001761).

BIOGRAPHY of the first author

Maja Brborić was born in Sremska Mitrovica, Serbia, in 1984. In 2008 she received a master's degree in environmental engineering and currently, she is a Ph.D. student at the Department of Environmental Engineering and Occupational Safety and Health, Faculty of Technical Science. Her main areas of research include water protection and ecotoxicology. She is currently working as a research associate at the FTN, University of Novi Sad.



PRISUSTVO POLICIKLIČNIH AROMATIČNIH UGLJOVODONIKA I PROCENA EKOTOKSIKOLOŠKOG RIZIKA U SLATKOVODNOM EKOSISTEMU REKE DUNAV, SRBIJA

Maja Brborić, Mirjana Vojinović-Miloradov, Jelena Radonić, Bojana Zoraja, Maja Turk-Sekulić

Rezime: Uzorci sedimenta kolektovani sa 10 lokacija duž reke Dunav u Srbiji analizirani su na prisustvo policikličnih aromatičnih ugljovodonika (PAH). Ukupne koncentracije 16 US-EPA PAH u uzorcima sedimenata varirale su od 99,48 µg/kg do 520,48 µg/kg. Molekularni dijagnostički odnosi ukazuju na to da je opterećenje PAH u sedimentu reke Dunav uglavnom izazvano prisustvom izvora pirolitičkog porekla. Upoređivanje nivoa kontaminacije propisanih Međunarodnim smernicama za kvalitet sedimenata i izračunavanje ukupnog toksičnog benzo [a] pirenskog ekvivalenta ukazuju na to da sediment reke Dunav ne predstavlja povećan ekotoksikološki rizik za bentosne organizme.

Ključne reči: pah, Dunav, sediment, procena rizika.

NEMANJA PETROVIĆ¹
JASMINA RADOSAVLJEVIĆ²
ANA VUKADINOVIC³

¹College of Applied Technical
Sciences Niš

²University of Niš,
Faculty of Occupational Safety

³University of Niš,
Faculty of Occupational Safety

¹nemanja.petrovic@vtsnis.edu.rs

²jasmina.radosavljevic@znrfak.ni.ac.rs

³ana.vukadinovic@znrfak.ni.ac.rs

MITIGATING THE URBAN HEAT ISLAND

Abstract: Modern urban morphology implies a densely built central structure of cities. The central zones of the majority of cities in Serbia represent the inherited structure of the former settlements. The fragmented street network, the emergence of new, bigger buildings, both residential and administrative, a high land occupancy coefficient, have caused the urban landscape to be less and less located for green areas. That is the reason why urban heat island effect appears. The purpose of this paper is to demonstrate how to solve the problem of the thermal island effect at the micro location level using green roofs. ENVI-met® is a software that allows a three-dimensional non-hydrostatic modeling of building-air-vegetation interaction. It is designed for microscale with a typical horizontal resolution from 0.5 to 5 meters and a typical period of 24 to 48 hours in most cases. The method used in this paper is a simulation made in the ENVI-met® software package.

Key words: urban heat island, green roof, simulation, ENVI-met®, environment.

INTRODUCTION

With the rapid and uncontrolled development of cities and the increasing needs of modern society has started to develop a phenomenon called the heat island effect. This effect is most easily and most clearly be defined as significant overheating of the thick center of the built structure compared to the surrounding rural areas. [1]

The thermal island effect can occur on the surface of the earth and in the atmosphere. The surface effect of the thermal island can be easily demonstrated during the hottest days of the year with the greatest sun insulation when surfaces such as pavements and roofs of buildings are heated up to as much as 50°C more than the ambient air, while the areas sheltered or those located in a rural setting where the most common substrate is the moist soil remains near the ambient air temperature [2]. This type of thermal island effect can be detected at any time of the day, but it is much easier to define it during the night when the absorbed heat is emitted into the surrounding environment that has significantly lower temperature than during a day due to the absence of sun radiation. That is the main principle of atmospheric effect of the thermal island. Because of that the mean annual air temperature in a city of 1 million inhabitants is higher by 1 to 3°C than air temperature around the city. During the period when the warming of the soil is higher, this temperature difference can go up to 12°C [3].

Huge quantities of solar radiation are stored and later reemitted to urban Environment due to the massive amount of construction materials. This so called “canyon effect” from building volumes [4] combined with the use of air conditioning, the anthropogenic heat generated by power plants and automobiles [5] are all contributing to the Urban Heat Island effect.

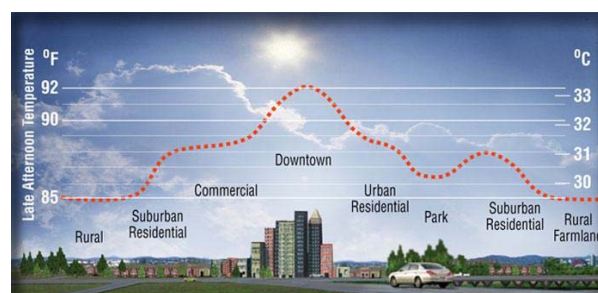


Figure 1. Urban heat island effect

One of the main tools in attempting to reduce the heat island effect is the involvement of vegetation into the urban environment using green roofs as the only way that does not change the physical structure of urban blocks.

METHODOLOGY

ENVI-met® simulation software is a holistic, three-dimensional, non-hydrostatic model that simulates the interaction between objects, atmosphere and vegetation. It is designed to operate at a microlocation level of a horizontal resolution of 0.5 to 5 meters, for a period of 24 or 48 hours, with a step from 1 to 5 seconds [6]. It provides the ability to intertwine different areas in the making of simulations such as: climatology, architecture, energy and spatial planning.

The software develops a prognostic model based on the principles of the law of fluid dynamics and thermodynamics. Results include:

- Short-wave and long-range radiation fluxes depending on shading, reflection and radiation re-emission by the system of objects and vegetation

- Transpiration, evaporation and heat flow from all types of vegetation in the air including complete simulation of all physical parameters of the plant (eg photosynthesis)
- Surface and wall temperature of all parts of objects
- Exchange of water and thermal energy of the soil
- Calculating biometeorological parameters
- Dispersion of inert gases and particles including sediment particles on leaves and other surfaces [6]

Also, ENVI-met® includes the interaction between objects, vegetation and various surface treatments, but also how they all affect atmospheric conditions. When modeling, there are 5 basic groups that can be classified into a simulation:

- The Atmospheric model, which calculates air movement, three-dimensional turbulence, temperature, relative humidity and takes into account obstacles such as objects and vegetation.
- Surface model, which calculates the emitted waves and reflected short-wave radiation from other surfaces, taking into account the association of short-wave and long-range radiation. Also, the albedo of the surface is also included in the results, the shadows created by the movement of the sun and water vapor from the plants and the soil.
- Vegetation model that calculates greenhouse temperature as well as other reactions in leaves to account for all physiological parameters of plants with meteorological parameters of the atmosphere. Vegetation is characterized by normalized density of leaf area and normalized root density. Evaporation and calculation of turbulence is based on airflow fields around vegetation and wood shape. The evaporation rate from the leaf surface affects the heat exchange between the leaves and the environment.
- Land model, which calculates soil and soil thermodynamic and hydrodynamic processes.
- Biometeorological model, which is able to calculate the PMV index from meteorological data [7].

CASE STUDY

In this research, data modeling was performed in ENVI-met® software Version 4.3.2 Summer 18 Release

Selected area is the central zone of the City of Niš. Niš is situated at the 43°19' latitude north and 21°54' longitude east, in the Nišava valley, near the spot where it joins the South Morava. The main city square, the city's central part, is at 194 m (636 ft) above sea level. Average annual temperature in the area of Niš is 11.9 °C (53.4 °F). July is the warmest month of the year, with an average of 22.5 °C (72.5 °F). The coldest month is January, averaging at 0.6 °C (33.1 °F). The average of the annual rainfall is 580.3 mm (22.85 in). The average barometer value is 992.74 mb. On average, there are 134 days with rain and snow cover lasts for 41 days.

The surveyed surface is square-shaped, with the side length of 180m. Satellite image of the area shows us small amount of green areas that are mainly covered with high trees and a big area used by flat roofs of buildings. For ease of modeling, the satellite image is rotated by 11.5 ° so that the directions for providing a larger child of objects are placed in the horizontal and vertical directions.



Figure 2. Satellite image of location

Chosen grid for this model is 3D grid with 3m division in all axes. The resolution of the model is taken according to the recommended values for one field (from 0.5 m to 10 m) in order to make the best relationship between the model's processing time and the relevance of the result. A more precise resolution requires a larger model, and the basic version of the software allows maximum working space size of 100x100x30 fields.

Table 1. Initial parameters

Start and duration of model run	
Start date	01.08.2018.
Start time	05:00
Total Simulation Time (h)	40
Initial Meteorological conditions	
Wind speed at 10m (m/s)	3.0
Wind direction	270° (W)
Roughness length at measurement site	0.01
Model rotation out of grid	11.5°
Temperature	
Initial Air Temperature (°C)	18.0
Humidity	
Initial relative humidity (%)	50
Geographic data for Niš, Serbia	
Altitude (m)	194
Latitude	43°19'
Longitude	21°54'
Number and size of grid and nesting properties	
Grid (x,y,z)	60, 60, 30
Grid size (m)	dx=3, dy=3, dz=3
Nesting grids	3

Baseline model is made according to relevant characteristics of existing condition. Position, size and

a shape of the buildings, position of the plants and surface materials and soil characteristics are representing the current condition of urban location. Green model has all the same characteristics as the baseline model, except flat roof areas that are converted to extensive green roofs.

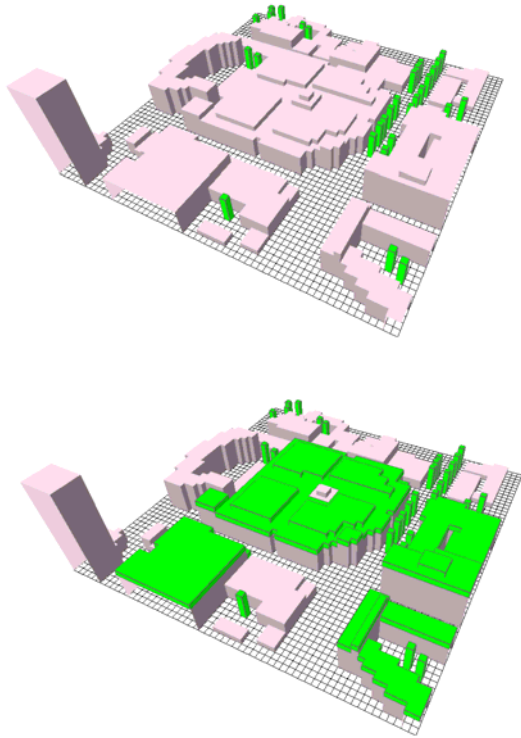


Figure 3. 3D model of actual location with and without green roofs

Area of the modelled location is 32.400 m². After developing model with implementation of green roofs as one of the ways in order to mitigate urban heat island effect we managed to increase area covered with vegetation for 10.341 m² (1/3 of the whole area). Average height of the green roofs is 16 meters.

RESULTS

The output parameters of the simulation that represent the basis of this work are the air temperature, relative humidity and mean radiant temperature for the two above mentioned cases. Since the simulation was made in the basic version of the software, some parameters could not be changed. In order for this effect to be best represented, it is necessary for the simulation to take several days, to harmonize the whole system and to act as a system in a real space, i.e. that all objects warm during the day, and during the night they cool down [8]. However, regardless of this, clear differences can be observed between the two cases analyzed. Also, it should be considered the fact that the results would be more realistic and would provide more informations if the wider location from the current one was observed, which was also in this case impossible due to the type of software in which it was done.

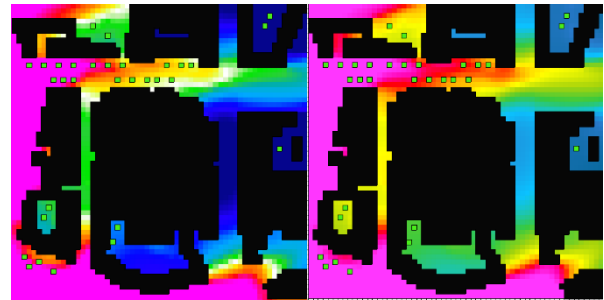


Figure 4. Air temperature at 3:00 PM
(baseline model - left, green roof – right)

Figure 4 represents the temperature distribution at the observed location at 3:00 PM at the pedestrian level, which represents the warmest period of the day. It can be seen that warm air comes with a wind from the west and that green roofs, although at an average height of 16m in relation to the pedestrian zone, affect the temperature decrease and thus mitigate the effect of thermal islands.

Temperature analysis is discussed at 22 PM (when there is no sunshine but there is a temperature emission from objects) and at 5 AM (when there is still no sunshine, and the objects have delivered most of the temperature to the surrounding area and reached the state of balance). Graphic results are given in the following Figures.

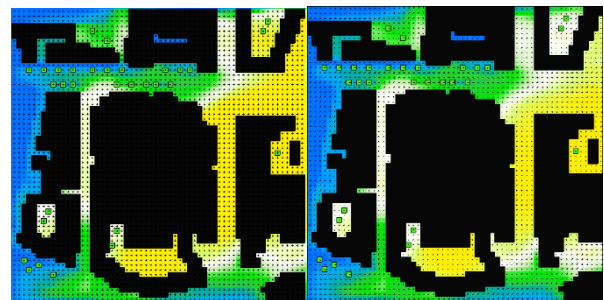


Figure 5. Air temperature at 22:00 PM
(baseline model - left, green roof model - right)

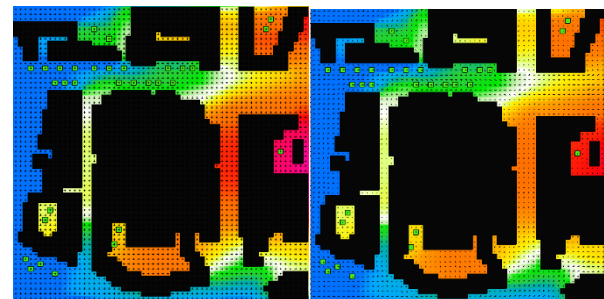


Figure 5. Air temperature at 5:00 AM
(baseline model - left, green roof - right)

The movement of cooler air from the roofs and its impact on the street level can be more clearly seen on the section through the observed location. The influence of wind direction on the effect of space cooling can be seen on the section.

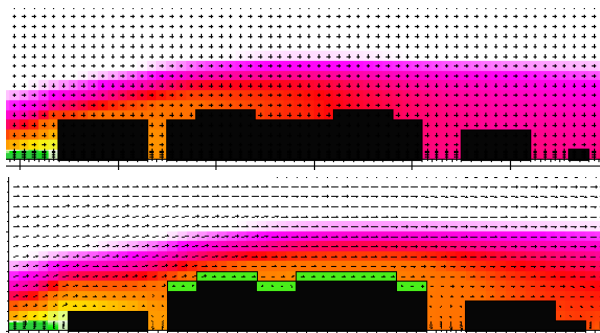


Figure 6. Air temperature at 22 PM – section
(baseline model – top, green roof model – bottom)

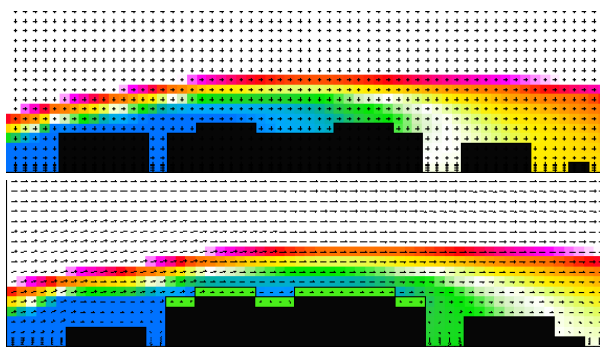


Figure 6. Air temperature at 5 AM – section
(baseline model – top, green roof model – bottom)

As shown in Figure 2, 4 measuring points (R1, R2, R3 and R4) are placed on the site and their values at these observed time intervals are given in the following table. Points R1 and R2 are located in a street that is oriented north-south and in which there is no significant movement of air currents, while points R3 and R4 are directioned east-west and are hit by wind currents. In addition to the temperature shown in Figures 4, 5 and 6, the table shows the data on relative air humidity as well as the mean radiant temperature. Relative humidity is the ratio of the current absolute humidity to the highest possible absolute humidity (which depends on the current air temperature). A reading of 100 percent relative humidity means that the air is totally saturated with water vapor and cannot hold any more, creating the possibility of rain [9]. The mean radiant temperature, T_{mrt} or MRT, which can be regarded as a weighted sum of all long- and short-wave radiant fluxes (including direct, reflected and diffuse components), to which a human body is exposed, is one of the most important meteorological parameters related to human energy balance and human thermal comfort. By definition, MRT is the 'uniform temperature of an imaginary enclosure in which the radiant heat transfer in the actual non-uniform enclosure [10].

Table 2. Values at measured points

	Baseline model			Green roof model		
	Air temperature (°C)					
	3pm	10pm	5am	3pm	10pm	5am
R1	30.94	28.04	22.09	30.89	27.94	22
R2	31.11	27.87	21.71	30.99	27.82	21.67
R3	32.36	27.72	20.86	32.28	27.71	20.86
R4	31.66	27.96	21.72	31.59	27.91	21.65
	Relative Humidity (%)					
	3pm	10pm	5am	3pm	10pm	5am
R1	47.97	52.60	58.91	48.42	52.96	59.29
R2	48.09	53.97	60.54	48.48	54.11	60.68
R3	47.16	55.84	64.01	59.97	55.83	64.01
R4	46.49	53.52	60.42	46.76	53.74	60.70
	Mean Radiant Temperature (°C)					
	3pm	10pm	5am	3pm	10pm	5am
R1	41.84	20.39	13.43	41.55	20.41	13.51
R2	41.93	20.47	13.67	41.56	20.45	13.71
R3	60.75	21.15	14.35	59.97	21.23	14.51
R4	69.23	20.16	11.98	69.10	20.15	12.01

At all measuring points, a drop in temperature in a model with green roofs can be noticed. This drop is small given that the green roof cover is an extensive green roof that has the least power to mitigate the effects of the thermal island [11]. The aim of the research is to demonstrate the applicability and consistency of the software package and in conditions that give insignificant differences in the values obtained.

In accordance with expectations, with the increase in the green area at the site and thus the increase in overall plant transpiration, in addition to reducing the temperature, the relative humidity of the air is increasing as well [12].

Urban environments are rich in materials that absorb solar energy and are reflected or emitted it into the surrounding area over time. As we have already said, the emitted energy can be represented as Mean radiated temperatures and, depending on the position of the measuring point, can vary widely in relation to the other observed parameters.

CONCLUSION

The urban heat island effect as one of the most present problems of contemporary society occurs in all types of city structures due to the reduced amount of vegetation and increased amount of man-made constructions. One way to reduce this effect is to implement a green roof system on all objects that support this type of construction. One way to reduce this effect is to implement a green roof system on all objects that support this type of construction. This would reduce the negative impact of the urban heat island and it would positively affect the air quality in urban areas. Although it can positively influence the reduction of the mentioned effect, we cannot talk about its eradication, because no matter how much vegetation

we put on the fifth facade of the objects (roofs), there will still be a great difference between nature and nature with the created conditions created by a man.

One way to analyse the justification of the adaptation and modification of flat roofs in green roofs is to use software packages like the ENVI-met®. This software cannot be applied to the entire area of the urban structure, but it is certainly good to simulate the natural conditions that prevail in that area at the micro-location level, block level or group of blocks in order to simulate the natural conditions and to predict what would be the difference if there were a change in these conditions.

REFERENCES

- [1] G. G. B. M. I. N. S. S. Dario Ambrosini, "Evaluating Mitigation Effect of Urban Heat Island in a Historical Small Center with the ENVI-Met Climate Model," *Sustainability*, vol. 6, pp. 7013-7029, 2014.
- [2] B. S. Berdahl P, "Preliminary survey of the solar reflectance of cool roofing materials," *Energy and Buildings*, vol. 25, pp. 149-158.
- [3] O. T.R., *Boundary Layer Climates*, New York: Routledge, 1987.
- [4] A. J. Arnfield, J. M. Herbert and G. T. Johnson, "Urban canyon heat source and sink strength variations: A simulation-based sensitivity study," in *Congress of Biometeorology and International Conference on Urban Climate*, Sydney, 1999.
- [5] A. M. RIZWAN, L. Y. DENNIS and C. LIU, "A review on the generation, determination and mitigation of Urban Heat Island," *Journal of Environmental Sciences*, vol. 20, no. 1, pp. 120-128, 2008.
- [6] E. GmbH, "Envi-met," 25 December 2017. [Online]. Available: <http://www.envi-met.com/#1509708337289-91f4c901-b2ed1509711808171>.
- [7] S. A., "Wind comfort in a public urban space - Case study within Dublin Docklands," *Front Archit. Res.*, vol. 2, pp. 50-66, 2013.
- [8] F. Salata, I. Golasi and R. d. L. Vollaro, "Urban microclimate and outdoor thermal comfort. A proper procedure to fit ENVI-met simulation outputs to experimental data," *Sustainable Cities and Society*, vol. 26, pp. 318-343, 2016.
- [9] HowStuffWorks, "What Is Relative Humidity and How Does it Affect How I Feel Outside?," InfoSpace Holdings LLC, 2018. [Online]. Available: <https://science.howstuffworks.com/nature/climate-weather/atmospheric/question651.htm>. [Accessed 14 11 2018].
- [10] A. Lai, M. Maing and E. Ng, "Observational studies of mean radiant temperature across different outdoor spaces under shaded conditions in densely built environment," *Building and Environment*, vol. 114, pp. 397-409, 2017.
- [11] M. Lalošević, M. Komatina, M. Miloš and N. Rudonja, "GREEN ROOFS AND COOL MATERIALS AS RETROFITTING STRATEGIES FOR URBAN HEAT ISLAND MITIGATION – CASE STUDY IN BELGRADE, SERBIA," *Thermal sciences Online*, no. 00, pp. 86-86, 2018.
- [12] L. Shashua-Bar and M. E. Hoffman, "Vegetation as a climatic component in the design of an urban street," *Energy and Buildings*, vol. 31, no. 3, pp. 221-235, 2000.

BIOGRAPHY of the first author

Nemanja Petrović was born in Niš, Serbia, in 1988.

He received master degree diploma in Architecture at the Faculty of Civil Engineering and Architecture. Now he is at PhD studies of Environmental Safety engineering at Faculty of Occupational Safety at

University of Niš. His main areas of research include green roofs, urban heat island, urban planning, ecological engineering, environmental management, etc. He is currently working as an assistant at the College of Applied Technical Sciences Niš.



SMANJENJE EFEKTA TOPLOTNOG OSTRVA

Nemanja Petrović, Jasmina Radosavljević, Ana Vukadinović

Rezime: Gusto izgrađena struktura gradova proizilazi iz potreba savremenog društva. Većina gradova u Srbiji nastali su oko nasleđene strukture naselja iz ranijih epoha. Nasleđena nepravilna ulična mreža, umetanje novih, velikih objekata sa visokim indeksom izgrađenosti u usku strukturu grada dovode do toga da je sve manje zelenih površina u centralnim gradskim zonama. Ovo je razlog za pojavljivanje efekta toplotnog ostrva. Svrha ovog rada jeste da pokaže način na koji može da se smanji efekat toplotnog ostrva na mikrolokacijskom nivou korišćenjem zelenih krovova. ENVI-met[®] je softver koji omogućava trodimenzionalno nehidrostatičko modeliranje interakcije između objekata, vazduha i vegetacije. Dizajniran je za rad na mikrolokacijskom nivou sa horizontalnom rezolucijom od 0,5 do 5 metara i sa najčešće korišćenim periodom trajanja simulacije od 24 do 48 sati. Metod za obavljanje simulacije u ovom radu je upravo softverski paket ENVI-met[®]

Ključne reči: efekat toplotnog ostrva, simulacija, ENVI-met[®], zeleni krovovi, životna sredina.

MILENA MANČIĆ¹
MIOMIR RAOS²
MILENA MEDENICA³
JELENA
MALENOVIĆ-NIKOLIĆ⁴
MILAN PROTIĆ⁵
MARKO MANČIĆ⁶

^{1,2,3,4,5}University of Niš,
Faculty of Occupational Safety in Niš
⁶University of Niš,
Faculty of Mechanical Engineering

¹milena.jovanovic@znrfak.ni.ac.rs

APPLICATION OF THE ENERGY BALANCE METHOD ON THE MILK AND DAIRY PROCESSING PLANT

Abstract: *An increase in energy efficiency of the industrial sector would significantly reduce the greenhouse gas emissions caused by the burning of fossil fuels and the production costs associated with energy use. The production of dairy products, such as milk powder and cheese, is a major industrial sector in Europe, and also in the U.S. and rest of the world. The goal of this paper is to evaluate energy efficiency of a milk and dairy production plant, and to perform a detailed analysis of the production processes with the emphasis on the use of the resources in the plant. A milk and dairy production plant is considered, and it produces a variety of different dairy products. The production process is scaled to 1,000 t of raw milk per year in order to produce products such as pasteurized milk, different types of fermented products (yogurts, sour cream, etc.) and different types of cheese.*

Key words: energy efficiency, energy balance method, milk and dairy production plant

INTRODUCTION

An increase in energy efficiency of the industrial sector would significantly reduces the greenhouse gas emissions caused by the burning of fossil fuels and the production costs associated with energy use [1]. The production of dairy products, such as milk powder and cheese, is a major industrial sector in Europe and also one of the most energy-intensive industries within the food sector [2]. The U.S. dairy processing industry consumes around \$1.5 billion worth of purchased fuels and electricity per year [3]. Energy efficiency improvements are a critical way for plants to reduce these costs, lower emissions of energy-related pollutants, and reduce susceptibility to volatile energy prices [3]. Denmark, for example, has a high share of agricultural products in their overall exports, of which 20% of the agricultural exports are dairy products. A total of 4.7 billion kg of raw milk are processed in 61 production plants, resulting in export revenues of 1.8 billion Euro [4].

The goal of this paper is to evaluate energy efficiency of a milk and dairy production plant, and to perform a detailed analysis of the production processes with the emphasis on the use of the resources in the plant. The benchmarking analysis was conducted in order to calculate indicators regarding the use of energy, and to compare it with respective industry values in order to determine savings potentials.

DISCRIPTION OF THE CASE STUDY PLANT

Small scale milk and dairy plant

The dairy plant operates 4,500 hours/year, and the production for the purpose of this study is scaled to 1000t/year of raw milk treated.

Out of total received raw milk, on a yearly basis, 17%-26% is processed into pasteurized milk, 52-56% into fermented milk products and 22-29% into different types of cheese.

At the receiving point of the raw milk, the temperature of milk is measured, and if the temperature is higher than the set point value, milk is cooled down to 5°C using plate type heat exchanger. As coolant, chilled water (mixture of water and ice with 0°C temperature) is used. Water is chilled using refrigeration system and stored in 5000 l open top tank which is located in an outside detachable housing constructed from metal plates without insulation. Flow rate of milk is 5,000 l/h. After cooling, milk is transferred from receiving storage tank to where is stored before further processing in pasteurization section.

Raw milk is first preheated to 37-40°C in cascade heat exchanger which uses heat recovery between "incoming cold raw milk" and "hot pasteurized milk". Preheated milk then goes into separator where milk skimming is performed. Afterward milk is additionally heated in pasteurizer to 72-75°C before entering into homogenizer. Homogenization process is performed at 120-200 bar pressure depending on the type of product. [6]

HTST (High Temperature Short Time) pasteurization of homogenized milk, which is next step in the production process, is carried out in pasteurizer for 30 seconds at the temperatures 92 - 95°C, which is higher than standard range of temperatures used for milk HTST pasteurization (72 - 75°C). Higher temperatures are necessary to disregard the impact of the input raw material quality. Subsequently pasteurized milk goes briefly into holding section (8 -12 minutes) before it is cooled down in a cascade heat exchanger.

When pasteurized milk production is finished, the final product is first cooled down to 5 - 6°C before going

into storage tank and afterward packed. Packed milk is than stored in refrigerated cold room (range of temperatures between 0 - 8°C) [6]

For the production of fermented milk products, raw milk goes through similar process as pasteurized milk (homogenization process is performed at 40°C). After heat treatment in pasteurizer (at 95°C), milk is cooled down to 42-45 °C. In the case of yogurt production, tempered yogurt milk is moved to temperature controlled fermentation tanks, where it is stored for a few hours. During that time, fermentation cultures are added, product is stirred and cooled down to 15 - 25°C, after which it is ready for packaging in filling machine. Packed products are stored in cold rooms (0 - 8°C). [6] In the case of cheese production, pasteurized milk is cooled down to 32-36°C, then transferred into fermentation tanks where is stirred for 30 minutes and fermentation cultures are added. Afterward, milk is moved into cheese vat, where at temperatures are 35 - 45°C, rennet is added and milk is coagulated. [6] After whey is drained, curd cubes first go into press, then they are being cut into smaller cubes and immersed into brine where they are left for 24h. In the second phase cheese is immersed into brine bath which contains salt and left to mature in ripening rooms for 21 - 28 days at temperatures between 15 - 20°C. After cooling, finished cheese is packed in vacuum bags or plastic containers depending on the type of cheese being produced, and stored in temperatures between 0-8°C. [6]

Heat is used for both process and space heating. Heat is supplied from wood fired boiler, hot water boiler with maximum outlet temperature of 110°C. Annual consumption of firewood is 200 m3 per the analysed production scaled quantity.

Cooling is performed using reciprocating compressor / evaporator system which use HCFC, used for the cold water production and cold room cooling.

None of the equipment that is used has variable-frequency drive.

For the cleaning of pasteurizer CIP system is used, with a capacity of 5000 l/h.

Sub metering of electricity consumption is not performed in the analysed case study, one electric meter is used for the entire plant.

PRESENT CONSUMPTION LEVELS

One milk and dairy production plant is considered, and it produces a variety of different dairy products. The production process is scaled to 1,000 t of raw milk per year in order to produce products such as pasteurized milk, different types of fermented products (yogurts, sour cream, etc.) and different types of cheese. Share in the total production between these 3 different product groups is given in the figure 1, and is an important factor in terms of energy efficiency, because of the difference in energy intensity between them. Production of cheese is by far most demanding in the term of resources and energy, followed by the group of fermented products (yogurts, sour cream etc.) and

pasteurized milk as the least energy intense product. Since energy efficiency is not monitored nor recorded for separate production processes, this factor must be consider each year.

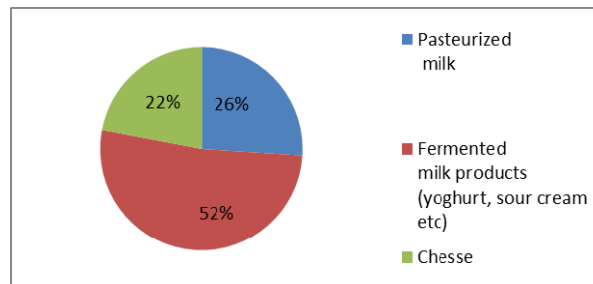


Figure 1. Share in the production between different product groups

ENERGY BALANCE OF THE PLANT

Two main forms of final energy used at the facility are: heat, which is generated on site in combustion process in boiler using firewood as fuel, and electricity, which is provided from electrical grid by state-owned transmission system operator. Heat is used for process demands, cleaning and space heating, while electricity is used mostly by electric motors which are used to drive fans, pumps, compressors and other equipment, and by electric heaters in cookers.

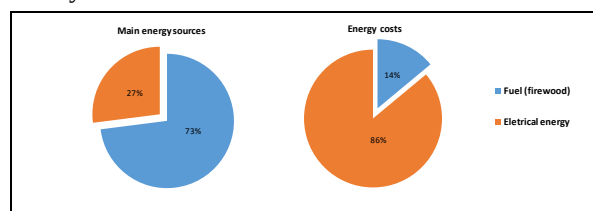


Figure 1. Energy sources and energy costs

Analysis of the annual consumption data of the plant indicated the following: The electricity consumption raises slightly in the summer period, while the monthly production rate is similar throughout a year, and the most significant electricity consumers, responsible for the summer increase of consumption, are cooling units used for both process purposes and storage of goods; consumption of electricity is proportional to the increase in production; Firewood (heat) used to fire hot water boiler is higher in the winter months, since hot water for space heating as well as process demands is supplied from the same boiler house, the cost of heat produced is low due to low purchase cost of firewood used.

Main raw material used in the production process is raw milk, with the share of over 97 % in total materials used. Less than 2 % is used for packaging, and around 1% for salt (used in cheese production), and cleaning agents.

Biggest losses in materials are related to cheese production, more precisely during whey drainage (approximately 850 kg of whey is recovered per 1t of milk). Because of the high temperatures used in

pasteurization process, recovered whey contains less protein compared to whey which is obtained in standard pasteurization process and the before can't be further processed into product with market value. Other losses include returned products, milk residues from pasteurizer and wash down process, packaging waste etc.

Water is mainly used for cleaning operations, but it is also used for cooling, sanitary purposes and as a boiler make-up feed water.

Main source of emissions to air on the site is hot water boiler. Emissions of carbon dioxide, sulphur-dioxide and nitrogen oxides which derive from the wood fuel combustion process in the boiler. Other emissions can be attributed to cooling systems (HCFC) and, indirectly to imported electrical energy.

Wastewater is generated on site mostly from cleaning operations. Waste water quality is regularly examined and the results shows that the tested parameters are within the limit values required by national regulations. Generated waste can be divided into three main categories according to the place of origin. First group would be packaging waste, such as cardboard boxes, plastic films, PET bottles and cups etc. Second group is formed from solid or liquid wastes and by-products originated during milk processing (e.g. whey residues, non-conforming products, sludge from separation during milk clarification and filtration, product loss on the heat transfer surface, curd waste, small pieces of cheese etc.). The third group is wood ash generated in combustion process.

BENCHMARKING

The benchmarking comparison was performed using the data provided from one small scale milk and dairy plant. In order to compare calculated values in contrast to benchmark values, two groups of products are selected - Milk and yogurt (which include thick yogurt and sour cream) and cheese (different types of cheese). Average share in total production between these two groups was taken, and energy consumption is estimated according to the benchmark values and annual production data. Because there is no breakdown of energy consumption for different production processes, separate indicators for the groups can't be determined precisely. The product group indicators are estimated based on the annual group type production data and benchmark specific values for the same group type to determine total consumption data as estimate for comparison to the actual data and actual consumption distribution. It should be noted that energy consumption can vary between the products that are within the same group (for milk and yogurt - minimum consumption for liquid milk, maximum for specialties). Calculated indicators and benchmark values are given in Table 1.

Table 1. Benchmarking for energy consumption

Small scale milk and dairy plant	Electricity (GJ/t processed milk)	Fuel (GJ/t processed milk)	Total energy consumption (kWh/l processed milk)	Total energy consumption (GJ/t processed milk)
Milk and yogurt	1.11	0.4	0.47	1.27
Cheese	1.29	1.24		
Energy consumption benchmark in European dairies	Milk and yogurt	0.15 - 2.5	0.18 - 1.5	0.09 - 1.11
	Cheese	0.08 - 2.9	0.15 - 4.6	0.06 - 2.08
Energy consumption benchmark in Australian dairies	N/A	N/A	N/A	0.5 - 1.2

Because of the environmental impact, indicators for consumption of cleaning agents were also calculated, and compared to the industry benchmark values. Same rules which are applied for energy efficiency benchmarking, regarding types of products that are being compared are relevant. It should be noted that main factor regarding consumption of cleaning agents is length and capacity of production runs.

Main conclusions that can be drawn from the analysis of materials productivity and benchmark comparison of cleaning agents consumption are:

- Biggest possible gain in resource efficiency with the respect to raw materials can be achieved by creating some kind of added value to whey which is given for free at this moment.
- Possible solution can be found in form of barter where whey would be traded with farmers for straw which could be used in co - combustion process with firewood.
- Indicators for consumption of cleaning agents are relatively close to the lower benchmark values for all types of agents
- Possibility to reuse cleaning solutions in some cases without compromising sanitary conditions is an option that should be taken into consideration and examined

Evaluation of water consumption and benchmarking indicated the following:

- Water consumption can be regarded as reasonably efficient (indicator is close to lower recorded values in EU dairies)
- Company could financially benefit from the implementation of low and no- cost measures.

Table 2. Benchmarking for water consumption

		Water consumption (l/kg processed milk)
75 % Milk and yogurt		2.25
25% Cheese		
Water consumption benchmark in European dairies	Milk and yogurt	0.8 - 25
	Cheese	1 - 60
Water consumption for dairies (1990)		1.3 - 2.5

It should be noted that almost exact amounts of CO₂ are generated through heat and electricity consumption (conversion factor for electricity is significantly higher than for wood combustion). HCFC contributes with the smallest amounts of CO₂ generation, but has the highest conversion factor.

Main conclusions regarding assessment of air emissions are:

- Company could benefit from periodical flue gas measurements, not just because of the CO₂ monitoring, but more importantly to check the efficiency of boiler
- Although only small quantities of refrigerant are used, regular leak inspections should be implemented, because of the high impact on the environment

By lowering carbon intensity of the plant, the plant could get 'lower carbon' and environmental credentials which are appealing to the new consumer trends.

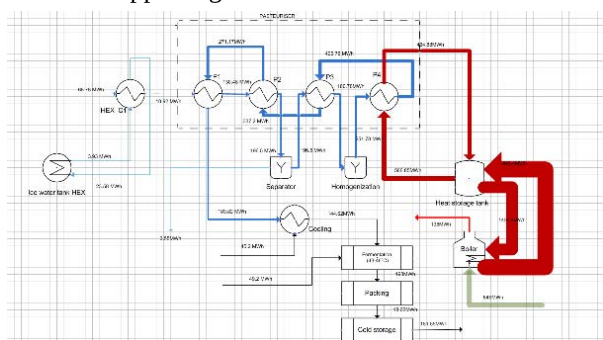


Figure 3. Scheme of the process

CONCLUSION

Evaluation of fuel consumption and comparison with relevant indicators, indicated the following:

- Fuel consumption is higher compared to the lower benchmark values for milk and yogurt production.
- One of the reason for the deviation from lower benchmark values is the pasteurization process, which is the most demanding in terms of heat consumption. Higher temperatures are required due to difference in raw milk quality. This increase in

energy use is translated into indicator value and has effect on both groups of products.

- Considering share in the production of different types of products and high demanding pasteurization process, realistic target value for the company should be 1 GJ/t processed milk, or aprox. 25% improvement
- Assessment has revealed that savings potentials in fuel consumption can be found on the supply side (using renewable energy, proper pipe insulation, waste heat utilization) and on the demand side (CIP optimization, space heating etc.),
- Fuel related investment measures should be thoroughly assessed, specifically because of the low price of firewood

Key findings resulted from detail assessment and benchmark comparison regarding use of electrical energy are given below:

- Electricity consumption is below average benchmark value (66% lower compared to average benchmark value for milk and yogurt production)
- 4-10 % of total electricity costs on a monthly basis, are accounted for excessive use of reactive energy.
- It is estimated that 24 % of total electricity consumption is used by cooling equipment.
- Assessment has revealed that high electricity savings potentials are expected in segments of cooling and compressed air use.

REFERENCES

- [1] F. Bühler, T.V. Nguyen, J. K. Jensen, F. M. Holm, B. Elmegaard, "Energy, exergy and advanced exergy analysis of a milk processing factory", *Energy*, Vol.162(2018), pp. 576-592
- [2] C. Ramirez, M. Patel, K. Blok, "From fluid milk to milk powder: energy use and energy efficiency in the European dairy industry", *Energy*, 31 (12) (2006), pp. 1984-2004, 10.1016/j.energy.2005.10.014
- [3] E. Masanet, A. Brush, E. Worrell, "Energy efficiency opportunities in the U.S. Dairy processing industry 2014" (May 2015), pp. 37-41, 10.1080/0198595.2014.10876999
- [4] Danish dairy industry, Danish Agriculture & Food Council (2015) http://www.agricultureandfood.dk/Danish_Agriculture_and_Food/Danish_dairy_industry.aspx#
- [5] R.C. McKenna, "Industrial energy efficiency: interdisciplinary perspectives on the thermodynamic, technical and economic constraints", Phd thesis, University of Bath (2009)
- [6] Best Available Techniques (BAT) Reference Document in the Food, Drink and Milk Industries, industrial Emissions Directive 2010/75/EU, Joint research centre, Directorate B – Growth and innovation Circular economy and industrial leadership, European IPPC Bureau, final draft 2018.
- [7] Y. Jo, D. M. Benoist, D. M. Barbano, M. A. Drake, "Flavor and flavor chemistry differences among milks processed by high-temperature, short-time pasteurization or ultra-pasteurization", *Journal of Dairy Science*, Vol.101, No 5, (2018), pp. 3812-3828

- [8] Y. D. Zhang, P. Li, N. Zheng, Z. W. Jia, J. Q. Wang, A metabolomics approach to characterize raw, pasteurized, and ultra-high temperature milk using ultra-performance liquid chromatography–quadrupole time-of-flight mass spectrometry and multivariate data analysis”, *Journal of Dairy Science*, Vol. 101, No 11, 2018, pp. 9630-9636
- [9] M. L. Ranieri, J. R. Huck, M. Sonnen, D. M. Barbano, K. J. Boor, “ High temperature, short time pasteurization temperatures inversely affect bacterial numbers during refrigerated storage of pasteurized fluid milk”, *Journal of Dairy Science*, Vol. 92, No 10, (2009), pp. 4823-4832
- [10] Lisbeth Meunier-Goddik, S. Sandra, “Liquid Milk Products: Pasteurized Milk” Reference Module in Food Science, 2016
- [11] P. M. Tomasula, M. F. Kozempel, “Flow Characteristics of a Pilot-Scale High Temperature, Short Time Pasteurizer”, *Journal of Dairy Science*, Volume 87, Issue 9, September 2004, Pages 2761-2768

BIOGRAPHY of the first author

Milena Mančić was born in Niš, Serbia, in 1987. She graduated from the Faculty of Mechanical Engineering, University of Nis. She is currently at PhD studies at the Faculty of Occupational Safety, where she works as a teaching assistant. Her main research area is renewable energy resources.



PRIMENA METODE ENERGETSKOG BILANSIRANJA NA PRIMERU POSTOJENJA ZA PRERADU MLEKA

*Milena Mančić, Miomir Raos, Milena Medenica, Jelena Malenović-Nikolić,
Milan Protić, Marko Mančić*

Rezime: Povećanje energetske efikasnosti u industrijskom sektoru znatno bi smanjilo emisije gasova staklene bašte prouzrokovane sagorevanjem fosilnih goriva, kao i troškove proizvodnje povezane sa korišćenjem energije. Proizvodnja mlečnih proizvoda, poput mleka u prahu i sira, je glavni industrijski sektor u Evropi, kao i u Sjedinjenim Američkim Državama i ostatak sveta. Cilj ovog rada je evaluacija energetske efikasnosti postrojenja za proizvodnju mleka i detaljna analize proizvodnih procesa sa posebnim osvrtom na korištenje resursa u posmatranom postrojenju. Razmatrano je postrojenje za proizvodnju mleka i mlečnih proizvoda. Proizvodni proces je veličine od oko 1.000 t sirovog mleka godišnje, kako bi se proizveli proizvodi poput pasterizovanog mleka, različite vrste fermentisanih proizvoda (jogurta, pavlaka i sl.) i različite vrste sireva.

Ključne reči: energetska efikasnost, metoda energetskog bilansiranja, postrojenja za preradu mleka.

ŽARKO VRANJANAC¹
GORAN JANAČKOVIĆ²

^{1,2}University of Niš,
Faculty of Occupational Safety in Nis

¹zarko.vranjanac@znrfak.ni.ac.rs
²goran.janackovic@znrfak.ni.ac.rs

EFFECTS OF BIOFUEL PRODUCTION ON WORKERS AND THE ENVIRONMENT: INDICATOR-BASED ASSESSMENT

Abstract: Biomass is the largest potential source of renewable energy in Serbia, but unfortunately this potential has not been utilized sufficiently. The estimated potential of biomass in Serbia is around 3.2 million tons of oil equivalents. Biofuels are one of the most important products of biomass. In this paper we present biofuel potential in Serbia, environmental advantages of use and potential occupational dangers, based on corresponding indicators.

Key words: biofuel, biomass, environmental effects, occupational effects, indicators

INTRODUCTION

In the era of striving for energy independence from fossil fuels, environmental protection and reducing greenhouse gas emissions, renewable energy sources are becoming the main topic of energy and environmental strategies. World oil supply is continuously decreasing and the relative price of oil rises, and according to estimates, the raw materials already in the middle of the 21st century will be considered as a commercial product. So today is considering the use of renewable energy sources, especially biomass, particularly in terms of obtaining biofuels. An increasing number of countries in the world gradually increases the percentage of biofuels mixed with fossil fuels and thus form a new policy of supply. Standards global final energy consumption indicate that about 16% of energy comes from renewable energy sources, whose share in electricity production is about 19%. Renewable energy sources are used, thanks to the closed flow of matter in the biosphere, which is realized obtaining electricity and heat, and when it comes to environmental pollution [1]. The world is in the focus of the development of new processes for the production of biofuels from biomass. For some areas, there is typical use of certain sources of biomass to produce fuels. Biomass energy from wood, crop leftovers and fertilizers are among primary sources of energy in developed regions. Biofuels can be produced directly from plants or indirectly from industrial, commercial, domestic and agricultural waste. In practice, most often are used the following types of biofuel: bioethanol, biodiesel and biogas. We can distinguish different fuel generations depending on the source material for production, costs of production, prices and CO₂ emissions [2].

BIOFUEL PRODUCTION

Biofuels are available in different aggregate states (solid, liquid or gaseous). They are developed from biomass materials, i.e. produced directly from different plants or indirectly from collected waste material (industrial, agricultural, commercial, or personal) [3].

There are three basic methods of biofuel production. The first is based on the burning of dry organic waste (household waste, industrial and agricultural waste, straw, wood and peat). The second is related to the fermentation of wet waste (animal manure) without the presence of oxygen to produce biofuel with 60% methane and the fermentation of sugar cane or corn to produce alcohol and esters. The last one refers to the energy obtained forestry, farming or fast growing trees for fuel production.

Biofuel power plants are plants whose products are electrical and thermal energy, which are created from biomass. Usually they are installed as cogeneration plants, whose operating principle is very similar to the work of thermal power plants using fossil fuels. They converts into thermal energy (steam in steam turbines, natural gas for gas turbines), then into mechanical and then into electricity. Power plant on bio fuels can be classified as power plants on wood biomass, power plants on non-wood biomass, power plants on biogas, and power plants using landfill gas.

Bio-power plant "Alholmens Kraft" is the largest in the world, and the installed capacity is 265 MW, located in the vicinity of the paper factory in Alholmen, near Pietarsaari (Finland). Bio-power plant has benefits from wood biomass as a primary, additional or alternative fuel [4].

In addition to other non-wood biomass, an important role may have remains from agriculture or agricultural biomass (corn, sunflower stalks, straw, shells, pitted cherries, grapes, apple peel). Experience from developed countries, especially in Europe Denmark show that it is a valuable source of energy, which should not be ignored. After the corn harvest, on treated land corn remains could be found. After the corn pick, on the ground stays some amount of corns, that so the average ratio of the grain and the ground (so-called reaper vest) is 53%:47%, there is a calculation that amount of biomass is roughly as numerous as the grains. For non-wood biomass, the moisture and ash equally affect amount of thermal power. The share of non-wood ash in plant residues can be up to 20%, and significantly affects the combustion

(e.g. straw has a higher proportion of Na, Ca, K, and lower ignition temperature) [5]. In countries with developed agriculture, legislation in the field of environmental protection and regulation of the process of recycling of manure and other organic waste encourages interest in the process of anaerobic digestion as a cheap and harmless process. In the industrial production of biogas, anaerobic digestion takes place in a heated closed containers of air that create ideal conditions for bacterial fermentation of organic materials. The resulting biogas is usually used to obtain heat and electricity by burning in boilers, gas engines or turbines.

Biogas can also be obtained from landfill waste. Landfill gas is formed by decomposition of organic substances under the influence of microorganisms in anaerobic conditions (absence of air). The average composition of landfill gas is 35-60% methane, 37-50% carbon dioxide and smaller amounts are found carbon monoxide, nitrogen, sulphur, fluorine, chlorine, aromatic hydrocarbons and other trace gases. In the centre of landfill overpressure gas is generated, and landfill gas passes through the gas probe. Bio-power plants using landfill gas should include setting up vertical perforated pipes into the landfill body (wells, pins, probes) and their horizontal connections. The compressor collects the landfill gas, dries it and directs to the gas engine. For security reasons it is advisable to install a high-temperature flare which takes excess gases [3].

SERBIAN REGULATIONS ON BIOFUEL PRODUCTION

Implementation of the use of bio power plants in Serbia depends on the three reasons: regulations of Serbia for the construction of a bio power plant, energy potential for biofuels in the Republic of Serbia and positive environmental and occupational aspects of using bio power plant.

Installations for using renewable energy from biomass as fuel/biogas energy are facilities for the performance of activities of electricity and/or heating. The plant can only produce electricity or heat, or simultaneously generate electricity and heat (plant with a combined production of electricity and thermal energy). Construction of the plant biomass/biogas and perform the activity of electricity and heat in such plants are regulated by numerous regulations of the Republic of Serbia which can be divided into two groups [6]. The first set of regulations covers an area of construction of a concrete energy facility and the procedure of obtaining a construction permit for such a facility, and the method of determining the suitability of the facility for use and obtaining the occupancy permit of the facility. The second group of regulations is related to the acquisition of the right to engage in the production of electricity and heat. The right to engage in the activity of thermal energy in the plant biomass is achieved:

- acquisition of the right to practice communal activities of general interest, and
- acquisition of rights to energy activities (obtaining a license for performing energy-related activities).

According to the Energy Law, the plant can be divided into the following classes [7]:

- plants that use renewable sources of energy-biomass/biogas,
- plants with combined production of electricity and heat (can acquire the status of privileged electricity producer if they have installed capacity up to 10 MW).

Rules on Criteria for Issuing Energy Permits, Contents and procedure of issuing energy permits, plants are divided into the following categories [8]:

- facilities for the production of electricity power from 1 to 10 MW,
- facilities for the production of electricity through the power of 10 MW and
- facilities for the production of thermal energy installed capacity of over 1 MW.

The issuance of a building permit for installations for the production of energy from renewable power 10 MW and more, is under the jurisdiction of the Ministry of construction, or autonomous province, and for plants with a combined production of 10 MW of power is under the jurisdiction of local authorities. Decree on conditions for obtaining the status of a privileged producer of electricity and the criteria for assessing compliance with these requirements defines which plants can acquire the status of a privileged producer, namely [9]:

- plants, biomass and biogas (power) that use biodegradable matter arising in agriculture, forestry and household, which includes: plants and parts of plants, plant residues arising from agriculture (straw, corn stalks, branches, stones, shells), manure from farms, remnants of forest plants (remains in deforestation), biodegradable residues in food and timber industries that do not contain hazardous substances and separated biodegradable fraction of municipal waste and
- plants (power plant) with a combined production of the production process simultaneously generate electricity and heat using fossil fuels (coal or natural gas), waste technological gases with the organic fraction and fossil fuels in combination with a renewable source of energy waste or waste gases from technological organic fraction.

Where appropriate, impact assessment studies on the environment are different:

- plants with a capacity of 50 MW or more (List I) - plants for which is required to develop impact assessment studies, and
- plants with a capacity of up to 50 MW, as well as projects that are implemented in a protected natural area and protected environment of an immovable cultural property, but also in other areas of special

purpose (List II) - plants which may require environmental impact assessment.

The total energy potential

In Serbia, in the last few years there is appearing of simpler forms of power plants on biogas, mainly in the north Serbia, in the vicinity of larger farms [6]. Plants on farms are designed for the digestion of raw materials from one or several neighbouring farms. Although it may vary in size, design and technology, most of them have a similar principle.

About 2,000 cows from the farm in Vrbas in the future could produce electricity. The first Serbian biopower plant, with an initial capacity of 1 MW, was put into operation in 2012. The drive to produce electricity from manure is a pioneering undertaking for the north Serbia region, which is currently using only about 3% of renewable energy sources [1].

The Action Plan of the Republic of Serbia for renewable sources of energy in regulated respect for the obligations undertaken under the Energy Community Treaty, were established path to reaching the target of 27% renewable sources of energy in gross final energy consumption in 2020 in Serbia and defined measures for greater use of renewable energy.

Table 1 shows expected pace of growth in the share of renewable energy in total energy consumption [6].

Table 1. The dynamics of growth of renewable energy sources in three sectors of energy consumption (%) [6]

Years	Heating and cooling	Electricity	Traffic
2013	26	29	0
2014	26	30	0
2015	26	30	2
2016	26	31	3
2017	27	32	5
2018	28	33	7
2019	29	35	8
2020	30	37	9

The total availability of biomass in Serbia is amounted to 12.461 million tons (Table 2 and Figure 1), from which one can get the energy equivalent to 1.300 million tons of light fuel oil [6].

The amount of the annual biogas production, based on available literature, is shown in Table 3 and Figure 2. Calculated data is an estimate, because the yield of biogas varies depending on the moisture content and content of organic matter in the substrate. Therefore, accurate data can be obtained by determining the proportion of dry biomass and organic substrate [6].

Table 2. Potential quantities of biomass from agricultural production in Serbia [6]

Biomass	Area, 10 ³ ha	Yield, t/ha	Total biomass 10 ³ t
Wheat	850	3,5	2975
Barley	165	2,5	412,5
Oats	16	1,6	25,6
Rye	5	2	12
Corn	1300	5,5	7150
Corn seeds	25	2,3	86,25
Cobs	-	-	1430
Sunflower	200	2	800
Husk sunflower	-	-	120
Soybean	80	2	320
Rapeseed	60	2,5	300
Hop	1,5	1,6	7,95
Tobacco	3	1	1,05
Orchards	275	1,05	289,44
Vineyards	75	0,95	71,55
TOTAL	3.055,5		12.461,31

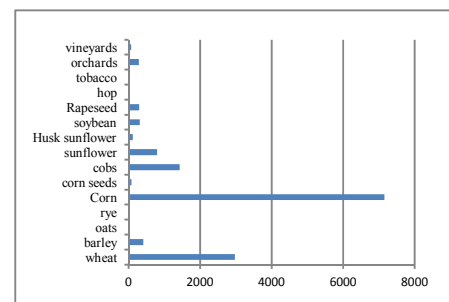


Figure 1. Quantities of biomass from the rest of the agricultural production in Serbia in the 10³ tons

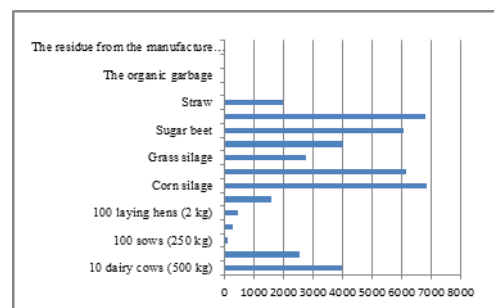


Figure 2. The quantity of biogas substrate processing m³/year

Calculation of daily production of biogas can be implemented for each type of substrate specific, and the total amount is calculated as the sum of production from all substrates. Based on the calculated annual quantities of biogas, it is necessary to determine the optimal installed power plants. If the calculation is for less power, all the gas produced will be used, will be burned in the gas flared or released into the atmosphere, which negatively affects the environment.

Selection excessive power plants can cause large and unnecessary costs [6].

Table 3. Approximate amount of biogas expected in the substrate processing [6]

Animal manure from:	Manure quantity, m ³ /year	Biogas obtained m ³ /year
10 dairy cows (500 kg)	180	4000
10 cattle (350 kg)	110	2570
100 sows (250 kg)	5,5	110
10 pigs (70 kg)	20	310
100 laying hens (2 kg)	-	460
100 turkeys (7 kg)	10	1600
Plant substrate:	Mass, t/ha/year	
Corn silage	40	6830
Silage plant mass	35-40	6140
Grass silage	25-30	2770
Cereals	8-10	4020
Sugar beet	100	6080
Potato	50	6780
Straw	8-10	1970
Combined:	Quantity, t/year	
Grease	1	90-100
Organic garbage	10	50
Residue from beer production	10	100-120
Residue from starch production	10	100-110

EFFECTS OF BIOFUEL PRODUCTION ON WORKERS AND ENVIRONMENT

Basic benefits provided by the production and use of biofuels are presented in Figure 3, from waste reduction to greater energy security [2].



Figure 3. Benefits of biofuel production and use [2]

Specific impacts of anaerobic digestion system on the environment will depend on the plant, but the common advantage of all the plants may include:

- Reduction of odours,
- Reducing the number of pathogens,
- Water quality improvement, and
- Reduction of greenhouse gas emissions.

Anaerobic digestion provides an effective reduction of odours. Natural manure fermentation is resulted in the production of ammonia, hydrogen sulphide and volatile fatty acids. Volatile fatty acids are contributed to the most of the formation of odours. In closed anaerobic digesters, who work correctly, with volatile fatty acids are metabolized by the action of anaerobic bacteria reducing total emission of odours from manure. Because of this, digestion systems leads to a significant reduction in odour compared with unprocessed manure. Anaerobic digestion is a process that is effective in reducing the number of pathogenic microorganisms. Studies have shown that anaerobic digestion can reduce the number of fecal coliform microorganisms for more than 99% and the number of fecal streptococci to 90%. By reducing the number of pathogenic species is reduced the risk of infection in humans and animals. Due to the degradation of certain compounds in wastewater through anaerobic digestion there can be achieved 70-90% reduction in the biological oxygen demand. Also, in combination with the technologies of nutrients, this can solve the problem of excessive nutrient content in the water and improve water quality. The process of reduction of greenhouse gas in anaerobic digestion systems is carried out in two ways. Degradation of manure under anaerobic conditions is reducing emissions of methane and nitrogen oxides, which are formed during the deposition and use of manure. Carbon dioxide is the main cause of global warming and the greenhouse effect. Evaporation of biogas also releases CO₂, but the difference with fossil fuels is that the CO₂ from biogas shortly before the release was absorbed from the atmosphere by photosynthetic activity of plants. Therefore, the use of biogas is regarded as CO₂-neutral and does not affect the increase in the amount of greenhouse gases. By using biogas contributes to mitigate global warming by reducing the consumption of fossil fuels to produce energy and fuel, however, and thus significantly reduces the emission of CO₂, CH₄ and N₂O. However, the biggest contribution to the biogas production unit to reduce emissions is reflected in the fact that burning methane (CH₄), which is harmful to the ozone layer about 22 times the carbon dioxide (CO₂) [3].

There are direct and indirect effects of use of biofuels. Some researchers state that the use of rape, soy or palm oil biofuel would pollute the environment more than conventional fuel [10]. The reason for negative effects can be, among others, cleared rainforests for cultivation. The climate impact of biofuels can be measured by greenhouse gas (GHG) balances, which identify all greenhouse gas emissions along the entire life cycle, and not only the production. The most

important is the CO₂ use by the plant and processing, cultivation of plants (use of fertilizers, diesel fuel, etc.), and fuel combustion in the car, in which CO₂ molecules previously absorbed by the plant would be released into the atmosphere. There are different other input materials and energy transformations, which also emit CO₂. Biofuels help to reduce adverse gases compared to fossil fuels, but direct and indirect land use changes (cultivation of energy crops and destruction of forests) cause very large CO₂ emissions, which cannot be reduced by means of using biofuel in transportation. The problem is the indirect land-use change, where the purpose of land use is changed, people or cattle are dislocated, and CO₂ balance also changed. These changes are not directly connected to GHG emissions, and cannot be simply included into economic or other analyses of biofuel effects.

Very important during the production of biofuels are also workplace hazards. The most significant danger is methanol, which is highly flammable. Personal protective equipment is needed for hands, eyes, and mouth. Disposal of waste material has to be also well organized. In [11], different incidents involving biodiesel are described: fire ignition (methanol), burning (caustic charged into reaction vessel), methanol/catalyst solution leakage and critical temperature achieving, electrical wiring faults, explosion of biodiesel during tank welding, solid potassium hydroxide contact injury. Representative hazards are presented in Table 4.

Table 4. Representative hazards in biofuels production

Hazard	Description of danger
Methanol	Flammable and toxic, burn in the open air, possible explosion in a tank or a room
Hydroxide or methoxide	Corrosive, water reactive (sodium), toxic, dust explosive
Contaminated feedstock oil	Slipping, self-combustible
Wash water	Highly polluted (methanol, acids, alkali etc.), potentially flammable
Glycerol	Combustible (over 160°C)
Biodiesel	Combustible (over 150 °C), hygroscopic, contaminated cold hydrolyse (flashpoint change)

As can be seen, there are reaction hazards, which can initiate fire or explosion, and general hazards (caused by corrosion of used equipment, exposure to caustic, acid and other dangerous matters, dissolving of biofuel into safety equipment causing failure of their protective functions).

RESULTS AND DISCUSSION

Renewable energy consumption indicator is the share of renewable energy in total final energy consumption. Renewable energy consumption indicator in Serbia,

Macedonia and Albania from 2006 to 2015 in relation to % of total final energy consumption is given in Table 5 [12].

Table 5. Renewable energy consumption indicator in Serbia, Macedonia and Albania from 2006 to 2015 in relation to % of total final energy consumption [12]

Year	Serbia	Macedonia	Albania
2006	15.68668356	19.64586697	31.71019543
2007	14.29340656	15.69944854	32.10093721
2008	15.56633957	15.59055064	35.91290611
2009	20.82235705	18.46546403	37.2166378
2010	20.59508764	22.3303036	37.11532977
2011	17.55075746	18.64403534	35.9625316
2012	19.60573384	18.28229655	40.0482996
2013	20.22826896	21.19708744	41.28897372
2014	23.42929075	21.20423858	38.68950076
2015	21.17388528	24.21812973	38.61521047
Avg.	18.89518107	19.52774214	36.86605225

Based on the obtained results, it can be concluded that the average annual value of Renewable energy consumption indicator in relation to % of total final energy consumption over the analyzed period had significantly higher values in Albania (Annual avg. 36.86605225) than in Macedonia (Annual avg. 19.52774214) and Serbia (Annual avg. 18.89518107).

By comparing the Renewable energy consumption indicator in the countries of the Western Balkans, a significant overview is obtained of the share renewables energy in total final energy consumption.

Based on these data, as well as data on the overall energy potential of Serbia, when it comes to biofuel production, it is undoubtedly that this area should be developed in the future. In this way, better results of biofuels production will be achieved both for the workers and for the environment.

CONCLUSION

Use of energy is important in improving people's standard of living. However, energy generation also can damage the environment. Whether such damage occurs depends largely on how energy is generated. Biofuel is considered a good source of energy supply for a number of economic, operational and environmental reasons. In addition, the advantages and disadvantages of biofuel production for the workers and environment, as well as the potential of the Republic of Serbia in the renewable energy sources, are considered.

By comparing the Renewable energy consumption indicators in the countries of the Western Balkans (Serbia, Macedonia and Albania), it can be concluded that the consumption of renewable energy in Serbia is significantly lower, so the general conclusion is that this area has yet to develop. To construct and utilize any structure, including the building of plants for

biofuel in the Republic of Serbia, it is necessary that the following conditions are met:

- obtaining an authorization;
- obtain location permit;
- obtaining a construction permit;
- construction of the facility and
- technical inspection of the facility and obtain occupancy permit.

It is very important to study environmental protection as well as employees. Exposing hazardous substances in the production process can lead to significant environmental consequences, but also endanger the lives of employees. Therefore, protection measures must be taken into account in all domains of the production process, and should be constantly improved.

REFERENCES

- [1] "Simplified national action plan for renewable energy sources of the Republic of Serbia", Ministry of energy, development and environmental protection of Republic of Serbia, Belgrade, 2012. (in Serbian)
- [2] R. Astbury: "A review of the properties and hazards of some alternative fuels", Process safety and environmental protection, Vol. 86, No. 6, 2008, pp. 5-17.
- [3] M. Dumitru, M. Bibu: "Researches on the digesters and reactors which can be used in a farm scale biogas plant", Scientific papers series Management, economic engineering in agriculture and rural development, Vol. 14, No. 3, 2014, pp. 63-68.
- [4] A. Demirbas: "Biodiesel a realistic fuel alternative for diesel engines", Springer Verlag London, 2008, pp.24-103.
- [5] K. Hjort-Gregersen: "Danish Farm Scale Biogas Concepts - at the point of commercial breakthrough", Proceedings of the International Conference Biomass for Energy and Industry, Würzburg, Germany, 8-11 June 1998, pp. 641-643.
- [6] M. Carić, D. Soleša: "Biomass as a renewable energy source and technology for the production of biogas, Five-day course", Privredna akademija, Novi Sad, 2013. (in Serbian)
- [7] "The law on energy", Official Gazette of Republic of Serbia, No. 145/2014.
- [8] T. Al Seadi, D. Rutz, H. Prassl, M., Köttner, T. Finsterwalder, S. Volk, R. Janssen: "Biogas handbook",

University of Southern Denmark, Esbjerg, Denmark, 2008, pp. 36-78.

- [9] "The policy of the Republic of Serbia in the field of renewable energy sources" Chamber of commerce and industry of Serbia, Belgrade, 2012. (in Serbian)
- [10] G. Woltjer, V. Daioglou, B. Elbersen, G.B. Ibañez, E. Smeets, D.S. González, J. Gil Barnó: "Study report on reporting requirements on biofuels and bioliquids stemming from the directive (EU) 2015/1513", Wageningen economic research, Netherlands environmental assessment agency (PBL), Wageningen environmental research, National renewable energy centre (CENER), 2017.
- [11] S.W. Harper, J.C. Etchells, A.J. Summerfield, A. Cockton, "Health and safety in biodiesel manufacture", Health and safety executive, Symposium series No. 154, pp. 1-9.
- [12] „Sustainable Energy for All (SE4ALL) database from the SE4ALL", Global Tracking Framework, World Bank, International Energy Agency, and the Energy Sector Management Assistance Program, 2017.

ACKNOWLEDGEMENTS

The paper is a part of the research done within the projects III43014 and III42006, funded by the Serbian Ministry of Education, Science and Technological Development.

BIOGRAPHY of the first author

Žarko Vranjanac was born in Niš. He completed his bachelor and master studies at the Faculty of Occupational Safety, University of Niš. He is currently a PhD student at the Faculty of Occupational Safety in Niš, study programme Environmental Engineering.

He has received a PhD scholarship by the Serbian Ministry of education, science and technological development. His research interests are environmental and occupational safety indicators.



UTICAJ PROIZVODNJE BIOGORIVA NA RADNIKE I ŽIVOTNU SREDINU: PROCENA BAZIRANA NA INDIKATORIMA

Žarko Vranjanac, Goran Janačković

Rezime: Biomasa je veliki potencijalni izvor obnovljive energije u Srbiji, ali se ovaj potencijal i dalje nekoristi u dovoljnoj meri. Procenjeni potencijal biomase u Srbiji iznosi oko 3,2 miliona tona ekvivalentne nafte. Biogoriva su jedan od najznačajnijih proizvoda biomase. U ovom radu, na osnovu odgovarajućih indikatora, predstavljen je potencijal biogoriva, prednosti korišćenja za životnu sredinu i potencijalne opasnosti pri radu.

Ključne reči: biogoriva, biomasa, uticaj na životnu sredinu, uticaj na radnike, indikatori

SRETEN ILIĆ¹
TATJANA GOLUBOVIĆ²
NATAŠA PAJIĆ¹
MARJAN MIRČEVSKI³

OPTIMIZATION OF DECONTAMINATION OF PEOPLE DURING THE REMEDIATION OF CHEMICAL ACCIDENTS

¹Military Technical Institute,
Belgrade,
²University of Niš,
Faculty of Occupational Safety
³University of Defense,
Military Academy Belgrade

¹ilicsreten@sbb.rs
²tatjana.golubovic@znrfak.ni.ac.rs
¹natasapajic969@gmail.com
³marjan.mircevski@gmail.com

Abstract: *This paper presents an approach to mass decontamination of people during the remediation of chemical accidents through the example of good practice demonstrated by the European Union countries. The focus is placed on the organization of the decontamination process using the elements of the decontamination station with the necessary equipment. Fear and panic are associated with nearly every chemical accident in urban areas and large industrial complexes. In case a large number of immobile persons also become contaminated, the need for decontamination usually exceeds the available capacities. This is why a new approach to the decontamination of people in the above situations should be considered.*

Key words: chemical accident, dangerous substances, decontamination of people.

INTRODUCTION

Most chemicals are by their nature harmful to humans and the environment, and any uncontrolled release of them can lead to unimaginable consequences and disasters. A risk of such occurrences exists in the operation and use of chemical industry facilities, plants, devices, installations and equipment, means of transport, etc., where hazardous chemical substance are produced, processed, transported, stored or otherwise used. These are substances which exhibit very toxic, oxidizing, explosive, ecotoxic, flammable, spontaneously combustible and other properties which pose a threat to human life and health and to the environment [1].

Chemical accidents are unintentional, sudden, uncontrolled events, or sequences of events when handling hazardous substances in the production, use, transport, traffic, processing, storage and disposal, where human contamination also occurs. The forms of the occurrence of chemical accidents are: fires, explosions, malfunctions, traffic accidents in road, river, railway and air traffic and damage to electric power, oil and gas installations [2].

Also, the possibility of a terrorist attacks using hazardous substances should not be excluded. These substances are namely pesticides, which are used with the intention of poisoning a large number of people. Terrorists may also act by causing damage to a chemical plant or causing a traffic accident during the transport of dangerous substances. The consequence of this is the endangerment of the life and health of people, the damaging of material goods and the causing of damage to the environment [3].

Depending on the dose, hazardous substances can cause a number of disorders in the population, ranging from coughing, choking, vertigo, vomiting, memory disorders, visual disturbances, psychological disorders,

to abdominal pain, loss of consciousness and severe forms of poisoning [4]. When people experience percutaneous, or skin-resorptive poisoning, a quick response is necessary and their decontamination should be given the highest priority.

There is still not enough attention paid to the issue of the decontamination of contaminated and injured persons [5].

THE MANNERS OF THE CONTAMINATION OF PEOPLE IN CHEMICAL ACCIDENTS

Dangerous substances released in gas or aerosol form quickly reach the atmosphere and form clouds. The limit of the pollution in relation to the surrounding air is determined by the value of the least dangerous concentration, i.e. the threshold dose for a given hazardous substance. Depending on the place of origin, primary and secondary clouds may be distinguished. The primary cloud is created at the site of the accident, and the duration of time of creation matches the duration of the chemical accident [1].

Atmospheric stability is a crucial meteorological element for the behaviour of the dangerous substance which has been released in a chemical accident. In the atmosphere there are horizontal, vertical, diagonal, and vortex currents, which are never uniform in direction and velocity, meaning that they are almost always turbulent currents, or turbulent diffusions.

Even during its creation, the cloud is exposed to the effects of the wind and moves from its place of origin in the direction of in which the wind blowing, all the while also dissipating in all directions. The highest concentration of the substance is in the center of the cloud at the moment of its formation, and with the passage of time and through spreading into the surrounding area the concentration decreases towards

the edge and throughout the entire cloud relative to the initial level of concentration.

The primary cloud moves as a more or less compact mass of air and hazardous substance, changing its dimensions and losing its concentration under the influence of turbulent diffusion, unevenness of the terrain, plant growth, building complexes and meteorological conditions. The basic dimensions that characterize the primary cloud are its depth and width. The number of contaminated people directly depends on these dimensions.

The secondary cloud is a part of the contaminated atmosphere formed exclusively from the evaporation of the hazardous substance from the location of the accident. It is defined by the threshold dose, similarly to the primary cloud. It is formed at the beginning of evaporation from a long-term flat source and follows the movement of the primary cloud, and its duration depends on the amount of the presence of the dangerous substance.

The contamination of people always occurs in the affected area, as gases, droplets and aerosols fall to the surface of the uncovered parts of their bodies. Due to the random distribution of the precipitation of droplets and aerosols to the surface of a person, any person who was not sheltered or protected must be presumed as contaminated. Due to the limited protective capability of clothes and footwear, people are considered contaminated regardless of whether or not only an uncovered surface of their bodies was contaminated.

The state created by the release of the dangerous substance in the zone of the cloud's dispersion is known as the chemical situation [1]. The prognosis of the chemical situation is the prediction of the situation following the chemical accident based on mathematical models, and provides data to the competent authorities on the likely dispersion of the clouds and the size of the affected area.

After the contamination of the exposed parts of the body or after the contamination breaks through the layers of clothing, hazardous substances penetrate through the skin and visible mucous membranes relatively easily [4]. This where emphasis is put on the speed and efficiency of the chemical decontamination of the population. The covered and uncovered parts of the skin and visible mucous membranes of humans can be contaminated by hazardous substances in the form of vapor, droplets and aerosols. In this case, it is possible to distinguish between external and internal contamination or intoxication. External contamination is defined as the presence of hazardous substances only on the surface of the skin, visible mucous membranes, clothing and footwear. If the dangerous substance has reached the bloodstream or internal organs it is considered as intoxication.

THE COMPLETE DECONTAMINATION OF PEOPLE

Decontamination includes a range of measures and activities and is undertaken in order to remove hazardous substances, primarily from humans, and for these purposes, decontamination stations are created. Decontamination can be complete or partial in its scope [2,4]. Partial decontamination is performed immediately after contamination has occurred.

The finishing decontamination of the population can be carried out individually or collectively in bathrooms or decontamination stations.

The area for the finishing decontamination of people consists of contaminated and clean surfaces, which are determined based on the blowing of the wind [4,5].

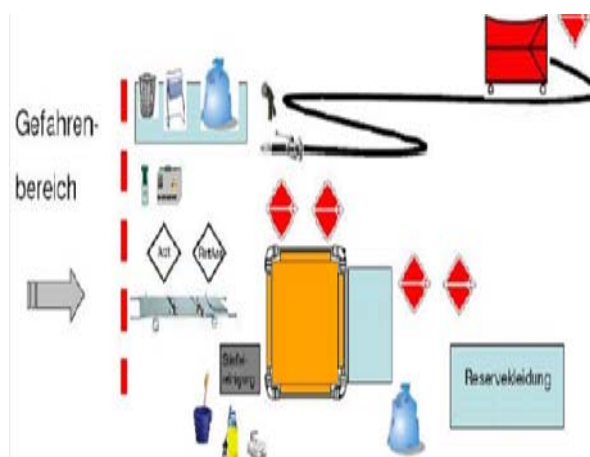


Figure 1. Representation of the area for the decontamination of the population [5]

The area for the decontamination of people generally includes [4]: an area for undressing and for the packing of clothes, an area for examination, triage and removal of hair, an area for the decontamination of sensitive body parts, an area for heating water, an area for bathing, an area for the removal of protective clothing, spare substances and agents for decontamination and an area for the examination and dressing of decontaminated persons.

This method of the finishing decontamination of people is organized when the primary, emergency decontamination has already been carried out.

THE URGENT DECONTAMINATION OF POPULATION - AN EXAMPLE OF GOOD PRACTICE

The speed with which partial decontamination is carried out greatly diminishes the consequences of contamination. It is achieved through good organization, timely preparation for decontamination, the preparedness of the decontamination staff, and above all, through the possession of high quality equipment [6]. Depending on the type and toxicity of the dangerous substance, the decontamination of the uncovered parts of the body must begin as soon as possible. People are given the highest decontamination priority in all situations.

The primary decontamination units in Hamburg consist of only two fire extinguishing vehicles, but such units are numerous (Figure 2) [6]. They allow for the decontamination of a large number of contaminated people in a short time, in the event of mass contamination of people.

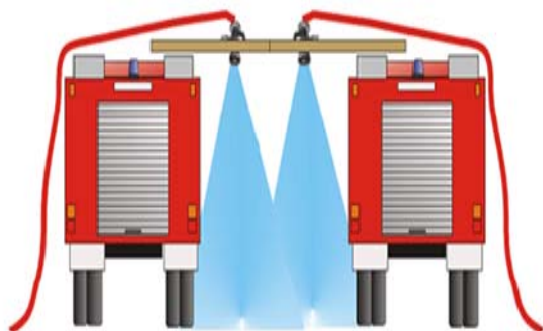


Figure 2. Decontamination unit [5]

Contaminated people are in a state panic and move erratically (Figure 3). A large number of stations are set up around the location of the accident, and people are directed to pass through a water curtain.

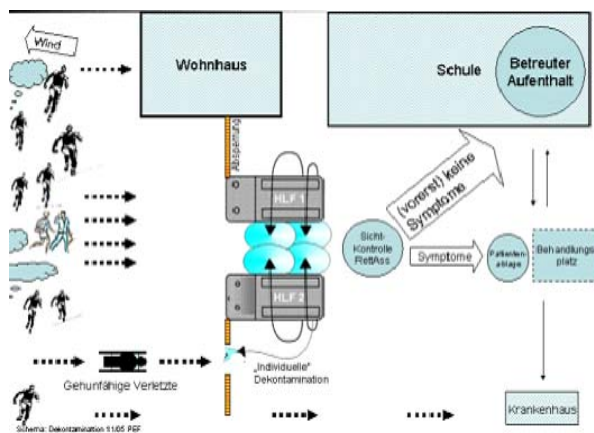


Figure 3. Representation of the organization of decontamination [7]

Because people are disoriented and panicked, this is done through a speaker system and by closing off passages. Attention is also given to the direction of the blowing of the wind, and the entire area is divided into clean and contaminated surfaces. After they pass through, examinations and triage are carried out, and the people who are being evacuated with stretchers, pass through a smaller passage, where individual decontamination is performed, similarly to the organization of the final decontamination. Those who have sustained serious injuries are transported to a hospital where they are provided adequate medical assistance.

CONCLUSION

Good organization, timely preparation for decontamination, the preparedness of the decontamination staff, the speed of decontamination, and above all the possession of high quality equipment, directly diminish the consequences the contamination of people. Such an approach to the obligations of the subjects of the system of protection against chemical accidents, as demonstrated by the authorities of the city of Hamburg, could also be applied in the urban areas of the Republic of Serbia, where exists a similar, if not a greater, danger from the occurrence of a chemical accidents due to the outdated technology of our country. This would require the acquisition of modern equipment and training for personnel who would perform the decontamination and population.

REFERENCES

- [1] Z. Luković, Z. Milenković, G. Marinković: "Privremeno uputstvo za procenu i prognozu hemijske situacije i pri dejstvu po objektima u kojima se nalaze opasne materije" Vojna knjiga, 2004, Beograd.
- [2] Zakon o vanrednim situacijama ("Sl. glasnik RS", br 111/2009, 92/2011 i 93/2012).
- [3] Š. Đarmati, "Posledice hemijske kontaminacije životne sredine", 1989, Beograd.
- [4] R. Jović, "Protivhemijska zaštita u miru i ratu", 1990, Beograd.
- [5] P. Sudhof, "Experimentelle Untersuchung und Optimierung der Dekontamination von Verletzten bei einer C(B)RN-Gefahrenlage durch Organisationen der nichtpolizeilichen Gefahrenabwehr", Otto-von-Guericke-Universität Magdeburg, Fakultät für Verfahrens- und Systemtechnik, 2016.
- [6] Pravilnik o sadržini politike prevencije udesa i sadržini i metodologiji izrade Izveštaja o bezbednosti i Plana zaštite od udesa, "Sl. glasnik RS", broj 41 od 15. juna 2010.
- [7] Massenankfall von kontaminierten Personen, Hamburger Dekon-Studie 12/2005, Hamburg.

BIOGRAPHY of the first author

Sreten Ilić was born in Šabac, Serbia, in 1972.

He graduated from the Military Academy in ABHO direction. His area of research is environmental pollution. Currently working at the Military Technical Institute as a leading researcher.



OPTIMIZACIJA DEKONTAMINACIJE LJUDI U TOKU SANACIJE HEMIJSKOG UDESA

Sreten Ilić, Tatjana Golubović, Nataša Pajić, Marjan Mirčevski

Rezime: U radu je prikazan jedan pristup masovnoj dekontaminaciji ljudi u toku sanacije hemijskog udesa, kroz primer dobre prakse zemalja Evropske unije. Težište je dato na organizaciji dekontaminacije, kroz elemente dekontaminacione stanice sa potrebnom opremom. U urbanim sredinama, kao i velikim industrijskim kompleksima, strah i panika kod velikog broja ljudi su prateća pojava skoro svakog hemijskog udesa. Ako pri tom dođe do kontaminacije većeg broja pojedinaca, a koji nisu onespособljeni za kretanje, potrebe za dekontaminacijom su daleko veće od raspoloživih kapaciteta. Zbog toga se nameće novi pristup dekontaminaciji ljudi u takvim situacijama.

Ključne reči: opasne materije, hemijski udes, dekontaminacija ljudi.

MILAN PROTIĆ¹
MILENA MANČIĆ¹
ANA MILTOJEVIĆ¹
MIOMIR RAOS¹

¹University of Niš,
Faculty of Occupational Safety in Niš

¹milan.protic@znrfak.ni.ac.rs

PROXIMATE ANALYSIS OF BIOMASS FUELS

Abstract: *In this paper we performed a thermogravimetric analysis of samples of biomass fuels. Six types of biomass were analyzed: beech stem, pine cones, pine needles, pine stem, sycamore bark and sycamore leaves. For each sample, the following parameters were determined: moisture, total volatiles, fixed carbon and ash.*

Key words: proximate analysis, thermogravimetric analysis, biomass.

INTRODUCTION

Biomass refers to any organic material that is available on a renewable or recurring basis, including agricultural crops, trees grown for energy production, wood waste and wood residues, plants (including aquatic plants and grasses), residues, fibres, animal wastes and other waste materials and fats, oils, and greases (including recycled fats, oils and greases) [1].

Energy generated from the biomass production is currently the fourth most common energy source in the European Union, after nuclear energy, other types of renewable energy and solid fossil fuel energy [2]. Compared to the primary production of renewables in the European Union, biomass energy has the largest share of 63.11% (123,592 ktoe), followed by hydro energy with a share of 16.46% (32,242 ktoe) and wind energy with a share of 11.11% (21,768 ktoe) [3]. In recent years, the interest in using biomass as an energy source has increased and it constitutes approximately 14% of world final energy consumption; it is estimated that 15-50% of the world's primary energy use could come from biomass by the year 2050 [3].

In the future, more biomass is expected to be converted to energy services in the EU countries to meet the long-term targets. Demand for biomass as energy source in the European Union will increase from the current 5.7 EJ/year to 10.0 EJ/year by 2020, and will also increase in the rest of the world, not only in Europe [3-5].

One of the distinctive features of biomass is its inherent renewability and sustainability. Energy conversion routes of biomass in most cases do not lead to greenhouse gas emissions and it is considered to be CO₂ neutral [6-10]. Biomass absorbs carbon dioxide during growth, through the process of photosynthesis, and emits almost the same amount of CO₂ during combustion [7]. Therefore, biomass helps the atmospheric carbon dioxide recycling and does not contribute to the greenhouse effect [7]. This is the reason why biomass can be considered as a CO₂ neutral fuel. The overall CO₂ emissions can be reduced, so biomass has a role in CO₂ reduction strategies. Biomass has the additional benefit of inherently lower levels of sulphur and nitrogen [8,11,12].

It is the only renewable energy source that can be converted into several forms of fuels – liquid (bio-oil), solid (char), and gas, with promising flexibility in production and marketing [13]. The biomass can be used either through blending with fossil fuels or through firing, as a fuel on its own [14]. The main concern relevant for the use of this energy source is related to low calorific value of biomass, and that is the reason why the calorific value is the key parameter to evaluate the fuel quality of a special biomass material in energy applications.

The other aspect where biomass has a prominent role, unfortunately a negative one, is wildfires. In this uncontrolled combustion processes, biomass represents the extremely flammable material. For proper understanding of wildfire ignition and propagation, adequate characterization of biomass materials is necessary.

Biomass fuels can be characterized through proximate and ultimate analyses [14]. These two analyses provide valuable information that is of special importance for proper design of biomass energy conversion devices as well as for credible wildfire propagation modelling. Proximate analysis provides information about moisture, volatile, fixed carbon and ash content. These values can be used for indirect estimation of higher heating values (HHV). On the other hand, ultimate analysis provides the elemental composition of the analysed sample [14-16].

Thermogravimetric analysis (TGA) can be used for a proximate analysis of biomass. This technique is widely used in laboratories [16-18]. The analysis evaluates the loss of weight of a sample when the temperature is increased in a controlled atmosphere. Studies can be performed in inert (nitrogen, helium, argon) or oxidizing (oxygen, synthetic air) atmospheres.

In this paper, we performed a proximate analysis of various biomass samples occurring in processes of controlled combustion as well as in wildfires.

MATERIALS AND METHODS

The proximate analysis of fuels was performed using a Perkin-Elmer thermogravimetric analyzer TGA 4000 (Norwalk, CT). The following biomass samples were tested: beech stem, pine cones, pine needles, pine stem, sycamore bark and sycamore leaves. All samples were grounded prior to the analysis. For all experiments, approximately 20 mg of a sample was placed in the ceramic crucible. Experiments were performed in triplicate for each sample and the obtained results correspond to the average of these measurements.

The calibration of the instrument, temperature, furnace, and weight calibration, was performed according to the manufacturer's recommendation. The temperature calibration was conducted by measuring Curie points of alumel, nickel and iron.

Nitrogen and oxygen were the purge and sample gases, at a flow rate of 20 ml/min each. Before the experiments, in order to eliminate residual traces of

gases from the previous experiments, a balance was flushed with nitrogen at a flow rate of 20 ml/min, for 20 minutes. Thermogravimetric analysis was performed according to the method proposed by Saldarriaga et al. [19].

The proposed method contains the following steps:

- holding for 5.0 min at 30°C;
- heating from 30°C to 105°C at 40°C/min;
- holding for 80 min at 105°C;
- heating from 105°C to 700°C at 15°C/min;
- holding for 30 min at 700°C;
- introducing oxygen with flow rate of 20 ml/min;
- holding for 5 min at 700°C and;
- cooling from 700°C to 30°C at 100°C/min.

RESULTS AND DISCUSSION

In the first step, TGA curves were created. The obtained plots for tested samples are shown in Figure 1.

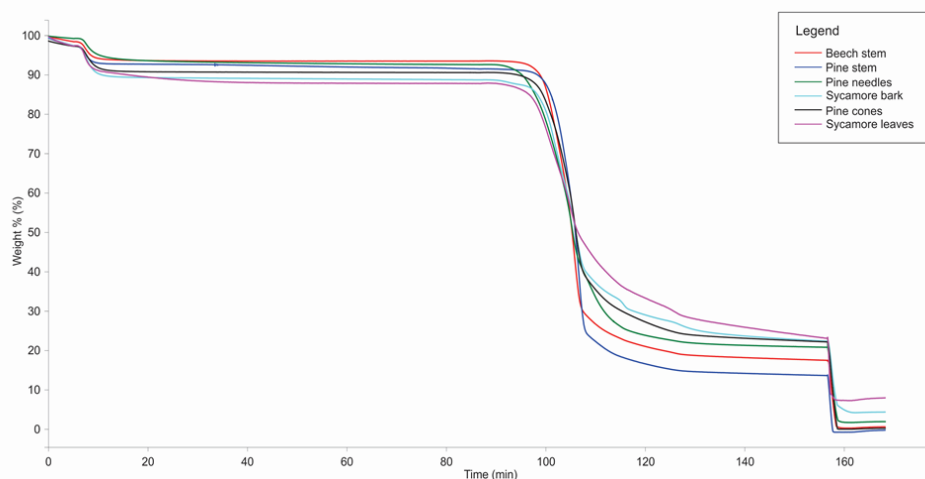


Figure 1. TGA plots for biomass samples

In the next step, differential thermogravimetric DTG curves were created using the Pyris software (Perkin

Elmer, USA). TGA and DTG plots for the beech stem sample are shown in Figure 2.

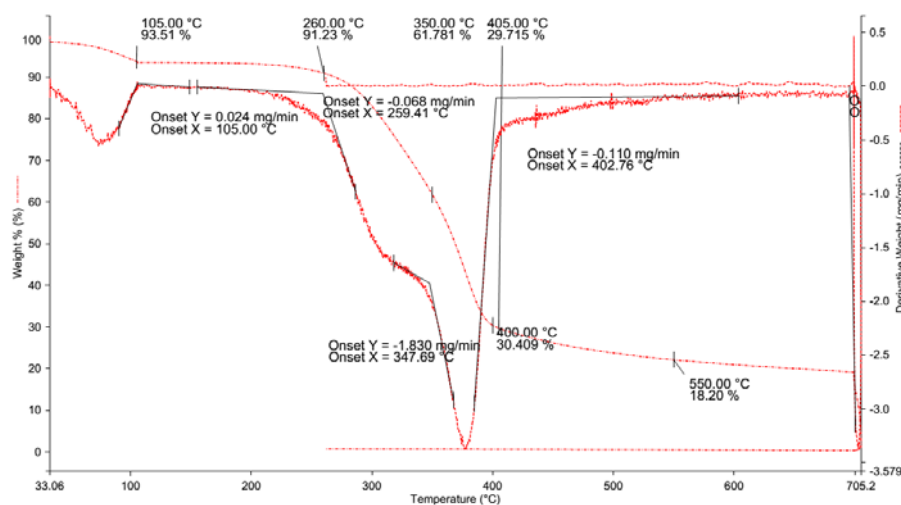


Figure 2. TGA and DTG curves for beech stem sample

Based on the shapes of TGA and DTG curves, it may be concluded that there were at least four stages of weight loss. The first stage, which started at 30 and ended at 105 °C, corresponds to dehydration of the fuel sample. The mass losses in this stage ranged from around 6.5%, for beech stem and pine needles, to 10.5%, for sycamore bark and leaves. Higher moisture content in the case of sycamore may be attributed to the fact that the bark and leaves were subjected to TGA immediately after they had been collected.

The second stage, which started around 250 and ended around 550 °C, was the stage of the highest weight loss (from ca. 63% to ca. 75%) and it is characterized as the stage of intensive devolatilization of fuel samples. During this stage, the samples go through active pyrolysis. It corresponds to the decomposition of cellulose and hemicellulose components and the partial loss of the lignin component. Two slopes of the DTG plot during this stage suggest that, during the TGA

analysis, the loss of hemicellulose starts first and is subsequently overlapped by the loss of cellulose, whereas the loss of lignin is slow, occurring over a wide range of temperatures. It is noticeable that the mass loss in the temperature range from 105 to 250 °C is negligible. This region corresponds to the evaporation of very low volatiles. At temperatures higher than 250 °C, the mass of produced volatiles begins to increase abruptly.

The third stage starts at 700 °C after the switch of sample gases (oxygen is introduced instead of nitrogen). In this stage, intensive oxidation of fixed carbon from fuel samples occurs and it is characterized by extremely rapid mass loss.

Finally, the fourth phase involves the slow cooling of the fuel sample. Residual mass corresponds to the ash content. The ash content was the lowest in the case of beech stem (1.5%), while sycamore bark had the highest amount of ash (7.3%).

Table 1. Proximate analysis of biomass samples

	Beech stem	Pine cones	Pine needles	Pine stem	Sycamore bark	Sycamore leaves
	wt.a.r. (%)	wt.a.r. (%)	wt.a.r. (%)	wt.a.r. (%)	wt.a.r. (%)	wt.a.r. (%)
Stage I	6.5	9.2	6.4	7.3	10.6	10.7
Stage II	75.3	67.5	71.3	78.5	63.5	65.6
Stage III	16.7	19.9	19.5	12.4	18.6	19.4
Ash	1.5	3.4	2.8	1.8	7.3	4.3

Mass loss values are reported in percentage by weight units, calculated on an as-received basis.

REFERENCES

- [1] P.L. 110-140 Energy Independence and Security Act of 2007
- [2] N. Bilandzija, N. Voca, B. Jelcic, V. Jurisic, A. Matin, M. Grubor, T. Kricka, "Evaluation of Croatian agricultural solid biomass energy potential", *Renewable and Sustainable Energy Reviews*, 93 (2018), pp. 225-230
- [3] AEBIOM. European biomass association, Statistical report - European bioenergy outlook. Brussels, Belgium; 2016.
- [4] A. Kumar, K. Kumar, N. Kaushik, S. Sharma, S. Mishra, "Renewable energy in India: current status and future potentials", *Renewable and Sustainable Energy Reviews*, 14 (2010), pp. 2434-2442
- [5] N. Scott-Bentsen, C. Felby, "Biomass for energy in the European Union – a review of bioenergy resource assessments", *Biotechnol Biofuels*, 5 (2012), p. 25
- [6] J. Sánchez, M. D. Curt, N. Robert, J. Fernández, "Chapter Two: Biomass Resources", *The Role of Bioenergy in the Bioeconomy*, 2019, Pages 25-111
- [7] A. Demirbas, "Sustainable cofiring of biomass with coal" *Energy Conserv Manage*, 44 (2003), pp. 1465-1479
- [8] A. Demirbas, "Biomass resource facilities and biomass conversion processing for fuels and chemicals" *Energy Convers Manage*, 42 (2001), pp. 1357-1378
- [9] M. Müller-Hagedorn, H. Bockhorn, L. Krebs, U. Müller, "A comparative kinetic study on the pyrolysis of three different wood species", *Journal of Analytical and Applied Pyrolysis*, 68-69 (2003), pp. 231-249
- [10] R.B. Gupta, A. Demirbas, "GDE gasoline, diesel and ethanol biofuels from grasses and plants", Cambridge University Press (2010)
- [11] M. Sami, K. Annamalai, M. Wooldridge, "Co-firing of coal and biomass fuel blends", *Prog Energy Combust Sci*, 27 (2001), pp. 171-214
- [12] P. Molcan, G. Lu, Bris T. Le, Y. Yan, B. Taupin, S. Caillat, "Characterisation of biomass and coal co-firing on a 3 MWth Combustion Test Facility using flame imaging and gas/ash sampling techniques", *Fuel*, 88 (2009), pp. 2328-2334
- [13] Z.Y. Zhao, H. Yan, "Assessment of the biomass power generation industry in China", *Renewable Energy*, 37 (2012), pp. 53-60
- [14] E. Lester, C. Avila, C.H. Pang, O. Williams J. Perkins, S. Gaddipatti, G. Tucker, J. M. Barraza, M. P. Trujillo-Urbe, T. Wud, "A proposed biomass char classification system", *Fuel*, 232 (2018), pp. 845-854

- [15] S. Gaur, T. Reed, "Thermal Data for Natural and Synthetic Fuels", Marcel Dekker, 1998
- [16] A. Özyuguran, S.Yaman, "Prediction of Calorific Value of Biomass from Proximate Analysis", Energy Procedia 107 (2017) 130 – 136
- [17] J.P. Elder, "Proximate analysis by automated thermogravimetry", Fuel, 62 (5) (1983), pp. 580-584
- [18] F.S. Sadek, A.Y. Herrell, "Methods of proximate analysis by thermogravimetry", Thermochim. Acta, 81 (1984), pp. 297-303
- [19] Saldarriaga JF, Aguado R, Pablos A, Amutio M, Olazar M, Bilbao J. Fast characterization of biomass fuels by thermogravimetric analysis (TGA). Fuel. 2015 Jan 15;140:744-51

BIOGRAPHY of the first author

Milan Protić was born in Niš, Serbia, in 1979.

He received the diploma in mechanical engineering and the Ph.D. degree from the University of Niš, Faculty of Occupational Safety in Niš.



His main areas of research include renewable energy sources, district heating systems, combustion and fire research.

He works as an assistant professor at the Faculty of Occupational Safety in Niš, University of Niš.

ACKNOWLEDGEMENTS

The instrument used in this study, thermogravimetric analyser TGA 4000, was purchased under the project: "Joint Training Programme for Forest Fire Prevention and Management". The project is co-funded by EU through the Interreg-IPA CBC Bulgaria–Serbia Programme.

TEHNIČKA ANALIZA BIOMASE

Milan Protić, Milena Mančić, Ana Miltojević, Miomir Raos

Rezime: U ovom radu je izvršena analiza uzoraka goriva na bazi biomase. Šest tipova biomase je ispitivano: stabljika bukve, šišarke bora, iglice bora, stabljika bora, kora platana, lišće platana. Za svaki od uzoraka određivana je: vlaga, ukupni volatili, fiksni ugljenik i pepeo.

Ključne reči: tehnička analiza, termogravimetrijska analiza, biomasa.

ANA MILTOJEVIĆ¹
TATJANA GOLUBOVIĆ²
MARINA STOJANOVIĆ³

University of Niš,
Faculty of Occupational Safety

¹ana.miltojevic@znrfak.ni.ac.rs
²tatjana.golubovic@znrfak.ni.ac.rs
³marina.stojanovic@znrfak.ni.ac.rs

POLYCYCLIC AROMATIC HYDROCARBONS IN THE WORKING ENVIRONMENT: TOXIC EFFECTS AND SAFETY ISSUES

Abstract: Polycyclic aromatic hydrocarbons (PAHs) are one of the most widespread classes of organic pollutants. They are formed by incomplete combustion of organic matter and they have been present on Earth since the life (organic matter) was created. However, the increase in PAH concentration in the environment is a consequence of industrialization and anthropogenic activity. The influence of PAHs on the occurrence of malignant diseases has been known for a long time. PAHs enter the body by inhalation of aerosols and particles produced by combustion or by inhalation of tobacco smoke, by ingestion of food and water contaminated with PAHs (grilled or smoked meat) and by skin absorption (contact with PAHs containing materials). After the absorption, due to their liposolubility, PAHs are either deposited in the adipose tissue or metabolized to more polar diols and diol epoxides. The PAH metabolites are more toxic than the starting compounds because they form adducts with DNA and blood proteins. Acute PAH poisonings are rare and occur due to contact with skin or eyes, or due to inhalation. On the other hand, chronic exposure to PAHs leads to organs damage and it is associated with the appearance of cancer of lung, skin, gastrointestinal organs, scrotum, glands, etc. Occupational PAHs intoxications are mostly accidental and occur under unexpected circumstances. The most important sources of PAHs in the working environment are aluminum and asphalt production, metal production, coke baking industry, tire production, work in mines, etc. In those activities where it is assessed that workers are exposed to PAHs, the efforts could be focused on lowering the exposure and ensuring that exposed workers are well-informed with the toxic effects of PAHs and that appropriate safety measures are applied.

Key words: polycyclic aromatic hydrocarbons, occupational exposure, toxic effects, safety issues, protective measures

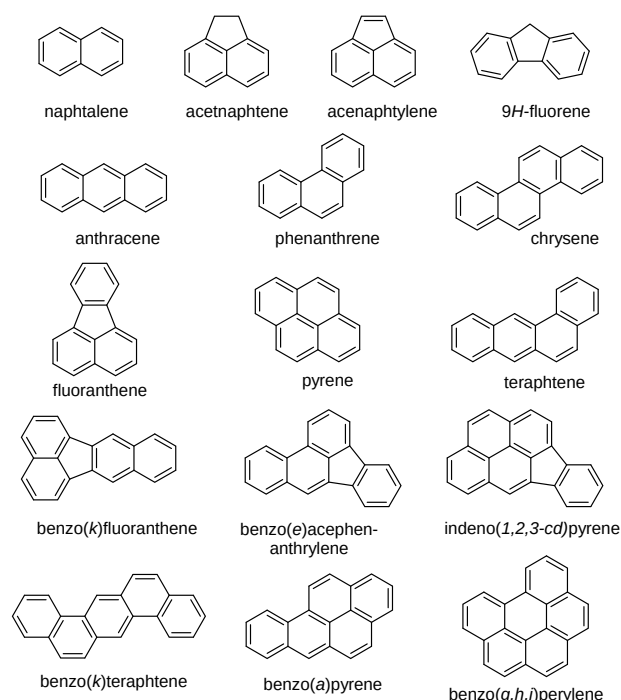
INTRODUCTION

The polycyclic aromatic hydrocarbons (PAHs) have been environmental contaminants since life (organic matter) on Earth was created [1]. Nevertheless, the level of PAHs in the environment significantly increased due to the anthropogenic activity. PAHs comprise a large family of hydrocarbons and each member consists of molecules containing two or more fused six-carbon-atom aromatic rings. The first and simplest member of the family is naphthalene [1]. Sixteen polycyclic aromatic hydrocarbons that are on the United States Environmental Protection Agency (US EPA) priority pollutant list are given in Figure 1. PAHs are produced by incomplete combustion, pyrolysis, or pyrosynthesis of organic matter [2]. The natural sources of PAHs are non-anthropogenic forest fires, volcanoes, coal, and oil. The anthropogenic sources of PAHs are numerous and they include burning of coal, wood, oil, petroleum products; PAHs are also found in motor vehicle exhaust fumes, in industries that produce or use coal tar, coke, or bitumen; they are produced in coal gasification plants,

smokehouses, incinerators, and aluminum production facilities. Cigarette smoke and food cooked at high temperatures, especially grilled and smoked meats, contain high amounts of PAHs [1].

The scientific investigation of PAHs and their health effects started in 1775 when Sir Percival Pott noted the connection between scrotum cancer in chimney sweeps and their exposure to soot and ash. Nowadays it is well known that carcinogenic agents from soot and ash are PAHs [1,2].

PAHs are typically solids with low volatility and low solubility in water. However, they are soluble in most organic solvents (Table 1). They are chemically stable, but most of them can be photo-oxidized and degraded to simpler substances [1].

**Figure 1.** PAHs on the US EPA priority pollutant list**Table 1.** Physical properties of selected PAHs [1].

PAH	T _m (°C)	T _b (°C)	S (mol/l)	logK _{ow}
Naphtalene	81	218	2,48×10 ⁻⁴	3,36
Acenaphthalene	93	279	2,55×10 ⁻⁵	3,92
Phenanthrene	100	340	7,25×10 ⁻⁶	4,57
Anthracene	218	342	4,10×10 ⁻⁷	4,54
Fluoranthene	107	384	1,29×10 ⁻⁶	4,90
Pyrene	149	404	6,68×10 ⁻⁷	5,18
Benzo(a)anthracene	157	438	6,14×10 ⁻⁸	5,61
Benzo(a)pyrene	178	495	1,51×10 ⁻⁸	6,04
Perylene	277	503	1,59×10 ⁻⁹	6,04
Coronene	438	590	4,67×10 ⁻¹⁰	6,90

T_m – melting point, T_b – boiling point, S – solubility in water, K_{ow} – octanol-water partition coefficient

Due to their solubility, PAHs are not expected to accumulate in water but they accumulate in sediments and soil. They could be found in almost all soils primarily due to the airborne deposition. Additionally, contamination of soil and water can be caused by spills. Soils near oil refineries and other industrial complexes usually contain high amounts of PAHs. Based on their high K_{ow}, PAHs have high potential to bioaccumulate [2].

MECHANISM OF ACTION

Major routes of human exposure to PAHs are inhalation of PAH-containing aerosols and particles, ingestion of PAH-contaminated food (especially grilled and smoked meat) and water, and absorption through the skin. Exposure may also occur via placental transfer and breast milk [2].

After absorption, PAHs enter the lymph and circulate in the blood to the target organs. As PAHs are highly liposoluble compounds, they could be either deposited in adipose tissue or biotransformed to more hydrosoluble metabolites. Biotransformation occurs in order to facilitate their excretion from the organism via bile and urine. The metabolism of PAHs takes place primarily in the liver and kidney, but also in the lungs, skin, small intestine, testes, adrenal, thyroid, and sebaceous glands. Biotransformation of PAHs includes several steps [2]:

- oxidation of PAH by the cytochrome P-450-dependent microsomal enzyme system to form epoxide metabolite;
- hydrolysis of the formed epoxide, by epoxide hydrolase, yielding dihydrodiol;
- oxidation of dihydrodiol, by the cytochrome P-450, to yield dihydrodiol-epoxide, the ultimate carcinogen.

These metabolites may be detoxified by further conjugation with glutathione, glucuronic acid or sulphuric acid. Glucuronides and sulfate conjugates of these metabolites are excreted in the bile, while glutathione conjugates are further metabolized to mercapturic acid metabolites in the kidney and are excreted in the urine [2].

Polycyclic aromatic hydrocarbons are generally nonmutagenic or very slightly mutagenic, but their metabolites have the capacity to bind to centers in biological molecules such as DNA and blood proteins (e.g. albumin, hemoglobin). PAH-DNA adduct has the capacity to cause tumor formation [2].

Although there are a number of effects that are due to the long-term or chronic exposure to PAHs, the ability of PAHs to induce acute (short-term) health effects in humans is not clear. The acute effects may occur as a result of skin, eye, or respiratory exposure, mostly due to the occupational exposures to high levels of pollutant mixtures containing PAHs and the symptoms are eye irritation, nausea, vomiting, diarrhea, confusion. On the other hand, chronic or long-term exposure to PAHs may include cataracts, kidney and liver damage aplastic anemia, skin damage and photosensitization. Long-term studies of workers exposed to mixtures of PAHs have shown an increased risk of skin, lung, bladder, scrotum, gastrointestinal cancers [2].

The most authoritative information on the possible carcinogenic effects of PAHs is provided by The International Agency for Research on Cancer – IARC. The classification of cancerogenic PAHs is given in Table 2. According to IARC acenaphthene, anthracene, benzo(g,h,i)perylene, dibenzofuran, fluoranthene, fluorine, 2-methylnaphthalene, naphthalene phenanthrene, and pyrene are classified as noncarcinogenic (IARC) [3].

Table 2. IARC classification of PAHs

PAH	IARC Group
Benzo(a)pyrene	1
Benzo(a)anthracene	2
Benzo(b)fluoranthene	2B
Benzo(k)fluoranthene	2B
Benzo(g,h,i)perylene	3
Chrysene	2B
Dibenzo(a,h)anthracene	2B
Indeno(1,2,3-c,d)pyrene	2B

Group 1 - carcinogenic to humans,

Group 2A - probably carcinogenic to humans,

Group 2B - possibly carcinogenic to humans,

Group 3 - not classifiable as to its carcinogenicity to humans

OCCUPATIONAL EXPOSURE

Generally, exposure to PAHs occurs through environmental, dietary and occupational sources. World Health Organisation (WHO) gave a list of the most important occupational and non-occupational sources of PAHs [4,5]:

- production of aluminium (mainly from anodes),
- metal production (particularly iron, and steel),
- foundries in the binding agents used in molding sand,
- domestic and residential heating,
- road paving and asphalt works,
- motor vehicle traffic and diesel exhaust,
- bushfires and structural fires,
- coal-fired power plants,
- incineration of refuse,
- tobacco smoking,
- medicinal use,
- cooking processes (food),
- coke ovens,
- spontaneous combustion of coal,
- remediation of contaminated land.

Occupational exposure can occur in a wide variety of exposure circumstances. Based on carcinogenic risk IARC classified occupational tasks associated with PAH exposure in several groups. Occupational exposures during coal gasification, coke production, coal-tar distillation, work as a chimney sweep, road paving and roofing with coal-tar pitch and aluminium production is classified to IARC Group 1 (carcinogenic to humans). Exposure during carbon electrode manufacture and exposure to creosote are considered by IARC to probably be carcinogenic to humans (IARC Group 2A). There are reports examining aspects of exposure in specific circumstances such as aluminium smelting and firefighting [6,7].

The first report of occupation-induced cancer dates back to 1775 when Sir Percival Pott published a paper in which he described the connection between scrotum cancer in chimney sweeps and their exposure to soot and ash. Later investigations revealed that PAHs, products of incomplete combustion of organic matter, present in soot and ash are powerful carcinogens [8]. A

study of roofers exposed to PAHs suggested an excess of lung, stomach, and bladder cancer [3]. Increased lung tumor rates linked to occupational exposure were found in coke-oven workers, asphalt workers and workers in Söderberg potrooms of aluminium reduction plants [5]. A 10-year longitudinal study of stokers exposed to PAH and benzene revealed an excess mortality, especially from cancer and circulatory diseases. An elevated concentration of 1-hydroxypyrene in the urine of bus drivers in the comparison with mail carriers reflected their PAH exposures [2].

Recently, Stec and co-authors [7] noticed higher cancer incidence among firefighters compared to the general population. They monitored and quantified 16 EPA priority PAHs in the following samples: the wipe samples from firefighters' skin (jaw, neck, hands), personal protective equipment (SCBA masks, zipflap, shoulders, gloves, hood, gloves) and working environment and from gas sampling in the fire stations and in fire engines. Additionally, 12 months after initial sampling, all samples were re-run for three other PAHs: 3-methylcholanthren, 7,12-dimethylbenzo[a]anthracene and dibenzo(a,e)pyrene, which may be more harmful than B[a]P. It was found that the main exposure route is via skin absorption. Cancer slope factors, used to estimate cancer risk, indicate a markedly elevated cancer risk among firefighters due to the PAHs exposure.

Some studies showed that in anode plant workers in an aluminium reduction plant, asphalt paving workers and creosote facility workers dermal exposure is several times the impact of inhalation exposure [5].

The literature survey revealed the lack of data about occupational exposure to PAHs in Serbia.

MEASUREMENT OF THE EXPOSURE LEVELS IN THE WORKING ENVIRONMENT

The degree of exposure to PAHs in the working environment can be determined either by in-air methods (monitoring the workplace and/or the employee's personal exposure) or by biological monitoring.

The most often used in-air sampling methods for PAHs are NIOSH methods 5506 and 5515 [9,10]. Air samples are collected by drawing a known amount of air through a cassette containing a PTFE filter in conjunction with a back-up sorbent tube. Then the sample from filter and sorbent tube are analyzed by gas chromatography (GC) and high-pressure liquid chromatography (HPLC). The presence of selected PAHs in the samples is determined by mass spectrometer (MS), fluorescence or ultraviolet (UV) detector. Pandey with his co-workers gave [11] a comprehensive review of sampling and analysis techniques for the determination of polycyclic aromatic hydrocarbons in the air.

The most effective method for determining the level of PAH exposure in workers is biological monitoring of 1-hydroxypyrene in the urine of exposed people by HPLC analysis. The drawbacks of this method are that it is time-consuming, inconvenient, useful only for exposures that have occurred in the previous 18 h and that it does not provide any information useful for evaluating binding of PAHs and their metabolites to DNA, that is the key to the initiation of cancer. Analytical techniques for monitoring PAH-DNA adduct in nucleated white blood cells and for measuring PAH-blood protein adducts (albumin and hemoglobin) have been developed. In general, biological monitoring can be an effective indicator of possible PAH exposure, but it is still difficult to assess the extent of exposure and the resultant dose, especially with low level environmental or occupational exposure [2].

EXPOSURE CONTROLS, PROTECTION MEASURES, AND FIRST AID MEASURES

The OSHA-mandated PAH workroom air standard is an 8 h time-weighted average (TWA) permissible exposure limit (PEL) of 0.2 mg/m³, measured as the benzene-soluble fraction of coal tar pitch volatiles. The National Institute for Occupational Safety and Health (NIOSH) has recommended that the workplace exposure limit for PAHs be set at the lowest detectable concentration, which was 0.1 mg/m³. In Serbia, maximum allowable concentrations of PAHs are given in the Standard "Safety precautions - Maximum allowable concentrations of toxic gases vapors and aerosols in working premises atmosphere" (SRPS Z.B0.001/1:2007) [5];

The most effective means of restricting PAH absorption is by controlling exposure and this could be accomplished in several ways [5]:

- areas with activities likely to generate PAHs should be enclosed and well ventilated;
- good housekeeping will minimize the exposure to particulate and potential contact with the skin;
- provision and use of change room facilities for scrupulous personal hygiene;
- no eating or smoking in PAH-contaminated areas;
- washing a skin contaminated with PAHs to reduce photo-sensitization and potential skin inflammation from UV exposure;
- inspection and maintenance routines for engineering controls;
- administrative controls (e.g. limits on overtime and the principle of periodic rotation of employees in areas where PAHs are generated);
- medical surveillance of employees especially if they are exposed above the PEL;
- education of employees that can be exposed to PAHs. Education is crucial in reducing PAHs exposure. The health risks due to the exposures to PAHs should be well understood, particularly by those undertaking work that is highlighted as potentially dangerous. Awareness-raising and

education efforts are required to increase the use of well-known and readily available controls to prevent exposures when doing the tasks that includes work with PAH or during which PAHs could evolve. General information on methods for preventing inhalation and skin contact with chemicals is provided in the code of practice for hazardous workplace chemicals;

- use of personal protective equipment (PPE). PPE should be used as a last resort, where other control measures have been unsuccessful. Workers should wear protective clothing and appropriate respiratory protection (half-face respirators and/or powered air purifying respirator, helmets fitted with P1 particulate filters, full-face respirators fitted with a P2 particulate filter). An air-line respirator may be required in the case of high-level exposure. Minimization of skin contact time or elimination should be strongly promoted via the prompt washing of contact areas and personal protective equipment. This may require the use of disposable coveralls and gloves. The use of water-based barrier creams prior to exposure can help to reduce skin absorption [5].

Employers are obliged to provide a safe and healthy working environment. In Serbia, regulations concerning the work with PAHs are the following:

- Safety precautions - Maximum allowable concentrations of toxic gases vapors and aerosols in working premises atmosphere (SRPS Z.B0.001/1:2007) [12];
- Rulebook on preventive measures for safe and healthy work concerning the exposure to chemicals ("Official Gazette of the Republic of Serbia", No. 106/09 and 117/17) [13];
- Rulebook on preventive measures for safe and healthy work concerning the exposure to carcinogens or mutagens ("Official Gazette of the Republic of Serbia", No. 96/11 and 117/17) [14];
- Rulebook on preventive measures for safe and healthy work concerning the use of means and equipment for personal protection at work ("Official Gazette of the Republic of Serbia", No. 92/08) [15];
- Rulebook on personal protective equipment at the workplace ("Official Gazette of the Republic of Serbia", No. 100/2011) [16];
- Rulebook on pre-emptive and periodical medical examinations of workers at high-risk jobs ("Official Gazette of the Republic of Serbia", No. 120/07, 93/08 and 53/17) [17].

First aid measures depend on the type of exposure. In the case of acute inhalation exposure to PAHs, ventilator support is tailored to the patient's clinical condition. In the case of clothing, skin contact with PAHs, contaminated clothing should be removed from exposed persons and the skin should be decontaminated by gently scrubbing it with soap and water. Ocular contamination can be treated with irrigation of the eye with saline or water followed by a complete eye examination [2].

CONCLUSION

Polycyclic aromatic hydrocarbons (PAHs) are one of the most widespread classes of organic pollutants. Although they are present in the environment since the life on Earth is formed, the increase in PAH concentration is a consequence of industrialization and anthropogenic activity. In general, PAHs have played an important role in developing awareness of the harmful role of pollutants in the human environment and the need to reduce the pollution.

The occupational sources of PAHs are numerous. Due to their carcinogenicity when working with PAHs, it is necessary to comply with occupational safety measures and use personal protective equipment. As the health risks due to the exposures to PAHs should be well understood, education of those who work with PAHs or can be indirectly exposed to them is very important in reducing PAHs exposure. Awareness-raising and education efforts are required to increase the use of available controls to prevent the exposure. Since the literature survey revealed the lack of data about occupational exposure to PAHs in Serbia, this is the issue that should be evaluated in more details in order to reduce the exposure of Serbian workers to PAHs and enhance safety measures.

REFERENCES

- [1] D. W. Connell, Basic concepts of environmental chemistry, 2005, CRC Press.
- [2] R. D. Harbison, A. Mayo-Perez, D. R. Johnson, M. M. Bourgeois: "Aromatic hydrocarbons", In: "Hamilton & Hardy's industrial toxicology", R. D. Harbison, M. M. Bourgeois, G. T. Johnson, Editors, 2015, John Wiley & Sons, Inc.
- [3] IARC: Working group on the evaluation of carcinogenic risks to humans: "Some non-heterocyclic polycyclic aromatic hydrocarbons and some related exposures", IARC Monographs on the evaluation of carcinogenic risks to humans, Vol. 92, 2010, pp. 1-853.
- [4] WHO: "Selected non-heterocyclic polycyclic aromatic hydrocarbons", WHO Environmental Health Criteria Publications, Vol. 202, 1998.
- [5] Australian institute of occupational hygienist (AIOH): "Polycyclic aromatic hydrocarbons (PAHs) and occupational health issues", 2016.
- [6] T. R. Driscoll, R. N. Carey, S. Peters, D. C. Glass, G. Benke, A. Reid, L. Fritschi: "The Australian work exposures study: Occupational exposure to polycyclic aromatic hydrocarbons", Annals of Occupational Hygiene, Vol. 60, 2016, pp. 124-131.
- [7] A. A. Stec, K. E. Dickens, M. Salden, F. E. Hewitt, D. P. Watts, P. E. Houldsworth, F. L. Martin: "Occupational exposure to polycyclic aromatic

hydrocarbons and elevated cancer incidence in firefighters", Scientific reports, Vol. 8, 2018.

- [8] G. Grimmer: "Environmental carcinogens: Polycyclic aromatic hydrocarbons", 1983, CRC Press.
- [9] NIOSH: "Polynuclear aromatic hydrocarbons by GC: Method 5515", In: P. M. Eller, M. E. Cassinelli, Editors, NIOSH Manual of analytical methods (NMAM), DHHS, National Institute for Occupational Safety and Health Publication, 1994, pp. 94-113.
- [10] NIOSH: "Polynuclear aromatic hydrocarbons by HPLC: Method 5506", In: P. M. Eller, M. E. Cassinelli, editors, NIOSH Manual of Analytical Methods (NMAM), DHHS, National Institute for Occupational Safety and Health Publication, 1998.
- [11] S. K. Pandey, K. H Kim, R. J. C. Brown: "A review of techniques for the determination of polycyclic aromatic hydrocarbons in the air", Trends in analytical chemistry, Vol. 30, No. 11, pp1716-1739.
- [12] "Safety precautions - Maximum allowable concentrations of toxic gases vapors and aerosols in working premises atmosphere", SRPS Z.B0.001/1:2007.
- [13] "Rulebook on preventive measures for safe and healthy work concerning the exposure to chemicals", Official gazette of the Republic of Serbia, No. 106/09 and 117/17).
- [14] "Rulebook on preventive measures for safe and healthy work concerning the exposure to carcinogens or mutagens", Official gazette of the Republic of Serbia, No. 96/11 and 117/17.
- [15] "Rulebook on preventive measures for safe and healthy work concerning the use of means and equipment for personal protection at work", Official gazette of the Republic of Serbia, No. 92/08.
- [16] "Rulebook on personal protective equipment at the workplace", Official gazette of the Republic of Serbia, No. 100/2011.
- [17] "Rulebook on pre-emptive and periodical medical examinations of workers at high-risk jobs", Official gazette of the Republic of Serbia, No. 120/07, 93/08 and 53/17.

BIOGRAPHY of the first author

Ana Miltojević was born in Niš, Serbia, in 1985. She received the diploma and the Ph.D. degree in chemistry from the University of Niš, Faculty of Sciences and Mathematics. She is currently working as an assistant professor at the



University of Niš, Faculty of Occupational Safety. Her main areas of research include organic chemistry, environmental chemistry, biochemistry, and toxicology.

POLICIKLIČNI AROMATIČNI UGLJOVODONICI U RADNOJ SREDINI: TOKSIČNI EFEKTI I BEZBEDONOSNA PITANJA

Ana Miltojević, Tatjana Golubović, Marina Stojanović

Rezime: Policiklični aromatični ugljovodonici (PAH-ovi) predstavljaju jednu od najrasprostranjenijih klasa organskih zagađujućih supstanci. Nastaju nepotpunim sagorevanjem organske materije i prisutni su na Zemlji od trenutka kada je nastao kopneni život (kopnena organska supstanca). Porast koncentracije PAH-ova u životnoj sredini posledica je industrijalizacije i antropogenih aktivnosti. Uticaj PAH-ova na pojavu malignih oboljenja odavno je poznat. PAH-ovi u organizam mogu dospeti inhalacijom čestica koje nastaju sagorevanjem u životnoj i radnoj sredini ili udisanjem duvanskog dima, ingestijom hrane i vode kontaminirane PAH-ovima (grilovano ili dimljeno meso, kontaminirana hrana i voda) i apsorpcijom preko kože, usled kontakta sa materijalima koji sadrže PAH-ove. Nakon apsorpcije, PAH-ovi se, kao liposolubilna jedinjenja, deponuju u masnom tkivu ili se metabolišu do polarnijih diola i diol-epoksida. Metaboliti PAH-ova su toksičniji od polaznih jedinjenja zbog sposobnosti građenja adukata sa DNK i proteinima krvi. Akutna trovanja PAH-ovima su retka i javljaju se usled kontakta sa kožom ili očima, ili usled inhalacije. S druge strane, hronično izlaganje PAH-ovima dovodi do oštećenja mnogih organa i povezano je sa pojavom kancera pluća, kože, gastrointestinalnih organa, skrotuma i žlezdi. Profesionalna trovanja PAH-ovima su uglavnom slučajna i dešavaju se pod nepredviđenim okolnostima. Povećanoj koncentraciji PAH-ova izloženi su radnici koji rade na proizvodnji aluminijuma i asfalta, rudari, odžačari, radnici u industriji pečenja koksa, radnici u štamparijama, čeličanama, u proizvodnji pneumatika i proizvodnji gume... Ukoliko se utvrdi prisustvo PAH-ova u radnoj sredini, potrebno je primeniti mere zaštite u cilju smanjenja izloženosti i izvršiti edukaciju radnika kako bi se upoznali sa toksičnim efektima PAH-ova i odgovarajućim bezbedonosnim merama.

Ključne reči: policiklični aromatični ugljovodonici (PAH), radna sredina, toksični efekti, bezbedonosna pitanja, mere zaštite.

LIDIJA MILOŠEVIĆ¹
EMINA MIHAJLOVIĆ²
MARTINA PETKOVIĆ³
IVAN MIJAILOVIĆ⁴

ANALYSIS OF AN EMERGENCY EVENT - HYDROCHLORIC ACID LEAK IN RAIL TRANSPORT

¹ University of Niš,
Faculty of Occupational Safety in Niš

² University of Niš,
Faculty of Occupational Safety in Niš

³ Higher Technical Professional
School in Zvečan

⁴ University of Niš,
Faculty of Occupational Safety in Niš

¹lidija.milosevic@znrfak.ni.ac.rs

²emina.mihajlovic@znrfak.ni.ac.rs

³martinaeco@yahoo.com

⁴ivan.mijailovic@znrfak.ni.ac.rs

Abstract: *This paper analyses an emergency event due to hydrochloric acid leak from a tank car at the Central Railway Station in Belgrade. The analysis considers the aspect of fire and rescue unit intervention, agents and equipment used during the intervention, aggravating circumstances, and weather conditions. An assessment of the emission of hydrochloric acid toxic fumes was performed, including the analysis of their human health impact.*

Key words: emergency, rail transport, hydrochloric acid, toxic areas, acute and chronic effects.

INTRODUCTION

The risk of emergency events during hazardous material transport is high, primarily in terms of the possibility of traffic accidents and of the inability to prevent the harmful effects caused by sudden and uncontrolled spread of substances into the environment. Emergency events due to chemical transport accidents have a 35% incidence compared to such events occurring in production and storage facilities. Rail transport of hazardous materials comprises the 25% of the world transportation activities [1]. Even though the percentage of emergency events is higher in road than in rail transport, rail transport accidents tend to pose bigger threats to human life and health. An emergency event is an accident caused by a natural or other disaster, which threatens human life and health and the environment; its effects can be mitigated or eliminated through regular activities of authorized bodies and services [2]. Emergency management involves the following stages:

- risk reduction/minimization - risk control measures preventing the onset of events that can lead to emergencies;
- preparedness - necessary in case the risk reduction measures are insufficient or unable to prevent an emergency;
- response - conducted in keeping with a strategic response plan for a specific emergency event and in keeping with the situational development;
- recovery - involves the implementation of measures for the reestablishment of normal functioning of those elements of the system whose functions were disturbed during the emergency.

As they unfold, all emergency events typically go through four stages:

- onset;
- initiation;
- culmination and subsidence.

The onset stage creates the necessary conditions for an emergency, including the activation of unfavourable natural processes, accumulation of technological oversights and design or production faults, overload of equipment, and overburdening of the workforce. This also involves large quantities of stored materials (flammable, combustible, unstable, corrosive, highly reactive, toxic, powdery, and inert) intended for processing and the extreme physical conditions of the production process (high and low temperatures, high pressure, vacuum, cyclic temperature and pressure changes, water hammers, etc.).

The initiation stage includes the emergence of irregularities pertaining to changes of process parameters (pressure, temperature, concentration, reaction speed, substance consumption, etc.), when they reach their critical value. External factors including extreme weather conditions and natural disasters are also involved. The human factor is the most influential, as more than 60% of accidents happen due to faulty design, construction, exploitation, or technical handling [3].

The culmination stage involves the release of large quantities of energy and mass, whereby even the smallest initial event can put in motion a chain reaction of accidents with multiple increases of intensity and scope (the 'domino' effect). During this stage, it is of paramount importance to predict the accident development scenario, which will allow the implementation of concrete safety measures in order to prevent, or at least reduce, human casualties and minimize material damage.

The subsidence stage begins from the moment the source of hazard has been removed and lasts until the effects of the event have been completely eliminated. The duration of this stage depends on the type, intensity, and scope of consequences [4,5].

ANALYSIS OF FIRE AND RESCUE UNIT INTERVENTION

This paper analyses the emergency event involving a leak of hydrochloric acid from a 50-tonne capacity tank car on a rail track at the Central Railway Station in Belgrade, at the address 1 Savski Square. The train containing tank cars was located at the coordinates 44°48'30.97" N 20°27'18.05" E, at 132 m.a.s.l. The location is surrounded by multiple residential areas with several thousand people, including Zeleni Venac, Andrićev Venac, and Savamala.

The leaking tank car was fourth in a series of twelve tank cars. The first car contained chlorine, the second and third contained caustic soda, the fourth and fifth contained hydrochloric acid, while the last seven cars contained butane. The cars were stationary on the track and disconnected from the locomotive [6].

The intervention involved 31 firefighters from four fire and rescue units: Zvezdara, Voždovac, Košutnjak, and Zemun. The first part of the intervention was finding a safe passage to the tank car, electricity shut-off and rail track grounding, in order to allow safe access and operation. Upon inspection by the initial attack group, safety zones were established and it was determined that a tank car carrying 50 tonnes of hydrochloric acid was leaking, forming a vapour cloud over a square metre surface.

The initial attack group was equipped with insulated extinguishers, hazmat suits, and the equipment required for leak sealing. A discharge line was formed with flat fan nozzles for firefighter protection and for clearing the fog created by the hydrochloric acid leak. The leak was successfully closed using a rubber gasket, the critical tank car was separated from the other cars and then moved to a dead-end siding, where the firefighters proceeded to clear the fog using fan nozzles.

A total of 750 000 l of water was used to clear the fog and protect and decontaminate the firefighters. The water was supplied from water tenders, which previously drafted water from hydrants and a fireboat. The intervention ended with the decanting of hydrochloric acid from the tank car into two water tenders.



Figure 1. *Emergency intervention for hydrochloric acid leak from a tank car*

Table 1 lists the equipment used by the fire and rescue units [5].

Table 1. *Equipment used in emergency fire intervention*

Type of equipment	Pieces
Command support unit	1
Fire engine	2
Water tender	5
Hazmat vehicle	1
Technical vehicle	1
Logistical support vehicle	1
Emergency decontamination vehicle	1
Collecting breeching	4
Dividing breeching	4
Discharge hose Ø75	5
Discharge hose Ø52	10
Nozzles Ø 52	4
Hazmat suit	4
Power aggregate	1
Fire hydrant pump	1
Fan nozzle	8
Monsoon nozzle	2
Insulation extinguisher	15
Fireboat	1
Rubber gasket	2
Cylinder air cushion	2

The aggravating circumstances during the intervention included the downtown location of the event, the specific location of tank car perforation, and the proximity of a live electric-contact grid. Since the event occurred in February during the night, the weather conditions (low temperature, rain, snow, high air humidity) and lower night visibility additionally impeded the intervention. Poor communication with the on-call employees of the Serbian Railways, longer period of obtaining a shunter locomotive to disassemble the train, as well as a lack of tank cars or tank trucks for decanting by the Serbian Railways, resulted in the entire operation lasting almost eight hours.

ASSESSMENT OF TOXIC AREAS AND HUMAN HEALTH IMPACT DUE TO HYDROCHLORIC ACID LEAK

Hydrochloric acid (HCl) is an acid formed by hydrogen chloride dissolving in water. It is a colourless, non-flammable, and water-soluble liquid with a pungent odour. Its boiling point is concentration dependent, the maximum concentration is 38%, with the relative density at 20°C around 1.19 g/cm³.

Assessment of toxic vapour emission from hydrochloric acid leak

The ALOHA software v.5.4.4 was used to simulate a sudden emission of hydrochloric acid due to a leak

from a tank car at the Central Railway Station in Belgrade [7]. The assessment determined the type and quantity of the hazardous material (HCl), the affected location (Central Railway Station in Belgrade), and potential human health effects. A vulnerability analysis was also performed, including the spread of the hazard area and impact factors, the threatened population depending on the area they inhabit, and fundamental support systems that can be affected by the event.

At the moment of emergency event inception, 15 February 2011 at 01:02 h, when the Command and Operations Centre of the Belgrade Fire and Rescue Brigade received the notification call, the wind speed was 3.7 m/s SE, air temperature was 1 °C, and air humidity was 80 %.

Prediction of toxic areas for hydrochloric acid emission for a worst-case scenario of the maximum leak of 50 tonnes was performed with the ALOHA software (Toxic Area of Vapour Cloud), as shown in Figures 2 and 3.

The Environmental Protection Agency (EPA) defines Acute Exposure Guideline Levels (AEGLs) as threshold exposure limits for the general public that are applicable to emergency exposure periods ranging from 10 minutes to 8 hours [8]. The three AEGLs are defined as follows:

Yellow area—AEGL-1 – airborne concentration of a substance at which the general population could experience notable discomfort, irritation or certain asymptomatic non-sensory effects.

Orange area—AEGL-2 – airborne concentration of a substance at which the general population could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

Red area—AEGL-3 – airborne concentration of a substance at which the general population could experience life threatening health effects or death.

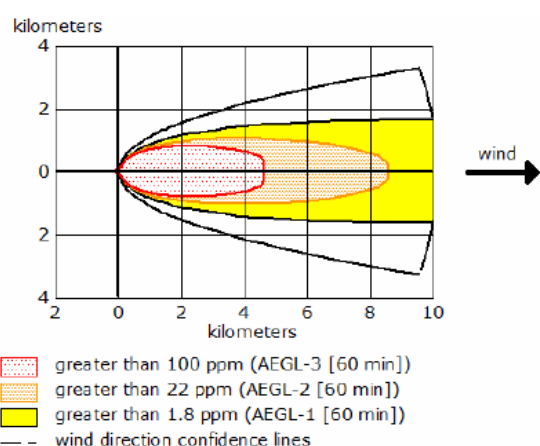


Figure 2. Prediction of toxic vapour areas due to HCl leak

Figure 2 reveals that the red area, in which hydrochloric acid concentration reaches up to 100 ppm, would spread over a diameter of up to 4.7 km, the orange area, with HCl concentration of up to 22 ppm, would spread over a diameter of up to 8.6 km, while

the yellow area, where HCl concentration reaches up to 1.8 ppm, would spread over a diameter of up to 10 km for emergency exposure periods of 60 minutes.



Figure 3. Map of toxic vapour area prediction for a HCl leak

The location of the emergency event was the central part of the city, in the vicinity of Hyde Park, the Clinical Centre, the Faculty of Medicine, a stadium, several schools, museums, hotels, shopping malls, and other public and residential buildings containing several thousand people. Figure 3 indicates that toxic areas in the event of a maximum hydrochloric acid leak would spread across the Novi Beograd area, which is home to more than 200,000 people.

Acute and chronic effects of toxic vapours due to hydrochloric acid leak

Acute and chronic effects on the skin due to hydrochloric acid leak can manifest themselves as serious irritations (redness, swelling, and pain) and skin damage – chemical burns that can leave permanent scars or even lead to death.

Vapours or dispersed liquid of concentrated hydrochloric acid can irritate the nasal cavity, cause throat pain, suffocation, coughing, and shortness of breath at concentrations from 50 to 100 ppm. Chronic exposure can cause nasal and throat burns and lesions. Exposure to high concentrations ranging from 1,000 to 2,000 ppm over only several minutes can cause pulmonary oedema [9,10].

Lower vapour or dispersed liquid concentrations can instantly cause eye irritation and redness. Concentrated vapours, dispersed liquid, or the liquid itself can cause serious irritation, burns, and permanent blindness. Anticipated health effects following HCl exposure in healthy humans for up to 1 hour are shown in Table 2 [10].

Table 2. Anticipated health effects following HCl exposure in healthy humans for up to 1 h

Severity	Concentration (ppm)	Effects
Mild effects	≥ 5	Eye and nasal irritation, irritation of the throat, slight cough, headache; no significant pathological changes anticipated
Moderate effects	≥ 20	Frequent coughs, eye and nasal burning, shortness of breath, flu-like symptoms; mild inflammatory changes might occur in upper respiratory tract
Severe effects	≥ 100	Suffocation, chest pain, burning throat, disorientation, corneal opacity; significant ulceration, erosion, and inflammatory changes might occur in upper respiratory tract; inflammatory changes including pulmonary oedema might occur in the lower respiratory tract.

CONCLUSION

The forces and assets used in the fire and rescue unit intervention were sufficient to successfully eliminate the hazard of hydrochloric acid leak from a tank car. Valuable property was saved, including the tank car itself and other tank cars in the train, and casualties were successfully avoided. This paper analyzed the worst-case scenario of uncontrolled emission of hydrochloric acid toxic vapours and the acute and chronic human health effects. Successful operation by the fire and rescue units helped avoid potential harmful health effects on over 200,000 people.

REFERENCES

- [1] S. Basbas, C. Pyrgidis: "Model development for rail transportation of hazardous materials in Greece". Journal of Environmental Protection and Ecology, Vol. 2, No. 2, 2001, pp. 418-427.
- [2] Zakon o smanjenju rizika od katastrofa i upravljanju vanrednim situacijama ("Sl. Glasnik RS, br. 87/2018")
- [3] Todorović, B., Vilić, D.: "Vanredne prilike", Privreda publik, 1989, Beograd
- [4] D. Avramović, D. Mladan: "State of Emergency and Emergencies – Comparative Aspects of Terminology and Content", Teme, Vol. 38, No. 2, 2014, str. 767-781
- [5] B. Anđelković: "Occupational Safety in the Context of Contemporary Technological Changes", Safety Engineering, Vol. 2, No.1, 2012, pp. 47-53
- [6] Emergency Management Sector, Emergency Management Office Belgrade: "Report on the Analysis of a Technical Intervention Involving Hazardous Materials, Municipality of Savski Venac", 2011
- [7] ALOHA (Area locations of hazardous atmospheres) 5.4.4. Version: "Technical documentation, Environmental Protection association (EPA)", Seattle, Washington, USA, 2013.
- [8] Chemical Release Investigation Kit & Template for Local Health Departments: "Hydrochloric Acid Fact Sheet", May 2014
- [9] Health Protection Agency: "Hydrogen chloride/hydrochloric acid Toxicological overview", Version 1, Prepared by S Bull, CHAPD HQ, HPA, 2007
- [10] National Research Council (US) Subcommittee on Rocket-Emission Toxicants: "Assessment of Exposure-Response Functions for Rocket-Emission Toxicants", National Academies Press (US), 1998, Washington DC

BIOGRAPHY of the first author

Lidija Milošević was born in Kruševac, Serbia, in 1974. She received her bachelor's, master's, and PhD degrees from the Faculty of Occupational Safety in Niš. Her main areas of research include indoor and outdoor fire and



explosion protection and emergency management. She is currently working as an assistant professor at the Faculty of Occupational Safety in Niš, University of Niš.

ANALIZA VANREDNOG DOGAĐAJA USLED ISTICANJA HLOROVODONIČNE KISELINE PRI ŽELEZNIČKOM TRANSPORTU

Lidija Milošević, Emina Mihajlović, Martina Petković, Ivan Mijailović

Rezime: U ovom radu analiziran je vanredni događaj koji je nastao usled isticanja hlorovodonične kiseline iz vagon cisterne na Glavnoj železničkoj stanici u Beogradu. Sagledani su aspekti intervencije vatrogasno spasilačkih jedinica, sredstva i oprema koja se koristila prilikom intervencije, otežavajuće okolnosti i meteorološki uticaji. Izvršena je procena emisije toksičnih para hlorovodonične kiseline i sagledan je njihov uticaj na zdravlje ljudi.

Ključne reči: vanredni događaj, železnički saobraćaj, hlorovodonična kiselina, toksične zone, akutni i hronični efekti.

VLADIMIR STANKOVIĆ¹
DEJAN JOVANOVIĆ²
DEJAN KRSTIĆ³
VERA MARKOVIĆ⁴
NENAD CVETKOVIĆ⁵

^{1,3}University of Niš,
Faculty of Occupational Safety
^{2,4,5}University of Niš,
Faculty of Electronic Engineering

¹vladimir.stankovic@znrfak.ni.ac.rs
²dejan.jovanovic@elfak.ni.ac.rs
³dejan.krstic@znrfak.ni.ac.rs
⁴vera.markovic@elfak.ni.ac.rs
⁵nenad.cvetkovic@elfak.ni.ac.rs

ELECTROMAGNETIC ENERGY FROM A 1.8 GHz MOBILE PHONE ABSORBED IN A CHILD'S HEAD

Abstract: *The increased use of mobile phones causes public concern over possible harmful effects of electromagnetic radiation to which mobile phone users, primarily children, are exposed. This paper discusses the distribution of electromagnetic energy absorbed in a child's head originating from a mobile phone that emits a signal at the frequency of 1.8 GHz. As the human body comprises different tissues and organs, each of these needs to be described in terms of their electromagnetic properties. To that end, a child head model that contains twelve different tissues was used for numerical calculation of the penetrated electromagnetic field. The results of Specific Absorption Rate (SAR) distribution are presented for a horizontal cross-section of a child head model.*

Key words: mobile phone, child's head, specific absorption rate.

INTRODUCTION

Ever-increasing use of mobile phones by children, as well as the overall increase in use among adults, has led to considerable human exposure to electromagnetic radiation. Considering the variety of content offered in smartphones, they are used by all age groups. Everyday use of mobile phones raises the issue of the impact of electromagnetic radiation on humans, especially on children.

Exposure to electromagnetic radiation emitted by mobile phones depends on the phone model, antenna configuration, and signal strength. A weak signal produces higher exposure levels, since the device requires a high-quality signal reception.

Despite the concern over health effects of long-term exposure to RF radiation, the popularity of using wireless devices among children is growing abruptly, even among smaller children. There are numerous phones specially designed for children, some even containing applications for preschool children [1].

Most studies dealing with the impact of mobile phone electromagnetic radiation focus on determining the absorbed energy in a standard adult human head model. Standards and instructions regarding the limits of exposure to electromagnetic fields were developed based on research conducted for adults only [2]. Therefore, it is necessary to determine whether such safety limits are sufficiently valid for children as well.

The International Agency for Research on Cancer (IARC) has designated electromagnetic field radiation as possibly carcinogenic to humans and classified it within group 2B. This recommendation stems from the research on the increased incidence of malignant brain tumours [3].

This paper presents a child head model and a mobile phone model used to analyze the impact of mobile phone electromagnetic field on children. The Specific Absorption Rate (SAR) distribution is presented for a

horizontal cross-section of a child head model at the level at which the phone antenna is charged.

ELECTROMAGNETIC PROPERTIES OF TISSUES

SAR is the quantity used to determine potential harmful effects of electromagnetic field on human health. It is directly dependent on the electromagnetic properties of tissues and organs and it is defined as follows:

$$\text{SAR} = \frac{\sigma |E|^2}{\rho}, \quad (1)$$

where E is the maximum value of internal electromagnetic field, σ is tissue conductivity, and ρ is tissue density.

It is more practical to use the averaged SAR, which is defined as the ratio of absorbed power in the biological tissue and the mass of that tissue. The quantity is obtained by integrating the following expression:

$$\text{SAR}_{\text{av}} = \frac{1}{V} \int_V \text{SAR} dV = \frac{1}{V} \int_V \frac{\sigma}{\rho} |E|^2 dV. \quad (2)$$

Averaged SAR is usually calculated for parts of the tissue of 1g ($\text{SAR}_{1\text{g}}$) and 10g ($\text{SAR}_{10\text{g}}$).

Since the human body comprises multiple tissues and organs, each of them needs to be described in terms of their electromagnetic properties. These properties include relative dielectric constant ϵ_r , conductivity σ , and relative magnetic permeability μ_r [4].

These parameters depend on the type of tissue and the operating frequency of the radiation source. This is primarily due to different water content as well as organic content in tissues.

The maximum allowed SAR values for exposure to time-variable electromagnetic field sources are called basic restriction, and they are based on directly

observed health effects and biological indicators. They amount to 1.6 W/kg for SAR_{1g} [5] and 2 W/kg for SAR_{10g} [6].

MODELS OF A CHILD'S HEAD AND A MOBILE PHONE

Determination of the impact of mobile phone electromagnetic radiation requires the determination of the penetrated electromagnetic field in a child's head and the absorption of electromagnetic energy, which results in increased temperature inside the head. In addition to operating frequency and the distance between the source and the object, the shape of the anatomical child head model also plays an important role in electromagnetic energy absorption.

To make the results as faithful as possible to the real values, it is necessary to create a 3D child head model that corresponds to a real child's head in its anatomical and morphological characteristics (Figure 1).

Software applications for 3D design and electromagnetic field calculation using the finite element method were used for the development of numerical models. The applications include Autodesk 3ds Max [7] and CST Studio Suite 2014, specifically its part CST Microwave Studio, which is used for microwave calculations [8].

The child head model consists of the following tissues and organs: skin, fatty tissue, muscles, the skull, the jaw with teeth, the tongue, the eyes, vertebrae, cartilage, the spinal cord, cerebrospinal fluid, the brain, and the pituitary gland [9, 10, 11].

Electromagnetic properties of tissues and organs at $f=1.8\text{GHz}$ are shown in Table 1.

Table 1. Electromagnetic properties of tissues and organs at $f=1.8\text{GHz}$ [4]

	ϵ_r	σ (S/m)	ρ (kg/m ³)
Cortical Bones	11.8	0.275	1908
Brain*	46.1	1.710	1046
Cerebrospinal Fluid	67.2	2.920	1007
Fat	11.0	0.190	911
Cartilage	40.2	1.290	1100
Pituitary Gland	58.1	1.500	1053
Spinal Cord	30.9	0.843	1075
Muscle	53.5	1.340	1090
Eyes*	46.3	1.369	1052
Skin	38.9	1.180	1109
Tongue	53.6	1.370	1090
Teeth	11.8	0.275	2180

* Electromagnetic properties defined as average value

For the purpose of this study, an actual smart phone was used as the electromagnetic radiation source. The mobile phone comprises the following parts: antenna, the display, and the housing. Antenna was modelled for

a frequency of 1.8 GHz, with a reference power of $P=1\text{W}$ [12] and an impedance of $Z=50\Omega$.

RESULTS

Generally, owing to the propagation of electromagnetic waves, one portion of the energy penetrates a specific biological object and becomes absorbed. The difference of wave energy at the boundaries of a biological object (input and output energy) constitutes the absorbed energy. The term Specific Absorption Rate (SAR) was introduced because of the need to precisely define this absorbed energy.

The simulation performed for this study involves the case of the impact of mobile phone radiation on a numerical child head model when the phone is used in its conversation mode. The phone is positioned against the child head model's ear and slanted towards the face covering the entire earlobe.

Figure 1 shows the cross-section of the child head model with directions along which SAR distribution analysis was conducted.

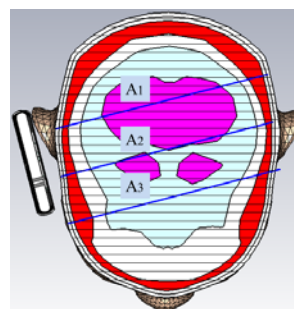


Figure 1. Cross-section and directions A1, A2, and A3 for result assessment

The values for the averaged SAR over 1g and 10g were calculated for this study. Figures 2 and 3 show the distribution of SAR_{1g} and SAR_{10g} inside the child head for a cross-section corresponding to the charge level of the PIFA antenna.

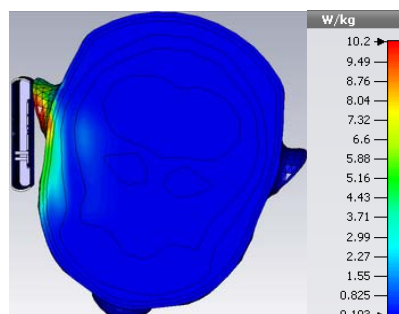


Figure 2. SAR_{1g} cross-section distribution

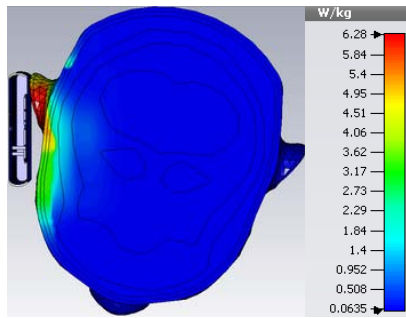


Figure 3. SAR_{10g} cross-section distribution

Figures 2 and 3 clearly indicate that the basic restriction are exceeded in the surface layers, primarily in the skin, fatty tissue, and muscles. The values go as high as 10.2 W/kg for SAR_{1g} and 6.28 W/kg for SAR_{10g} .

Figures 4 and 5 show the dependence of SAR_{1g} and SAR_{10g} values on the distance for different directions.

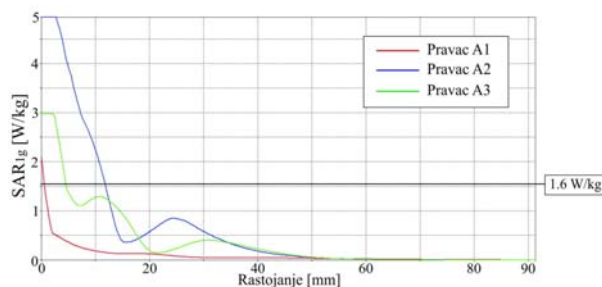


Figure 4. SAR_{1g} distribution along directions A1, A2, and A3

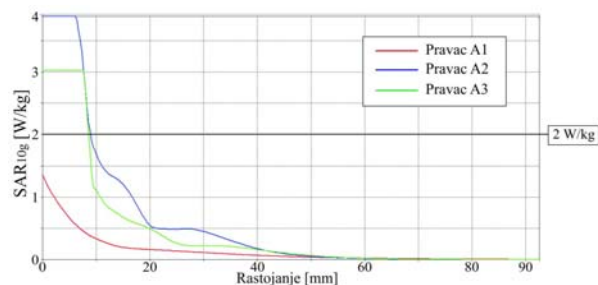


Figure 5. SAR_{10g} distribution along directions A1, A2, and A3

For the analyzed cross-section, the maximum SAR_{1g} value is about three times higher than the basic restriction, while the maximum SAR_{10g} values is about double the basic restriction. Both SARs have high values in tissues up to the depth of 10mm, after which their values drop below 2W/kg. After 50mm, the values become negligible or almost equal to zero, which means that electromagnetic energy is almost completely absorbed before it reaches this depth.

BIOLOGICAL EFFECTS

Numerous scientists have warned against long-term exposure to low-level RF radiation, which can cause an array of negative health effects, including malignant conditions, neurological disorders, immune system disorders, reproductive system disorders, hormonal changes, headaches, irritability, fatigue, cardiovascular effects, and others [13-17]

In several Swedish studies of the connection between mobile phones and tumours, the researchers searched the Swedish Cancer Registry for patterns of increased risk of acoustic neuroma and glioma after 10 years of mobile phone use. Since the evidence of risks that a prolonged use of mobile phones poses was strong, the authors concluded that "For people who have used these devices for 10 years or longer, and when they are mainly used on the one side of the head, the risk of malignant brain tumours is doubled, and even higher in case of people who have begun to use mobile phone before their 20 years" [13, 18, 19, 20].

According to a study of mobile phone use among children and adolescents (average age of 13), there is a significantly higher risk of brain cancer due to exposure longer than 2.8 years after the first use of mobile phone [21].

Several researchers attempted to find a connection between leukaemia and mobile phones. A study conducted in Thailand revealed a trebled risk of leukaemia in mobile phone users and more than a quadrupled risk for any type of lymphoid leukaemia [22].

Swedish neuroscientists studied the effects of RF-EM fields on neurons of young rats by placing a mobile phone on the side of the cage containing the rats, thus simulating electromagnetic radiation exposure similar to the use of phones by humans. The rats were exposed to mobile phones for 50 days over two hours per week, which resulted in damage to neurons in their brains [23, 24].

Children can be subject to harmful RF effects because their nervous systems are still developing, they have increasing levels of cell division, their immune systems are undeveloped, they have thinner skulls, and their brain tissue has higher conductivity. The RF penetration for children is greater in relation to the size of their head and they have a higher risk of lifetime radiation exposure than adults [25].

The risk of Attention Deficit Hyperactivity Disorder (ADHD) due to extended mobile phone use was found in a Korean study involving first grade schoolchildren, aged 7 and 8, as well as children aged 12 and 13 [26].

According to an empirical study from 2013, mobile phones were found to cause the so-called digital dementia [27]. This phenomenon is widely known as the *Fear of Missing Out* (FOMO) and it is becoming an increasing issue among children and young people.

There are also records of extended mobile phone use as a cause of stress, sleep disorders, and symptoms of depression among young people [28].

CONCLUSION

This paper covered the investigation of the impact of electromagnetic radiation from mobile phones using a numerical child head model. A modern smartphone model was used as the source of electromagnetic radiation. It consisted of a housing with a display and a PIFA antenna. The simulation concerned a case when the mobile phone antenna radiates at a power of 1W. The analysis was conducted for the operational frequency of 1.8GHz.

The distribution of electromagnetic field in the child head model was analyzed for several different directions along the same horizontal cross-section. The cross-section was selected so as to correspond to the cross-section with high mobile phone radiation values. The analysis of obtained SAR values showed that multiple tissues and organs had values exceeding the designated basic restriction for all directions.

At the given frequency for mobile phone radiation of 1.8 GHz, the obtained values for both SAR_{1g} and SAR_{10g} exceeded the basic restriction. The obtained values were as much as six times higher than the basic restriction for SAR_{1g} and about three times higher for SAR_{10g}.

For almost all directions, the areas with higher electromagnetic energy absorption included the skin, the fatty tissue of the head, the head muscles, and the skull.

REFERENCES

- [1] Cell Phones: technology, exposures, health effects, available at http://www.ehhi.org/reports/cellphones/cell_phone_report_EHHi_Feb2012.pdf
- [2] C. C. Gordon, T. Churchill, C. E. Clauser, et al. 1988: "Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics", Technical Report NATICK/TR-89/044. US Army Natick Research, Development and Engineering Center, Natick, Massachusetts. 1989. As cited in B. Beard, W. Kainz: "Review and standardization of cell phone exposure calculations using the SAM phantom and anatomically correct head models", Biomed Eng Online, Vol. 3, 2004, pp. 34.
- [3] IARC Classifies Radiofrequency Electromagnetic Fields as Possibly Carcinogenic to Humans, available at http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf
- [4] Dielectric properties of tissues, available at <http://www.itis.ethz.ch/itis-for-health/tissue-properties/database/dielectric-properties/>
- [5] ANSI/IEEE C95.1-1992, "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz".
- [6] Regulation of the limits of exposure to non-ionizing radiation, Official Gazette of RS, no. 36/09, December 2009.
- [7] 3ds Max, available at <http://www.autodesk.com/products/3ds-max/free-trial>.
- [8] CST Studio Suite 2012, available at <https://www.cst.com/Products/CSTMWS>.
- [9] V. Stanković, D. Jovanović, D. Krstić, V. Marković, M. Dunjić, "Calculation of Electromagnetic Field from Mobile Phone Induced in the Pituitary Gland of Children Head Model", *Military Medical and Pharmaceutical Journal of Serbia*, ISSN: 0042-8450, UDC: 613.168::616.2]:[537.531::616.432-053.2, DOI: 10.2298/VSP151130279S
- [10] V. Stanković, D. Jovanović, D. Krstić, V. Marković, N. Cvetković, "Temperature distribution and specific absorption rate inside a child's head", *International Journal of Heat and Mass Transfer*, Vol. 104, 2017, pp. 559-565, <http://dx.doi.org/10.1016/j.ijheatmasstransfer.2016.08.094>
- [11] V. Stanković, "Analysis of penetrating electromagnetic field from MOBILE phones using a numerical model of the child head in different microwave ranges", Doctoral dissertation, Niš 2018.
- [12] C95.3-2002 - IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100kHz-300GHz, <http://standards.ieee.org/findstds/standard/C95.3-2002.html>.
- [13] L. Hardell, M. Carlberg, K. H. Mild, "Epidemiological evidence for an association between use of wireless phones and tumor diseases," *Pathophysiology*, 2009.
- [14] L. Hardell, M. Carlberg, and K. H. Mild, "Pooled analysis of case-control studies on malignant brain tumours and the use of mobile and cordless phones including living and deceased subjects," *Int. J. Oncol.*, vol. 38, no. 5, pp. 1465-1474, 2011.
- [15] E. Cardis, "Brain tumour risk in relation to mobile telephone use: Results of the INTERPHONE international case-control study," *Int. J. Epidemiol.*, vol. 39, no. 3, pp. 675-694, 2010.
- [16] R. Cooke, S. Laing, and A. J. Swerdlow, "A case-control study of risk of leukaemia in relation to mobile phone use.," *Br. J. Cancer*, pp. 1-7, 2010.
- [17] T. S. Aldad, G. Gan, X.-B. Gao, and H. S. Taylor, "Fetal radiofrequency radiation exposure from 800-1900 mhz-rated cellular telephones affects neurodevelopment and behavior in mice.," *Sci. Rep.*, vol. 2, p. 312, 2012.
- [18] L. Hardell, A. Hallquist, K. H. Mild, et al.: "Cellular and Cordless Telephones and the Risk for Brain Tumors", *European Journal of Cancer Prevention*, Vol. 11, 2002, pp. 377-386.
- [19] L. Hardell, A. Hallquist, K. H. Mild, et al.: "Case-Control Study on the Use of Cellular and Cordless Phones and the Risk for Malignant Brain Tumors", *International Journal of Radiation Biology*, Vol. 78, 2002, pp.931-936.
- [20] L. Hardell, K. H. Mild, M. Carlberg, et al.: "Tumor risk associated with use of cellular telephones or cordless desktop telephones", *World J Surg Oncol*. Vol. 4, 2006; pp. 74.
- [21] D. Aydin, M. Feychting, J. Schuz, T. Tynes, T. V. Andersen, L. S. Schmidt, A. H. Poulsen, C. Johansen, M. Prochazka, B. Lannering, L. Klæboe, T. Eggen, D. Jenni, M. Grotzer, N. Von der Weid, C. E. Kuehni, and M. Roosli, "Mobile phone use and brain tumors in children and adolescents: a multicenter case-control study," *J. Natl. Cancer Inst.*, vol. 103, no. 16, pp. 1264-1276, 2011.

- [22] D. W. Kaufman, T. E. Anderson, and S. Issaragrisil, "Risk factors for leukemia in Thailand," *Ann. Hematol.*, vol. 88, no. 11, pp. 1079–1088, 2009.
- [23] J. L. Eberhardt, B. R. Persson, A. E. Brun, L. G. Salford, L. O. Malmgren: "Blood-brain barrier permeability and nerve cell damage in rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones", *Electromagn Biol Med.*, Vol. 27(3), 2008, pp. 215-229.
- [24] L. G. Salford, A. E. Brun, J. L. Eberhardt, et al.: "Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones", *Environmental Health Perspectives*, Vol. 111, 2003, pp. 881-883.
- [25] L. Kheifets, M. Repacholi, R. Saunders, E. van Deventer: "The sensitivity of children to electromagnetic fields", *Pediatrics*, Vol. 116(2), 2005, pp. 303-313.
- [26] Y.-H. Byun, M. Ha, H.-J. Kwon, Y.-C. Hong, J.-H. Leem, J. Sakong, S. Y. Kim, C. G. Lee, D. Kang, H.-D. Choi, and N. Kim, "Mobile phone use, blood lead levels, and attention deficit hyperactivity symptoms in children: a longitudinal study," *PLoS One*, vol. 8, no. 3, p. e59742, 2013.
- [27] A. K. Przybylski, K. Murayama, C. R. Dehaan, and V. Gladwell, "Motivational, emotional, and behavioral correlates of fear of missing out," *Comput. Human Behav.*, vol. 29, no. 4, pp. 1841–1848, 2013.
- [28] C.-F. Yen, T.-C. Tang, J.-Y. Yen, H.-C. Lin, C.-F. Huang, S.-C. Liu, and C.-H. Ko, "Symptoms of problematic cellular phone use, functional impairment and its association with depression among adolescents in Southern Taiwan," *J. Adolesc.*, vol. 32, no. 4, pp. 863–873, 2009.

ACKNOWLEDGEMENTS

This research was supported by project III43012 of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

BIOGRAPHY of the first author

Vladimir B. STANKOVIĆ was born in Niš, Serbia, in 1978. He received the degree in Engineering, M.Sc. degrees and PhD degree from the University of Niš, Faculty of Electronic Engineering. He is employed at the Faculty of Occupational Safety as an assistant professor, and he is the member of the Laboratory of Electromagnetic Radiation. His main area of research includes electromagnetic radiation.



APSORBOVANA ELEKTROMAGNETSKA ENERGIJA U GLAVI DETETA OD MOBILNOG TELEFONA NA 1.8 GHz

Vladimir Stanković, Dejan Jovanović, Dejan Krstić, Vera Marković, Nenad Cvetković

Rezime: Sve intenzivnija upotreba mobilnih telefona izaziva zabrinutost u javnosti zbog mogućih štetnih efekata elektromagnetskog zračenja kojima su izloženi korisnici ovih uređaja, prevashodno deca. U ovom radu je prikazana raspodela apsorbovane elektromagnetske energije u glavi modela deteta koja potiče od mobilnog telefona koji emituje signal na frekvenciji od 1.8 GHz. Kako se ljudsko telo sastoji od različitih tkiva i organa, svaki od njih je neophodno opisati odgovarajućim elektromagnetskim karakteristikama. Dat je prikaz modela glave deteta koji se koristi za numerički proračun prodrlog elektromagnetskog polja. Prikazani su rezultati raspodele SAR (SAR - Specific Absorption Rate) za horizontalni poprečni presek modela glave deteta.

Ključne reči: mobilni telefon, glava deteta, specifična stopa apsorpcije.

SIMONA KARAMANOLOVA¹

¹Academy at The Ministry of the
Interior in Sofia,
Fire Safety and Civil Protection
Faculty,

athletkata94@abv.bg

PHOTOVOLTAIC SYSTEMS FOR ELECTRICITY

Abstract: *The paper analyzes the trends of photovoltaic systems in Bulgaria. The types, the structure and the purpose of the individual elements which form photovoltaic systems have also been discussed.*

Key words: photovoltaic systems, elements, construction, types.

INTRODUCTION

With the reduction of energy stocks, the issue of energy supply is becoming more and more relevant. As energy costs rise, solar power is becoming a fast growing energy source. If the quick mining of minerals continues they will be exhausted very quickly. For this reason, the development of alternative sources of electricity, such as renewable energy sources, is increasingly advancing nowadays. The part of renewable energy sources is photovoltaic systems (PVS). Their use is progressing extremely fast, because of their efficiency and technology. In percent, 0,5 - 1% of global electricity is covered by photovoltaic systems. At the same time photovoltaic power has a capacity to produce 80 million kWh in one year. This is enough to cover the annual need for electricity for over 20 million households in the world [1].

Trends in the development of photovoltaic systems

The efficiency of a photovoltaic system is the measurement of how much of the available solar energy a solar cell converts into electrical energy. However, there has been a rapid growth in the number of these systems used. In fact, at the end of 2015, the proportion of photovoltaic systems used was not so high as other energy sources, although their development is the highest (fig.1) [2].

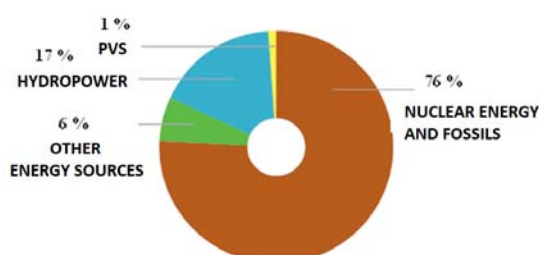


Figure 1. *The proportion of photovoltaic systems compared to total electricity consumption in the world*

It is analyzed that China holds the first position for using photovoltaic systems with installed 43,5 GW.

The European leader and the second in the world is Germany with 40 GW. From the beginning of the development of this type of renewable energy sources, Germany used to be the most iconic PV market for years. This has been achieved thanks to a combination of several elements: a long term stability of support schemes; the confidence of investors; the appetite of residential, commercial and industrial building owners for PV. Other countries in the world and in Europe, which show significant growth construction of PV systems are: USA - 7,3 GW, India - 5 GW, Korea - 1 GW, Australia - more than 1 GW, UK - 10 GW, Japan - more than 10,8 GW, Italy - 8 GW, Greece - 2,6 GW, Romania - 1,3 GW and Bulgaria - 1 GW (fig.2).

For the construction of photovoltaic systems in Bulgaria, the most important thing is relief. In the last years, the increase in photovoltaics has become visible in our country. In Bulgaria, there are more common ground photovoltaic systems. Until today, 1316 photovoltaic centrals with installed 1000,28 MW have been built (3-rd place of countries in Southeast Europe). But the trends show that facade and roof PVS have been increasingly used.

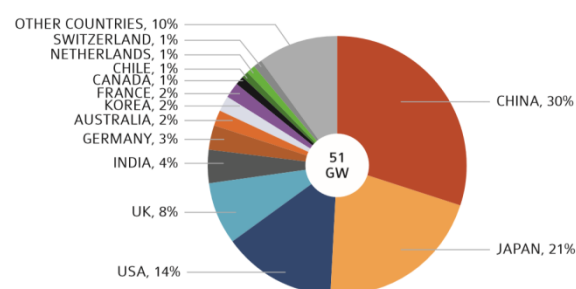


Figure 2. *Global Financial Market of photovoltaic systems in 2015 year*

Types of photovoltaic systems

Depending on their location, there are two types of PVS: ground and rooftop or building - integrated (fig.3).



Figure 3. Ground, facade and roof photovoltaic systems

For the construction of ground photovoltaic systems, the most important thing is relief. Ground - mounted PV systems are usually large, utility - scale photovoltaic power stations. The land, where are building these solar parks must be equal to a slight south slope. Also the frame can be built out of galvanized steel or aluminum and is attached to the ground with a concrete foundation. Ground photovoltaic parks should be built out of the settlements. Bulgaria owns the biggest ground photovoltaic park on the Balkan Peninsula - PV "Karadjalovo" with 60MW. The World biggest ground photovoltaic park is in Arizona (USA) - Agua Caliente Solar Project - 397MW. Integrating photovoltaics into a building's facade or roof are more common in European countries and their development is increasingly visible in Bulgaria. A building integrated photovoltaics system integrates photovoltaic modules into the building envelope itself, typically in the roof or facade (or both). These systems can simultaneously act as building envelope material and a power generator; offering the potential for material cost savings. For instance, building integrated photovoltaics may be used in place of traditional glass roofing, or skylight systems. They can also be incorporated into awnings of the building facade. It is important to know that in building integrated photovoltaics, some of their elements are located into the building.

Categories of photovoltaic systems

Photovoltaics is a method of generating power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. There are three categories of photovoltaic systems: Off - Grid (standalone), Grid - Tied and Hybrid systems [3].

Off - grid systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC and/or AC electrical loads. The most important thing for these standalone systems is that the only source of electricity is photovoltaic modules and their elements. To ensure access to electricity at all times, off-grid solar systems require battery storage and a backup generator.

Grid - Tied systems are designed to operate in parallel with and interconnected with the electric utility grid. A bi-directional interface is made between the PV system

AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance. This allows the AC power produced by the PV system to either supply on-site electrical loads, or to back-feed the grid when the PV system output is greater than the on-site load demand. At night and during other periods when the electrical loads are greater than the PV system output, the balance of power required by the loads is received from the electric utility.

Solar hybrid power systems are hybrid systems that combine solar power from photovoltaic system with another power generating energy source such as wind turbines or diesel generators.

Elements of PVS

The main elements of all photovoltaic systems are photovoltaic cells and inverters. Solar cells are the most important element, because they produce direct current electricity from sunlight. They are connected to each other in photovoltaic modules and photovoltaic modules form rows. Everyone knows that sunlight consist of direct and indirect light. All photovoltaic cells use not only direct light to generate electricity, but also indirect. Solar cells are made from different materials like: monocrystalline silicon, polysilicon and amorphous silicon (fig.4).



Figure 4. Photovoltaic materials - monocrystalline silicon, polysilicon and amorphous silicon

Inverters are used to convert the direct current (DC) electricity generated by photovoltaic modules into alternative current (AC) electricity, which is used for local transmission of electricity. It can be said that the inverters are the brain of PV system. Inverters can also provide diagnostic information. There are different types of inverters for each photovoltaic system: string inverters, central inverters and microinverters (fig.5). According to the type of photovoltaic systems they can also be autonomous, non-autonomous and hybrid.



Figure 5. Different types of inverters

Ground PV systems and rooftop or building - integrated PV systems have differences between each other. Ground PV system has a purpose for high power and often are connected with local electricity. Except PV cells and inverter, these PV systems also have: switchboard, controllers - switches, transformers and inverter coolers. All of them are in transformer inverter station (fig.6).

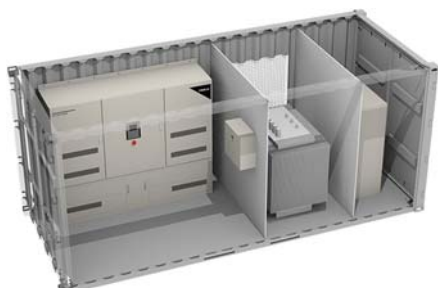


Figure 6. Transformer inverter station

For storing electricity in building - integrated PV systems, they have batteries. Batteries accumulate excess energy created by PV systems and store it to be used at night or when there is no other energy input. Also these systems have controllers. They prolong the battery life. The most basic function of battery controllers is to prevent battery over-charging. Principal scheme of building - integrated PV systems is shown in (fig.7) [2].



Figure 7. Principal scheme of building - integrated PV system:

1. Photovoltaic module;
2. DC protection;
3. Inverter - AC protection;
4. Battery;
5. Switchboard

Important moments during installation of PVS

A very important moments during the installation of photovoltaic systems are: sizing of cables, connecting the cables, the temperature of modules, the ventilation of the inverters, the structure and roofs of different buildings, the slope of the modules, how much is the sun shading and others. Wiring is an important task when installing PV systems. Cables must endure atmospheric conditions, UV radiation, height temperature and humidity of the environment. Properly

connected and sized wiring won't require any maintenance for years. Exterior modules and other PV components connection wires and cables should be used with UV radiation resistible insulation. The temperature range is also important. Exterior cables should allow for temperature range from -45°C to up to +80°C or even more. Application of such cables will enable efficient system operation for the next two decades or longer. From a fire-fighting point of view and in performance of the safety technique PV cables must be in protective tubes, which are underground. Shading is another factor, which is a problem in PV modules since shading just one cell in the module can reduce the power output to zero.

An unwanted side-effect is increasing the operating temperature of the PV module. These increases in temperature have a major impact on the PV module by reducing its voltage, thereby lowering the output power. Also very important thing is ventilation of the inverters. They emit a lot of heat, which can cause ignition and fire after that. When PV systems are built on roofs or are building - integrated, solar array frames are tilted so that modules face the sun. Array frames can be fixed, adjustable or tracking. Adjustable frames allow the tilt angle to be varied manually to maximize output throughout the year. This type of framing is used for stand-alone systems where the installation is usually on the ground. Some partially integrated systems use special mounting structures to hold the modules but require an additional waterproof membrane under the solar component. Solar tiles or shingles are designed to replace conventional tiles or roofing. They allow easy access to the rear of the tiles for ventilation and maintenance. The roof space must be ventilated to keep the tiles cool. PV roofing elements need to be compatible with any other roofing elements for structural and aesthetic reasons. Practice shows that flat roofs are the most efficient for PV systems.

PV systems are always installed on the rooftop or outdoor, ground integrated, which give high possibility of getting stuck by the lightning. This is very dangerous and predisposes the occurrence and development of a fire. Consequently, this would affect the level of power generated as well as economic issues and can cause major damage to all PV components. In order to avoid faults and equipment damages that lead to severe effects, the lightning protection in PV installations is very important and practically needed.

There are two types of protection for roof - mounted photovoltaic systems to secure the installation itself and the building - both inside and outside. The outside protects against direct lightning strikes by using one or more lightning strikes that attract lightning and lead them to the ground (fig.8). Inside lightning protection reduces the risk of overvoltages induced in the installation. Therefore, determination of the necessity for lightning protection and the risk connected to lightning is obliged to be evaluated as it is the essential ways in adopting the correct protective measures for the PV systems.



Figure 8. *Outside lightning protection*

CONCLUSION

The photovoltaic installation must be well maintained throughout its all service life. Each photovoltaic system must have independent monitoring to watch all PV system components and parameters, such as local temperature, solar radiation, instantaneous power, accumulated total energy and others.

As the number of photovoltaic systems and installation increases, the risk of fire is rising. These systems contain enough elements, which may cause a fire and also they can be dangerous for the firefighters. In order to deal with fires in photovoltaic installations, firefighters need to be very familiar with the PV device

because there are many factors that can lead to serious incidents.

REFERENCES

- [1] www.bpva.bg - Bulgarian photovoltaic association.
- [2] TRENDS 2016 IN PHOTOVOLTAIC APPLICATIONS, Survey Report of Selected IEA Countries between 1992 and 2015.
- [3] <http://energia.elmedia.net/bg/> - Year - I, Issue 1, December 2009 - ENERGY - Magazine for equipment, technology and engineering - Photovoltaic systems, use of solar energy to generate electricity.

BIOGRAPHY of the first author

Simona Karamanolova was born in Yambol, Bulgaria in 1994. She has graduated from the Academy of the Ministry of Interior in Sofia, Bulgaria and holds a Bachelor's degree in Fire Safety and Civil protection. She is an engineer of Fire Safety and Civil protection. Simona is currently working in Regional fire department - Opan, to the Regional Directorate of Stara Zagora. Right now she is studying master's degree in the Academy of The Ministry of Interior in Sofia, Faculty of Fire Safety and Civil Protection.



FOTONAPONSKI SISTEMI ELEKTRIČNE ENERGIJE

Simona Karamanolova

Rezime: *U radu su analizirani trendovi razvoja fotonaponskih sistema u Bugarskoj. Takođe, razmatrani su tipovi, struktura i namena pojedinih elemenata fotonaponski sistema.*

Ključne reči: fotonaponski sistemi, elementi, konstrukcija, tipovi.

SRĐAN GLIŠOVIĆ¹
ŽARKO JANKOVIĆ²
MILENA PETRIČEVIĆ³
NEBOJŠA MILKIĆ⁴

^{1,2}University of Niš,
Faculty of Occupational Safety
³HAUSER, Niš,
⁴NAUTILUS Ivago, Niš,

¹srdjan.glisovic@znrfak.ni.ac.rs
²zarko.jankovic@znrfak.ni.ac.rs
³milena_b@yahoo.com
⁴nmilkić@sbb.rs

NANOSAFETY - AN OCCUPATIONAL AND ENVIRONMENTAL CHALLENGE OF OUR TIMES

Abstract: *To predict occupational impacts and health consequences of a novel technology, it is necessary to timely investigate related hazards, emissions and other side effects. Nanomaterial-based technology is a typical advancement of our times, and it is being steadily applied in consumer products, antibacterial protection, energy production, remote sensing, and targeted drug delivery. Nevertheless, acceptable exposure limits at the workplace and handling protocols for the main nanomaterials are usually unavailable. The general population also might be exposed to diverse nano-substances in various lifecycle stages of different products. The safety aspects of producing and applying nanomaterials are gaining importance internationally, yet there is a limited amount of knowledge about their harmful effects. The intention with this article was to bring about a short survey on challenges that emerge with manufacturing and use of widely applied nanomaterials and nano-related products.*

Key words: Nanomaterials, Nanosafety, Risk Assessment, LCA

INTRODUCTION

Occupational and environmental consequences of emerging technologies typically remain unnoticeable until they are widely applied into products of mass consumption. To predict occupational impacts and health consequences of any novel technology, it is necessary to timely investigate related hazards, emissions and other side effects. However, appraisal of a long existing technology is very demanding, let alone when projections are to be made for a future development of a new one.

Nanomaterials are a typical technology advancement of our times, and they are being steadily applied in consumer products, antibacterial protection, photovoltaic technology, remote sensing, and targeted drug delivery. Nanotechnology is expected to deliver a spectrum of benefits to mankind by enabling reduced use of virgin materials and decrease in energy consumption, thus decreasing amount of byproducts and harmful release. In spite of the fact that nanosubstances exhibit unique properties that are suitable for a spectrum of novel applications, there are numerous related risks that have to be taken into account, mitigated and controlled.

Nano-related technology is not an industrial sector as such, but rather a bunch of technologies applied to improve diverse commercial products. Nano-substances are steadily being used in many commercial products because of their outstanding surface-to-volume ratio and reactivity [1]. Therefore, a timely identification of their occupational and environmental impacts is of utmost importance. Some researchers even indicate that nano-production-related impacts may prevail over benefits of applying nano-based products [2]. There is noticeable lack of information on artificial nanomaterial production and related emission rates [3]. One of the reasons is the fact that the manufacturers are

often unwilling to provide information on production volumes [4].

Acceptable exposure limits for the main nanomaterials at the workplace and handling protocols for them are usually unavailable. The general population also might be exposed to diverse nanosubstances in various life cycle stages of different products, such as anti-bacterial clothing, sunscreens, solar panels or batteries.

CHALLENGES RELATED TO NANO-SUBSTANCES AND THEIR APPLICATIONS

The amount of data indicating toxicity of data is growing. It has been shown that, TiO₂, ZnO and carbon nanotubes are cytotoxic to bacteria [5,6]; while nanosilver shows toxicity caused by release of metal [7,8]. It seems that fullerene is toxic to aquatic organisms and humans [9]. In spite of scientifically confirmed certain toxic effects, the mechanisms of nano toxicity is widely debated. Those nanosubstances are finding their way in aquatic environments, which finally leads to human exposure to their harmful effects.

Aggregation and transport of nanomaterials are under various scientific observations for years now. Many researches strive to reveal how solution chemistry, hydrodynamics and pollution concentration influence transport of nanoparticles (Figure 1). Some researchers² suggest assessments of production conditions and lifecycle impacts for certain nano-substances, such as carbonic nanomaterials.

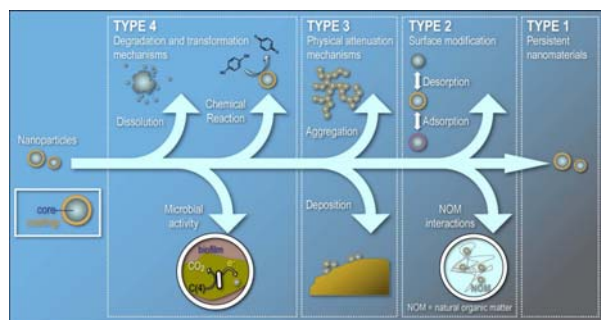


Figure 1. Nanoparticle fate (Credit: the International Council on Nanotechnology, Rice University, Houston, Texas, <http://icon.rice.edu>) [10,11]

In that respect, investigating life cycles of nano-enabled products might prove noteworthy, in spite of a considerable lack of data (Figure 2).

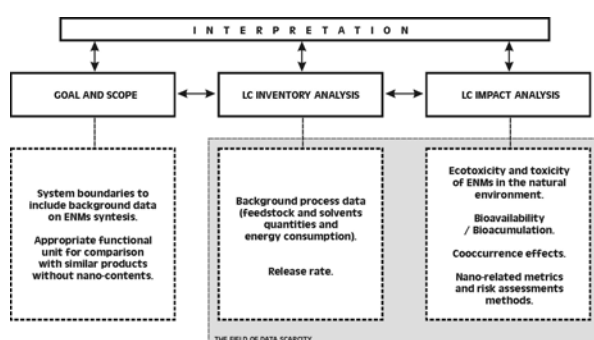


Figure 2. Nano-based product lifecycle data deficit (CREDIT: Glisovic, S., Pesic, D., Stojiljkovic, E. et al. *Int. J. Environ. Sci. Technol.* (2017) 14: 2301. <https://doi.org/10.1007/s13762-017-1367-2>) [12]

Nanomaterials are being released during raw material production, during consumer product manufacturing, during usage and through waste treatment and handling. Every single life cycle stage requires particular attention, beginning with occupational hazards related to nanoparticle and nano-enabled product manufacturing.

Broadly used nanomaterials

Probably one of the most widely used nanomaterials in industry is nano-phase of titanium dioxide (TiO₂) [13]. Nano-TiO₂ is broadly applied in products of mass consumption (e.g. sunscreen products and toothpastes) and for disinfection, but it was proven toxic for cells and bacteria¹⁶. Transport of manufactured nano-TiO₂ was investigated by Godinez and Darnault [14] revealing that in saturated porous media, the transport depends on flow velocity, and the presence of surfactants [14]. The detectable levels of concentration have already been reached in wastewaters [15]. The future use of nano-TiO₂ is expected to continue to increase exponentially, as well as related occupational and health hazards.

Nano-silver is also one of the most often applied nanomaterials in consumer products, although toxic to certain aquatic organisms. It seems that nano-silver in

surface water might be hazardous (Gottschalk et al. [16]). It is expected that a future enlarged release would cause various harmful effects. Although silver nanoparticles may not be of high toxicity, the reason for a particular concern is a probable increase of antibacterial silver applications, which would lead to increased emissions [17]. It is also used in consumer electronics because of remarkable conductivity. Silver is largely used in clothing for its antibacterial features, and clothes are the principal provider of silver nanoparticles emissions [18] which harmful effect still remains under investigation. Taking into account that, as a rule, the fabrication of nano silver is reported on a mass basis, to convert mass to particle number, the following equation was used [18]:

$$n = (6 \cdot m) / (\rho \cdot \pi \cdot d^3) \quad (1)$$

where m stands for mass flow; ρ for the density; while $d(m)$ denotes the average particle diameter.

OCCUPATIONAL RISKS AND SAFETY CONCERNS

Risks emerging from nano-technology have been tackled during the previous decade by many prominent institutions and researchers, such as Royal Society (RS Report) [19], The Nanotechnology Research Center (NIOSH Progress Report) [20], Kumar and colleagues [21], Miseljic and Olsen (2014) [22], etc. Obvious progress has been made in terms of safe handling of various nanomaterials, but safety goals would be achieved only if the advantages of nano-based products significantly prevail over the risks that follow with their manufacturing and use. A safe nanotechnology would require better understanding of nanoparticles interaction with a human organism and an eco-system during every phase of a nano-enabled product lifecycle.

It is still debatable, but quite probable, that nanosafety might fit into the conventional risk assessment approach that combines hazard identification with exposure assessment for appraisal of possible impacts on humans. Nevertheless, the toxic effects induced by inhalation of artificial nanomaterials are found to be related to their surface area, rather than to the concentration of the particles [23]. In addition, there is always uncertainty when one extrapolates findings derived from animal models to humans. There are available data on exposure of particular nanoparticles to human cells, but data are scarce on the effect of interaction with other chemicals or any possible synergistic effects due to combinations of nanosubstances [24]. The way out could be to apply EPA's so called Interaction-based hazard index (HI) [25] to estimate risks due to exposure to mixture of nanomaterials, but the obstacles for one such approach are both data deficit and lack of relevant research.

Latest findings from diverse research areas indicate that certain products and substances could be subjects of redesign in order to make them safer for humans and the environment. In the focus of nano reengineering are

both safe design and environmentally benign disposal of nanoproducts. Preventive risk appraisal for regulatory purposes is also of particular importance for nanotechnologies. Technology development should precede technology developments whenever it is possible [17]. By now there is a requirement that nano-containing products must be properly labeled.

DISCUSSION

Nano-related risk appraisal and mitigation obviously rely on information on types and quantities of nanomaterials applied. Few existing inventories undoubtedly offer valuable insight into nano-materials applied in products of mass consumption. The first EU nano-product inventory was established in 2009 by the European Consumers Organization [26]. The Danish Ecological Council and DTU Environment in 2012 formed The Nanodatabase - an inventory of nano-enabled products in the EU market [27]. Every product in the database comes with a short description of the nano-content, and a color code that denotes occupational, consumer and environmental exposure, as well as health hazards and environmental risks. Exposure potential color codes were designated in accordance with the intake pathways (dermal contact, respiration, digestion) and release potential. Also, an updated Nanotechnology Consumer Products Inventory (CPI), comprising over 1800 mass consumption products from 32 countries, was released in 2013 by the Woodrow Wilson International Center and the Project on Emerging Nanotechnology with aim to provide resources for consumers and researchers.

To increase nanosafety, the following areas of research might be of great importance:

- Collecting data to set permissible exposure limits for key nanomaterials in the workplace, in terms of human health effects;
- Development of standardized handling protocols for work with nanomaterials;
- Investigating suitability of current regulations for controlling environmental pollution by nanosubstances;
- Developing viable and verifiable methodology to cope with simultaneous exposure to more than one nanomaterial and related risk assessment procedures.

It is noteworthy that the Joint Research Centre of the EU Commission launched in 2011 the first European nanomaterial repository. The repository contains frequently used nanomaterials, such as silver nanoparticles, titanium dioxide, carbon nanotubes, zinc oxide, silicon dioxide and gold. Ultimately, the repository would lead to harmonized, science-based risk assessments, and thus contribute to responsible development of safe nano-enabled products.

CONCLUSION

Nano-based substances provide a range of benefits compared to traditional materials, and thus facilitate the development of novel applications. Hence, nanotechnology is arguably one of the most promising technical developments for decades. However, still there is a need for a comprehensive regulatory framework that would cover fields of occupational safety, human health, and environmental protection. Apparently, both workforce and general public remain unaware of risks associated with technology advancements mentioned. Any attempt to design a feasible nano-related risk mitigation strategy would obviously require a multidisciplinary approach. The first step should be identification of the critical gaps in the body of knowledge that must be addressed in order to achieve safe manufacturing, handling and disposal of nano-based products. With development of standardized handling protocols for work with nanomaterials and with new regulation enforcement, a new era in safety science would commence, and occupational risk assessment would reach new frontiers.

REFERENCES

- [1] Felekis, T. A., and Katsaros N., Environment and nanotechnology: a promising challenge. *J. Environ. Prot. Ecol.*, 2009, 10 (4), 1146–1154.
- [2] Nentwich M, Greßler S. Nano and the environment—part I: Potential environmental benefits and sustainability effects. NanoTrust-Dossier No. 026en, March 2012: <http://epub.oew.ac.at/ita/nanotrust-dossiers/dossier026en.pdf>. Accessed 10 Sept 2018
- [3] Hendren CO, Mesnard X, Droge J, Wiesner MR (2011) Estimating production data for five engineered nanomaterials as a basis for exposure assessment. *Environ Sci Technol* 45:2562–2569. doi:10.1021/es103300g
- [4] Kushnir, D., and Sanden, B. A., Using topic models to monitor and map technological development: retrospective exercise after twenty years of carbon nanomaterial patenting, Ph.D. Thesis, Environmental System Analysis, Chalmers University of Technology, Goteborg, 2012.
- [5] Xia, T., Kovochich, M., and Liong K., Comparison of the Mechanism of Toxicity of zinc oxide and cerium oxide nanoparticles based on dissolution and oxidative stress properties. *ACS Nano*, 2012, 2 (10), 2121–2134.
- [6] Kang, J. L., Moon, C., Lee, H. S., Lee, H. W., Park, E. M., Kim, H. S., and Castranova, V., Comparison of the biological activity between ultrafine and fine titanium dioxide particles in RAW264.7 cells associated with oxidative stress. *J Toxicol Environ Health Part A*, 2008, 71, 478–485.
- [7] Mahendra, S., Huiguang, Z., Colvin, V. L., and Alvarez, P. J., Quantum Dot Weathering Results in Microbial Toxicity. *Environ. Sci. Technol.*, 2008, 42 (24), 9424–9430.
- [8] Benn, T. M., and Westerhoff, P., Nanoparticle Silver Released into Water from Commercially Available Sock Fabrics, *Environ. Sci. Technol.*, 2008, 42(11), 4133–4139.

- [9] Wiesner, M. R., Hotze, E. M., Brant, J. A., and Espinasse B., Nanomaterials as possible contaminants: the fullerene example. *Water Sci. Technol.*, 2008, 57 (3), 305-310.
- [10] ICON, Advancing the Eco-Responsible Design and Disposal of Engineered Nanomaterials, An International Workshop. International Council on Nanotechnology, Rice University, Houston, Texas, No. 5, 2010.
- [11] Alvarez, P., Colvin, V., Lead J., and Stone, V., Research Priorities to Advance Eco-Responsible Nanotechnology. *ACS Nano*, 2009, 3 (7), 1616-1619.
- [12] Glisovic, S., Pesic, D., Stojiljkovic, E. et al. *Int. J. Environ. Sci. Technol.* (2017) 14: 2301. <https://doi.org/10.1007/s13762-017-1367-2>
- [13] Papageorgiou, D. G., and Bakoglidis, K., Use of Nanomaterials for the Improvement of Various Industrial and Biomedical Applications. A Review, *J. Environ. Prot. Ecol.*, 2012, 13 (2), 593-602.
- [14] Godinez, I. G., and Darnault, C. J. G., Aggregation and transport of nano-TiO₂ in saturated porous media: Effects of pH, surfactants and flow velocity. *Water Res.*, 2011, 45 (2), 839-851.
- [15] Kiser, M. A., Westerhof P., Benn, T., Wang, Y., Pérez-Rivera, J., and Hristovski, K., Titanium Nanomaterial Removal and Release from Wastewater Treatment Plants. *Environ. Sci. Technol.*, 2009, 43 (17), 6757-6763.
- [16] Gottschalk, F., Sonderer, T., Scholz, R., and Nowack, B., Modeled Environmental Concentrations of Engineered Nanomaterials (TiO₂, ZnO, Ag, CNT, Fullerenes) for Different Regions. *Environ. Sci. Technol.*, 2009, 43, 9216-9222.
- [17] Glisovic, S. Life Cycle Modelling in Life Cycle Analysis of Nanoparticles: Risk, Assessment, and Sustainability (ed. Vaseashta, A.), DEStech Publications, Lancaster, PA, 2015, pp. 55-95.
- [18] Arvidsson, R., Molander, S., and Sandén, B A., Impacts of a Silver-Coated Future: Particle Flow Analysis of Silver Nanoparticles. *J. Ind. Ecol.*, 2011, 15 (6), 844-854.
- [19] The Royal Society and The Royal Academy of Engineering, Nanoscience and nanotechnologies: opportunities and uncertainties. Report, The Royal Society Publications, UK, London, 2004.
- [20] Nanotechnology Research Center, Filling the Knowledge Gaps for Safe Nanotechnology in the Workplace. A Progress Report from the NIOSH, Department of Health and Human Services Centers for Disease Control and Prevention National Institute for Occupational Safety and Health, USA, 2004-2011.
- [21] Kumar, A., Kumar, P., Anandan, A., Fernandes, T. F., Ayoko, G. A., and Biskos, G., Engineered nanomaterials: Knowledge gaps in fate, exposure, toxicity, and future directions. *J. Nanomater.*, DOI: 10.1155/2014/130198, 2014.
- [22] Miseljc M, Olsen SI (2014) Life-cycle assessment of engineered nanomaterials: a literature review of assessment status. *J Nanopart Res* 16(6):2427. doi:10.1007/s11051-014-2427-x
- [23] Oberdorster, G., Stone, V., and Donaldson, K., Toxicology of nanoparticles: a historical perspective. *Nanotoxicology*, 2007, 1 (1), 2-25.
- [24] Petrov, L., Iliev, V., Elias, A., Tomova, D., Li Puma, G., Photocatalytic properties of modified TiO₂ coatings for purification of waste water and air. *J. Environ. Prot. Ecol.*, 2007, 8 (4), 881-909.
- [25] US EPA, Supplementary guidance for conducting health risk assessment of chemical mixtures. EPA/630/R-00/002, Cincinnati, Ohio, USA, ORD/NCEA, 2000.
- [26] BEUC (2016) The European Consumer Organization. <http://www.beuc.org>. Accessed 28 Aug 2018
- [27] Nanodatabase (2016) The Danish Consumer Council. The Nanodatabase. <http://nanodb.dk>. Accessed 28 Aug 2018

ACKNOWLEDGEMENTS

Extended content on the subject is available in International Journal of Environmental Science and Technology, Springer, doi 10.1007/s13762-017-1367-2, and authors seize the opportunity to thank the Journal for opportunity given to share their findings with international scientific community.

BIOGRAPHY of the first author

Srdjan Glisovic is an Associated Professor of University of Nis. He graduated from University of Nis (mech. engineering), and defended his doctoral dissertation at University of Novi Sad (environmental science). His research interests comprise:

industrial ecology, LCA, LCM, and sustainable design. Dr Glisovic is the author or coauthor of over 80 papers published in national and international journals or conference proceedings.



NANOBEZBEDNOST - IZAZOVI ZAŠTITE NA RADU I ZAŠTITE ŽIVOTNE SREDINE NAŠEG DOBA

Srđan Glišović, Žarko Janković, Milena Petričević, Nebojša Milkić

Rezime: *Da bi se predvideo dugoročni uticaj bilo koje nove tehnologije na ljudsko zdravlje i biofizičko okruženje, neophodno je blagovremeno istražiti relevantne rizike, emisije i ostale neželjene efekte. Tehnologije zasnovane na nanomaterijalima su tekovina savremenog doba i sve češće ulaze u sastav proizvoda široke potrošnje kao sredstvo za antibakterijsku zaštitu, ali se primenjuju i u energetici, u senzorima za detekciju polutanata, ili za preciznu administraciju medikamenata. Međutim, vrednosti prihvatljivih nivoa izloženosti nanočesticama na radnom mestu najčešće nisu dostupne, kao ni protokoli za bezbedno rukovanje najrasprostranjenijim nanomaterijalima. Najšira populacija takođe može da bude izložena dejstvu raznovrsnih nanosupstanci tokom različitih faza životnog ciklusa mnogih proizvoda. Bezbednosni aspekti proizvodnje i primene nanomaterijala dobijaju na značaju širom sveta, ali su saznanja o njihovim štetnim efektima još uvek veoma oskudna. Ovaj rad predstavlja nastojanje da se prikaže kratak pregled izazova koji proističu iz proizvodnje i upotrebe široko primenjenih nanomaterijala, kao i proizvoda koji se zasnivaju na upotrebi nanosupstanci.*

Ključne reči: nanomaterijali, nanobezbednost, procena rizika, analiza životnog ciklusa (LCA)

ANA STOJKOVIĆ¹

¹University of Niš,
Faculty of Occupational Safety

¹ana.stojkovic@znrfak.ni.ac.rs

RECYCLING PLASTIC MATERIALS AND IMPACT ON HUMAN HEALTH

Abstract: *Plastic materials are chemically resistant, cheap, lightweight, with a wide range of physical and optical properties. Plastic materials are most commonly used for the manufacture of various types of packaging, although they have been increasingly used for the production of a wide range of components in almost all branches of modern industry. The possibility of reprocessing and recycling is yet another advantage in economic and environmental point of view. However, there are numerous studies of the World Health Organization that discuss the toxicity and carcinogenicity of plastics during processing and subsequent exploitation. There is a tendency in the world to substitute plastic masses for “green materials”. In analogy to this, the paper presents the technologies for the recycling of plastics, their characteristics and the impact of their use on human health.*

Key words: recycling, plastic materials, health.

INTRODUCTION

Synthetic materials are substances that do not occur in nature, or rather, they would not exist without human intervention. However, today they play an important and ubiquitous role in everyday life. They are widely accepted for their diversity and their ability to be used in various fields: from the auto industry, through food packaging and building insulation to electronic devices and furniture. Recycling of plastic implies a chain and comprehensive process. Plastic waste is first sorted because there are several types of plastic that is recycled. And for each type, there is a special label on the basis of which plastic recycling is done. Materiality of the material has a central importance in the recycling process. As a rule, this similarity can be achieved by a previous relatively expensive classification. In order to obtain high quality plastic weights, only the same plastics should be processed. Separation of plastic materials can be broken down into recognition and separation. Characterization and full identification of plastic materials is an extensive job, which requires complex analytical procedures and state-of-the-art equipment. However, in some cases, only the assessment or orientation determination of the type of tested plastic material is sufficient. Simple and fast identification methods have been developed and adopted for such purposes. Recognizing the used polymeric packaging is the simplest if it contains a recycling label with the specified type of polymeric material from which it was made. When separating plastics, the crushed plastic material is sorted according to its physical properties such as density, networking and electrical conductivity. For industry, the separation processes are based on the difference in density. By means of these processes, fractions of up to 98% of purity can be separated from the mixture of plastics.

Difficulties occur when separating soft PVC types. The principle of hydrocyclone technique is based on the separation of fractions of different specific masses (density) in the field of the action of the centrifugal force. In addition to these methods of separation, flotation procedures are also known, separation based on different electrical conductivity, and the like.

By chemical recycling, plastic materials are decomposed into polymers of smaller molecular weights (usually liquids or gases), which are used as raw materials for the production of new petrochemical products or plastics. In the last few years, much attention has been paid to this recycling approach in order to produce different types of fuel from plastic waste. Some polymers can be profitably processed by adopting this approach. Polyethylene terephthalate (PET), certain polyamides and polyurethanes can be effectively depolymerized. The resulting chemicals can then be used to produce a new plastic that does not differ substantially from the initial untreated polymer.

The average generation of municipal solid waste in the EU is 520 kg per person per year and is projected to increase to 680 kg per person per year by 2020 [1]. In Serbia, on average, 0.87 kg of municipal waste per capita is generated, representing 320 kg of waste per person per year. [2]. Plastic packaging material is the packaging material with the highest growth rate in the last decade. Even within the EU, there is a wide range of priorities in the management of solid municipal waste, from those that are largely focused on landfilling to those focused primarily on incineration, while the percentage of recycling varies considerably.

METHODS OF PROCESSING PLASTIC WASTE

Used plastics products can be reused or processed using different methods, depending on the target set. The most common processing methods are:

- melting, without changing or changing the macromolecular structure very little;
- chemical, hydrolysis or alcoholism monomers can be obtained, or organic materials, such as gases and oils, can be obtained by hydrogenation from the starting material;
- controlled burning, whereby energy and combustion products are obtained as carbon dioxide and water.

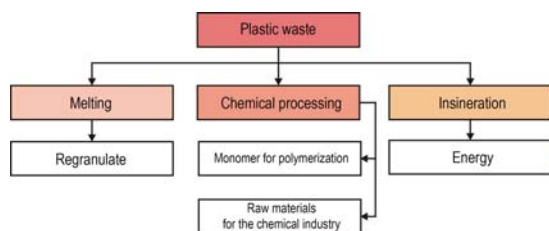


Figure 1. Methods of preparation of plastic waste

Melt processing. Thermoplastic regeneration is one of the oldest and most common recycling processes. The basis of this recycling method is the ability to re-melting as much as possible in thermoplastics. After grinding and pressing plastic waste using special devices and final separation and transfer, the output material is regranulated, the warehouse is still used for various purposes.

Chemical processing. Chemical processing can be divided into two groups. Processes of processing in which macromolecules (polymers) are translated into low molecular weight substances. Thus, polymers obtained by polycondensation or polyaddition reactions can be degraded to the starting monomers in the presence of certain reagents. In this way, many types of plastic materials such as polyesters, polyamides, polyurethanes, polycarbonates, etc. can be processed. because they have chemically active and easily shared connections. These procedures can be covered by the general term - solvolysis. Depending on this, in the presence of a solvent, the action takes place (alcohol, water, etc.), it is about hydrolysis, alcohols, glycolysis, aminolysis or methanolysis. The use of recyclates obtained by these procedures is still limited. The use of methanolysis or glycolysis in the PET packaging processing is known. This process produces raw materials for the production of heigenic pure PET or PUR, which can also be used for food packaging. [3,4] Analysis of the results achieved so far in PET recycling and specific goals in plastic recycling for the period 2015-2019. still shows a negative trend because the goals adopted are twice lower than the actually

collected and recycled quantities of PET waste, which results in insufficient investments in the development of infrastructure for the collection of packaging waste and the difficult operation of PET recycling plants in Republic of Serbia.[5]



Figure 2. Average annual quantity of PET packaging in the Republic of Serbia

Processes of processing in which hydrocarbons in the form of gas or oil can be obtained from a macromolecule containing plastic waste, which can be further processed by petrochemical processes in refineries. This group of methods can be carried out by reductive (hydrogenation or pyrolysis) or oxidative (synthesis gas production) mode. These methods are known as: degradative extrusion, hydrogenation, pyrolysis, and gasification.



Figure 3. Model of targets

Increasing the targets and increasing investment in the PET waste collection infrastructure would make it possible to increase the quantity of recycled PET by 2020 by 5,000 tons. This growth would enable the annual revenue from collecting PET waste to increase by EUR 1.25 million, and recycling revenues by EUR 2.72 million. At the same time, the increase in collected and recycled volumes would lead to the creation of new jobs. The burning of plastic waste results in the utilization of plastic waste and the generation of energy. Considering that virtually the total energy of oil is preserved in plastic products, it is of great use that oil energy is accumulated in plastic products, used for energy purposes, but only at the end of their useful

cycle. This method of utilization of plastic waste should only be applied in cases where waste can no longer be recycled in other ways. Since plastic materials have relatively new materials, there are still many open questions about their deposit for a longer period of time. Studies have shown that the decomposition process has the effect of thickness of plastic material. While the processes of disintegration occurred in the foils and thinner parts, the thicker parts did not show any visible degradation. Also, the experiments found that microorganisms do not have any influence on the degradation of certain types of plastic materials such as PP and PE, while in other species, for example, with polystyrene or polyurethane, they accelerated the degradation process. For now, plastic materials together with other waste are deposited in landfills for solid municipal waste. It can be assumed that due to the lesser space in the future, the costs of depositing will rapidly increase and that today's waste management solutions will not be able to maintain. It should be emphasized that plastic materials in regulated landfills are the smallest polluters of watercourses, because they are not dissolved in water, and also do not pollute the air.

IMPACT ON HUMAN HEALTH

Most of the polymers in pure state are due to poor physical properties of low value. For the purpose of improving or altering the chemical, mechanical and physical properties of the polymer, various additives are added. Additives are a complex group of certain chemical derivatives and minerals that play a key role in creating unique polymers. Different stabilizers (durability) are distinguished, softeners (which ensure flexibility), paints, antistatic agents, biocides, foams, lubricants, and many others.

Additives protect the polymers from the influence of heat, environmental and aging, and have a number of other useful functions (antimicrobial, antistatic, acting as antioxidants, absorbing UV radiation, etc.). They can be deliberately added with a specific goal such as increasing the flexibility or durability to heat, and there may be unintentional add-ons. With deliberately added additives, their quantity and chemical characteristics are known. If there are unintentional additives, their chemical composition, properties and concentrations are unknown, and they can cause a serious analytical problem.

Some additives (paints, stabilizers, softeners, etc.) may contain certain heavy metals or their ions that can pose a threat to health if they migrate from the system. Most are chronic poisons, so you should carefully monitor their use and regulate the amount. Another problematic group is the residues of the polymerization process, such as monomers and oligomers that can be poisonous. Between chemical substances that exist in the material and additives can interact and thus create new, unknown chemical substances that can be hazardous to human health.

Today, more than 70,000 synthetic chemicals have been identified, with the introduction of about 1,000 new ones every year. Most of these chemicals are labeled "harmful to human health" or "toxic", although, unfortunately, only 7% of them have been properly tested to detect their effect on human or other life forms. It is therefore very important to learn the facts and to know the possible effects of these materials on human health.

According to the United States Organization for Safety and Health Administration (OSHA), the general distribution of harmful chemicals is:

- chemical substances dangerous to health, eg carcinogenic, irritant substances that can damage organs such as the lungs, skin, eyes, etc.
- physically dangerous chemical substances, eg. flammable and explosive substances, gases under pressure in which there is a risk of fire and explosion.

It is important to note that harmful chemical or physical matter can be toxic under some conditions, and harmless under another, depending on the dose and some other parameters. In most cases, the oxygen and water vapor permeability properties, or CO₂ permeability (for carbonated drinks), are important for packaging. For that reason, multilayer polymers are used because they provide a good combination of these properties at an acceptable price. When several polymers are combined into multiple thin layers, several properties can be combined (for example, the PE layers are watertight and the layers of poly (vinyl alcohol) (PVAL) are oil-tight). When using multilayer structures, the possibility of multiple migration of matter must be considered (migration can occur from various layers, since each layer can have different additives such as phthalates and bisphenol A which are used as a softener). These contaminating chemicals may come into contact with food by migrating or go into the gaseous phase, so a person can inhale them. The disadvantages of such multilayer polymers are seen in the way they are treated as waste. A large number of additives are used to improve the shape, appearance and production of food packaging materials, so the provisions of the law on their use are constantly updated. The EU Directive 2002/72/EC (and Amendment 2004/19/EC) contains a list of assessed monomers and supplements and the specific migration limit (SML). SML is the amount of matter in milligrams (mg) allowed to pass from the polymer to kilogram (kg) of food. The World Health Organization (WHO) in its latest report, which presents the results of a study on the effects of chemicals on hormonal disorders and human health, carried out in cooperation with the UN Environment Program (UNEP), warns that dangerous substances that can cause cancer, asthma, allergies, infertility and the birth of children with defects, is everywhere in our homes.[6]

WHO warns that certain compounds used in children's toys, PVC carpentry and floors, car dashboards and

even credit cards have a bad influence on the human hormone system and state that the prohibition of these compounds may be the only way to protect themselves.

The report states that chemical substances from the group of **phthalates** harm fertility, and are associated with an increasing rate of illness in children, including even leukemia. Phthalates are esters of phthalic acid and aliphatic alcohols. These are liquids that are added to plastics to increase their mobility. They are also known as plasticizers or softeners. That means they are in almost everything that surrounds us.

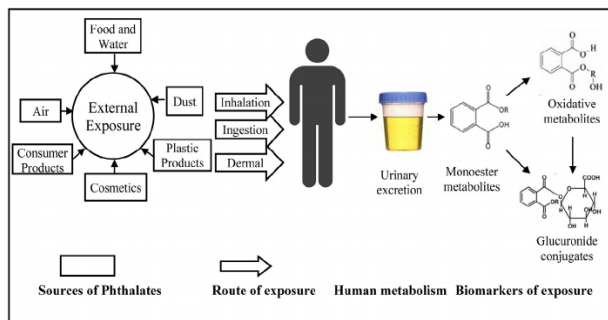


Figure 4. General scheme of human biomonitoring of phthalates by urinary metabolite analysis. [7]

Problem is also the **bisphenol A** that is also found in the things that surround us everyday - bottles, cans, sunglasses. According to the WHO report, it affects the natural hormones that are crucial to our growth, development and health, and can cause brain damage, developmental retardation, autism and various other disorders.

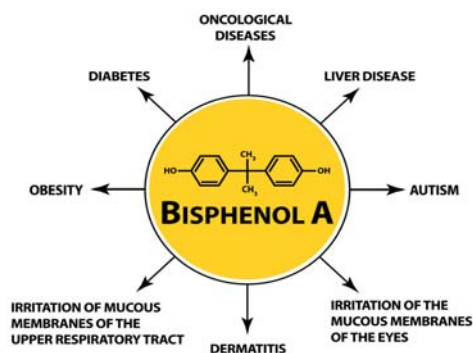


Figure 5. Bisphenol A and impact on human health

Dioxin is a chemical compound based on chlorine, which is obtained artificially in the production of polyvinylchloride (PVC). In addition, it is used for the production of herbicides and warfare. Dioxin belongs to very toxic compounds. According to official research, when comparing toxicity, the most toxic is toxin botulism, then tetanus toxins, third most commonly in diphtheria toxins, and fourth in dioxin. Polyvinyl chloride (PVC) is used in large quantities in

modern life, but its by-product is dioxin one of the most toxic chemical compounds. The largest quantities of dioxins are released by burning plastic. In environments where large amounts of plastic are burned, smoke returns to the atmosphere as a precipitate or rainfalls on the ground, and contaminates the soil. Through plants and grass, dioxin is introduced into animal organisms and it is eating it and we enter it into our organism. In small quantities, dioxin is released when plastic bottles and bags are heated or frozen. What is worrying is that very small amounts of dioxins that are not so dangerous are deposited in our body, in the fat tissue, until they reach dangerous carcinogens as well as deadly doses.

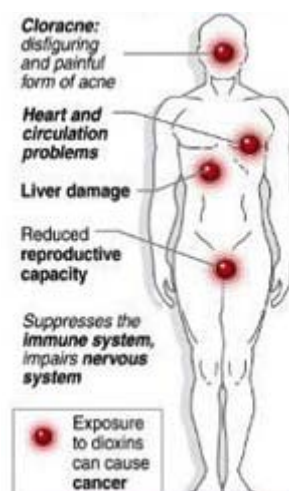


Figure 6. Dioxin and impact on human health

The effect of dioxin on the body. What makes dioxin a very dangerous compound is the fact that in small quantities it can cause a decrease in the immunity of an organism (immunosuppression). By immunity, every organism is highly susceptible to the effects of viruses and bacteria. The death dose of dioxin for the mouse, in laboratory conditions, is one microgram per kilogram of body weight, and one hundred times the lower concentration of dioxin is carcinogenic. Chlorine dioxin by its action in stronger doses on the skin can cause the appearance of acne that is very long treated. It has been proven that dioxin in small quantities also causes many diseases: tumors, endocrine gland diseases, diabetes, skin diseases, and affects the fertility and brain functions (memory) negatively. Systematic overviews and statistical data processing in the most developed countries have revealed an increase in the number of malignant diseases, and one of the causes is the introduction of dioxins in the body (inhalation and nutrition). [8]

American scientists have found that dioxin is released even when heating or cooling foods in plastic containers. It is particularly dangerous to heat food in plastic packaging in a microwave oven. The same report states that human health is very damaging to pesticides used in agriculture, as evidenced by

"significant evidence" of their association with prostate cancer in men.

On the other hand, in Germany, the carpentry industry drops out of plastic and switches to wooden joinery, and such doors, windows and doors at a very low price reach the stores selling carpentry in our country. German building codes extend materials that will not affect the loss of some raw materials over the next 200 years. Simply put, the PVC window will not be recycled for at least the next 50 years due to its lifetime, and this may cause the import of basic raw materials. In order to prevent the outflow and ALU raw materials on the carpentry, the action of replacing woodwork with woodwork began.

CONCLUSION

The share of plastics in production rose sharply in the early 1960s. The introduction of cheap petrochemical production and new technologies have announced a lifetime of plastic. Analogously, the huge problem is waste of plastic origin. In the last twelve years, there has been a sharp increase in the use of plastic packaging, and the production of PET bottles has increased by 700%, while the recycling increase is only 5%. It should be emphasized that for decomposition of PET packaging it takes between 100 and 1000 years. Plastic waste takes up huge landfills. By recycling 1 ton of PET, 4.8 m³ of landfill is preserved.

Toxic substances that are found in polymeric migration materials migrate to food, human skin and its endocrine system. In the same way, they cross into the soil, the sea, the groundwater, in other words, the entire ecosystem. It is necessary to know how these substances affect human health and its environment. Due to their multiple nature, it is not possible for all of them to examine and know their toxicity, carcinogenicity or any other form of harm. Everyday research leads to new knowledge, and thus to the answers to the questions asked. If polymers are observed globally, then it can be freely said that their application represents a very small risk to health and the environment, because it must be borne in mind that many other environmental pollutants and various other effects on human health such as stress, diet, numerous harmful ingredients in food and water (which have not come from polymeric materials), bad human habits (smoking), etc., are far more dangerous and have a very harmful effect on human health. Because of this, polymers are an essential material for the future, and for that reason their use will grow and expand. Also, the harmful effect should not be neglected, but further

research and development of their polymers with much less harmful effect is necessary.

REFERENCES

- [1] EEA 2008, Better management of municipal waste will reduce greenhouse gas emissions. Copenhagen, Denmark: European Environment Agency.
- [2] G. Vujić, B. Batinić, N. Stanisavljević, D. Ubavin; M. Živančev, Analysis of the state and strategic framework for waste management in the Republic of Serbia, Recycling and sustainable development, 2011, 4 (1), 14-19.
- [3] J. Hopewell, R. Dvorak, E. Kosior, Plastics recycling: challenges and opportunities. Philosophical Transactions of the Royal Society B: Biological Sciences, 2009, 364 (1526), 2115-2126.
- [4] E. J. North, R. U. Halden, Plastics and Environmental Health: The Road Ahead. Reviews on Environmental Health, 2013, 28(1), 1-8.
- [5] Strategy waste management for the period 2010-2019., Official Gazette of RS No. 29/10
- [6] B. Nedić, D. Jovanović, M. Čupović, Polymers In The Food Industry and it's Harmful Health Effect, XVIII International Scientific Scientific Meeting ECOLOGICAL TRUTH, Faculty of Engineering - Bor, Apatin, 2010.
- [7] A. Ramesh Kumar, P. Sivaperumal, Analytical methods for the determination of biomarkers of exposure to phthalates in human urine samples, Trends of Analytical Chemistry 75, 2016, 151-161
- [8] B. Nedić, D. Jovanović, Application of polymers in the food industry and their harmful effects on health; 5. Symposium Recycling Technologies and Sustainable Development, Technical Faculty - Bor, Soko Banja, 2010.

BIOGRAPHY of the first author

Ana Stojković was born on 16.02.1989. in Niš, and is still living there. She has graduated from the Faculty of Occupational Safety in Niš in 2015, with excellent grades. She started her PhD studies in 2015. Since 2009, she has been working at the



Faculty of Occupational Safety as a trainee researcher within the project of the Ministry of Education of Science and Technological Development for Young People.

RECIKLAŽA PLASTIČNIH MATERIJALA I UTICAJ NA ZDRAVLJE LJUDI

Ana Stojković

Rezime: *Plastični materijali su hemijski rezistentni, jeftini, lagani, sa širokim opsegom fizičkih i optičkih osobina. Primena plastičnih materijala je najzastupljenija za izradu raznih vrsta ambalaža, mada je zastupljenost plastičnih materijala sve više uzela maha u izradi širokog spektra komponenti u skoro svim granama moderne industrije. Mogućnost ponovne prerade i reciklaže, još jedna je u nizu prednosti koja se pre svega ispoljava gledano sa ekonomskog, ali i ekološkog aspekta. Međutim, postoje brojna istraživanja Svetske zdravstvene organizacije koja ukazuju na toksičnost i kancerogenost plastičnih masa pri njihovoj preradi i kasnijoj eksploataciji. U svetu postoji tendencija supstitucije plastičnih masa alternativnim „zelenim materijalima“. Analogno tome, u radu su dati prikazane tehnologije reciklaže plastičnih masa, njihove karakteristike i uticaj njihovog korišćenja na zdravlje ljudi.*

Ključne reči: reciklaža, plastične materije, zdravlje

MANDALINA MILOŠEVIĆ¹
RAŠA MILANOV²
BOJKA BLAGOJEVIĆ³

¹"Vetervit" d.o.o.-Minicevo
²Ministry of Health - Belgrade
³University of Nis,
Faculty of Occupational Safety

¹ vetervit.minicevo@yahoo.com

FISHING AND THE RISK OF DECREASE IN MARINE DIVERSITY

Abstract: *Fish has an existential importance in the diet of the population of poor countries, while in developed countries fishery is fueled by the consumption of fish and fish products because of their high nutritional value. Almost one third of humanity uses fish meat in the diet as the main source of proteins of animal origin. Overfishing of fish and seafood in seas and oceans is a direct consequence of the impact of socio-economic factors. Some countries, such as Argentina, the Scandinavian countries, the countries of the Asian continent and Russia, base their economic growth and value their BDP on the basis of exports of fish caught in their waters. Of these countries, Argentina occupies a leading position, and one of the most renowned firms dealing with catch and processing in Argentina is "Pescargen" S.A. Institutional conditions, environmental conditions, socio-economic, biological and technological factors have influenced the pattern of exploitation of the fish in the seas and oceans. Due to fishing and treatment technology advancement (grading, filleting, canning) there is a rapid exploitation of fish from the ocean, far from the coast.*

Key words: fishing, freezing and processing, on-board freezing method, Patagonian hake fish, risk

INTRODUCTION

Fishing is one of the oldest existential crafts. People have used fish as a basic source of proteins, minerals and vitamins in their diet since ancient times. Due to its nutritional value and relatively low price, fish meat takes an important place in the diet of the population. In some countries, fish meat and seafood are the main source of meat in the diet of the population. Fish meat is approaching nutritional values of the meat of warm-blooded animals, but by the richness of biologically valuable proteins, minerals and vitamins, it is far ahead of all kinds of meat. Of particular importance is the essential amino acid in fish meat proteins which play a major role in human nutrition, since it stimulates the creation and regeneration of cells in the body. The insignificant content of connective tissues is why it is easily digestible in the human body, and is therefore highly valued in human nutrition. (Petrovic, Elezovic, 1996).

Fish are classified into: Marine fish (Small blue fish, Large blue fish, White fish, Wild fish, Headbands) and Freshwater fish (freshwater fish of open water, Freshwater fish from the fishpond).

The quality of fish also depends on the species, age, sex, season, origin, nutrition, as well as the way of catching, freshness, or length and conditions of transport and storage. Adult fish contain more fat, while meat of fish that feed on small fish is more pronounced taste. A number of fish species are considerably tastier than others, which means that the quality depends on the type of fish in the first place (Petrovic, Elezovic, 1996)

FISHERY HISTORY

The first fishing boats were rafts and boats built of timber, truncheon trunk, leather and bark of wood, back to the Neolithic age more than 9,000 years ago. The first major venture in fishing was made by Egyptians who, more than 2,500 years ago, made primitive overseas vessels for catching fish in the open sea.

In the 15th century, in Netherlands developed the technology for making fast sea ships "stray" in the hunting of Herring was developed in Netherlands. In the 19th century, the so-called "huts" appeared in English fishing ports, a special type of fishing boats which influenced and changed the way of fishing on open seas.

Modern fishing

Today, ships for catching fish in the oceans are technically and technologically modernized and have very high capacities, starting from small ones that can store up to 30 tons of fish per day, to the big ones that can transport over 300 tons of fish. These are modern ships, the so-called "trawlers-net".

Freezing of newly caught fish on board itself has become more and more popular in recent years. In modern catches on oceans, fish are quickly frozen and stored at low temperatures on the boat itself. The fish that is frozen at sea is of very good quality compared to that frozen on land. Also, a longer period of time is needed for the distribution of fish, if it is caught at sea, and then transported in factories to land for further processing, and then transported again on board to buyer. Modern long-distance vessels have standardized dimensions and freezing equipment. The temperature must be constant in the range of -35°C to -40°C.

RISK FACTORS AFTER THE SEA DIVERSITY

Overfishing of fish in seas and oceans is one of the greatest ecological risks for marine biodiversity. Reduction of the fish fund, which has drastically increased in the last twenty years, is a direct consequence of the increase in the number of inhabitants on earth. The constant increase in the population in the world is also conditioned by the increase in food consumption, which further causes a greater dependence on natural resources. Fisheries have an existential significance in the diet of the population of many poor countries that have access to the sea, and in developed countries fishery is encouraged by the consumption of fish and fish products because of their high nutritional value. Third of mankind on the planet, fish is the main source of proteins of animal origin, which is why there is a danger that we will completely lose one of the most important foods in our diet.

An excessive catch of fish in seas and oceans is disproportionate to natural renewable potentials - so many fish are caught, so the fish fund does not come to restore it. The United Nations Food and Agriculture Organization (UNFAO) recently issued a warning about the overfishing of fish that states: "The situation is extremely serious, because 75% of the World Fish Fund is fully exploited, overburdened or endangered by extinction."

World sea fishing and production have been growing nearly five-fold over the past forty years. In this period fish catch has risen from 18 million tonnes in 1970 to 86 million tonnes in 2010, while in 2015 it exceeds 100 million tonnes. In the period from 1970 until today, the catch of fish on the world level is growing at a rate of 6% to 10% annually. This growth of fish catch drastically violates marine diversity and balance in marine ecosystems.

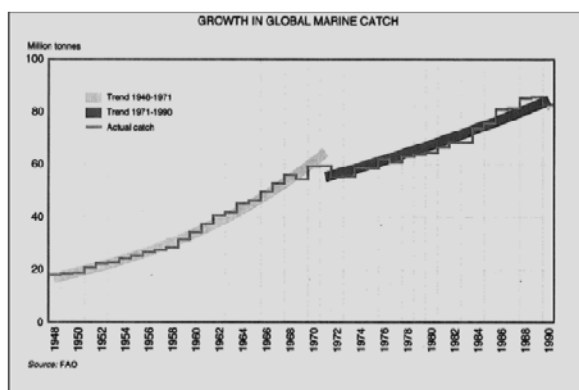


Figure 1. Growth of global fish harvest (FAO 2010)

Climate changes

A very important factor that affects the reduction of marine diversity is climate change. These changes, which are more and more pronounced from day to day, drastically affect the quality of the waters of the sea and the oceans, and result in a large migration of fish, a

reduction in their fund in a certain area, a change in their physical and chemical composition, and even the complete disappearance of certain fish kinds of.

Physical-chemical factors of sea water directly affect the living world in the water. The unfavourable conditions caused by the increase in the water temperature due to global warming, reduced oxygen content, and the increase in acidity and the change of pH water from the sea, have resulted in a drastic change in marine diversity. These changes affect the migration of fish and their quest for richer areas of food, that is, fish migrate to greater depths and cooler waters that have more oxygen.

According to new research, parts of ocean-free oxygen have quadrupled in the last 50 years. In this period, oceans lost about 2% of dissolved oxygen, which is crucial for maintaining marine diversity. These zones with very little oxygen are known as "dead zones".

Reduction of oxygen and pH changes is a limiting factor when it comes to the functioning of ocean ecosystems, the diversity of the sea world and geochemical cycles and is directly related to the capacity of the fish fund in seas and oceans. (FAO and UNEP, 2017; Gilles Hosch, 2017)

MODERN FISHING TECHNOLOGY

Fishing, as one of the most important maritime activities, includes activities: fishing, fish processing, fish trade, fish products and seafood.

Today, at the fast pace in the world, many forms of fishing technology, especially marine, are developing, because the sea and the oceans are the richest fish. High nutritional value and quality of fish meat and seafood, require extraordinary technology of catching on ships, long-haul, processing, transport and traffic. The other side and merciless struggle for profit has caused the construction and use of large ships that can capture huge quantities of fish at deeper depths.

There are two types of technologies for catching fish on open seas and oceans:

- 1) Ships that catch fish and warehouse are in the depots in low temperature, until they enter the port, where the fish is sent for further processing in factories on land. These factories are mostly located in the ports themselves.
- 2) Ships that have a whole technological process of processing and freezing on board shipboard on-board freezing technologies. These are dedicated ships with a capacity of 300 tons at 24h. They have a so-called sternal slope to draw the net onto the high deck. From there, through the holes of the fish, the fish is thrown into the wells on the lower deck, where it is cleaned, washed, packed and frozen, and if necessary conserved or processed. The temperature at which the processed and packaged fish must be very low from -35°C to -40°C, and these ships also have refrigerators. The crew on these boats has at least 50 sailors and fishermen and 60 to 200 factory workers trained for processing fish.

These boats are known as factory boards, and some ships of large companies have storage capacities up to 1,000 tons and can be kept at sea for up to 120 days. They mainly fish in the southern parts of the Atlantic and the Indian Ocean. (FAOUN Statistics, 2015; Vetervit d.o.o, 2010)

According to the UNIMO (International Maritime Organization of the United Nations) for 2016, 4 million fishing commercial vessels have been registered, 1.3 million are ships with closed space. All have been mechanized and 40,000 of these ships have over 100 tons of load capacity. Two-thirds of these ships, on their decks, are engaged in some of the processing operations of fisheries.

Socio-economic factors have largely influenced the pattern of exploitation of the fish world in the seas and oceans. The emergence of science and mechanics, which has been enhanced by electronic harvesting plants, the modern design and production of ever larger boats that are sustainable and that use deep-sea detection and navigation devices have affected the efficiency and development of overexploitation of excess fish.

Fishing in Argentina

Some countries, such as Argentina, the Scandinavian countries, the countries of the Asian continent and Russia, base their economic growth and value their BDP based on exports of fish caught in their waters. Argentina has a remarkable geographical position, the large volume of fishing, as well as two large ports for the arrival of fishing boats. Fish in this area of the Atlantic Ocean are of high quality and great biological value.

In this paper, we will list only some of the fish species that are most represented in the catch in the southern Atlantic Ocean (area Patagonia), and have the highest growth in harvest for the past forty years. At the same time, these fish species are the most sought after in European as well as in the world market, but due to uncontrolled catch, they have become deficient:

1) Hake lat. *Macrurus Magellanicus* - the Southwest Atlantic, catchment area (FAO Area 41). This fish belongs to the Cod family. It feeds on smaller fish such as Enchovy and small Shrimps and Lobsters, lives about 20 years, and receives full maturity in the fifth year of life. Ships for catching fish with large capacities must strictly adhere to the allowed quotas and recommendations for catch, time period (season), geographic coordinates on the ocean (catch zones) for which they have been granted permission and can not deviate from it. (K.M.Gjerde, 2006; FAOUN, 2016).

Quotas that are approved for catching fish on seas and oceans are less and less every year, so the fish on the market are getting smaller. For some species of fish, catching licenses are not issued in recent years, so demand for these fish species is higher.

CONCLUSION

Institutional conditions, environmental conditions, socio-economic, biological and technological factors have influenced the pattern of exploitation of the fish in the seas and oceans. In the case of technical and technological improvement of fishing, it is possible to rapidly exploit fish from the ocean far from the coast and factories. The emergence of science and mechanization, the modern design and the production of ever larger ships, have influenced the efficiency and development of over-harvesting fish on the oceans. All of this has led to the disturbing fact that entire populations of some species of fish are on the verge of extermination. This trend of overcrowding led to the overall disturbance in the equilibrium of the ecosystem of the sea and the oceans and the reduction of the diversity of the fish world.

Introducing fishing quotas on seas and oceans will significantly reduce the intensity of overfishing of fish and seafood, and reduce the degradation of marine diversity. It will greatly contribute planned use of natural resources of sea and oceans, as well as the renewal of the fish fund over a long period of time.

The adoption of these restrictive measures and their consistent implementation in practice, today and in the future, will be the most critical environmental and socio-economic challenge of the century.

REFERENCES

- [1] M. Petrovic, I. Elezovic - Veterinary Specialist Institute - "Applicable legislation in the field of veterinary-sanitary, health and quality control of animals for slaughter and animal products", Nis, 1996.
- [2] "Vetervit" d.o.o. - Minicevo, documentation on imports of frozen sea fish from Argentina in the period from 2005 to 2010.
- [3] C. Woodard, Ocean's End: "Travels Trough Endangered Seas", 2001.
- [4] Food and Agriculture Organization of the United Nations - FAOUN 2015, "Fisheries and Aquaculture statistics 2015".
- [5] G. Hosch, F. Blaha "Seafood traceability for fisheries compliance", Rome, 2017
- [6] Food and Agriculture Organization of the United Nations - FAOUN: "Global and regional policies and strategies for identification and protection of VMEs", 2016.
- [7] K. Juris, M. Gjerde, "High seas Marine protected areas and deep-sea fishing", 2006
- [8] Food and Agriculture Organization of the United Nations and UNEP - Ecosystem - Based Management of Fisheries: "Opportunities and challenges for coordination between Marine Regional Fishery Bodies and Regional seas conventions", 2017

BIOGRAPHY of the first author

Mandalina Milosevic, was born in Serbia, September 1, 1978 in Zajecar.

She graduated from the Faculty of Occupational Safety at Nis - University of Nis in 2004.

From 2004 she has been working in the company "Vetervit" doo-Minicevo, where she is in charge of import/export, quality control, health safety of goods and storage of frozen sea fish from Argentina. She is also responsible for environmental protection and workplace safety.



RIBARSTVO I RIZIK PO MORSKI BIODIVERZITET

Mandalina Milošević, Raša Milanov, Bojka Blagojević

Rezime: Ribarenje ima egzistencijalni značaj za prehranu stanovništva siromašnih zemalja, dok je u razvijenim zemljama ribarstvo podstaknuto konzumacijom ribe i ribljih proizvoda zbog njihove velike prehrambene vrednosti. Skoro jedna trećina čovečanstva koristi riblje meso u ishrani kao glavni izvor proteina životinjskog porekla. Prekomerno izlovljavanje riba i morskih plodova u morima i okeanima je direktna posledica uticaja socijalno-ekonomskih faktora. Pojedine zemlje kao sto su Argentina, Skandinavske zemlje, zemlje Azijskog kontinenta i Rusija, zasnivaju svoj ekonomski rast i vrednuju svoj BDP na osnovu izvoza ribe izlovljene u njihovim vodama. Među navedenim zemljama, vodeće mesto zauzima Argentina, a jedna od najpoznatijih kompanija koja se bavi izlovom i preradom ribe u Argentini je "Pescargen" S.A.

Biološki, ekološki, socio-ekonomski, i tehnološki faktori su uticali na obrazac eksploatacije ribljeg fonda u morima i okeanima. Usled tehničko-tehnološkog unapređenja ribarenja (klasiranje, filetiranje, konzerviranje), uključujući i poznavanje "on-board freezing" tehnologije, došlo je do ubrzane eksploatacije ribe, daleko na pučini mora i okeana.

Ključne reči: ribarenje, on-board freezing metod, patagonski oslić, *macruronus magellanicus*, rizik.



SOCIAL AND HEALTH ASPECTS OF OCCUPATIONAL SAFETY



ŽARKO ĆULIBRK¹

¹Faculty of Security and Protection,
Banja Luka,

¹ culibrk.zarko@fbzbl.net

SOCIAL ASPECTS OF OCCUPATIONAL SAFETY - SOCIAL EMERGENCIES IN INDUSTRY

Abstract: *The main topic of this paper is social emergencies in the industry. The methods used in this paper are explicative and descriptive analysis, and content analysis. Social emergencies in the industry are briefly described, with an emphasis on civil emergencies in the industry. Strike, workplace violence, mass panic and stampede are described. The aim of this paper is to highlight the importance of awareness about social emergencies in the industry, as an important segment of occupational safety.*

Key words: social emergencies, social emergencies in industry, industrial security and protection, occupational safety.

INTRODUCTION

Social emergencies are the result of the conscious human action and not the consequence of random accidents or natural forces. In their essence, these emergencies can be of military (armed) character and non-military (unarmed) character. Social emergencies are often complex and consist of military and non-military elements at the same time, and there are social emergencies (e.g. terrorism) that can be of military, non-military or combined character. Some of the social emergencies have existed for centuries (e.g. wars), while others are a result of the technology development (e.g. cyber terrorism). Social emergencies in industry are most often associated with: civil emergencies, i.e. civil unrest, which occur in the industry in the form of strikes and the workplace violence; the use of explosive devices and failures in industrial plants (in the form of diversionary attacks and sabotage); and individual industrial accidents, i.e. accidents at work, which are considered to be industrial emergencies. Being familiar with the social emergencies in the industry is a significant aspect of the industrial safety and protection.

CIVIL EMERGENCIES AND OTHER SOCIAL EMERGENCIES IN INDUSTRY

Civil emergencies are the result of the civil disorder or occur in places where more citizens are present. Civil unrest or riots are gatherings of citizens which could jeopardize the functioning of the rule of law and can occur in multiple forms. One of the forms is the protests that can be in the form of peaceful street demonstrations, can be violent protests, and can also turn into a civil rebellion. The rebellion can lead to uprisings or revolutions, and to an armed rebellion. A significant form of the civil unrest is strikes, the workplace violence, and the violence at sports events. Each of these forms, even those "most calm", represent a certain civil emergency. For industrial safety, the most important civil emergencies are strikes and the workplace violence.

Strike

The strike represents an organized, collective and simultaneous cessation of work or slowdown, or in some other way disabling the development of a normal production process or the work process in one or more economic organizations or social activities, performed by workers or employees, in order to achieve or obtain certain economic or political rights. The strike is one of the basic and the most important trade union means of a struggle. There are various forms of strikes, but they can all be divided into two basic types: strikes in which production is completely suspended and strikes in which production slows down or stops for a short time.

The first type includes: partial strikes (when a part of the workers of an organization or a branch of industry is striking); individual strikes (strike by workers of one economic organization); local strikes (strike by workers in one place or region); and general or national strikes (the strike in an entire industry or across the country). In all these cases, workers generally stop production and leave jobs. However, there are cases where production is stopped, but jobs have not been abandoned with the goal of more successful fight against strike-breakers. Such a strike is called a sit-down strike.

The second type includes various forms of strikes like: a) a strike in which production does not stop, but the pace and labour productivity are reducing; b) a strike in which workers of individual plants or sections alternately, by agreement, stop production for one to two hours a day; c) a strike in which workers stop working for five to thirty minutes several times during the working day; d) a strike in which workers cease to work overtime or cease to do jobs that do not correspond to their qualifications or do not correspond to the jobs stipulated by the collective agreement; e) a special type of the strike is the case when workers begin to do some socially useful jobs for which they have not received an order and permission from anyone they eventually managed to get their work paid (undertaken by unemployed workers, and most

common in Italy); f) a strike in which workers do not stop production, but occupy a factory or other organization in which they work and keep it under their control until they are satisfied with their demands (firstly carried out in Poland in 1831) g) a strike in which workers do not stop production, but begin to strictly and fully respect and apply work rules and instructions (especially technical rules), which often leads to the fact that production has to stop or at least slow down (most common in the Great Britain).

Any strike may be official or unofficial, depending on whether the union organization has given its consent for strike's performance or has not approved it. According to the aim to be achieved, the strike can come as a result of a struggle to improve the position of the workers or to preserve the rights previously acquired and as a means of providing assistance to workers who are already striking, in which case we have the so-called "a strike of solidarity" which contributes to the success of the strike to which support is provided and thus develops the awareness of the workers about the need for a unique approach and struggle.

Every highly developed society is very sensitive to disturbances that occur in the functioning of the economic mechanism due to strikes. The more developed economy, the damage caused by strikes is greater. The state, as a rule, in all the larger labour disputes directly mediate between the two sides in the dispute and trying to obtain them for amicable solution.

The significance and size of the strike movement is determined by three basic criteria - the number of strikes, the number of their participants and the number of lost working hours. By combining these elements, along with other facts, conclusions can be drawn on the growth or decline of the strike movement. In socialist countries, in which a strike as an institution is not accepted, it is in practice known as the cessation of work. The cessation of work has not been declared illegal, but it is a possible form of expressing dissatisfaction, and the struggle of workers against decisions and situations that constitute a violation of their legal and legitimate interests and rights.

Workplace violence

With the development of industry, workplace violence is also gaining importance. Workplace violence, irrespective of whether it is initiated by the members of the working collective or not, poses a threat to both the employees of the company and its management. Thus, workplace violence has become the leading cause of death in the workplace in the leading industrialized country - the United States, and has raised the issue of the quality of industrial safety and protection. According to statistics from the US National Institute of Occupational Safety and Health (NIOSH), during the 1980s more than 750 homicides were registered in the workplace. In addition, according to the National Safe Workplace Institute (NSWI), in 1992 there were about 110,000 cases of workplace violence. Workplace

violence is not a new phenomenon, but in recent decades the frequency and severity of incidents involving this form of violence have been increased. According to the U.S. Bureau of Labor Statistics, during 1993, there were 1,063 homicides in the workplace, of which 59 were committed by employees or former disgruntled workers. According to the same data in 1993, there were 22,396 physical attacks in the workplace, of which more than 1,300 were the consequences of the violence of workers or former employees. In addition to incidents involving employees and former workers, the number of incidents involving entering the working space of the unemployed, including unhappy spouses, has increased drastically. The most prominent organization, with a significant number of cases of workplace violence, is the US Postal Service, in which during the observed 18 months 1992-1993 were registered 500 cases of assaults by employees on managers and 200 cases of assaults by managers on employees.

Generally, workplace violence is defined as a physical attack, physical harassment, threat or verbal harassment at the workplace. Although incidents involving threatened behaviour - a threat by throwing a bomb or threatening vengeance, are statistically less closely monitored, they are also likely to rise.

Mass panic and stampede

An important form of civilian emergencies is a mass panic, which occurs when a greater number of people are affected by certain fears. The mass panic can be manifested as a long-term fear (often driven by false rumours), which may lead to disturbances in the normal functioning of the society, or as the current situation which may lead to fatal outcomes (panic in case of fire, a terrorist attack, etc.). The mass panic can be manifested as a reaction of the population because of the fear of a potential or actual disaster at a nearby industrial plant or as an immediate reaction of employees due to an accident in the company. A panic among employees can cause a stampede - an uncontrolled movement of a large number of people in a relatively small area, for example, in closed facilities, at large events, mass public gatherings, etc. The cause of the stampede may also be a panic, but there are the stampede when there is no panic (for example, the movement of people in a narrow space).

Other social emergencies in industry

Other social emergencies in industry include actions and procedures that endanger the industrial production, life and health of employees and the environment in which the industrial plant is located. The most important are the use of explosives, intentional failures and individual workplace accidents.

The use of conventional explosives and improvised explosive devices can also cause emergencies, which are reflected, for example, in the killing and wounding of people (workplace violence), in the collapse of buildings, etc. Explosive devices can be used in a war,

in terrorist activities, in diversionary attacks, in sabotage, etc.

Intentional failures in industrial plants can also be caused by diversionary attacks and sabotage. Diversionary attack is a deliberate, covert and unexpected action carried out by individuals, groups or organizations, state organs or armed forces in peace and war that use explosives to destroy people, inflict material damage, or achieve political and psychological effects. Sabotage is a deliberate and concealed causing of material damage to labour organizations and the economy, by an attack on economic goods by individuals or groups who work in facilities where damage appears to be.

Individual workplace accidents are deaths, injuries, illnesses and other workers' suffering due to negligence, improper handling of resources, fire, explosions, radiation and various other causes. Individual workplace accidents are considered as industrial emergencies, although they can also be considered in the context of social emergencies in industry.

OTHER SOCIAL EMERGENCIES RELATED TO INDUSTRY

Other social emergencies are related to the industry in a direct or indirect manner. Some of them have direct consequences and cause direct damage to the industry and the economy in general (war, terrorism). On the other hand, industry can have an impact on some of the social emergencies, and this impact can be direct (unemployment as a complex emergency) or indirect (the industry is "responsible" for the emergence of the nuclear, biological and chemical weapon).

War is the most dangerous form of security threats and represents a destructive emergency. The war is a complex massive armed conflict between states, military-political alliances, or various social forces within a country, in which violence is used and where armed struggle is pursued in order to achieve political, economic and military goals. The armed struggle is the basic form of the manifestation of the war, which includes various forms of an unarmed struggle (economic, political, psychological and propaganda struggle), making war the most complex emergency.

Terrorism is a specific conflict in which terrorists seek to defeat opponents contrary to the laws of warfare, in order to achieve a particular political objective. Acts of terrorism can significantly jeopardize the industry as well as the wider area (depending on the intensity and type of attack and the type of industrial plant being targeted).

The complex emergencies are a consequence of a difficult situation in the social life of a country and are often the result of accumulated dissatisfaction due to the poor efficiency of the state in solving various social difficulties. These emergencies are preceded by a period of social and economic instability, which

"announces" a complex emergency. They may occur isolated or simultaneously all at once, since they are interrelated causally and consequently.

Chemical, biological, radiological and nuclear (CBRN) emergencies may be caused by the use of nuclear, radiological, chemical and biological weapons (weapons of mass destruction - WMD). They can be complex and include the combined use of the aforementioned weapon types, or the specific ones, which indicate the use of some of the components of this type of weapon. So in this second case we have chemical, biological, nuclear and radiological emergency situations.

Other social emergencies include different forms of crime (organized crime, economic crime, hostilities and fires), individual human accidents, and others.

CONCLUSION

Each of the listed social emergencies in industry carries its own risk and affects industrial safety and protection in its own way, and therefore none of them should be ignored, whether it be strikes, workplace violence or other social emergency situations in industry. Some parts of the world are more or less susceptible to social emergencies in industry due to a greater or lesser degree of social and technical and technological development. Social development and technological advancement enable better occupational safety. Likewise, understanding the causes, but also the awareness of the existence of various social emergencies in industry will ensure better quality of occupational safety.

REFERENCES

- [1] K. Štrbac: *Humanitarne organizacije u zbrinjavanju civilnog stanovništva u vanrednim situacijama*, Vojnoizdavački zavod, 2008, Beograd, str. 20.
- [2] *Politička enciklopedija*, Savremena administracija, 1975, Beograd, str. 1066-1068.
- [3] S. Mijalković, D. Keserović: *Osnovi bezbjednosti*, Fakultet za bezbjednost i zaštitu, 2010, Banjaluka, str. 174-175.
- [4] T. D. Schneid, L. Collins: *Disaster management and preparedness*, Lewis Publishers, 2001, Boca Raton – London – New York – Washington, D.C., str. 22-24
- [5] Ž. Čulibrk: *Reagovanje, koordinacija i saradnja hitnih službi u vanrednim situacijama*, Fakultet za bezbjednost i zaštitu, 2011, Banjaluka.
- [6] Ž. Čulibrk: *Upravljanje vanrednim situacijama*, Fakultet za bezbjednost i zaštitu, 2015, Banjaluka, str. 104, 107-108.

BIOGRAPHY of the first author

Žarko Ćulibrk has a PhD in security and protection. He is an expert in the field of terrorism, crisis management and emergency management. He has participated in a number of national and international symposiums, conferences and scientific meetings and several scientific research projects.



He is an editor and a reviewer of several books and an encyclopedia. He is the author of the textbook Emergency Management, the first of its kind in Bosnia and Herzegovina, and the initiator of the introduction of this subject into higher education. He is the initiator of the introduction of Industrial Security and Protection into higher education too. He is also the author of the textbook Supranational Systems of Security. As a lecturer, in the title of associate professor, he is engaged at the Faculty of Security and Protection in Banja Luka, where he teaches Terrorism, Emergency Management, Crisis Management and Industrial Security and Protection.

DRUŠTVENI ASPEKTI ZAŠTITE NA RADU - DRUŠTVENE VANREDNE SITUACIJE U INDUSTRIJI

Žarko Ćulibrk

Rezime: *Za osnovnu temu rada uzete su društvene vanredne situacije u industriji, a tokom izrade rada korištene su uglavnom eksplikativna i deskriptivna analiza, te metoda analize sadržaja. Ukratko su opisane društvene vanredne situacije u industriji, sa naglaskom na građanskim vanrednim situacijama u industriji. Opisani su i objašnjeni štrajk, nasilje na radnom mjestu, masovna panika i stampedo. Cilj ovog naučnog rada je da ukaže na značaj poznavanja društvenih vanrednih situacija u industriji, kao važnog segmenta zaštite na radu.*

Ključne reči: društvene vanredne situacije, društvene vanredne situacije u industriji, industrijska bezbjednost i zaštita, zaštita na radu.

VLADICA SIBINOVIĆ¹
ALEKSANDRA ILIĆ
PETKOVIĆ²
VESNA NIKOLIĆ³

EDUCATION IN THE FIELD OF OCCUPATIONAL SAFETY AND HEALTH OF HEALTHCARE WORKERS IN PSYCHIATRIC INSTITUTIONS

¹Clinical Centre Niš, Psychiatry
Clinic
²University of Niš,
Faculty of Occupational Safety
³University of Niš,
Faculty of Occupational Safety

¹sibinovicv@yahoo.com
²aleksandra.ilic@znrfak.ni.ac.rs
³vesna.nikolic@znrfak.ni.ac.rs

Abstract: *Healthcare workers in psychiatric institutions face numerous challenges - from stress, burnout syndrome, dissatisfaction and lack of motivation to workplace violence. This is a motive to explore the possibilities of improving their safety and health at work. One of the possible responses to these challenges is the improvement of legal regulations on occupational safety and health by identifying this category of employees. Another response is the improvement of their education regarding workplace safety and health.*

Key words: education, occupational safety and health, healthcare workers, psychiatric institutions.

INTRODUCTION

The analysis of population's health condition and its well-being has shown certain improvement in the world in the last decades. The methods of prevention, diagnosis, treatment and recovery have been enhanced. Still, there are certain conditions that are getting worse. They are worth exploring in order to see what can be done in a better way [1].

In upgrading the health protection system, it is especially important to reconsider the position and problems of those persons who provide healthcare services - healthcare workers. There are numerous challenges regarding occupational safety and health of healthcare workers. They are not the same for all categories of healthcare workers and they also vary depending on the type of service these workers provide. Healthcare workers in psychiatric institutions deserve special attention. Psychiatry is one of the most stressful medical specialties since healthcare providers deal with chronically ill or incurable patients with mental illness [2].

This is why it is important to consider the issues of occupational safety and health that the employees in psychiatric institutions face with. Indicating possible solutions is a good starting point for improving the quality of healthcare services they provide to the patients in psychiatric institutions. Safe, healthy and satisfied healthcare workers provide better health protection to their patients [3]. In this way, the overall health protection in one country is ameliorated.

WORKPLACE RISKS AT PSYCHIATRIC INSTITUTIONS

The analysis of literature on workplace safety and health of healthcare workers in psychiatric institutions has pointed to some problems that these employees frequently deal with. We can identify several risk groups: workplace stress, burnout syndrome, workplace dissatisfaction, lack of work motivation and workplace violence.

Healthcare institutions often represent a very stressful place for healthcare providers [4]. Stress at work is a series of harmful physiological, psychological and behavioural reactions on the situations in which job demands are not in line with worker's abilities and needs. According to some authors, frequent sources of stress at work include: work overload, poor interpersonal relations in the workplace, organisational structure, responsibility without the possibility of influence, poorly defined roles, insufficient number of team workers, unclear division of responsibilities, danger of physical assault and aggression, poor psychological environment [5], etc. Previous research has shown that frequent stressors in healthcare workers include: emergency conditions, on-call scheduling, decision-making after night shifts, routine medical work, little chance of promotion, poor teamwork [6].

Workplace stress can cause numerous negative consequences on the employees, one of which is burnout syndrome. It is a condition of exhaustion or frustration caused by excessive dedication to a goal. This negative work-related psychological feeling incorporates a whole range of symptoms, such as physical fatigue, emotional exhaustion and the loss of motivation [7]. This is when a worker suffers from mental fatigue (emotional exhaustion), depersonalisation, as well as the feeling of reduced achievement [8], which causes progressive energy loss [9]. When an employee experiences burnout, he/she develops a cynical attitude and distance to others, which results in isolation from them [10]. According to some studies, burnout syndrome is more present in healthcare workers who are in daily contact with their patients [11]. Nowadays, healthcare workers are expected to show continuous assertiveness, technical abilities, physical readiness, and emotional and intellectual efforts. Burnout syndrome may occur as a result of these efforts. Then healthcare workers lose enthusiasm for work, withdraw in communication with patients and colleagues, become less productive and absent from work more often, and the entire healthcare

institution is bearing the consequences of such a situation. Every employee has certain expectations from the work organisation and when their needs and expectations are satisfied, they are more productive compared to their colleagues [12]. Thus, another risk to the safety and health of healthcare workers is the lack of motivation for work and job dissatisfaction. Low work motivation of healthcare workers has a major impact on the patients themselves, and the managers of health institutions should pay special attention to this issue [13]. It is closely related to employee satisfaction. Job satisfaction represents individual's cognitive (assumptions and beliefs about work), affective (emotions about work) and evaluative (job assessment) reactions towards their job. Healthcare workers' job satisfaction is a factor which determines the quality of healthcare and affects the work of the whole health system. Research has shown that gender, age, level of education, years of experience, interpersonal relationships, organisation of work, wages and working hours are important factors of healthcare workers' job satisfaction [14].

Workplace violence, as a violent act directed at a person at work or duty, is a phenomenon that seriously endangers the health of employees worldwide [15]. There are numerous definitions of workplace violence. It can be understood as incidents in which assaulted persons are threatened to or attacked in work-related circumstances, including arrival and departure, an explicit or implicit challenge to their safety, well-being or health [16]. The presence of violence against health workers in psychiatric settings is illustrated by the fact that one of the first models of training on workplace violence took place at the Canadian St. Thomas Psychiatric Hospital in 1976 [17]. Despite state regulations and organisation warnings, it continues to exist as a workplace hazard in healthcare facilities [18].

In addition to the abovementioned risks to safety and health at work of healthcare workers, there are some additional hazards. One of those is the quality of team members' communication within a health institution, which affects the condition of patients [19]. Following this, hostile behaviour in the workplace, which can be labelled as mobbing, occurs [20]. Furthermore, the work-family conflict can have a negative impact on safety and health at work, and as a result, healthcare workers can suffer from physical and mental health problems [21]. There are many other dangers that are present, but they are not so common.

THE IMPORTANCE OF LEGAL REGULATIONS REGARDING OCCUPATIONAL SAFETY AND HEALTH OF HEALTHCARE WORKERS IN PSYCHIATRIC INSTITUTIONS

Occupational safety and health is a right recognised in the legal system of the Republic of Serbia. It is guaranteed to all employees, without exception, by the Constitution of the Republic of Serbia [22]. When it

comes to the legal regulation of workplace safety and health of healthcare workers in psychiatric institutions, we can say that legal solutions are divided into several groups.

The first one consists of occupational safety and health regulations that apply to all categories of employees, including healthcare workers in psychiatric institutions. Those are the Occupational Safety and Health Law [23], as well as dozens of regulations and rulebooks based on the Law [24].

The second group consists of the regulations referring to the general regime of labour relations in the Republic of Serbia, thus they pertain to labour relations of healthcare workers in psychiatric institutions. Occupational safety and health is not the subject matter of these regulations, but they briefly mention this issue through the provisions that pertain to all categories of employees, including healthcare workers in psychiatric institutions. The basic law in this area is the Labour Law [25], as well as numerous rulebooks dealing with labour relations, including healthcare workers in psychiatric institutions [24]. In addition to the Labour Law, certain segments of occupational safety and health are regulated by other laws, such as the Law on Prevention of Harassment at Workplace [26] or the Law on Prohibition of Discrimination [27], etc.

The third group of regulations, which is the most specific for regulating occupational safety and health of healthcare workers in psychiatric institutions, are those which deal with the healthcare system of the Republic of Serbia [28]. The Law on Health Care [29], the Law on Protection of Persons with Mental Disorders [30] and accompanying legal acts [28] are of special importance for healthcare workers in psychiatric institutions. Similar to the previous group of regulations, occupational safety and health is not the subject matter of these regulations. However, by regulating the problems of healthcare protection, they partly manage the issue of occupational safety and health of these employees.

The analysis of these groups of regulations has shown that they do not recognize occupational safety and health of healthcare workers in psychiatric institutions in any special way. In other words, the specificity of their occupational safety and health is insufficiently dealt with in the current legislation.

Despite the abovementioned limitations, there is a document which may overcome the existing imperfections – the Act on Risk Assessment. Therefore, this is an act that all the employees can rely on since it is obligatory for every employer, including healthcare institutions. This document identifies the hazards for every job position and accordingly, risk assessment may result in imposing occupational safety measures. In the very process of assessing the risks to the employees, persons who perform risk assessment in a particular healthcare institution have an important role. Risk assessment is performed according to a particular methodology and prescribed procedure. It is

based on the analysis of the likelihood of occurrence and hazard severity, health damage or work-related illness of the employee [31]. The assessment determines what is considered a risk to a healthcare worker, which results in imposing measures on the employer. The identification of work-related hazards is performed on the basis of collecting data from the employer's documentation, monitoring work processes, obtaining information from employees and other sources and classifying them into the types of possible threats they pose [32]. According to current regulations, healthcare workers face the following risks: stress, monotony, responsibility in receiving and transmitting information, the use of appropriate knowledge and skills, responsibility in behavioural rules, responsibility for rapid changes in work procedures, work intensity, spatial conditions of the workplace, conflict situations, insufficient work motivation, management responsibility, violence [32]. If they are identified during the risk assessment the Risk Assessment Act may prescribe certain occupational safety measures, such as informing the workers about their work goals and duties regularly, developing a good work atmosphere and harmonious communication, education on public relations and communication with clients, application of non-violent communication, etc.

IN PLACE OF CONCLUSION - NECESSITY FOR EDUCATION IN THE FIELD OF OCCUPATIONAL SAFETY AND HEALTH OF HEALTHCARE WORKERS IN PSYCHIATRIC INSTITUTIONS

Based on all of the above, it can be concluded that the response to the safety and health challenges of healthcare workers lies in education in the field of workplace safety and health. When it comes to the education of healthcare workers in psychiatric institutions in the field of occupational safety and health, there is a range of opportunities available in formal, non-formal and informal education.

Regarding formal education of healthcare workers, the issue of their safety and health at work can be studied within a given school subject at the level of secondary or higher education. It can be studied within a specific school subject or within the curriculum of another subject. For example, in some faculties, this issue is partially studied in the subjects such as occupational medicine, medicine and society, health management and the like [33]. Moreover, this knowledge could be deepened at the level of medical residency programs. There are other options, apart from formal education. In that sense, when establishing an employment relationship with a worker, the employer is required to train him/her for safe and healthy work [23]. Within this form of non-formal education, a healthcare worker needs to acquire adequate theoretical and practical knowledge and thus be ready for safe and healthy work. As it is evident that there are serious educational

problems at the "employer – occupational safety and health service/person – employee" level [34], healthcare institutions, as employers, need to pay special attention to this matter. Also, healthcare workers are expected to be fully committed to this kind of training. Therefore, it is advisable to test their knowledge periodically and innovate it.

In conclusion, there are numerous different challenges to occupational safety and health of healthcare workers in psychiatric institutions. They can be tackled in several different ways and from multiple levels. One option is the improvement of legal regulations pertaining to occupational safety and health, which shall recognise the uniqueness of this profession through the adoption of a rulebook on workplace safety and health of healthcare workers. Another option with great potential is education in the field of occupational safety and health, starting with formal education of healthcare workers, through non-formal, to informal education, which can always result in new knowledge in this field.

REFERENCES

- [1] W. Holland: "Perspective: lessons from the past", *International journal of health planning and management*, Vol. 31, 2016, pp. 5–24.
- [2] C. Liu, L. Wang, Q. Zhao: "Factors related to health-related quality of life among Chinese psychiatrists: occupational stress and psychological capital", *BMC Health Services Research*, Vol. 15, 2015, available at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4314731/> (16.10.2018).
- [3] J. Rey, G. Walter, M. Giuffrida: "Australian psychiatrists today: proud of their profession but stressed and apprehensive about the future", *Australian and New Zealand Journal of Psychiatry*, Vol. 38, 2004, pp. 105–110.
- [4] J. Roza et al.: "Situational Factors Associated With Burnout Among Emergency Department Nurses", *Workplace Health & Safety*, Vol. 65, 2017, pp. 262–265.
- [5] O. Družić Ljubotina, L.J. Friščić: "Professional stress in social workers: sources of stress and burnout", *Chronicle of Social Work*, Vol. 21, 2014, pp. 5–32 (in Croatian).
- [6] B. Knežević i dr.: "Healthcare workers in hospitals and stress at work: research in Zagreb", *Safety*, Vol. 51, 2009, pp. 85 – 92 (in Croatian).
- [7] H. Freudenberger: "Staff burnout", *Journal of Social Issues*, Vol. 30, 1974, pp. 159–165.
- [8] C. Maslach: "Burned out", *Human Behavior*, Vol. 5, 1976, pp. 16–22.
- [9] J. Škrinjar: "The relationship between occupation and strategies for facing and overcoming burnout syndrome", *Croatian review of rehabilitation research*, Vol. 32, 1996, pp. 25–36 (in Croatian).
- [10] C. Maslach: *"Burnout: The cost of caring"*, Englewood Cliffs, 1982, New York.
- [11] C. Maslach, S. Jackson: "The measurement of experienced burnout", *Journal of Organizational Behavior*, Vol. 2, 1981, pp. 99–113.

- [12] K. Temesgen, M. Aychew, C. Leshargie: "Job satisfaction and associated factors among health professionals working at Western Amhara Region, Ethiopia", *Health and Quality of Life Outcomes*, Vol 16, 2018, available at <https://hqlo.biomedcentral.com/articles/10.1186/s12955-018-0898-7> (16.10.2018)
- [13] D. Djordjević et al.: "Motivation and job satisfaction of health workers in a specialized health institution in Serbia", *Vojnosanitetski pregled*, Vol. 8, 2015, str. 714–721 (in Serbian).
- [14] M. Grujić et al.: "Work motivation and job satisfaction of health workers in urban and rural areas", *Vojnosanitetski pregled*, Vol. 73, 2016; pp. 735–743.
- [15] Y. Yao et al.: "General self-efficacy and the effect of hospital workplace violence on doctors stress and job satisfaction in China", *International Journal of Occupational Medicine and Environmental Health*, Vol. 27, 2014, pp. 389–399.
- [16] M. Fišeković Krečić: "Examining workplace violence predictors of employees in primary health care in Belgrade", PhD thesis, University of Belgrade, Faculty of Medicine, 2016, Belgrade (in Serbian).
- [17] J. Lipscomb, M. El Ghaziri: "Workplace violence prevention: Improving front-line health-care worker and patient safety", *New Solutions*, Vol. 23, 2013, pp. 297–313.
- [18] S. Arbury et al.: "Workplace violence training programs for health care workers, an analysis of program elements", *Workplace Health & Safety*, Vol. 65, 2017, pp. 266–272.
- [19] M. Manojlović, C. Antonakos: "Satisfaction of intensive care unit nurses with nurse-physician communication", *Journal of Nursing Administration*, Vol. 38, 2018, pp. 237–243.
- [20] B. Kordić, L. Babić: "Maltreatment at work and career counseling", *Engrami*, Vol. 36, 2014, pp. 5–14 (in Serbian).
- [21] Y. Zhang, L. Punnett, A. Nannini: "Work-Family Conflict, Sleep, and Mental Health of Nursing Assistants Working in Nursing Homes", *Workplace Health & Safety*, Vol. 65, 2017, pp. 295–303.
- [22] Constitution of the Republic of Serbia, "Official Gazette of the Republic of Serbia", No. 98/2006 (in Serbian).
- [23] Occupational Safety and Health Law, "Official Gazette of the Republic of Serbia", No. 101/2005, 91/2015, 113/2017 (in Serbian).
- [24] Ministry of Labour, Employment, Veterans' Affairs and Social Affairs of the Republic of Serbia, available at <https://www.minrzs.gov.rs/uredbe-i-pravilnici.html> (11.10.2018) (in Serbian).
- [25] Labour Law, "Official Gazette of the Republic of Serbia", No. 4/2005, 61/2005, 54/2009, 32/2013, 75/2014, 13/2017, 113/2017 (in Serbian).
- [26] Law on Prevention of Harassment at Workplace, "Official Gazette of the Republic of Serbia", No. br. 36/2010 (in Serbian).
- [27] Law on Prohibition of Discrimination, "Official Gazette of the Republic of Serbia", No. 22/2009 (in Serbian).
- [28] Ministry of Health of the Republic of Serbia, available at <http://www.zdravlje.gov.rs/showpage.php?id=136> (11.10.2018) (in Serbian).
- [29] Law on Health Care, "Official Gazette of the Republic of Serbia", No. 107/2005, 72/2009, 88/2010, 99/2010, 57/2011, 119/2012, 45/2013, 93/2014, 96/2015, 106/2015, 113/2017 (in Serbian).
- [30] Law on Protection of Persons with Mental Disorders, "Official Gazette of the Republic of Serbia", No. 45/2013 (in Serbian).
- [31] I. Krstić, B. Anđelković: "Professional risk", Faculty of Occupational Safety, 2013, Niš (in Serbian).
- [32] Rulebook on Manner and Procedure for Risk Assessment at Work and Work Environment, "Official Gazette of the Republic of Serbia", No. 72/2006, 84/2006, 30/2010, 102/2015 (in Serbian).
- [33] Faculty of Medicine in Niš, available at <https://www.medfak.ni.ac.rs/index.php/sr/sad-pred-m-2018> (5.10.2018) (in Serbian).
- [34] V. Nikolić, B. Anđelković: "Safety and Protection System and Human Resources Development and Knowledge Management" Faculty of Occupational Safety, 2018, Niš (in Serbian).

BIOGRAPHY of the first author

Vladica Sibinović graduated from the Faculty of Medicine in Niš in 1995 and passed his specialist exam in the field of psychiatry at the same college in 2005. He is the head of the Department for Diagnosis and Treatment of Mental Disorders at the Psychiatry Clinic within the Clinical Centre



Niš. As a psychiatrist and psychotherapist, he published a number of articles in scientific journals. He also participated in numerous courses for healthcare workers in psychiatric institutions.

OBRAZOVANJE ZA BEZBEDNOST I ZDRAVLJE NA RADU ZDRAVSTVENIH RADNIKA U PSIHIJATRIJSKIM USTANOVAMA

Vladica Sibinović, Aleksandra Ilić Petković, Vesna Nikolić

Rezime: Izazovi bezbednosti i zdravlja na radu zdravstvenih radnika u psihijatrijskim ustanovama su raznovrsni i brojni, počev od stresa i burnout sindroma, preko nezadovoljstva i nedostatka motivacije, pa sve do nasilja na radnom mestu. Ovo je motiv za istraživanje mogućnosti unapređenja njihove bezbednosti i zdravlja na radu. Jedan od mogućih odgovora na ove izazove jeste unapređenje pravne regulative o bezbednosti i zdravlju na radu kroz prepoznavanje ove kategorije zaposlenih. Drugi odgovor može biti unapređenje kvaliteta njihovog obrazovanja za bezbednost i zdravlje na radu.

Ključne reči: obrazovanje, bezbednost i zdravlje na radu, zdravstveni radnici, psihijatrijske ustanove.

ŽARKO DIMITRIJEVIĆ¹
ALEKSANDRA
ILIĆ PETKOVIĆ²

¹Žarko Dimitrijević PR public
enforcement officer Niš

²University of Niš,
Faculty of Occupational Safety

¹dimitrijevic.zarko@gmail.com

²aleksandra.ilic@znrfak.ni.ac.rs

WORKPLACE STRESS OF EMPLOYEES IN PUBLIC ENFORCEMENT OFFICES

Abstract: *Employees in Public Enforcement Offices are facing a great amount of workplace stress on a daily basis. Conflict situations regularly arise between public enforcement employees and other participants in the procedure: debtors, creditors and third parties, but also between the employees of other institutions- state bodies and organizations. Public enforcement officers, not only perform their functions with public authority, but at the same time, they are employers, and consequently obliged to take care of workplace health and safety of their employees. The techniques for stress reduction of employees, both during office and field work, are severely limited, but they are nevertheless possible and should be adequately employed and developed. In practice, the most frequent conflict situations between various participants are described and recommendations concerning specific measures are given with the purpose of stress reduction in employees.*

Key words: stress, public enforcement officers, employees, regulations, occupational safety.

INTRODUCTION

In the legal system of the Republic of Serbia the right to private property is guaranteed by the document of the highest legal power – the Constitution [1]. Infringement of this right, even when based on the law, produces a great measure of discontent in the owners of the property. Be it visible or not, such actions produce stress reactions in all participants. Public enforcement officers and their employees are facing, on a daily basis, situations in which creditors attempt to effectuate their right to the property at the expense of the current property of debtors. Both parties, usually vehemently express their discontent concerning the current situation, resulting in the stress for the Public Enforcement Office employees. Taking into account three basic authorizations concerning material property- *usus*, *fructus* and *abusus*, the level and duration of the stress will not always be equal.

Workplace stress is a series of harmful physiological, psychological and behavioural reactions of an individual to situations where the requirements of the job are not in harmony with his/her abilities, capacities and needs. The most common sources of workplace stress include: excessive workload, too few associates in the team, danger of physical assault and aggression, etc. [2]. Workplace stress can lead to numerous negative consequences for the employees. One of the most frequent consequences is the appearance of so-called, burn-out syndrome, as a result of excessive workload of employees, encompassing a whole range of symptoms, such as, physical fatigue, emotional exhaustion and loss of motivation [3, 4].

These symptoms can possibly be seen in Public Enforcement Office employees. The most frequent stress is associated with the cases dealing with monetary claims. Very often, the level of monetary

claim is not in the slightest correlation with the level of dissatisfaction displayed by all actors in the claim. The well accepted opinion that the higher the amount of monetary claim, the higher the dissatisfaction of the actors, is not necessarily always true. Very often, Public Enforcement Office employees are exposed to a higher level of stress when enforcing a low-amount monetary debt, than when enforcing a debt of millions, especially when employing the most “painless” means of enforcement- blocking the bank account of a state budget user. Therefore, the level of stress caused by these situations depends on the process itself, more specifically, on the applied enforcement actions.

Possibly, the highest level of stress is produced in the cases involving enforcement of non-monetary claims. The evictions of sick and elderly, families with small children and other socially disadvantaged persons are among the most difficult duties of the public enforcement officers and their associates. In these situation, the stress is not directly caused by the party acted upon, but rather by actions of other actors: police officers assessing the safety of the action, locksmiths tasked with opening of locked premises and their subsequent securing, animal control officers tasked with subduing and securing pets and other animals found on the location that can endanger the safety of persons involved in the enforcement procedure, material moving workers tasked with fast and efficient removal and packaging of things avoiding any damage, drivers whose duty is to safely transport the material and persons found at the location of enforcement. Very often, at the location, there are other creditors, involved in separate cases who want to follow the procedure, as well as lawyers and third parties.

Nevertheless, stress is not limited to field work only. Quite the contrary, due to the frequency of contacts,

stress is more common in Public Enforcement offices. On a daily basis, various actors in the process phone the office or come personally, asserting their claims, requesting information or actions from the employees. Sometimes they are polite, sometimes they are very impolite. The very fact that creditors call requesting explanations or debtors call arguing and wanting to end the proceedings as favourably for themselves as possible, creates a minor stress and there will be many such calls during a workday.

Many years of practice showed that there are mechanisms that if applied in Public Enforcement offices can drastically reduce stress which is transmitted to all employees. Further in this paper, authors will try to define and recommend possible measures for stress reduction for Public Enforcement Office employees.

MECHANISM OF “OBSTRUCTIVE APPLICATION” OF THE PRINCIPLE OF WRITTEN AND ORAL COMMUNICATION

The content of the principle of oral and written communication is established by the Enforcement and Security Act [5]. Both courts and public enforcement officers, act, as a rule, based on written submissions and other documents, but can also conduct a hearing of a party in a case, outside of court-appointed date, in order to clarify certain issues or possible resolution proposals [5]. The literal interpretation of this provision of Enforcement and Security Act, means that the party can ask for a hearing during the procedure but that it is up to courts and public enforcement officers to decide whether they will grant the request.

Nevertheless, it is in the nature of human beings to personally investigate matters that are connected to them and the best way to do that is by a personal interview. This is the reason why the greatest number of both creditors and debtors express the desire for the personal interview with public enforcement officers. It is physically impossible for public enforcement officers, on top of all daily obligations, to grant all requests for hearing. Further, such manner of work would add to the workload not only of public enforcement officers but also of all other employees involved with the case. Consequently, taking into consideration the legal requirements, we have in the practise two modes of application of the principle of written and oral communication with the person performing the office with public authority: restrictive and extensive, which are both in reality the obstruction of the idea that public enforcement officers could conduct hearings of the parties involved in the proceedings.

Restrictive mechanism of obstructive application of the principle of written and oral communication

Public enforcement officers, in view of the number of cases, cannot possibly hear all parties in all cases who desire to be heard. The law has provided public

enforcement officers with the opportunity to make their own judgement. [5]. This decision is made based on the facts of the case, disregarding any other reasons. However, the assessment of the facts of the case requires time. The expenditure of time makes the proceedings costly so it was necessary to find a way which at the same time fulfills the request of the parties and does not add to the cost. One possible model is the restrictive mechanism. This entails that public enforcement officers communicate orally exclusively with other lawyers, meanings, only with persons acquainted with the law and procedure. The idea is that few lawyers would engage in oral communication with public enforcement officers concerning a case unless that is really necessary. In its basic form, restrictive mechanism, requires that all information is given to the clients only by phone or at the cashier's post, in the office of public enforcement officers and only regarding the amount owed. All other information is conveyed to the party in form of a written document sent by public enforcement officers. The described mechanism, protects the employees from stress in the highest degree. They actually do not have any communication with clients or that communication is reduced to a bare minimum. However, the requests of the clients, mostly debtors, remain unresolved which results in their dissatisfaction and consequent feeling that their right to property and legal protection had not been adequately observed, regardless of the fact that they are currently in the position of a debtor.

Extensive mechanism of obstructive application of the principle of written and oral communication

Extensive mechanism of obstructive application of the principle of written and oral communication entails that every client that requests information about the procedure or wants to be heard in the proceedings can have that opportunity but in a specific manner. Most of all, the requests of the client will be heard by an employee, specifically designated for that purpose, so called, “filter-employee”. This is a specially trained employee who will try to understand the requests of the clients and attempt to accommodate them, resolving the current problem. At the same time, he will estimate whether it is necessary to include somebody else who has a need expertise in the resolution of the problem. Usually, this would mean a lawyer but it is not necessarily always so. Quite often, the requests of the clients are of such nature that they have no connection with the current proceedings, but with some potential, future proceedings requiring advance estimation of costs in order to determine whether it is feasible for them to let the office lead the procedure. Further, the requests for interpretation of the documentation or something in that line are quite frequent. “Filter employee” directs clients to a proper person. If a person pointed to by the “filter employee” is unable to resolve the problem, an appointment with a public enforcement officer can be made

In this manner, the rights of the clients are observed to the fullest degree. In the most complicated case, the problem will be handled by minimum of three persons, not only one. The amount of dissatisfaction of a client is reduced and accordingly also the part transmitted to employees.

MECHANISM OF SEPARATE ACTION

Current research in medicine reveals that the highest levels of stress are transmitted through affective states. Mechanism of separate action is based on this premise and attempts to separate the clients in affective states and the employees. Naturally, when it comes to field work this principle is not applicable, but one should apply the mechanism of reality check which will be discussed later in this paper. However, in the office, it is necessary to separate a place for contact with clients from an employee-only part of the office. Sometimes, a hearing can be stressful by itself, let alone, everyday participation in arguments and explanations. It is therefore necessary to divide the office into reception and employee-only area.

In the reception area there will be a telephone operator, records management office and a special room for hearings. All contacts with clients will occur within this area. The work on cases must not be disturbed by any conversation other than communication between the employees. In this manner stress will be transmitted to the employees only through documentation. Even if a contact with clients occurs by means of referral by the filter employee, this will be less often than in the case where several employees must be exposed simultaneously to the clients' comments.

Work area, meaning operation area must be supplied with all equipment needed for the work but also with the capacity of prompt communication with the reception in order to secure optimal logistic support for the employees there. In this manner, the level of service will be improved and accordingly also the satisfaction of the clients, be it creditors or debtors. The greatest professional affirmation for a public enforcement officers is when the same creditors repeatedly hire the same public enforcement officer in order to secure their claims.

MECHANISM OF REALITY CHECK

A common saying "it is not so important what you say as how you say it" is in the heart of the mechanism of reality check. Therefore, in order to reduce workplace stress all employees should be specifically trained to present things as they really are. As human beings, while working with clients it is often very difficult to abstain from giving some personal contribution or expressing some personal views but this is exactly the mistake.

In communication with clients we must always assess the situation objectively. Clients must be apprised of all consequences of the acts they may intend to perform or abstain from performing. Hiding the consequences may

actually be a cause of stress. Most of all, client might become dissatisfied and very likely to transfer the stress to the employee.

Further, when informing the client about the situation, the employee must not be unnecessarily harsh, disrespectful or threatening. At all times communication must be calm and civilized. Public enforcement officers and their employees represent the state, they are executors of a public offices and authority [5], so they must serve as an example of civil and efficient communication with clients. Failing to do so will only increase the dissatisfaction of clients and add to the stress of all employees.

Finally, the mechanism of reality check requires professional attitude towards cases and careful observance of the right of all parties to equal treatment in the proceedings. The principle of equality of rights means that the set of rights that each party receives from the law must be viewed in the same way regardless of the type of the party involved in the proceedings. Disregarding social stereotypes and personal attitudes, public enforcement officers and their employees, are obliged to treat all parties in the proceedings with respect and due diligence in order to ensure the protection of their rights. Both public enforcement officer, in the position of public authority, as well as courts and other institutions if legal procedure directs clients to them through the public enforcement officers, are obliged to follow the same principles.

CONCLUSION

When analysing the problem of professional stress of the employees in Public Enforcement Offices, one must be mindful of several facts. Enforcement and Security Act requires that public enforcement officers execute acts with public authority defined by this and other acts. [5]. This shows that the Republic of Serbia recognizes the importance and role of public enforcement officers for the enforcement of claims. Public enforcement officers can perform activities as entrepreneurs or as members of partnership companies whose members are exclusively public enforcement officers. The state ministry appoints a public enforcement offices after the completed public application process and currently there are 236 public enforcement officers registered in Serbia [6]. Public enforcement officers can only be persons who fulfil a series of conditions prescribed by the law, including a law degree, completed public enforcement officer examination, completed bar examination, good reputation needed for the post of public enforcement officer, etc. [5]. Public enforcement officer has numerous authorities and duties, such as, such as issuing enforcement warrants based on valid documents in order to secure payment of claims arising from communal services arrears or similar cases, as well as to determine means and subjects of enforcement, to acquire information on debtors etc. [5]. Finally, public enforcement officers in their work apply a set of

regulations which define the area of their action. These regulations include, apart from the Constitution of the Republic of Serbia, [1] and Enforcement and Security Act [5], General Administrative Procedure Act [7], Public Surveying and Cadastre Act [8], Tax procedure and Tax Administration Act [9], Judicial Taxes Act [10], Contracts and Torts Act [11], Police Enforcement Act [12], etc.

Taking all this into account, we can conclude that employees in Public Enforcement Offices, as executors of public authority, bear a serious responsibility and that great care should be taken to maintain professionalism, impartiality and efficiency [13]. For this reason, it is necessary to carefully assess their occupational safety, especially the mechanisms for their protection from adverse workplace influences arising from psychological and physiological strain associated with their workplace tasks in Public Enforcement Offices [14].

REFERENCES

- [1] The Constitution of the Republic of Serbia, "Official Gazette of the Republic of Serbia", No. 98/2006 (in Serbian).
- [2] O. Družić Ljubotina, L.J. Frišić: "Profesionalni stres kod socijalnih radnika: izvori stresa i sagorijevanje na poslu", Ljetopis socijalnog rada, Vol. 21, 2014, pp. 5-32 (in Croatian).
- [3] H. Freudenberger: "Staff burnout", Journal of Social Issues, Vol. 30, 1974, pp. 159-165.7,]
- [4] J. Škrinjar: "Odnos zanimanja i strategija suočavanja i svladavanja burnout sindroma", Hrvatska revija za rehabilitacijska istraživanja, Vol. 32, 1996, pp. 25-36 (in Croatian).
- [5] Enforcement and Security Act, "Official Gazette of the Republic of Serbia", No. 106/2015, 106/2016, 113/2017 (in Serbian).
- [6] Republic of Serbia, Public Enforcement Officers Chamber, available at <http://www.komoraizvršitelja.rs/?q=izvršitelji> (1.11.2018).
- [7] General Administrative procedure Act, "Official Gazette of the Republic of Serbia", No. 18/2016 (in Serbian).
- [8] Public Surveying and Cadastre Act, "Official Gazette of the Republic of Serbia", No. 72/2009, 18/2010, 65/2013, 15/2015, 96/2015, 47/2017, 113/2017, 27/2018, 41/2018 (in Serbian).
- [9] Tax Procedures and Tax Administration Act, "Official Gazette of the Republic of Serbia", No. 80/2002, 84/2002, 23/2003, 70/2003, 55/2004, 61/2005, 85/2005, 62/2006, 63/2006, 61/2007, 20/2009, 72/2009, 53/2010, 101/2011, 2/2012, 93/2012, 47/2013, 108/2013, 68/2014, 105/2014, 91/2015, 112/2015, 15/2016, 108/2016, 30/2018 (in Serbian).
- [10] Judicial Taxes Act, "Official Gazette of the Republic of Serbia", No. 28/94, 53/95, 16/97, 34/2001, 9/2002, 29/2004, 61/2005, 116/2008, 31/2009, 101/2011, 93/2012, 93/2014, 106/2015 (in Serbian).
- [11] Contracts and Torts Act, "Official Gazette of the Republic of Serbia", No. 29/1978, 39/85, 45/1989, 57/1989, "Sl. list SRJ", br. 31/1993, "Sl. list SCG", br. 1/2003 (in Serbian).
- [12] Police Enforcement Act, "Official Gazette of the Republic of Serbia", No. 6/2016, 24/2018 (in Serbian).
- [13] M. Ilić, A. Ilić Petković, M. Jovanović: "Strategic approach achievements in the public administration reform in the Republic of Serbia in the process of European Union accession", Teme, Vol. 37, 2013, pp. 1749-1762. (in Serbian).
- [14] Regulations on actions and procedures for risk assessment in workplace and work environment, "Official Gazette of the Republic of Serbia", No. 72/2006, 84/2006, 30/2010, 102/2015 (in Serbian).

BIOGRAPHY of the first author

Žarko Dimitrijević graduated from the University of Niš, Faculty of Law in 2004 and obtained his PhD degree from the same University in 2016. He passed two specialist exams in 2012: Bar examination and the examination for public enforcement officers.

He is an accredited mediator, public enforcement officer, trainer, and a lecturer. He published a number of articles in scientific journals and participated in numerous courses for law experts around the globe.



STRES NA RADU ZAPOSLENIH U KANCELARIJAMA JAVNIH IZVRŠITELJA

Žarko Dimitrijević, Aleksandra Ilić Petković

Rezime: Zaposleni u kancelarijama javnih izvršitelja se suočavaju sa ogromnom količinom stresa. Konfliktne situacije nastaju između javnih izvršitelja i svih učesnika u postupku: dužnika, poverioca, trećih lica, ali i između zaposlenih u drugim institucijama - državnim organima i organizacijama. Javni izvršitelj ne samo da je nosilac funkcije javnih ovlašćenja, već je i poslodavac, te je u obavezi da se stara o bezbednosti i zdravlju zaposlenih. Tehnike umanjavanja stresa zaposlenih u kancelarijama i na terenu su veoma limitirane, ali su naravno moguće, te ih na pravi način treba upotrebljavati i razvijati. U radu se opisuju najčešće konfliktne situacije između različitih aktera i daju preporuke o konkretnim merama koje za cilj imaju smanjenje stresa kod zaposlenih.

Ključne reči: stres, javni izvršitelji, zaposleni, propisi, bezbednost i zdravlje na radu.

JELENA AVRAMOVIĆ¹
ANA VELIČKOVIĆ²
VLADA VELJKOVIĆ³

¹University of Niš,
Faculty of Technology in Leskovac

²University of Niš,
Faculty of Technology in Leskovac

³University of Niš,
Faculty of Technology in Leskovac

¹avramjelena@yahoo.com

²anamarjan@yahoo.com

³veljkovicvb@yahoo.com

THE SOCIO-ECONOMIC FACTORS OF BIODIESEL PRODUCTION

Abstract: *At the end of the 20th century, the topic of biofuels appeared as a promising solution to many problems. Increased concern over energy security due to dwindling of oil supplies and constant conflicts in the oil exporting countries forced energy depended countries to search for alternatives. Growing biofuel sector provided the possibility for the development of rural areas, and creating job opportunities for the local population. Awareness of the danger of climate change and global warming promoted the biofuels for it was believed that burning biofuels was carbon neutral contributing to the reduction of greenhouse gas emissions. However, although biofuels have a lot of advantages, there are also some drawbacks that should be investigated, such as the influence of biofuels on the food market, the labour conditions and workers' rights, the inconsistency of biofuel policies, the land change, etc.*

Key words: biodiesel production, workers' rights, labour conditions.

INTRODUCTION

The society is facing depletion of fossil fuels and severe climate change in a near future. The concern about world's fossil fuel reserves and the tendency of reducing the climate change related to greenhouse gas emissions have led to the conclusion that it will not be enough to only reduce the amount of fossil fuels used, but also the source of energy used should be changed. Hence, the renewable and sustainable energy sources have become the subject of many researches. Over the past two decades, the use of biodiesel has been publicly recommended for many reasons, both practical and environmental. It is believed that the possibility of the production and use of biodiesel will reduce the dependence on the imported oil, raise the security of the European energy supply, encourage the sustainable exploitation of natural sources, and reduce the emissions of greenhouse gases from transportation [1].

However, though biodiesel has many advantages compared to fossil fuels, there are several important issues that should be taken into consideration when planning biodiesel production and use, such as the effect of biodiesel on food and energy markets, the opportunity of improving working conditions and worker rights, the influence of biodiesel policy, as well as the feedback effects of the biodiesel sector on the society. Furthermore, the positive and negative sides of all the above-mentioned issues should be carefully weighed. This paper deals with all the important questions related to the socio-economic issues of the use and production of biodiesel.

THE EFFECT OF BIODIESEL ON ENERGY MARKET

In the beginning, biodiesel was presented as a "win-win" solution to energy and environmental problems, since it can be produced from oilseed crops that capture

and store energy from the sun. The burning of biodiesel is considered carbon neutral because it will only release the amount of CO₂ previously absorbed from the atmosphere by the plants for the process of photosynthesis. Theoretically, a clean renewable domestically grown liquid energy can reduce dependency on fossil fuels, preserve foreign exchange, make opportunities for new jobs and reduce net greenhouse gas emissions [2]. Many countries have reduced their dependence on fossil fuels and their usage of foreign oil with the use of locally produced biodiesel. The biodiesel industry has a task to create a balanced energy policy and contribute to the development of a stronger self-sufficient community through the community-based biodiesel distribution program that brings economic, social, and environmental benefits to the community. Namely, local farmers are growing the feedstock and sell them to the local biodiesel production facility that produces and distributes the biodiesel to the end consumer. In that way, the money remains in the community, the negative influence on the local environment is reduced, and local energy security is ensured [3].

THE EFFECT OF BIODIESEL ON FOOD MARKETS

In the agricultural market, there is a competition between the biodiesel industry and the food and feed manufacturers for the same commodity [4]. The growing request for bioenergy influences agricultural systems and food prices. Agriculturists choose to cultivate certain crops depending on their prices. When profits from biomass cultivation exceed profits from food production, they will shift from food towards energy crop cultivation, until agricultural goods prices increase, which consequently increases food prices [5]. However, taking into account the greater size of the energy market in comparison to the food market, a

small change in energy request would significantly influence the request for food crops, which will enhance the price of biodiesel and affect food crops prices [4]. It is believed that the connection between food and energy prices through biofuel policies caused the food price crisis in 2006 [6].

The use of edible oils in the biodiesel production induced the food versus fuel controversy. Namely, for years some edible oils were widely used in biodiesel production due to their availability and low price. The crops cultivated for the use in human nutrition and edible oils were converted to fuel despite the hunger and famine in the world [7]. Although advocates of bioenergy suggest that competition between food and fuel could be avoided by growing energy crops on less fertile land, this has not yet been economically analyzed [5]. Another possibility would be the use of waste oils, non-edible oils from oilseed varieties having high oil content that are grown on less fertile land, or using co-products of, for example, industrial corn processing, such as corn germ, very rich in oil content [8]. Microalgae present third generation feedstock for biodiesel production and a very promising alternative to oily feedstock, since they give higher energy yield per square area in comparison to land crops, they do not compete with food supplies, require smaller area for cultivation, and can be cultivated on areas that are not suitable for cultivation of plants, so they do not threaten arable land [9,10].

IMPROVEMENT OF WORKING CONDITIONS AND WORKER RIGHTS

Implementation of biofuel production can contribute to the development of rural areas and provide the non-agricultural income to many small farms, since majority of feedstock for biodiesel production are planted in this areas. An expanded biofuels sector can benefit to the development of local economies of many rural agricultural areas, and offer the possibility of creating an additional employment not only in the plant construction period but in the refineries that require expertise in chemistry, engineering and management, as well [11]. In this way, young people would be motivated to stay, i.e. live and work in these communities [12]. Nevertheless, there is a shortage of evidence on the significant, long-term positive job impacts of the increased biofuel production in rural areas [12]. In addition, the majority of the working positions in the biodiesel production sector are only for low qualified seasonal field workers, often migrants that are especially vulnerable facing health risks, first of all due to the inadequate use of agrochemicals. Very often, they are not familiar with the risks of their work, nor are secured with safety equipment. Better working conditions and worker rights should be a part of the standards for biodiesel production and trade [13].

BIODIESEL POLICIES

In energy markets, liquid biofuels compete with petroleum-based fuels. While different policies like mandated blending of biodiesel with petro-diesel, subsidies, and tax incentives can promote biodiesel use, limitations like the lack of vehicles that run on biodiesel blends, can discourage their use. Although the prices of biofuels and fossil fuels move together, the current technologies for biodiesel production make the price of biodiesel too high for it to compete with fossil fuels without the active government policies through subsidies and tax credits, the import tariffs and the designated goals [4].

The main driving force for governments' involvement in the renewable energy sector should be the improvement of overall social welfare. Energy security, supply, affordability, and sustainability, adaptation to and mitigation of climate change, and employment opportunities, first of all in rural regions, are the energy, environmental, and social reasons for the governments' involvement in the renewable energy sector. However, the government must implement policies with public support, thus ensuring the support for the re-election [14].

White et al. (2013) [14] explained the importance of policy consistency in the developing renewable energy sector. Governments' non-predictable policy presents the main obstacle that causes short- and the long-term problems for the renewable energy industry. If the state budgets are adopted annually, with no legally bonded decisions in the coming years, the consequential uncertainty is making difficult to increase capital for investments. Policy changes of great extent may suddenly occur within the following year due to the increased lobbying activity, rapidly making profitable businesses unprofitable and making future investments in the industrial development more difficult. The industry must make an effort to constantly be aware of the current situation, so it could influence in time the government's decision process to the greatest extent possible. The main request of the investors or those who support the development of renewable energy sector for is the implementation of predictable, long-term stable policies that minimize insecurity, and not necessarily subsidies [14].

CONCLUSIONS - FEEDBACK EFFECTS OF BIODIESEL PRODUCTION AND USE

Besides positive effects of growing biofuel sector, such as the poverty reduction in developing countries, the development of rural areas and creating job opportunities, as well as the social welfare of developed countries, there are many, socio-economic, environmental and health side effects, financial and non-financial, which present additional expenses for the society that should be taken into consideration when developing a biofuel policy [2,15]. Though biodiesel produced in the community contributes

energy security, it should not be produced at any cost, especially if an area is not convenient for cultivation of feedstock for its production. In that case, transportation of these crops to the production place causes the emission of greenhouse gases and imposes the additional costs for the society. The increased demand for biodiesel requires large arable areas for the planting crops. However, land change must be done very carefully to ensure that no land used for food is used for growing crops for biodiesel production [16,17,18]. Considering alleviated global warming as one of the objectives of biodiesel support policies, fuel efficiency, and forest conservation and restoration will be the more effective solution since more carbon would be sequestered over a 30-year period by converting the cropland to forest [19]. Unfortunately, it seems that in the recent future, the policy-driven growing demand for biodiesel will most likely lead to an accelerated conversion of non-agricultural lands to crop production [4]. Growing demand for biofuels and its impact on food supplies and prices has raised a great concern for the poor although it has been emphasized that biofuels do not have to inevitably negatively affect food since it can be produced on lower quality lands [11]. But even if the more agricultural area would be available for growing crops, it is questionable whether the reduction of greenhouse gas emission gained by the use of biofuels justifies the increased nitrous oxide emissions from the fertilizer used in growing crops [20]. These concerns about economic and environmental impacts hopefully will be overcome by the growing orientation towards second- and third-generation biofuels, directly investing in the feedstock that have the highest positive greenhouse gas balances with the lowest environmental and social costs [20], but at this moment, biofuel seems to be an expensive choice of reducing greenhouse gases considering all the costs invested in their development, including subsidies and tax reductions [13].

REFERENCES

- [1] F. Neuwahl, A. Lösche, I. Mongelli, L. Delgado: "Employment Impacts of EU Biofuels Policy: Combining Bottom-up Technology Information and Sectoral Market Simulations in an Input-output Framework", *Ecological Economics*, Vol. 68, 2008, pp. 447–460
- [2] K. Jaeger, T. M. Egelkrau: "Biofuel economics in a setting of multiple objectives and unintended consequences", *Renewable and Sustainable Energy Reviews*, Vol. 15, 2011, pp. 4320–4333.
- [3] <http://www.biodiesel.com/biodiesel/benefits/>
- [4] FAO: "The state of food and agriculture; BIOFUELS: prospects, risks and opportunities", Food and Agriculture Organization of the United Nations; 2008, Rome
- [5] D.J.A. Johansson, C. Azar: "A scenario based analysis of land competition between food and bioenergy production in the US", *Climatic Change*, Vol. 82, 2007, pp. 267–291.
- [6] S. Nazlioglu, C. Erdem, U. Soytaş: "Volatility spillover between oil and agricultural commodity markets", *Energy Economics*, Vol. 36, 2013, pp. 658–665.
- [7] J. Kansedo, K.T. Lee: "Process optimization and kinetic study for biodiesel production from non-edible sea mango (*Cerbera odollam*) oil using response surface methodology", *Chemical Engineering Journal*, Vol. 214, 2013, pp. 157–164.
- [8] V.B. Veljković, M.O. Biberdžić, I.B. Banković-Ilić, I.G. Djalović, M.B. Tasić, Z.B. Nježić, O.S. Stamenković: "Biodiesel production from corn oil: A review", *Renewable and Sustainable Energy Review*, Vol. 91, August 2018, pp. 531–548
- [9] Bojana R. Danilović, Jelena M. Avramović, Jovan T. Čirić, Dragiša S. Savić, Vlada B. Veljković: "Production of biodiesel from microalgae", *Hemjska industrija*, Vol. 68, 2014, pp. 213–232.
- [10] A.F. Clarens, E.P. Resurreccion, M.A. White, L.M. Colosi: "Environmental life cycle comparison of algae to other bioenergy feedstocks", *Environmental Science & Technology*, Vol. 44, 2010, pp. 1813–1819.
- [11] B.D. Solomon: "Biofuels and sustainability", *Annals of the New York Academy of Sciences*, Vol. 1185, 2010, pp. 119–134.
- [12] Institute of Medicine: "The nexus of biofuels, climate change, and human health: Workshop summary", The National Academies Press, 2014, Washington, DC.
- [13] Y. Greiler: "Biofuels, opportunity or threat to the poor?", Natural Resources and Environment Division, Swiss Agency for Development and Cooperation SDC, 2007
- [14] W. White, A. Lunnan, E. Nybakk, B. Kulisić: "The role of governments in renewable energy: The importance of policy consistency", *Biomass and Bioenergy*, Vol. 57, 2013, pp. 97–105.
- [15] K. Janda, L. Kristoufek, D. Zilberman: "Modeling the Environmental and SocioEconomic Impacts of Biofuels", IES Working Paper 33/2011. IES FSV, Institute of Economic Studies, Faculty of Social Sciences Charles University, 2011, Prague
- [16] C.C. Tsao, J.E. Campbell, M. Mena-Carrasco, S.N. Spak, G.R. Carmichael, Y. Chen, Biofuels That Cause Land-Use Change May Have Much Larger Non- GHG Air Quality Emissions Than Fossil Fuels, *Environmental Science & Technology*, Vol. 46, 2012, 10835–10841
- [17] J.H. Ng, H.K. Ng, S. Gan: "Recent trends in policies, socioeconomy and future directions of the biodiesel industry", *Clean Technologies and Environmental Policy*, Vol. 12, 2010, pp. 213–238.
- [18] R. Righelato, D. V. Spracklen: "Carbon Mitigation by Biofuels or by Saving and Restoring Forests?", *Science*, Vol. 317, 2007, pp. 902–906.
- [19] S.B. Živković, M.V. Veljković, I.B. Banković-Ilić, I.M. Krstić, S.S. Konstantinović, S.B. Ilić, J.M. Avramović, O.S. Stamenković, V.B. Veljković: "Technological, technical, economic, environmental, social, human health risk, toxicological and policy considerations of biodiesel production and use", *Renewable and Sustainable Energy Reviews*, Vol. 79, 2017, pp. 222–247.
- [20] L. Ruth: "Bio or bust? The economic and ecological cost of biofuels", *EMBO Reports*, Vol. 9, 2008, pp. 130–133.

ACKNOWLEDGEMENTS

This work has been funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Serbia (Project III 45001).

BIOGRAPHY of the first author

Jelena Avramović was born in Leskovac, Serbia, in 1979. She received the diploma in chemical engineering and the Ph.D. degree in technological engineering from the University of Nis, Faculty of Technology. Her main areas of research include biodiesel production, new catalysts, etc. She is currently working as Senior research associate at the Faculty of Technology in Leskovac, University of Nis.



SOCIO-EKONOMSKI FAKTORI PROIZVODNJE BIODIZELA

Jelena Avramović, Ana Veličković, Vlada Veljković

Rezime: *Krajem dvadesetog veka tema biogoriva iskrsla je kao obećavajuće rešenje mnogih problema. Sve veća zabrinutost za energetske sigurnost, usled trošenja zaliha nafte i stalni sukobi u zemljama koje se bave izvozom nafte primorala je energetske zavisne zemlje da tragaju za alternativom. Razvoj sektora biogoriva pružio je mogućnost za razvoj ruralnih oblasti i otvaranje novih radnih mesta za lokalno stanovništvo. Razvoju sektora biogoriva išla je u prilog svest o klimatskim promenama i globalnom zagrevanju, jer se smatralo primena biogoriva doprinosi smanjenju emisije gasova staklene bašte. Međutim, uprkos mnogim prednostima biogoriva, postoje i sporedni i neželjeni efekti koje bi trebalo uzeti u obzir, kao što je uticaj biogoriva na tržište hrane, uslove rada i prava radnika, zatim nedoslednost u politici biogoriva, izmena namene zemljišta, itd.*

Ključne reči: proizvodnja biodizela, prava radnika, uslovi rada.

ALEKSANDAR
TRIFUNOVIĆ¹
SVETLANA ČIČEVIĆ²
ALEKSANDAR ŽUNJIĆ³
SLOBODAN MITROVIĆ⁴
MAGDALENA DRAGOVIĆ⁵

NEW PEDAGOGICAL APPROACHES IN DIGITAL MEDIA - ENHANCED TRAFFIC SAFETY TRAINING FOR CHILDREN

^{1, 2, 4} University of Belgrade,
Faculty of Transport and Traffic
Engineering in Belgrade
² University of Belgrade,
Faculty of Mechanical Engineering in
Belgrade
³ University of Belgrade,
Faculty of Civil Engineering in
Belgrade

¹ a.trifunovic@sf.bg.ac.rs
² s.cicevic@sf.bg.ac.rs
³ azunjic@mas.bg.ac.rs
⁴ cobaja@sf.bg.ac.rs
⁵ dim@grf.bg.ac.rs

Abstract: According to World Health Organization (WHO) estimates, 186,300 children die annually from road traffic crashes globally, equivalent to over 500 child deaths daily. Road traffic injuries are among the top four global causes of death in children between the ages of 5 and 14 years. Among these deaths, children as pedestrians accounted for about 38%. To create effective intervention programs, the research on pedestrian safety risks associated with age is needed. For these reasons, an experiment was conducted to explore the impact of using tablet PC devices for learning purposes in the field of traffic safety. The results indicate that children show better performances when working with tablet PC, than in simulated traffic situations. Thus, it is important to take these findings into account when aiming to train children for road safety.

Key words: Traffic safety, Tablet PC, training, children.

INTRODUCTION

Modern traffic imposes complex and high requirements on all participants, particularly children. The lack of maturity of children and their modest life and traffic experience, as opposed to the exposure and risks propensity and challenges, leads children to be one of the most vulnerable categories of traffic participants. Given that traffic is one of the most important and the most difficult experiences in life for every child, it is not easy for them to adapt to an environment which is permanently in motion.

Children constitute an important class of the road users, and despite the fact that they are not allowed to drive motorized vehicles (except bicycles) themselves and therefore seldom hurt other road users, their ability to anticipate hazards can protect them from being hit by others, such as when crossing the road (Meyer et al., 2014). Their ability to perceive unsafe situations can also reduce the likelihood that they will be injured or killed in accidents. Previous studies have aimed to understand and identify factors of child pedestrian risk. For instance, in relation to the most common road traffic accident situation among children, unsafe street crossing, studies show that advanced perceptual and cognitive skills are needed (Schwebel, et al., 2012). Research had recognized that young children have lower hazard perception skills than adults (Meyer et al., 2014) and are more prone to impulsive actions in traffic (Briem and Bengtsson, 2000). Children have difficulties assessing a car's approaching speed and therefore interpret distance between themselves and a car as greater than it actually is (Connelly, 1998). Further, even if children may choose the same gap size for crossing the street, their risk of accident involvement is

increased as they delay the start of the crossing, thereby reducing the available time to cross the street safely (Pitcairn and Edlmann, 2000). Some studies find that tablet PCs are convenient for traffic safety education of children (Trifunović et al., 2018; Čičević et al., 2017).

Tablets have been shown their potential to be used in education of children since their commercial exploitation from 2010. However, there are some drawbacks in their usage. Some educators are enthusiastic regarding tablets' use in education as a new medium (Galloway 2008), whereas others claim tablets are not appropriate for children (House 2012).

Some findings suggest that tablet design is suitable for children. Because tablets are user-friendly children become enthusiastic and competent quickly (Lynch and Redpath, 2014). Several technologies (mobile, multimedia...) are combined in a tablet device, and they form so-called "digital playground" for children. Empirical arguments lead to the conclusion that the kinaesthetic characteristics of the tablet and their ability to be used for learning through gaming lead to a positive approach in education (Papadakis, 2016).

This research illustrates the benefit of conducting traffic safety studies and testing of children using tablet PCs, and also discusses both methodological challenges and their potential solutions.

METHODOLOGY

Participants and Experimental Procedure

The research sample consisted of 98 children. Of the total number of the respondents, 49 (50%) were females and 49 males. The sample is comprised of several groups: children attending primary school, from

the first (aged from 6.5 to 7.5 years), second (aged from 7.5 to 8.5 years), third grade (ages from 8.5 to 9.5 years) and fourth grade (ages from 9.5 to 10.5 years).

In the experiment a test was presented to children, designed to examine their behaviour in simulated traffic situations and with Tablet PC.

Traffic situations presented to children were:

- Pedestrian behaviour at crosswalks with traffic light (red and green light);
- Behaviour at the traffic light for cyclists (red and green light);
- Crossing the street on a pedestrian crossing;
- Crossing the street outside a pedestrian crossing.

Identical traffic situations are presented on Tablet PC and in simulated traffic environment. All subjects were tested for two different conditions and all traffic situations.

DATA ANALYSES

The answers were recorded in paper form. These data are loaded and processed in a database made in MS Excel. Statistical analysis was performed by the statistical software package IBM SPSS Statistics v. 22. The basic statistical analysis of data included descriptive statistics and cross tabulation. Normality distribution was tested by inspection of histograms and the Kolmogorov-Smirnov test. As the Kolmogorov-Smirnov test has determined that results do not significantly deviate from a normal distribution, the decision was to use Student's T-test and ANOVA. Bonferroni Post Hoc test has been used for additional comparisons (Trifunović et al., 2017, Trifunović et al., 2018). All tests were carried out on the basis of the recommendations of the textbook "SPSS Survival Manual" (Pallant, 2013). The threshold of statistical significance (α) is set at 5%.

RESULTS AND DISCUSSION

In this experiment, it was shown that all respondents were able to recognize the traffic concepts of sidewalk, roadway, bicycle path, pedestrian and bicycle traffic light.

Further, children behaviour in different traffic situations presented on tablet PC and in simulated environment were compared.

Children knowledge on behaviour required in traffic situations and the meaning of elements of traffic signalization is presented in Figure 1. Children show 100% correct responses for the situation when crossing the street is prohibited (red light is on) for pedestrian and bicyclists, while the lowest percentage of correct answers when traffic light indicate that crossing the street is permitted (when the green light is on).

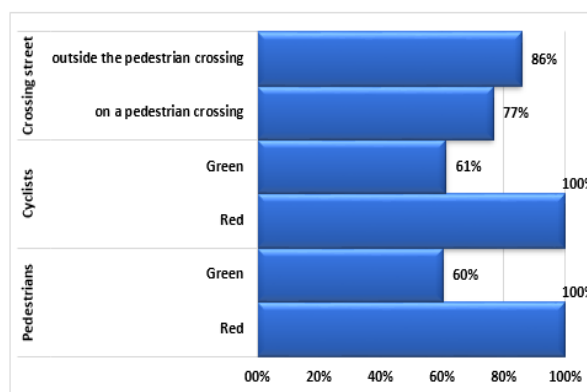


Figure 1. The mean percentage of correct answers for different traffic situations

Age differences

The results of One-way ANOVA showed statistically significant differences in interpreting the green light for pedestrians on a traffic signal among the children in different grades ($F=6.979$; $p<0.001$) children.

There are also statistically significant differences for green traffic lights for cyclists with respect to participants age ($F=5.916$; $p<0.001$).

In other words, there are significant differences in children answers, i.e., the knowledge upon traffic situations for the first in comparison to the third and fourth grade, as well for the second in comparison to the third and fourth grade.

Figure 2 shows descriptive statistics on children's accuracy, by age group, for particular behaviour in different traffic situations.

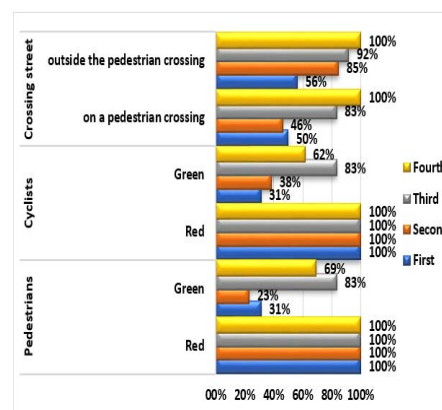


Figure 2. Age differences in percentage of accurate responses for different traffic situations

The results showed statistically significant differences for crossing the street on a pedestrian crossing for the first in comparison to the third and fourth grade ($F=7.928$; $p<0.001$), as well for the second in comparison to the third and fourth grade, for crossing the street outside of pedestrian crossing ($F=7.229$; $p<0.001$). On the basis of the data shown above we can conclude that older children show better knowledge

and understanding of traffic rules in different traffic situations.

Simulated traffic situations vs. Tablet PC

Children answers to same traffic situations presented on Tablet PC and in simulated traffic environment are presented in Figure 3.

The results of Student's T-Test showed statistically significant differences in performances between the two conditions (simulate traffic situations vs. tablet PC) for: green traffic lights for pedestrians ($t = -2.326$; $p < 0.001$), green traffic lights for cyclists ($t = -2.137$; $p < 0.001$), crossing the street on a pedestrian crossing ($t = -2.099$; $p < 0.001$) and crossing the street outside of pedestrian crossing ($t = -1.325$; $p = 0.007$). Children show better performances when the same traffic situation was presented on tablet PC, than in simulated traffic environment.

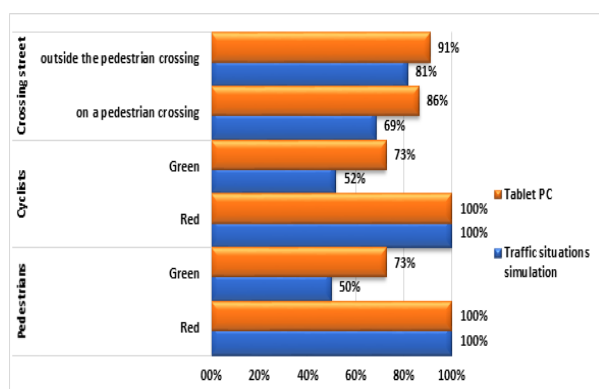


Figure 3. Children performances in simulated traffic environment vs. Tablet PC condition

CONCLUSIONS

Based on the data collected and analyzed in our research, it can be derived several conclusions:

- Children show better knowledge upon the situation when crossing the street is prohibited either for pedestrians or for cyclists, while the percentage of correct answers is decreasing in the situation when crossing the street is allowed;
- Knowledge and understanding of traffic rules in different traffic situations increase with age;
- Children show better performances when the same traffic situation was presented on tablet PC, than in simulated traffic environment.

Using of tablet PC has shown advantages over simulated traffic environment as a means for various traffic related contents presentation, most probably due to children immaturity and lack of experience in real traffic situations. A better understanding of how children respond to the different experimental environment (traffic situation simulation vs. tablet PC presentation) can be used for the improvements of children training process for traffic safety. Thus, tablet PCs could become a popular instruction tool that can improve children's learning, and hence their performances. However, future research should

continue to investigate children behaviour in a larger number of different traffic situations, as well as to cover different age groups of respondents. Using the tablet computer requires further research to fully understand the potential of application of new information and communication technologies in the educational process and evaluation of children's performances, as well in conforming to individual differences. These facts and the results should be used in practical terms that enable children to learn in the ways they prefer, using modern technologies. In this way, the area of road safety will be closer, more accessible and more interesting to children, that should use it to acquire new knowledge, develop appropriate attitudes and proper behaviour in traffic, which will finally result in increasing the level of overall security of the youngest participants in traffic. In addition, the knowledge, attitudes and behaviour acquired in early childhood provide important foundations which will facilitate the knowledge to be acquired in the future, in educational settings for driver training and assessment (Trifunović et al., 2018; Čičević et al., 2017).

REFERENCES

- [1] V. Briem, H. Bengtsson: "Cognition and character traits as determinants of young children's behaviour in traffic situations", *International Journal of Behavioural Development*, 24(4), 2000, pp.492-505.
- [2] H. L. Burdette, R.C. Whitaker: "Resurrecting free play in young children: looking beyond fitness and fatness to attention, affiliation, and affect", *Archives of pediatrics & adolescent medicine*, 159(1), 2005, pp.46-50.
- [3] S. Čičević, M. Dobrodolac, A. Trifunović, D. Lazarević: "Difference in Psychomotor Skills while Working on Tablets PC and Smartphones", *IETI Transactions on Ergonomics and Safety, International Engineering and Technology Institute, Hong Kong, China*, Vol. 1, Issue 2, 2017, pp. 29-37.
- [4] M.L. Connelly, H.M. Conalen, B.S. Parsonson, R.B. Isler: "Child pedestrians' crossing gap thresholds", *Accid. Anal. Prev.* 30 (4), 1998, pp. 443-453.
- [5] J. Galloway: "Harnessing technology for every child matters and personalised learning". Routledge. 2008.
- [6] R. House: "The inappropriateness of ICT in early childhood education: Arguments from philosophy, pedagogy and developmental psychology", in S. Suggate and E. Reese (Eds.), *Contemporary debates in childhood education and development*, 2012, pp. 105-121.
- [7] J. Lynch, T. Redpat: "Smart technologies in early years literacy education: A meta-narrative of paradigmatic tensions in iPad use in an Australian preparatory classroom", *Journal of Early Childhood Literacy*, 14(2), 2014, pp. 147-174.
- [8] S. Meyer, F. Sagberg, R. Torquato: "Traffic hazard perception among children", *Transportation research part F: traffic psychology and behaviour*, 26, 2014, pp. 190-198.
- [9] A. Nguyen, M.M. Borghese, I. Janssen, I: "Pedestrian traffic safety and outdoor active play among 10-13 year olds living in a mid-sized city", *Preventive medicine reports*, 10, 2018, pp. 304-309.

- [10] J. Pallant: "SPSS survival manual", McGraw-Hill Education, London, UK, 2013.
- [11] S. Papadakis, M. Kalogiannakis, N. Zaranis: "Comparing tablets and PCs in teaching mathematics: an attempt to improve mathematics competence in early childhood education", *Preschool and Primary Education*, 4(2), 2016, pp. 241-253.
- [12] T.K. Pitcairn, T. Edlmann: "Individual differences in road crossing ability in young children and adults", *Br. J. Psychol.* 91, 2000, pp.391-410.
- [13] D.C. Schwebel, A.L. Davis, E.E. O'neal: "Child pedestrian injury: a review of behavioural risks and preventive strategies", *Am. J. Lifestyle Med.*, 2012, pp. 292-302.
- [14] M.S. Tremblay, C. Gray, S. Babcock: "Position statement on active outdoor play", *Int. J. Environ. Res. Public Health* 12 (6), 2015, pp. 6475-6505.; (Suppl), S99-123 (e12).
- [15] A. Trifunović, S. Čičević, D. Lazarević, S. Mitrović, M. Dragović: "Comparing tablets (touchscreen devices) and PCs in preschool children' education: testing spatial relationship using geometric symbols on traffic signs", *IETI Transactions on Ergonomics and Safety*, 2, 2018, pp. 35-41.
- [16] A. Trifunović, D. Pešić, S. Čičević, B. Antić: "The importance of spatial orientation and knowledge of traffic signs for children's traffic safety", *Accident Analysis & Prevention*, 102, 2017, pp. 81-92.
- [17] H. Wang, D. Tan, D.C. Schwebel, L. Shi, L. Miao: "Effect of age on children's pedestrian behaviour: Results from an observational study", *Transportation Research Part F: Traffic Psychology and Behaviour*, 58, 2018, pp. 556-565.
- [18] World Health Organization. "Global status report on road safety 2015". World Health Organization, 2015.

ACKNOWLEDGEMENTS

This study was supported by The Ministry of Education, Science and Technological Development of Serbia (projects 36027, 36022 and 36006).

BIOGRAPHY of the first author

Aleksandar Trifunović was born in Kragujevac, Serbia, in 1990.

He is an Assistant at the Faculty for Transport and Traffic Engineering - University of Belgrade, at the Department for Technical Sciences.

Aleksandar is a Ph.D. student at the University of Belgrade. His scientific and research experience involves Traffic Safety, Geometrical modelling, Traffic Psychology, Children and Traffic Safety, Mobile Technologies and Learning. He is the author and co-author of more than ninety papers published in journals and conference proceedings.



NOVI PEDAGOŠKI PRISTUPI - PRIMENA DIGITALNIH MEDIJA U OBUCI DECE O BEZBEDNOSTI U SAOBRAĆAJU

*Aleksandar Trifunović, Svetlana Čičević, Aleksandar Žunjić,
Slobodan Mitrović, Magdalena Dragović*

Rezime Prema procenama Svetske zdravstvene organizacije (WHO), na svetu 186.300 dece godišnje strada u saobraćajnim nezgodama, što predstavlja više od 500 nastradale dece na dan. Saobraćajne nezgode spadaju u jedan od četiri vodeća globalna uzroka smrtni dece između 5 i 14 godina starosti. Od navedenog broja, 38% dece stradaju kao pešaci u saobraćaju. Da bi se unapredila bezbednost dece u saobraćaju, pored edukacije, neophodno je i konstantno istraživanje rizika stradanja dece u saobraćaju. Navedeni razlozi su inicirali sprovođenje eksperimentalnog istraživanja, koje ima za cilj da ispita primenu digitalnih medija i multimedijalnih sadržaja u edukaciji dece o bezbednosti saobraćaja. U eksperimentu je učestvovalo 98 ispitanika. Rezultati su pokazali da deca imaju veći procenat tačnih odgovora na tablet računaru, kada im se zada da rešavaju zadatke vezane za ponašanje u saobraćaju, za razliku od istih takvih saobraćajnih situacijama koje im se zadaju u simuliranim saobraćajnim uslovima. Navedeni rezultati ukazuju na prednost upotrebe tableta u procesu obuke dece o bezbednim načinima ponašanja u saobraćaju kao i značaj edukacije za povećanje nivoa opšte bezbednosti ove populacije u saobraćaju.

Ključne reči: bezbednost saobraćaja, tablet računari, obuka, deca.

IVANA ILIĆ KRSTIĆ¹
ALEKSANDAR ILIĆ²
DANIJELA AVRAMOVIĆ³

^{1,3}University of Niš,
Faculty of Occupational Safety in Niš
²University of Belgrade,
Military Academy in Belgrade

¹ivana.ilic@znrfak.ni.ac.rs

THE THREE DIMENSIONS OF SUSTAINABLE DEVELOPMENT: ENVIRONMENT, ECONOMY AND SOCIETY

Abstract: *This paper discusses the concept of sustainable development, and specifically its three main dimensions. The aim of the paper is to point out the multidimensional and multifunctional aspect of the complex relationship between the environment, economy and society. Nowadays, the concept of sustainable development is adopted as the most recent form of social development paradigm both globally and locally.*

Key words: sustainable development, environment, economy, society.

INTRODUCTION

In broadest terms, sustainability refers to the capacity to continue activities or processes for an indefinite period of time. It can be associated with any number of economic, social or environmental activities and may have different meanings within different disciplines. There are many definitions of sustainability and sustainable development. The most commonly listed definition is the one by the United Nations Environment and Development Council 1987 (the Brundtland Commission). Sustainability means different things to different people and in different (and sometimes conflicting) ways; for example, it can be used to suggest that something is financially sustainable, "environmentally acceptable", that it has a long-term prospect or can continue indefinitely. Regardless of the differences in interpretation, there is a general consensus that sustainability is linked to the goal of maintaining society's well-being over time. However, there are disagreements on how to integrate the issues of sustainability in the field of environmental protection, economics and society.

SUSTAINABILITY FROM AN ECONOMIC PERSPECTIVE

There are various theoretical approaches in the interpretation of sustainability. The commonly used approach to sustainability is the one referring to the three pillars – the environment, society and economy. Essentially, this concept suggests that sustainable development can only be achieved when each pillar is promoted in agreement with the other two. Although this approach provides a useful categorization of the relevant dimensions of sustainability, it is difficult to operationalize, mainly because it has no analytical basis for making decisions on any compromises between the three pillars. [1]

The application of the general concept of sustainability can have different forms depending on the framework used. For example, within ecological frameworks, sustainability refers to the capacity of biological

systems to maintain their functions and processes over time. This perspective focuses on natural capital and often emphasizes the irreversibility of some natural resources and the rights of non-human beings. Within economic frameworks, sustainability is often considered to be achieved if society's well-being is maintained over time. [2] There are different formulations of this concept. Well-being is usually broadly defined – in addition to the consumption of marketed goods and services, enabled by economic production (income), it includes household and environmental services and other non-market outputs, such as social cohesion.

Some economic interpretations of sustainability

Economists interpret sustainability in different ways. Not all of these interpretations explicitly considered sustainability, but the idea was the same - to achieve a certain level of well-being. Over time, the term "sustainability" is used more often. Dasgupta and Heal (1974), Solow (1974) and Stiglitz (1974) gave three basic contributions to the economic theory of sustainability. Their models represent well-being over time in terms of maximizing the benefits. They showed the maximum level of usefulness that can be achieved over time with the final level of natural resources. The impact may be either constant or declining over time, depending on what is assumed about core capital, technological progress, and the rate at which future benefit is reduced. [3]

Specifically, Solow (1974) showed that, under certain conditions, sustained well-being over time can be achieved by maintaining the total capital of capital. That is, the exhaustion of natural capital can be eliminated by investing in industrial capital or other types of capital. By maintaining the level of productive capital, the highest possible level of constant consumption per person can be achieved over time. As Pezzey and Toman noted, although Solow did not explicitly talk about sustainability, "[his] was the first readable paper proposed in the context of the theory of formal economic growth as a sustainable society goal",

and this differs from the traditional economic approach to maximizing the present value of well-being. Solow's maintenance of total capital is similar to the "rule" proposed by Hartwick (1977). Hartwick's rule is that if all renters invest in reproducible capital from exhausting resources, then non-decreasing consumption over time is achieved. However, such "rules" require that different forms of capital be close, if not perfect, substitutions. [4]

In this context – where well-being is at least sustained over time – sustainability can be achieved by preserving the total capital. Capital is widely defined as a "productive" base that provides opportunities to obtain a variety of goods from it. It includes all the capital assets of the society that are produced (roads, buildings, machines), natural capital (ecosystems, minerals, fossil fuels), human capital (education, skills, knowledge) and social capital (institutions and relationships that regulate interactions between people). People value natural capital, while knowledge includes basic and applied research and intellectual property, which can also be interpreted as produced capital.

The implication of such an interpretation of sustainability is the assumption that natural capital can be exhausted, provided that the company invests in other forms of capital (to compensate for this decrease), so that total capital does not decrease over time. This assumes that different forms of capital are substitutes. For example, the level of total capital could be increased by investing in manufactured capital to offset the loss of natural capital. Similarly, the accumulation of human capital through educational achievement and acquisition of skills can be substituted for the produced capital. Technological progress can also increase the "effective" share of the capital, allowing production with fewer physical inputs.

Another significant feature of sustainability is the level of well-being that is considered sustainable. The sustainability criterion of 'well-being maintenance' focuses on changes in well-being over time, and not on whether the highest possible level of well-being is achieved at any time. Therefore, in theory, the attainment of constant well-being at an existential level of consumption can satisfy this interpretation of sustainability. A wider and more important view of sustainability also requires that resources be used and effectively deployed over time – whereby production is carried out with minimum costs and resources are directed to the areas that contribute most to the benefits. Given economic efficiency at any time, economic sustainability can be interpreted as the allocation of resources over time (savings and investments) in a way that ensures the highest level of well-being for present and future generations. [5]

Well-being is difficult to define

The concept of well-being is central to the economic interpretation of sustainability. Conventionally, national statistical institutes and certain economic models use income or consumption of goods and

services that have visible economic value (market goods and services) as a well-being indicator. This generally excludes non-market outputs that contribute to well-being, for example, usefulness derived from entertainment activities, volunteer work or social interactions supported by various forms of social capital. This does not mean that economists do not recognize the importance of these forms of well-being, but many economic models do not take them into account because of the difficulty of defining and measuring their value more precisely.

How substitutable is natural capital and other forms of capital?

The fundamental issue of the economic view of sustainability is the degree to which different forms of capital can be substituted for one another in order to maintain well-being. This is debatable, as there are wide-ranging views on whether it is ethically obligatory and technically feasible to replace natural capital with other forms of capital. The idea that natural capital can be replaced by other forms of capital is commonly referred to as "weak sustainability". Weak sustainability implies that, after natural capital has been exhausted, other forms of capital can be increased in order to restore total capital, and thus maintain consumption (or well-being) per person. This suggests that natural and other forms of capital can substitute one another to a large extent, even if there is high consumption of natural resources. This can be acceptable to a society that wants, for example, to spend a natural resource such as coal or biodiversity in exchange for more road or healthcare infrastructure. Based on this interpretation, the levels of different forms of capital are irrelevant; it is the total capital that is important for sustainability. By contrast, "strong sustainability" rejects the idea of substitution, based on the assumption that natural capital is not complementary to other forms of capital, including social capital, and is therefore largely "incompatible". This view is usually supported by environmental economists (Daly 1990). [6] Despite this, there is a wide range of opinions about what strong sustainability is. Strictly interpreted, strong sustainability implies that each component of the environment and each species must be preserved for an indefinite period and that it is ethically unacceptable and economically unsound for future generations to be compensated for loss of natural capital through the consumption of services from other forms of capital. This implies that a very large, potentially infinite, value is placed on these sources. Other views suggest that non-renewable and renewable forms of natural capital can be interchangeable as long as the total amount of natural capital is retained. However, there is some common ground between advocates of weak and strong sustainability. Many agree that some portion of natural capital is essential for the production of other forms of capital (manufactured, social and human) and that it is not possible to maintain every natural capital for an

indefinite period of time. [7] Indeed, natural systems evolve and cannot be preserved in the original form. Most advocates also accept that certain natural resources are not interchangeable, at least below a certain threshold, especially those resources that are necessary for life. Therefore, different views notwithstanding, two paradigms do not always have to be in conflict. It is true that maintaining a minimum level of natural capital (an aspect of strong sustainability) may also be in line with weak sustainability. This might happen because society could be expected to place greater value on scarce natural resources.

Thus, the debate concerning weak and strong sustainability is characterized by the debate concerning the degree of substitution and the mechanism for determining the appropriate degree of substitution, instead of discussing whether any substitution can occur at all. From an economic perspective, the relative prices (broadly defined, as they reflect the social value of all forms of capital for the community) are the primary mechanism through which decisions on the substitution of types of capital can be made. However, as discussed below, while prices are revealed in places where markets are present, provided those markets function effectively, this is not the case with certain types of capital, especially natural capital. This means that other approaches, such as taxes or regulations, may be needed to protect the natural capital that is considered vital. However, a strong approach to sustainability does not provide an obvious analytical framework or mechanism for determining when this can be the case, or for establishing the community value of different types of capital. Over time, it is difficult for market efficiency or any other mechanism to allocate resources in a sustainable manner due to a high level of uncertainty regarding the degree to which substitution is really possible. Substitution options partially determine future technical advancements and advantages of future generations, two factors that are not completely unrelated. It is assumed that we cannot know precisely what the needs of future generations will be, so it is difficult to know what should be preserved. Further complication in explaining sustainability arises from the fact that technological changes imply that we will be able to do more with less, and we may be able to redirect the dependence on some non-renewable sources on other non-renewable or renewable resources.

APPLYING SUSTAINABILITY CONCEPTS IN PRACTICE

As already mentioned, sustainability implies that all resources are used efficiently – both within and between generations – and that the productive base of society (total capital) is more or less preserved over time. Market and prices play an important role in this context. When the markets are complete and well-functioning, they provide a mechanism for determining the cost of resources, depending on their value in use.

Prices will also reflect the value that a company places on individual resources. If prices are raised in response to scarcity of resources, then prices provide incentives for consumers and manufacturers to use resources more efficiently or to look for a replacement. These processes contribute to the improvement of well-being and are therefore relevant to sustainability.

However, there are several reasons why market processes cannot provide an optimal level of sustainability. First, market mechanisms are not perfect, thus affecting sustainability, which means that basic capital is used inefficiently and, consequently, well-being is at a lower level than it can be. Specifically, incomplete information about the value that the community places on non-traded capital services reduces the efficiency of market allocation. Second, even if the current generation is effectively using resources, capital investment may be deficient. This can leave future generations with inadequate resources to maintain a level of well-being equal to that of the current generation. Decisions of the current generation can be insufficiently sustainable due to incomplete information on the environmental processes or the extent to which different forms of capital can be replaced with one another. In addition, as mentioned above, there is uncertainty regarding the preference of future generations as to how their needs are to be met.

Despite these problems, previous generations have shown increased willingness to provide a better life for their descendants and have made numerous innovations and capital investments to be used by the generations to follow. This is reflected in the actions already taken to incorporate the idea of sustainability into the development policies of many countries. There are a number of practical steps that have the potential to improve decision making in this context. These include improvement of:

- the efficiency of using resources (for example, through adequate prices or regulations that provide net benefits);
- our understanding of ecological systems;
- our ability to measure fixed capital.

These steps are interconnected because improvements in one area will help our understanding of other areas. Practical endeavours in the second and third area are important for understanding the substitution rate between different types of capital at present and in the future, as well as the level of capital changes.

Improving the efficiency of resource use

If markets operate efficiently, scarce resources – including environmental resources – are directed toward use and the users who value them the most. In principle, this can lead to the allocation of resources that maximizes the well-being of a society. However, when markets do not function properly (for example, due to a lack of effective competition or a lack of information) or are incomplete (for example, as a result of externalities or good characteristics of specific goods and services), the well-being cannot reach its full

potential. Indeed, market values do not have to be in line with what the society values, or even with the interests of the economy as a whole in the long run. Consequently, there may be a role for governments to resolve externalities, facilitate the operation of efficient markets and take into account the good aspects of the environment and other resources. [8] Policies intended to tackle market failures can only be promoted based on economic efficiency. However, there may be many circumstances when actions undertaken today can impose costs on future generations. In these cases, it may be necessary to explicitly consider the impact on well-being among generations when formulating a sustainable development policy. One example is climate change, where the effects of greenhouse gas emissions will be tackled mainly by the future generations. However, market failure in itself does not justify the intervention of the government. Government action to tackle market failures is warranted only where the benefits to society outweigh the costs of intervention. Making this assessment can be complicated due to the long-term nature of the issue of sustainability, inadequate information, priorities changing over time, uncertainty and confused management arising from the involvement of different levels of government. Given these conditions, policy options may or may not be able to improve the results for the community as a whole and they need to be carefully evaluated to ensure that government intervention does not exacerbate matters. Moreover, in the context of sustainability, they may often challenge very indirect and poorly targeted policies.

The most appropriate form of intervention will depend on the underlying source of market failure and the costs and benefits of different policy options. The Commission has generally advocated the policy of targeting the source of the problem, as this will usually be more efficient - for example, using a broad limitation of gas and greenhouse gas emissions (directly internalising the sources of externalities through pricing) can be a cheaper and more efficient option than setting up specific technologies to reduce emissions. Market approaches will often be the most efficient means of resolving market failure. This includes creating financial incentives to direct resources toward the areas where they are valued the most by putting prices on ecological outputs – either by creating a market (for example, emission and trade licenses) or by using taxes or subsidies. It cannot always be possible to use an explicit market-based approach to resolve the failure of a market when property rights are difficult to define or enforce, or where it is difficult to measure outputs. For example, some ecosystem services cannot be traded in markets because ownership of the ecosystem service cannot be defined or enforced. In such circumstances, direct regulatory approaches may be more convenient, by efficiently putting an “implicit” price on the relevant resource. [9]

Improving our understanding of ecological systems

The existence of natural thresholds beyond which environmental damage is irreversible means that there are restrictions on the substitution of natural capital. In many cases, these limits are not known. Improving our understanding of the impact of using certain resources (e.g. water) on the functioning of ecological systems would be useful, both from the perspective of governments that make decisions on environmental protection and from the perspective of improving the accounting of natural capital. Scientific agencies are already doing significant work in this regard. If it is accepted that capital (produced, natural, human and social) is the basis for consumption (broadly defined) and thus contributes to the well-being, then the approaches that measure changes in the total state of the capital can provide an indication of sustainability and can inform policy analyses. Capital measures should include assessments of scope and interest, so that changes in capital can be assessed over time. There have been some attempts to extend the assessments of produced capital in traditional national accounts with assessments of natural, social and human capital. This is sometimes called “extended wealth” or “adjusted net savings”. [10] There are various limitations and practical difficulties in evaluating extended wealth measures. One of the main challenges is to determine prices for natural capital. While some exhaustible environmental resources, such as coal and oil, are traded on markets and have monitored prices, these prices may not reflect the full value of resources due to market failures, such as underdeveloped externalities. In addition, in most cases environmental resources are not traded on the markets and therefore have no observed market value. Therefore, it is necessary to estimate economic prices for these resources. The prices must take into account the various contributions of natural capital to well-being - both direct (as natural wealth items) and indirect (contributions of ecosystem services, such as water purification). [11]

Specific natural capital is also very difficult to quantify. A similar issue can also be raised regarding the more intangible dimensions of social capital, such as cultural diversity, social cohesion and self-respect. [12] Therefore, although extended capital measures may involve investments in some forms of capital, such as human capital (through education and its impact on labour income) and natural capital (through environmental conservation), many social values are much more difficult to define, let alone quantify. In addition, social capital is often not the product of a deliberate investment strategy but rather a function of complex social and cultural interactions, so the same inputs of produced and human capital can yield substantially different outputs in terms of social capital. Given the inherent difficulties associated with the development of comprehensive measures of capital actions and the uncertainty about future preferences (and hence the future values of different forms of capital), Stiglitz and associates recommend a “control

panel” of indicators for sustainability assessment. [13] This includes physical indicators of the state of the environment. In addition to better measures of capital in all of its forms, there is a need to determine the preferred composition of core capital that the future generations would inherit. This requires consideration of the readiness of the community to replace different forms of capital and, in particular, the understanding of the values that people place on various aspects of well-being, especially those pertaining to natural and social capital. A key component of this assessment is the assessment of the implications of well-being associated with natural capital losses.

CONCLUSION

In the broadest sense, sustainable development refers to a balance between the consumption of available resources and the ability of social systems to meet the needs of present and future generations. This means maintaining the Earth’s capacity to ensure quality living not only for every living person, but also for any of its yet-unborn future inhabitants. Therefore, sustainable development means maintaining the conditions for quality development, as material prerequisites of the survival of not only the present but also the future generations of people. In this sense, sustainable development brings a new optimistic vision of global development, i.e. development for everyone, placing an emphasis on new economic and technological development strategies, which have to meet the increasingly rigorous economic, as well as ecological, criteria. The state, education and culture, citizens’ associations, the media, and other numerous actors of social reproduction flows must each in their own way contribute to the intensification of environmental awareness. This process must be complementary to the process implemented through a market regulation mechanism, in which ecological criteria should also be incorporated. Therefore, [12] sustainable development is one that permanently maintains humans as a biological species and as cultural and social beings. Economic activity has to be sustainable, which means that planet Earth, with its potentials, must not be degraded by the people currently inhabiting it. Thus, the right of the current generation to exploit resources and the environment should not threaten the same right for the following generations. Another reason in support of sustainable development is of an ecological nature. If nature is a value in itself, then every aspect of economic activity that disturbs the wealth of resources is unacceptable. A third potential reason to justify the concept of sustainability might reside in the economic argument that sustainable development is more efficient. In other words, disrespecting the concept of sustainability leads to inefficient economic development, in terms of ever-increasing waste of global resources and energy.

REFERENCES

- [1] Daly Herman E., “Ecological Economics and Sustainable Development”. *Selected essays of Herman Daly*. - Northampton, USA, Edward Elgar Publishing, 2007.
- [2] Arrow, K., Dasgupta, P., Goulder, L., Daily, G., Ehrlich, P., Heal, G., Levin, S., Maler, K., Schneider, S., Starrett, D., and Walker, B. 2004, ‘Are we consuming too much?’, *Journal of Economic Perspectives*, vol. 18, no. 3, pp. 147-172.
- [3] Dasgupta, P. and Heal, G. 1974, ‘The optimal depletion of exhaustible resources’, *Review of Economic Studies*, vol. 41, pp. 3-28.
- [4] Markulev, A. and Long, A. “On sustainability: an economic approach”, *COMMONWEALTH OF AUSTRALIA* 2013 ISBN 978-1-74037-439
- [5] Stavins, R., Wagner, A. F., Wagner, G. 2003, ‘Interpreting sustainability in economic terms: Dynamic efficiently plus intergenerational equity’, *Economics Letters*, vol. 79, pp. 339-343.
- [6] Daly, H 1990, ‘Towards some operational principles of sustainable development’, *Ecological Economics*, vol. 2, no. 1, pp. 1-6.
- [7] Neumayer, E. 2010, *Weak Versus Strong Sustainability: Exploring the Limits of Two Opposing Paradigms*, third edn, Edward Elgar, Cheltenham UK.
- [8] Banks, G. 2009, *Markets: How Free?*, address to the Governing the Economy Symposium, Whitlam Institute, Sydney, 30 November.
- [9] Murtough, G., Aretino, B. and Matysek, A. 2002, *Creating Markets for Ecosystem Services*, Productivity Commission Staff Research Paper, Canberra.
- [10] Biddle, N., Davis, E., Myers, J., Dodhy, RS. 2009, *Exploring Measures of Low Social Capital*, Australian Bureau of Statistics Research Paper. Cat. no. 1351.0.55.024, Canberra.
- [11] Arrow, K., Dasgupta, P., Goulder, L., Daily, G., Ehrlich, P., Heal, G., Levin, S., Maler, K., Schneider, S., Starrett, D., and Walker, B. 2004, ‘Are we consuming too much?’, *Journal of Economic Perspectives*, vol. 18, no. 3, pp. 147-172.
- [12] Barbier, E. 1987, ‘The concept of sustainable economic development’, *Environmental Conservation*, vol. 14, no. 2, pp. 101-110.
- [13] Stiglitz, J., 1974, ‘Growth with exhaustible natural resources: Efficient and optimal growth paths’, *Review of Economic Studies*, vol. 41, pp. 123-137.

ACKNOWLEDGEMENTS

Prepared as a part of the project *Sustainability of the Identity of Serbs and National Minorities in the Border Municipalities of Eastern and Southeastern Serbia* (179013), conducted at the University of Niš - Faculty of Mechanical Engineering, and supported by the Ministry of Science and Technological Development of the Republic of Serbia.

BIOGRAPHY of the first author

Ivana Ilić Krstić, PhD, is an assistant professor at the Faculty of Occupational Safety in Niš, Serbia. She is the author or co-author of over 50 scientific papers published in scientific journals and proceedings of scientific conferences.



She is a member of the BENA organization. Her academic interests include: social development, occupational and natural environment, sustainable development and social indicators of sustainable development.

OSNOVNE DIMENZIJE ODRŽIVOG RAZVOJA: ŽIVOTNA SREDINA, EKONOMIJA I DRUŠTVO

Ivana Ilić Krstić, Aleksandar Ilić, Danijela Avramović

Rezime: U radu se razmatra concept održivog razvoja i ukazuje na njegove bazične dimenzije koje ga čine. Ima se za cilj da se sa multi dimenzionalnog i multi funkcionalnog aspekta ukaže na kompleksnu vezu između životne sredine, ekonomije i društva. Uzimajući u obzir činjenicu, da se koncept održivog razvoja danas usvaja kao najnoviji vid paradigme društvenog razvoja, kako na globalnom, tako i na lokalnom nivou.

Ključne reči: održivi razvoj, životna sredina, ekonomija i društvo.

BILJANA NIKOLIĆ¹
MARIJOLA BOŽOVIĆ²
MARTINA PETKOVIĆ³

¹Higher Technical Professional
School in Zvečan

²Higher Technical Professional
School in Zvečan

³Higher Technical Professional
School in Zvečan

¹first@eunet.rs

²martinaeco@yahoo.com

³m.bozovic@vts-zvecan.edu.rs

ENVIRONMENTAL PROTECTION IN INTERNATIONAL AND NATIONAL FRAMEWORK

Abstract: *The modern society is becoming more consolidated and there is a lot of debate regarding unifying all societies into a single one. This unification is sometimes contradictory; however, it is obvious that current societies are more dependent on each other than they have ever been throughout the history of mankind. There are various differences between individual societies. Most of these differences are tied to different economic interests as well as various socio-economic or, rather, historical circumstances which occurred during the development of the society (country). Resolving global issues is a necessity to preserve mankind as a community and the solutions require all societies to act together as one team. One of these issues is environmental protection – preserving ecological balance on Earth, which means solving all contemporary ecological issues. The topic of this paper is to review environmental protection within international and national framework.*

Key words: environmental protection, legal framework, global issues.

INTRODUCTION

Protection of human environment, as a global issue, is closely tied to solving other global issues that modern mankind is faced with, the biggest ones being: rational and complex usage of natural resources; reviving international cooperation in science studies and usage of scientific/technical revolution to benefit mankind.

The global nature of ecological issues requires an international cooperation in order to be able to solve them. Global actions which are considered and which will be taken to mitigate and solve the ecological crisis must be planned with agreement from all interested countries, because all the actions are taken on a national level. Industrial development during its early years brought degradation (pollution) of the environment on both local and regional scale. Although later on, with the intensive development of the industry and urbanization, the consequences of increased pollution affect not only local borders, but the state ones as well. The consequences of polluting the environment in a modern society now have a global impact, and they manifest by anthropological pollution of the atmosphere, climate changes, geochemical anomalies, etc.

Environmental pollution across the state borders doesn't only happen through the flow of air and water, another prominent case is exporting of the so-called "dirty technology". In recent years, industrial developed countries in which there are new ecological regulations that must be enforced to protect the environment but lead to a profit loss, export their "dirty industry" to undeveloped or countries in development. Those industries have drastically affected air pollutions and have often led to massive poisoning of workers. This is exactly the reason behind international initiative to regulate transfers of "dirty industries".

Current ecological issues which require an urgent solution, often with international cooperation, were pointed out in the "Vienna declaration" (Vienna declaration was endorsed by participants of the First international round of agreements about education and politics regarding natural environment in June of 1993). This declaration expressed concerns tied to pollution of air, water and soil, many plants and animals becoming endangered and other damage caused to the environment by pollution. The particularly important part is the demand for legal regulation of transport and disposal of scrap materials that could cause serious health issues or further the damage done to the environment.

INTERNATIONAL COOPERATION IN ENVIRONMENTAL PROTECTION

International cooperation in environmental protection can be observed from different points of view: legal, economic, civilizational etc. Regardless of the point of view, the international cooperation has a common goal - environment and its protection, which means that other societies must be considered in some sense as well.

International cooperation of countries in regards to protection and developing the environment can be attained in 3 ways: under the authority of OUN, regional state alliances and continental cooperation of certain countries. Solving environmental issues on a global scale provides a considerable effort to initiatives under the OUN. This particular method of cooperation tackles certain ecological problems which are aimed at one country but the issues can be solved with help from other countries. United Nations have recently adopted United Nations Environment Program (UNEP) which plays a considerable role in alerting the public of the

growing danger which is caused by harming the ecological balance.

United Nations Environment Program (UNEP) plays a part in preventing air and water pollution as well as supporting rational usage of natural resources. UNEP is especially engaged in improving international regulations aimed at the environment. There are two fundamental principles that are at the core level of international protection law and improvement of the environment – sovereignty of a country over its national resources and holding a country accountable for activities that cause harm to the environment of another country or to an environment that is not under jurisdiction of said country. The principle of responsibility is a part of the UN's Stockholm declaration on the environment in which is stated that countries, apart from the already mentioned sovereign right to utilize their national resources, have the "responsibility to make sure that activities under their jurisdiction or control do not cause harm in an environment that is considered to be a part of other countries or in areas outside the borders of national jurisdiction" (Principle 21). In principle 22 of the aforementioned declaration there is an order about countries cooperating on further development of international law in regards to harm and compensation for harm done to victims of pollution or other damage done to the environment caused by activities under the jurisdiction or control of such states, in areas that are not under their jurisdiction (Principle 22, Stockholm declaration).

In recent years, there is a number of UN specialized agencies which started implementing environmental protection in their general activities. For example, International Labour Organization (ILO) working on issues of the work environment is implying that there is a connection between natural environment and issues that pollution causes in both natural and work environments. UN's Food and Agriculture Organization (FAO) does a lot of work on issues such as rational use and protection of water, which is impossible to be done without them also tackling ecological issues. The World Health Organization (WHO), apart from dealing with health protection problems, also tries to solve ecological issues. This is the reason why WHO is trying to define standards in regards to the environment and identifying the impact that a certain environment may have on people's health. Apart from the ones already mentioned, there are other UN specialized agencies which, in their own way, contribute to improvement of environment protection. The World Meteorological Organization is engaged in making a unified worldwide system dedicated to weather assessment and making an effort to investigate the atmosphere. The International Maritime Organization (IMO) is tasked with protecting the seas from pollution. The International Atomic Energy Agency (IAEA) deals with issues such as the harmful impact of amplified radioactivity on the environment.

Certain collaborations in the field of environmental protection and improvement take place between countries that are a part of the same economic/political groups. The most important groups are the CMEA (Council for Mutual Economic Assistance which stopped existing in the 90s); the OECD (Organization for Economic Co-operation and Development) and the EEC (European Economic Community). These groups, apart from the general activities for which they were founded, focus on developing various ways of co-operation in the field of environment protection and improvement. The OECD (which was founded in 1961) adopted the so-called leading principles on environment and later on they adopted the Declaration on environmental policy (Vukasović V., cit. Delo, str. 109). The European Economic Community is intensifying the cooperation in the field of environment protection and improvement, from it's regulations to mutual investigative efforts.

In Europe, the cooperation in the field of environment is being progressively developed and is being regulated by international agreements, decisions from the European Community and by adopting other documents that have a legal and a political dimension. European Community Council has the right to adopt certain legal acts related to environment protection and must be enforced. Those legal acts are:

- Rule books - which must be enforced by all members;
- Directives - which must be implemented in existing laws and rule books of member states within a certain time frame
- Decisions - which are directly binding, for all persons, institutions or countries which are highlighted

Important incentive to environment protection and improvement was provided at the UN conference on environment and development which was held in Brazil in 1992. The Rio declaration on environment and development was adopted. This declaration is actually the reaffirmed declaration from the first UN conference on environment and it should serve as a foundation for building a new and balanced global partnership and cooperation between countries with the goal of protecting the environment.

Ministry conferences which are attended by ministries from Central and Eastern Europe, UN and EU officials and Government/Non-Governmental Organizations are taking care of issues that come with environment protection. It is important to note the Lisbon agreement, which takes the complexity of environment protection regulations to a new level, and also has some implications on measures taken to tackle climate change and energy policies.

ENVIRONMENT PROTECTION IN OUR COUNTRY

In Serbia nowadays there are many different ways in which the environment is being degraded and they are becoming even more present. There are five main culprits which have a bad impact on the environment. In our country those culprits are quick and a specific industrialization process; urbanization; the use of “profit oriented” technology; “spendthrift” approach to resource usage and the mechanism of market economizing. One of the main reasons of disrupting the ecological balance or pollution of the environment, in Serbia and other countries, is the use of technology which is not oriented towards saving natural resources and the continued use of such technology creates certain side effects which pollute the environment. The import of technology was followed by rapid development of manufacturing capacities, productivity growth and many other positive consequences.

Degradation of the environment in Serbia was caused and is still being caused by people involved in organizing and acting in the market which think that free market will, not only in the market sphere but also in the environment protection field, lead to optimal solutions for the society. Although, experience so far has shown that the market itself can't guarantee rational behavior towards the environment.

Pointing out the culprits that lead to the degradation of the environment is also a way to point out the source of ecological imbalance. All of the culprits can be sorted in two general groups. First group is made up of reasons that come directly from the relationship between humans and the environment which is currently taking place in the modern society – irrational behavior towards non-renewable natural resources, using technologies that are not kind to nature and polluting the environment with products of mass productivity and spending. Second group is made up of reasons that originate from the socio-economic “mechanisms” which have been present for a very long time, such as setting a clear productivity goal and maximizing profit, and only then making products that will satisfy basic human needs.

In the ex-SFRY, constitutional law on a healthy life environment was put into action with the 1974. Constitution. This constitution is especially important because it is the first constitutional document in the world that had a completely new individual law on the right for a healthy environment. The following laws only improved on the original concept. Apart from the cooperation with the UN, Yugoslavia had multiple cooperation agreements with some countries (especially neighboring countries), it also worked with intergovernmental committees and mixed committees which were taking care of protecting the environment. These kinds of agreements were reached with Hungary, Austria, Bulgaria, Romania and Italy.

In the early years of the 21st century, on the basis of adopted universal and regional international standards, even in the Republic of Serbia lawmakers were hard at

work to make new ecological lawmaking which was supposed to bring a whole new level of quality to the improvement and protection of the environment or its basic components, flora, fauna, water, soil, air etc. In 2004. and 2009. there were multiple regulations which make up the “ecological law” whose purpose is to get our country in line with many other countries which have already adjusted their internal law with the international law and 730 European standards.

In 2004 there were multiple ecological regulations: Regulation on environment protection, “Official Gazette of the Republic of Serbia”, No. 135/2004, 36/2009, 36/2009, 72/2009, 43/2011, 14/2016, 76/2018, Regulation on integrated prohibition and control of pollution of the environment, “Official Gazette of the Republic of Serbia”, No. 135/2004, 25/2015, Regulation on assessing the impact on the environment, “Official Gazette of the Republic of Serbia”, No. 135/2004, 36/2009. New reform of the ecological lawmaking was made in 2009, when the following regulations were put into effect: Regulation on protection from non-ionizing radiation, Regulation on handling waste, Regulation on chemicals, Regulation on packaging and package type waste, Regulation on protecting air and Regulation on protection from loud noises in the environment.

Raising awareness about the importance of environment protection is provided through educational institutions, scientific-investigative and technological development, synchronization or the work flow, publicly informing and popularizing environment protection (Nikolić, V., 2003; Nikolić, V., 2010). Citizen communities in the field of environment protection plan, propose and implement their protection programs, they protect their own rights and interests in the field of environment protection, suggest activities and safety measures, involve themselves in the process of making decisions in line with existing regulations, contribute to or work on the common goal of raising awareness of the environment. People involved in the environment protection system are required to work together, provide coordination and synchronization regarding planning and acting on ideas, while Republic of Serbia (or rather the institutions), make agreements in the field of environment protection with other countries and international organizations.

CONCLUSION

Concerns regarding the environment culminated in the 70s due to the growing pollution problem and lack of proper solutions for solving ecological issues. For decades, modern science and practice have shown the connection and mutual dependency of the environment and economy. Consumer oriented approach and recklessly spending available natural resources by people are the cause of ecological issues. To overcome these challenges, it is necessary to implement strict social changes which will require a change from the model of economy development to the model of sustainable economy. Recognizing the environment as

a crucial part of further societal and economic development has raised awareness on protecting the environment. There is a need for making preventive programs and using available resources to protect the environment. Intensive international cooperation has been able to formulate multiple conventions and agreements in the field of ecology. During the period between the Stockholm conference in 1972 and the UN conference on environment and development in 1992, it was confirmed that there were multiple negative impacts on the environment caused by human activity. The apparent degradation of the environment has caused the consumers to make their purchase choices based on how much a company was ecologically responsible. In that sense, there is an increasing number of corporations which will strive to achieve optimal and ecologically sustainable work ethics. On the basis of the data provided and a detailed perspective on the most important conventions and agreements in the field of ecology, it is safe to conclude that there is a lot of international mechanisms in place, however it is necessary to insist on a more effective and intensive implementation.

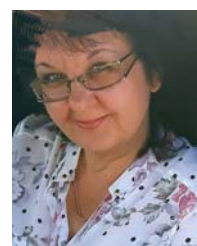
REFERENCES

- [1] Nikolic, V., *Organizational Learning - An Integrative Approach to Learning in the Workplace*, Proceedings: International Conference of Dependability and Quality Management, Research Center of DQM, Beograd, 2010, pp. 59 -70
- [2] Nikolić, V., Savić, S., *Obrazovanje za bezbedan rad i upravljanje profesionalnim rizikom*, Zbornik radova sa 11 savetovanja sa međunarodnim učešćem: Rizik požara, eksplozije, havarije i provala u osiguranju i organizacija sistema zaštite, Dunav Preving a.d., Beograd, 2003.
- [3] Nikolić, S., *Upravljanje ljudskim resursima – Organizacija preduzeća*, Ekonomski fakultet, Niš, 2003.
- [4] Vuksanović, B., *Priručnik za učešće javnosti u odlučivanju javnosti o životnoj sredini*, Regionalni centar za životnu sredinu u centralnoj i istočnoj Evropi, Kancelarija u Jugoslaviji, Beograd, 2000.
- [5] Regulation on environment protection, "Official Gazette of the Republic of Serbia", No. 135/2004, 36/2009, 36/2009, 72/2009, 43/2011, 14/2016, 76/2018,
- [6] Regulation on integrated prohibition and control of pollution of the environment, "Official Gazette of the Republic of Serbia", No. 135/2004, 25/2015,
- [7] Regulation on assessing the impact on the environment, "Official Gazette of the Republic of Serbia", No. 135/2004, 36/2009.

BIOGRAPHY of the first author

Biljana Nikolić was born in Nis, Serbia, in 1971.

She received the diploma in environmental protection and the Magister degree in environmental protection from the University of Nis, Faculty of Occupational safety in Nis.



Her main areas of research include environmental safety, occupational safety, etc.

She is currently working as an Instructor, Higher Technical Professional School in Zvečan.

ZAŠTITA ŽIVOTNE SREDINE U MEĐUNARODNIM I NACIONALNIM OKVIRIMA

Biljana Nikolić, Marijola Božović, Martina Petković

Rezime: *Savremeno društvo postaje sve jedinstvenije, tako da se govori o ujedinjavanju svih društava u jedno društvo. Ovo ujedinjavanje ide i protivrečnim putem, ali "nesumnjivo je da su dosadašnja društva u okviru čovečanstva mnogo zavisnija od drugih, nego što je to ikad do sada bio slučaj. Postoje suprotnosti između pojedinih društava (država). One nastaju, pre svega, zbog različitih ekonomskih interesa, ali i različitih društveno - ekonomskih i uopšte različitih civilizacijskih okolnosti i uslova u kojima su se pojedina društva razvila. Rešavanje globalnih problema je pretpostavka opstanka čovečanstva kao ljudske zajednice i njihovo rešavanje zahteva i predstavlja angažovanje svih društava - društava kao ljudske zajednice. Jedan od takvih problema je i zaštita životne sredine - očuvanje ekološke ravnoteže na planeti, a to znači rešavanje savremenih ekoloških problema. U radu se daje osvrt na pregled zaštite životne sredine u međunarodnim i nacionalnim okvirima.*

Ključne reči: zaštita životne sredine, pravni okviri, globalni problemi.

KATARINA ILIĆ¹

¹Clinical Centre Niš
¹katarina.iiilic@gmail.com

THE STRUCTURE OF RESEARCH ARTICLES IN THE FIELD OF OCCUPATIONAL SAFETY: HAVE SERBIAN ACADEMIC WRITERS REACHED INTERNATIONAL STANDARDS?

Abstract: *The aim of this research is to study the structure of research articles written in English by academic writers of Serbian background in the field of occupational safety in order to determine whether these authors have reached the international standards in academic writing. Bearing in mind the fact that the style and method of writing need to be adapted to the academic audience, it is clear that writing for the international community entails the norms of international academic discourse. This paper analyses the structure of research articles as a whole, from introduction to conclusion. The data comes from a corpus of 40 papers published in Facta Universitatis, Series: Working and Living Environmental Protection and Safety Engineering. The results will show whether Serbian academic writers follow the conventions of international writing style, which will help them integrate better into the international academic world.*

Key words: academic discourse, international academic community, writing conventions, occupational safety.

INTRODUCTION

English has nowadays undisputably become the language of scientific research, which makes the Anglo-American academic writing style the standard for modern international academic communication [1]. Therefore, academic writing for international readership shall include the norms and conventions applied in the international academic community. Using English in academic research brings with it a number of benefits, such as the rapid dissemination of human knowledge. In that sense, when non-native English speaking scholars continue to publish in their first language, their publication is likely to be less significant [2]. For that reason, writing in English and accepting Anglo-American writing conventions will result in a better acceptance and evaluation of a scientific paper. This standpoint also applies to Serbian authors who do not only write in their native language but also in English.

It is widely believed that scientific writing is a unique form of argument where the text is merely the channel which allows scientists to communicate independently existing truths describing what the natural and human worlds are actually like. However, this realistic point of view is gradually being replaced by the belief that knowledge is not a privileged representation of reality, but the agreement of academic communities [3]. Therefore, the manner of conveying scientific information has become as relevant as the information itself.

In the 20th century, numerous contrastive analyses of the academic discourse showed that the way in which scientific results are presented largely depends on the

culture the authors belong to. One of the first was conducted by Robert Kaplan, who claimed that logic, which is the basis of rhetoric, was evolved out of a culture. Rhetoric is not universal either, but varies from culture to culture. Therefore, the English language, as the universal language of science, is closely related to Anglo-European cultural pattern. In his research, Kaplan examined student compositions from different cultural communities and concluded that Oriental writing is characterized by indirectness, Russian authors often use parallel constructions and English speakers do not employ digressions [4]. What is more important than the results of this study is the awakened awareness of culturally-conditioned forms of academic writing.

Writing for the international academic community in the English language entails international standards of scientific writing. If the international academic community is the target audience for non-English academics the question is how to produce an effective academic text in English in order for it to be adequately accepted by international readership [5]. The first step in producing an acceptable piece of scientific writing in English is recognizing the academic conventions of this language. As Blagojević states, English writing style cherishes 'the reader-friendly discourse', which means that the author helps the reader through the text by stating the ideas explicitly. Furthermore, a well-formulated text is devoid of repetitions and digressions, the aim of the text is stated at the very beginning and only relevant facts are included [5, 6]. Another basic assumption of a quality academic text is its organization and structure. Namely, scientific articles

follow the conventions of the so-called IMRaD format (Introduction - Method - Results - and - Discussion) [6], which is, however, not always employed by the authors of non-English origin [6].

When it comes to text organization, academic articles written by Serbian authors are often characterized by long, unbroken stretches of text, while English articles are regularly divided into rhetorical units and sub-units within them. If it is assumed that the content of an article is much easier to follow when it is divided into units, it follows that the authors who utilize the IMRaD format show more concern for their readers and guide them through the text [1]. The research into the rhetorical structure of academic texts started with the endeavours of John Swales, who was the first one to notice the lack of attempts to define an appropriate methodology that would be used in the analysis of a scientific article. He primarily dealt with article introductions and thus developed his CARS (Creating a Research Space) model dividing each introduction into "moves" and each "move" into "steps" [8]. However, there have not been many attempts to analyse the structure of a research article as a whole, from *introduction* to *conclusion* [9], which leaves enough space for further research into this area of academic discourse.

Bearing in mind the abovementioned, this study explores the hypothesis that authors from different cultures organise their scientific writing in accordance with their own cultural patterns and persist to adhere to their national writing style. Therefore, the aim of this paper is to illustrate the rhetorical organization of research articles (RA) in the field of occupational safety and health written by Serbian authors in English and compare it to the model accepted in the international community.

METHOD

The sample on which we conducted the research is 40 research articles written by Serbian authors in the English language. The research articles were published in two journals, *Facta Universitatis, Series: Working and Living Environmental Protection and Safety Engineering*, in the period from 2015 to 2018. We selected these journals since they are issued in Serbia and thus the authors are primarily from Serbian-speaking community.

The model applied in this paper will be the combination of Swales' CARS model [8, 10], Pho's top-down identification of the moves and steps in the whole article [9] and Blagojević's method of determining discourse strategies [6]. Discourse strategies typically encountered in each section of a research article following the IMRaD format, which we will try attempt to identify in our sample, are as follows:

Introduction:

- Outlining the purpose of the research,
- Hypothesis-raising,

- Establishing the territory,
- Presenting the present work,
- Indicating RA structure,
- Summarising previous research;

Method:

- Describing data collection procedure (sample/instruments),
- Justifying data collection procedure,
- Describing data analysis procedure;

Results/Discussion:

- Preparing for the presentation of the results,
- Reporting specific/individual results,
- Interpreting results;

Conclusion:

- Highlighting overall research outcome,
- Comparing results with literature,
- Indicating limitations,
- Recommending further research.

The quantitative part of the analysis will determine the number of research articles which contain the IMRaD format and the number of each discourse strategy, while the qualitative part will illustrate the discourse strategies and interpret their usage.

RESULTS AND DISCUSSION

The analysis of the IMRaD format

As one of the first prerequisites for accepting a research article in the international academic community is its IMRaD structure, we tried to closely inspect the text division of the sample. The results of the analysis have shown that 9 out of 40 papers follow the strict IMRaD format, which is only 22.5%. The strict format means that no other sections are present in the paper apart from the abovementioned ones. Though this number is surprisingly low, it is important to notice that a large number of articles contain a modified version of this format. We observed the following:

- All research articles contain *Introduction* and *Conclusion*.
- Apart from the *Introduction*, *Method*, *Results and Discussion* and *Conclusion*, there are articles which consist of some additional sections, such as *Lessons Learned* or *Motivation for Work*, which are not typically encountered in the Anglo-Saxon discourse practice.
- The section most commonly added to the IMRaD format is the one called *The Experimental*, *The Experimental Research*, *Experiment*, *Qualitative Analysis* or *Case Study*. There are 10 (25%) papers in total containing such a rhetorical unit. It is either used prior to *Results and Discussion* unit or instead of it. However, according to the rules of the IMRaD structure, the description of the experiment itself is to be contained in the *Results and Discussion* section as it incorporates the preparation for presenting the results and report on specific results [9].

- Particular rhetorical units in the sample contain a modified heading. For example, *Numerical Method and Modelling*, *Working Method and Materials* or *Measurement Methodology* are used for the *Methods* section while *Numerical Results* or *Measurements* are used for *Results and Discussion*.

There are 15 papers altogether with a modified version of the IMRaD format, which, together with 9 articles with its unaltered version, make up the total of 24 (60%) articles whose authors are to some extent familiar with the norms of the IMRaD structure. The remaining 16 papers incorporate the sections whose headings are primarily named after the subject of the section itself. The obtained results unambiguously speak in favour of the idea that the importance of academic writing is not sufficiently recognized among Serbian writers. These variations in composing research articles may result in failing to meet the discourse expectations of the members of the international academic community, who are accustomed to different rhetorical patterns [1].

The analysis of discourse strategies

In order to reveal the discourse strategies which Serbian-speaking authors most frequently use, a quantitative analysis was conducted. The results are offered in **Table 1**.

Table 1. Quantitative distribution of discourse strategies in the sample

Outlining the purpose of the research	13
Hypothesis-raising	1
Establishing the territory	28
Presenting the present work	12
Indicating RA structure	1
Summarising previous research	18
Describing data collection procedure (sample/instruments)	32
Justifying data collection procedure	9
Describing data analysis procedure	20
Preparing for the presentation of the results	12
Reporting specific/individual results	36
Interpreting results	17
Highlighting overall research outcome	15
Comparing results with literature	5
Indicating limitations	0
Recommending further research	3

The results indicate that the so-called “Serbian type” of the rhetorical structure almost always contains the report on specific/individual results (90%), which means that research results are ascribed a key importance in the paper. Also, the majority of articles incorporate the description of the data collection procedure (80%), which is, according to Pho [9], a basic move of the *Methods* section. However, the moves which logically belong to the *Methods* are frequently found in the *Introduction* or *Analysis*

section, which may confuse the reader. The third most commonly used strategy is “establishing the territory” (70%), which is an integral part of the *Introduction*. In this section, the authors establish what is already known about the topic. Yet, they rarely introduce their own research in the *Introduction*, which is obvious from the infrequent use of the following strategies: “outlining the purpose of the research” - 32.5%, “presenting the present work” - 30%, “hypothesis-raising” - 2.5% and “indicating RA structure” - 2.5%. As for the *Conclusion*, it is noticed that the researchers in the field of occupational safety and health tend to summarize their own research results in the final section of an article rather than “highlight overall research outcome” (37.5%), “compare results with literature” (12.5%), recommend further research” (7.5%) or “indicate limitations” (0%).

Despite the infrequent use of the standardised discourse strategies among Serbian authors, there are the examples in which the researchers aptly utilise Anglo-American practices. The following section will show some of them, which can be of practical use for their further research.

1. *Outlining the purpose of the research*. As it was mentioned above, the authors seldom choose to state the purpose of their study in the *Introduction*. This strategy can be recognised by the use of the following nouns: purpose, objective, object, goal and aim [11], as in the following example:

“The aim of this paper is to highlight the importance of indicators for disaster management, define resilience and risk indicators that can be used at the community level in the Republic of Serbia, and determine their preference by applying the fuzzy AHP method.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 14, No 1, 2017, pp. 11 - 22)

2. *Hypothesis-raising* contains the examples where the authors set forth their hypothesis for what should be done, studied or analysed to examine the problem fully [11]. The analysed sample contains only one such example:

“The starting hypothesis of the research was: The age, years of work experience and qualifications of the respondents do not influence their attitudes regarding higher salary, promotion opportunities, good work performance, job security, better work organisation, better physical working conditions, better social climate, greater respect for the employees' rights and respect for regulations related to health and safety at work as motivational factors for dedication at work.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 14, No 3, 2017, pp. 207 - 224)

3. *Establishing the territory* contains the review of what is already known about the topic and shows the topic prominence, by which the author tries to attract the attention of the reader [9, 11]. As Swales points out, there is a strong tendency for topic generalizations in

this strategy [8]. It mainly consists of the sentences such as:

“The impact of pollutants as a consequence of a traffic activity (CO, NO_x, CO₂, SO_x, VO_x) has been well documented [1-3]. Recently, since recognizing the problem of global warming caused by GHG emissions, more attention has been focused on CO₂ emissions.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 12, No 2, 2016, pp. 87 - 92)

4. *Presenting the present work* is a very important strategy because it is where the readers become familiar with the basic attitudes and claims of the author [11]. It is realised in the following way:

“In this paper magnetic flux density generated by an

Electrical radiant heating system (EHRS) is considered.” (Safety Engineering Vol. 7, No. 2, 2017, pp. 61 - 65)

5. *Indicating RA structure* does not seem to take up an important place in the *Introduction* of the occupational safety and health publications as there is just one article with this strategy:

“This paper, in the further course, first exposes the original experimental research on a simple mechanical model (stand) and then on a real supporting structure of the bridge crane with trail. The results of numerical simulation of the bridge crane and comparison with the results of the experiment are given at the end of the paper.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 14, No 2, 2017, pp. 139 - 148)

6. Summarising previous research is a strategy by which authors establish a solid theoretical basis for their own research and also try to attract the attention of readers [11]. Almost half of the Serbian authors employ this strategy, as in the example:

“Up to now, the authors have proposed complex

and simplified solutions for the force between

cylindrical magnets [4], axially [3], [5] and radially [6],

[7] magnetized ring permanent magnets or cuboidal

magnets [8]. Also, there are many papers where

the magnetic force between permanent magnet and magnetic plate is modelled too, but it is performed

only using image method [2], [9].” (Safety Engineering Vol. 8, No. 1, 2018, pp. 33 - 37)

7. *Describing data collection procedure (sample/instruments)*. This is a strategy in

which authors describe the sample and the research instruments such as questionnaires, interviews, tests etc [9]. Interestingly, the authors in this research more commonly use this strategy that the description of the data analysis procedure. An example of this strategy was shown below:

“The survey was conducted in the area of the city of Niš, which comprises of the city of

Niš and the municipalities of Aleksinac, Svrlijig, Merošina, Ražanj, Gadžin Han and Doljevac. The examined area included six municipalities and five city municipalities, with

376309 inhabitants living in 285 settlements [4]. Figure 1 shows the area involved in the survey.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 13, No 2, 2016, pp. 121 - 128)

8. *Justifying data collection procedure* explains why the measures and steps are taken [12]. It is used far less than *describing data collection procedure* (only 22.5%). It can be seen in the following example:

“Actually, instead of the classical volumetric titration potentiometric titration was applied in order to obtain sharp titration ending point.” (Safety Engineering Vol. 6, No. 1, 2016, pp. 7 - 11)

9. *Describing data analysis procedure* is a strategy which serves as a description of the statistical tests techniques and calculation for the data [12]. Again, it is employed less frequently than *describing data collection procedure* (50%). It is realised in the following way:

“Pairs of elements at each level are compared according to their relative contribution to the hierarchical level above (starting from criteria towards alternatives)... The comparison is done in pairs at each level, starting from the top of the hierarchy, and presented in a square matrix form $A = [\tilde{a}_{ij}]_{i,j = 1,n}$, where $\tilde{a}_{ij}$ is the value of the relative importance of each criteria / sub-criteria / alternative i in relation to the criteria / sub-criterion / alternative j , where $\tilde{a}_{ij} = 1$ for $i = j$, and $\tilde{a}_{ij} = 1/\tilde{a}_{ji}$ for $i \neq j$.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 14, No 1, 2017, pp. 11 - 22)

10. *Preparing for the presentation of the results* is a strategy which normally occurs at the beginning of the *Results and Discussion* section. Here, most authors restate the data collection and analysis procedure [9], as in the example below:

“The simulations were realized on laptop Lenovo B51- 30-80LK00H6YA with Intel Pentium N3700 1.6 GHz (2.4 GHz), four cores, TDP 6W,

4GB of DDR3L memory at 1600MHz). The simulation time was set on

300 seconds for every simulation. The durations of complete simulations on noted laptop were about 22 hours, average. The simulation duration depends from many different factors, especially from simulation model complexity and mesh cells dimensions.” (Safety Engineering Vol. 7, No. 2, 2017, pp. 67 - 72)

11. *Reporting specific/individual results* is the most prototypical strategy of the *Results and Discussion* section. It was illustrated in the example below:

“The calculation results for major pollutants and CO₂ obtained by COPERT are presented in Table 1 and 2. Table 1 shows the specific emission factors for major pollutants and CO₂, while in Table 2 presents annual emissions from traffic in the city of Niš.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 13, No 2, 2016, pp. 87 - 92)

12. *Interpreting results* is a strategy by which authors try to situate their research findings in the field and/or give reasons for some unexpected results [13]. In the articles of Serbian researchers, it is used in 42.5%, as in the example:

“Results indicate that there were some positive correlations between SO₂, NO₂, CO, PM₁₀, whereas correlation between SO₂ and CO is not noticeable since these two have different main sources, heating plant and traffic.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 13, No 2, 2016, pp. 93 - 103)

13. *Highlighting overall research outcome* indicates the significance of the results since by stating the main points of the study, the researcher makes it easier for readers to follow their thinking and enables them to understand the core content of the article without perusing the entire paper [14]. This is the most commonly used strategy in the *Conclusion* section of the given sample (37.5%). An example is shown below:

“Results obtained in this case study, according to the positive feedback from the EPCS, have contributed to the following: increased operators’ reliability; reduced human error occurrence and increased awareness on significance of occupational safety and health measures application; prevented occupational injuries and fatalities; increase in productivity, and decrease in lost work hours and expenses; and improvement of environmental protection (standards) practice, through reduction of damage in electric power plants, reduction of environmental pollution, and substantial economic loss.” (Facta Universitatis, Series: Working and Living

Environmental Protection Vol. 14, No 3, 2017, pp. 187 - 196)

14. *Comparing results with literature*. The frequency of occurrence of the strategy, by which research results are compared with previous studies, indicates that such evaluation of the present study is not commonly employed by Serbian researchers (12.5%). However, there are some remarkable instances, as illustrated below:

“The fact that higher salary is a significant motivational factor for dedication at work is in line with the data obtained in previous research [8, 9, 10, 12] and indicates that this motivational factor has not lost importance even though socioeconomic circumstances under which the working process takes place have changed.” (Facta Universitatis, Series: Working and Living Environmental Protection Vol. 14, No 3, 2017, pp. 207 - 227)

15. *Indicating limitations*. In evaluating their study, authors indicate the significance of their research rather than discuss its limitations. Still, it is surprising to notice that there are no articles in the sample referring to the limitations.

16. *Recommending further research*. Apart from outlining the research, the *Conclusion* section also contains recommendations [14]. However, only 7.5% of Serbian authors recognized this strategy as substantial. An example is shown below:

“This research could be continued in several aspects, such as simulation with arrangement of fire detectors according to some typical way (triangle, hexagonal) or simulation of no typical objects with special content inside (for example, objects with different kind of roof with curvatures in theirs form and similar).” (Safety Engineering Vol. 6, No. 1, 2016, pp. 13 - 20)

CONCLUSION

The present study attempted to identify the rhetorical structure employed by Serbian academic writers in the field of occupational safety and health. Despite the limited sample size, the findings indicate that Serbian researchers still need to work on the organisation of their RA articles in order to reach the standards accepted in Anglo-American academic community.

Further studies could incorporate the analysis of certain linguistic features such as nominalization, discourse linkers or hedging devices to provide a better insight into the writing habits of Serbian authors.

Since the main goal of writing a research article is to

help the readers understand the idea the writer intends to propose, appropriate writing skills will ensure that the new knowledge is shared with the audience [12]. Therefore, this and similar studies can be useful for both professionals who use professional literature and those who write papers [11].

REFERENCES

- [1] S. Blagojević: "National writing habits as a potential hindrance to international academic communication", In: I. Lakić, B. Živković, M. Vuković, Academic discourse across cultures, Newcastle upon Tyne, 2015, Cambridge Scholars Publishing, pp.6-19.
- [2] J. Flowerdew: "Problems in writing for scholarly publications in English: the case of Hong Kong", Journal of second language writing, Vol. 8(3), 1999, pp. 243-264.
- [3] K. Hyland, F. Salager-Meyer: "Why is scientific writing so interesting?", Review of information science and technology, Vol. 42(1), 2008, pp. 297-338.
- [4] R.B. Kaplan: "Cultural thought pattern in intercultural education", Language learning, Vol. 16, 1966, pp. 1-20.
- [5] S. Blagojević: "How to help a reader through an academic article? Signalling devices in research articles written by English and Serbian academics", Facta Universitatis, series: Linguistics and literature, Vol. 10(2), 2012, pp. 79-87.
- [6] S. Blagojević: "Da li se u akademskom pisanju za međunarodnu zajednicu (i dalje) mogu identifikovati elementi akademskih obrazaca sopstvene kulture?", Susret kultura, Knjiga 1, 2010, 531-538.
- [7] P.K.R. Nair, V.D. Nair: "Organization of a research paper: the IMRAD format", In: Scientific writing and communication in agriculture and natural resources, 2014, Cham, Springer, pp. 13-25.
- [8] J. Swales: "Genre analysis. English in academic and research settings", Cambridge, 1990, Cambridge University Press.
- [9] P.D. Pho: "How can learning about the structure of research articles help international students?", 19th ISANA International education association conference proceedings, 2008, available at http://isana.proceedings.com.au/docs/2008/paper_Dzung.pdf.
- [10] J. Swales: "Aspects of article introductions", Language studies unit, University of Aston, 1981, Birmingham.
- [11] I. Lakić: "Analysing genre: research article introductions in economics", JoLIE, Vol. 3, 2010, pp. 83-99.
- [12] N. Musa, N. Khamis, J. Zanariah: "The structure of method section in engineering research articles", Asian social science, Vol. 11(17), 2015, pp. 74-82.
- [13] W. Amnuai: "The textual organization of the discussion sections of accounting research articles", Kasetsart journal of social sciences, 2017, available at <https://www.sciencedirect.com/science/article/pii/S2452315117302199?via%3Dihub>.
- [14] G. Zamani, S. Ebadi: "Move analysis of conclusions as components of research articles in Persian and English", Cypriot journal of educational sciences, Vol. 11(1), 2016, pp. 9-20.

BIOGRAPHY of the first author

Katarina Ilić graduated from the Faculty of Philosophy in Niš, at the Department for English Language and Literature, where she also received her M.A. degree. She is a PhD student in philology at the same faculty. Her main field of interest is academic discourse. She is currently working in the Clinical Centre Niš as an associate for international relations.



STRUKTURA ISTRAŽIVAČKIH RADOVA IZ OBLASTI ZAŠTITE NA RADU: DA LI SU SRPSKI AUTORI DOSTIGLI MEĐUNARODNE STANDARDE?

Katarina Ilić

Rezime: Cilj ovog istraživanja je da ispita strukturu naučnoistraživačkih radova pisanih na engleskom jeziku od strane autora srpskog porekla iz oblasti zaštite na radu kako bi se ustanovilo da li su ovi autori dostigli međunarodne standarde u akademskom pisanju. Imajući na umu činjenicu da stil i metod pisanja treba prilagoditi akademskoj publici, jasno je da pisanje za međunarodnu zajednicu uključuje norme međunarodnog akademskog diskursa. Ovaj rad analizira strukturu naučnoistraživačkih članaka u celini, od uvoda do zaključka. Podaci dolaze iz korpusa sačinjenog od 40 radova objavljenih u časopisima Facta Universitatis, Series: Working and Living Environmental Protection and Safety Engineering. Rezultati će pokazati da li srpski autori prate konvencije međunarodnog stila pisanja, što će im pomoći da se lakše integrišu u međunarodni akademski svet.

Ključne reči: akademski diskurs, međunarodna akademska zajednica, konvencije u pisanju, zaštita na radu.

TAMARA VUKIĆ¹
VESNA NIKOLIĆ²

¹ University of Niš,
Faculty of Philosophy, Department
for Pedagogy

² University of Niš,
Faculty of Occupational Safety

¹tamara.vukic@znrfak.ni.ac.rs

²vesna.nikolic@znrfak.ni.ac.rs

METHODOLOGICAL CHARACTERISTICS OF ADULT EDUCATION IN THE SYSTEM OF SAFETY

Abstract: *The results of theoretical research on methodical characteristics of adult education in the system of occupational and environmental safety are presented in the paper. Starting from the observation of adults as learners and the description of the relevant didactical and methodical knowledge, the paper provides the recommendations and advice for choosing the adequate methods in the adult education.*

Key words: adult education, methodology, safety, protection

INTRODUCTION

Methodical characteristics of adult education in the safety and environmental protection system must be considered in direct relation to adult education theory, andragogical didactics, and especially considering the innovative concepts that marked the adult education in recent years. Many of these concepts apply the “popular education” principles that emphasize the active role of adult learners while analysing certain problems and developing practical skills. The roots of this approach can be found in the pedagogical philosophy of Paulo Freire (1970) whose approach starts with the students’ needs and reveals the assumptions and social circumstances for learning through the problem setting process. Instead of the traditional trainer (instructor)-student learning model, “popular education” emphasises the importance of the student-student and student-trainer (instructor) learning model and puts the adult learner in the centre of the educational process. Considering all above mentioned, this paper focuses on the methodical characteristics of adult education in the occupational safety and environmental protection system. Within the descriptive research method, the relevant theoretical and empirical resources were analysed, which enabled the systematization of certain knowledge and creation of recommendations and suggestions for didactical and methodical work in the safety system.

ADULTS AS LEARNERS

The adult education is characterised by an effort to adapt to the possibilities and the conditions of adult learning. The teaching organization and schedule, as well as the curriculum are customized to the adults’ learning process, but, considering the methodics, there isn’t much customization. In this regard, the solutions typical for the youth education are being applied in the adult education, everyone has to adapt to the same educational norms and standards (Simel, 2011), i.e. it is believed that teaching, learning and evaluation methods suit each student, regardless of age (Florea, 2014). Although many aspects of effective teaching may be applied to all age groups (Collins, 2014), the adult

education in the safety and protection system must begin with understanding that adult learners require an approach and methodics different from those used in the education of children and youth. The best way to present the adult learners’ characteristics is by describing the principles (Collins, 2014) upon which their learning is based.

Adults have a wealth of life experience and knowledge – it is necessary to link the adults’ experience and knowledge to the new information, as well as to use their experience as a knowledge resource for other adult learners and for the instructor/trainer/teacher himself (Ihejirika, 2013).

Adults are autonomous and self-directed – they learn the contents they want and those which they perceive as meaningful (Illeris, 2004). In this case, the teacher/trainer serves as a facilitator and not just as the resource of information.

Adults are goal-oriented – it is necessary to create educational programs with clearly defined elements considering the previously set goals.

Adults are practical and oriented towards the relevance of learning – it is necessary to help adults to find a reason for learning certain contents by connecting them to their jobs or to some other important responsibilities.

Adults (all learners) deserve respect – it is necessary to acknowledge their experiences and to allow free expression of opinions.

Adults have intrinsic and extrinsic motivation for learning – it is necessary to point out the benefits of learning and to create comfortable and challenging learning atmosphere.

Adults learn best when they participate actively in the learning process – it is necessary to limit lecturing and to provide opportunities for sharing experiences, posing questions and exercising that requires a practical use of skills or knowledge.

Not all adults learn the same way – it is necessary to adjust to the different learning styles of adults by using a variety of methods as well as visual, auditory and kinesthetic techniques.

Adults learn more effectively when they receive timely and appropriate feedback and support – it is necessary

to provide opportunities for receiving feedback from peers, instructor/trainer and the learners themselves.

Adults learn better in informal and personal environment - it is necessary to promote group interaction (Collins, 2014).

These characteristics need to be considered when creating educational activities for adults in order to optimise the learning process. This requires the adjustment of the learning environment, learning methods and the approach in which the teacher/trainer becomes a facilitator of learning (Kamp, 2011). This means that the teacher/trainer is more oriented towards the facilitation of the learning process for the adult learners, and much less towards the mediation and transmission of knowledge (Farkas, 2012). Moreover, the “traditional teacher” who transfers the educational content is not desirable (Jelenc Krašovec, 2004). The role of the facilitator can be defined as an assisting role of a teacher/trainer which includes: understanding the processes occurring during the learning/teaching; finding the ways to represent the existing experiences; showing the sensitivity for the “learner’s self perception”; creating the atmosphere which is flexible and oriented towards showing the respect for the adults’ personality; understanding that adults are afraid of mistakes and failure, more than children are (Alibabić et al., 2012, p. 24).

The teacher/trainer as a learning facilitator uses the methods/techniques which put the learners in the centre of the educational process. Such teaching model is suitable for adult education, because it requires the recognition of the adult learners’ needs (Jelenc Krašovec, 2004) and learning interests, its incorporation into lesson planning, enabling adults to learn from each other (Clausen, 2009), confronting their problems and providing solutions, providing experiences and supporting reflection (Jelenc Krašovec, 2004).

ADULT LEARNING METHODS

Effective and active adult learning is provided by combining adequate methods which, through their diversity, meet the adult learners’ needs (Kamp, 2011). Commonly used methods in adult education are presented in the Table 1.

Table 1. Characteristics of teaching methods used in adult education

LECTURE
Oral presentation of the learning content, i.e. presentation of a large amount of information <i>Advantages:</i> preparation of lectures is quick and easy, large amount of information can be delivered in a short time which makes it economical <i>Disadvantages:</i> monotony, it is difficult to maintain concentration, there is little time for communication
PRESENTATION
Transmission of information by using visual teaching aids

Advantages: attractiveness, multisensory learning, it can be used successfully with large groups of learners

Disadvantages: one-way communication, learners are passive, expensive equipment which requires trained handling

MODIFIED LECTURE

Teacher presents the content orally, actively including the learners

Advantages: planning and preparation of the modified lectures is easy, it can be used successfully with large groups, it is economical, cooperation between teacher and learners is encouraged

Disadvantages: learners are passive due to the need of high concentration, it is not suitable for the development of skills

SIMULATION

Simulation of real life situations by using different means or equipment

Advantages: technical, mechanical and operational skills necessary in one’s work are practiced, decision-making skills can be acquired, usage of experiential learning (learners are active and responsible for their learning)

Disadvantages: preparation and analysis are required after the exercise, it can hardly be adapted to individual needs within the large groups

GROUP DISCUSSION

Active teaching method which relies on participation and interaction of learners discussing the certain subject

Advantages: interest and activity of learners are stimulated, it relies on learners’ knowledge and experience, there is a possibility for creating unusual solutions, it broadens learners’ aspects, there is criticism of the attitude or opinion, rather than the person, communication and social skills are promoted, feedback on the subject knowledge and on learners’ communication skills is provided

Disadvantages: it can be hard to control the discussion, it takes a lot of time, it is easy to miss the subject of the discussion, it requires careful planning

DEBATE

Debate is used when there isn’t only one solution to the certain problem. It includes two teams representing their opposite attitudes.

Advantages: learners are required to think about the reasons for their attitudes, it supports interest and activity of the learners who have the leading role, presentation and speaking skills are required, argumentation skills and team work are promoted

Disadvantages: it takes a lot of time, small number of learners dominates, most of learners are passive, it requires learners to be skilled in debates

BRAINSTORMING

Teacher poses questions and learners are required to answer quickly. This provides many ideas which represent a starting point for discussion

Advantages: interest and activity of learners are stimulated, it relies on learners' knowledge and experience, there is a possibility for creating unusual solutions, a large number of data can be generated in a short amount of time, creative ideas and solutions are presented, it provides insight into learners' previous knowledge

Disadvantages: brainstorming has to be quick, otherwise learners become bored, it is brief (this activity is appropriate for introducing learners into certain teaching content), not all of the learners are included, the loudest ones dominate, the obtained data must be "analyzed" straightaway

DEMONSTRATION

Teacher/trainer performs and shows how a task or a skill should be done

Advantages: demonstration makes understanding and memorizing easier, learners' interest is stimulated, theory and practice are connected, it represents the active way of learning, it keeps the learners' attention, practical application of a certain method is demonstrated, learners are active when demonstrating by themselves, it is adequate for those who learn best by observing

Disadvantages: sometimes demonstration requires expensive equipment, plenty of materials and a lot of time for preparation, there is a possibility that the demonstration occupies the learners' attention rather than the contents they should learn, it is not suitable for larger groups, after the learners demonstrate something themselves, the feedback is required

CASE STUDY

This teaching method provides insight into a specific problem. It includes group discussion and leads to the generalization

Advantages: it can be performed individually and/or grouply, it helps the development of critical thinking and problem solving abilities, learners are actively involved in the teaching process, social skills are developed, learning process can be observed, the group is involved in real life situations, the importance of different perceptions and approaches is demonstrated, the awareness of individual strengths is supported, learners are separated (liberated) from their own real life situation

Disadvantages: case study can be difficult to standardize and control, precise elaboration and instructions are needed, the goal has to be clearly defined by a teacher, it has to be authentic, relevant and related to the real life situations, careful preparation is required in order to cover the training objectives/tasks

ROLE PLAY

Learners perform the real life situations and practice new forms of behavior that can be applied at work or that can help them prepare for future situations

Advantages: real life situations are simulated, learners are active, there is a possibility for observing the world from another perspective, skills

which promote taking a stand on a certain topic and protecting it are developed, dramaticness, everyone enjoys it, it pulls out the everyday situations' tension and intrigue, it can be performed individually and/or grouply, the critical thinking ability and social skills are developed

Disadvantages: acting may be overstating or weak and therefore, the purpose of learning may be lost, role play can be difficult to standardize and control (learners can exaggerate while getting into the character), extra time for analysing is needed after the exercise, excessively highlights those members of the group who like to stand out

FISHBOWL

Learners are divided into two groups. Members of the first group are performing a scene or discussing about a certain subject and members of the second group are observing (they participate nonverbally)

Advantages: fishbowl allows learners to observe/experience a certain subject through role play, there is a possibility for feedback, learners can be introduced to a certain problem, it works on multiple levels

Disadvantages: this method involves a great risk-clear rules and a good coordinators are needed, learners can be passive (it is necessary to create special tasks for them)

BUZZ GROUPS

After a lecture, a teacher/trainer divides learners into small groups in which they talk about their reactions, experiences or the application of what they have learned

Advantages: discussion about the most important subjects is enabled, buzz groups represent an opportunity to consider the possibilities for application of the knowledge, there is criticism of the attitude or opinion, rather than the person, learners are more secure in small groups, time for thinking is provided

Disadvantages: it can lead off the topic, it lasts too long and can hardly be controlled, it requires good planning and conducting, each group works at their own speed, which leads to losing the overall work pace

GAMES AND «ICEBREAKERS»

This method includes fun games that help learners to build trust, develop identity and group self consciousness. They also provide dynamics and tempo

Advantages: level of energy is raised, freedom of opinion is provided, learning becomes interesting

Disadvantages: some may think that the games are trivial (they usually need to have a specific purpose and goal), sometimes their usage is excessive

GAME

This method includes competition or cooperation of learners in order to repeat or determine learning contents

Advantages: learners' activity is enabled, games

help the development of self consciousness and social skills, learning through fun is provided, learning process can be observed

Disadvantages: extra time for preparation and analysis is needed after the exercise, it may not be suitable for all the learners, there is a small danger of creating a negative atmosphere

CONSULTATIONS

Within this method, the session is focused only on one person (trainer and/or small group of learners are considering a certain case or problem of one of the group members)

Advantages: consultations help learners to think about different subjects, to get insight into other people's problems and to receive help in solving their own problems; consultations can be performed individually and/or grouply, they help the development of critical thinking and problem solving abilities

Disadvantages: help of experienced leader is needed in order to direct the conversation, ie to help learners to get to the solution, consultations require a lot of time, they can be difficult to standardize and control, they can be tiring, clear instructions and good preparation is needed, learners may be occupied with their own concerns

(According to: Alibabić et al., 2016, pp. 29-31; Čalina et al., 2012, pp. 13-19)

In addition to the above mentioned methods, there are some other methods that can be used in adult education such as: *panel discussions, small group tasks, visits/field trips, seminars, tutorials, individual projects, diaries, work between sessions* (Daines et al., 1993), *snowball, meta plan, mind map, project work, problem tree, goal tree* (Alibabić et al., 2016).

The diversity of teaching methods makes the learning process easier and helps learners solve the tasks they are facing (Alibabić et al., 2016). In addition, relying on different teaching methods and techniques provides the learning experiences and empowers the learners' interaction (Giannoukos et al., 2015). The application of different activities, ie methods, when working with adults is also necessary because adults love diversity. Therefore, there is a need for: using: visual aids, using Power Point effectively, making diagrams, guiding note taking, encouraging learners to ask questions, asking them questions and providing answers, encouraging the group discussion, using brainstorming, role plays or simulations, activating learners through written tasks, illustrating through case studies or practical examples, structuring the lectures in order to solve a problem, preparing supplementary handouts, guiding learners and summarizing (Post, 2010).

RECOMMENDATIONS FOR METHOD SELECTION

Some adult learners prefer visual learning that includes the usage of CDs, video tapes, PowerPoint presentations or flyers; others prefer listening, so they

find oral lectures more enjoyable (Post, 2010). Some learners like to study independently, by reading and taking notes, some study through work and direct experience, while others study best through group activities which include elements of competition (Alibabić et al., 2012; Čalina et al., 2012). Therefore, each individual studies in their own way, in accordance with their own style of learning, which can be defined as "a way of thinking, processing and understanding the information, which includes a description of attitudes and behaviors that define our learning preferences" (Čalina et al., 2012, p. 8). During this process, adults will tend to learn in accordance with their preferable style in each study session, because they recognize a connection between their defined style of learning and their success in learning (Athanasios et al., 2014). Regardless the fact that it is impossible for the teacher to consider each attendant's learning style in his working group, one thing's for sure – they are diverse. Thus, it is necessary that the teaching methods used in class suit different learning styles (Alibabić et al., 2016; Čalina et al., 2012) and that the instruction is adjusted to the specific styles used in the learning process in adulthood (Collins, 2014), which creates the possibility for more successful studying (Alibabić et al., 2012).

Methods that include emotional tension (dialogue, discussion, brainstorming, role play and simulation) are the most convenient for those individuals who tend to learn through direct experience. Others, who tend towards reflective perception while learning, find that methods and activities which enable the observation of phenomena and concepts from different angles are more likely to suit them. In such case, it is the teacher's task to encourage the learning process and to create rich and sensitive studying environment (teacher as facilitator). The individuals who are fond of abstract conceptualization should be secured with an environment enriched with symbols, since they are directed towards gaining convenient knowledge, rather than that which can be of use. The teacher is the source of abstract knowledge, the lecturer, the one who gives the explanations and asks the questions. Studying professional literature is also important for these individuals. When working with them, suitable methods seem to be systematical lecturing and studying literature and other resources, while the representation of theories and systems (tables, schemes) should be followed by a discussion. Activities or simulations are rather to be avoided. It is necessary to provide enriched behaviouristic environment for those individuals who are keen on experimenting. Considering the fact that they enjoy problem solving and creating their own complex projects, practical and extracurricular activities (study situations) and project work are the methods that work best for them (Sørli et al., 2004).

A research whose subject were the characteristics of learning methods in adulthood (Trivette et al., 2009) has shown that the most efficient way to *introduce* the trainees to the new knowledge, materials or practice are

out-of-class activities and self-instruction, as well as warming exercises and quizzes. This kind of method requires for the learners to actively participate in the tasks or exercises before they move on to hearing the teacher's presentation, which is how they are introduced to the presented subject. In order *to illustrate the usage* of new knowledge, materials or practice it is possible to use role play or simulation, as well as demonstrations which include adult students. Alongside these, the combination of role play with demonstration of real-life situations could also be convenient. Watching videos can also be efficient, but considerably less than active incorporation of learners into the process of illustration itself. One of the most efficient methods for *practicing the usage* of recently incorporated knowledge is the combination of real-life situations and role play. Besides that, it is convenient to apply solving of problematic tasks, incorporation of the knowledge into the real-life situations, the practice of role playing, or written exercises. The estimation of advantages and weaknesses of learners, as well as reviewing of their solutions to given problems or answers to questions have proven to be most efficient in order to *evaluate the usage* of knowledge, materials or practice. For the learners *to reflect on their achievements* it is useful to have them engaged in the planning of future steps in the learning process. Getting the trainees to write about their newly acquired knowledge and skills, and giving a positive feedback information, as well as a group reflection about feedback information are all also efficient strategies. In order to evaluate the mastery of knowledge, skills or practice, it is useful for the learners to perform self-evaluation, and also to follow standards and external criteria.

The manual for efficient adult learning (Effective Adult Learning, a Toolkit for Teaching Adults, 2012), in the part dedicated to basic teaching methods, cites that *case studies, role plays and discussions in small groups* help the students to get the essence of the study material individually, as well as to apply gained skills by interacting with others. The best way to use these is for improving newly gained skills, in those situations where students ought to empirically understand a certain situation; for getting a feedback, applying new knowledge in specific situations, as well as for practicing problem solving. *Training in the classroom, lectures and short lectures* provide the information in those cases when interaction and discussion are undesirable or inapplicable. They are useful for those cases when it is necessary to present the data in a short amount of time, when the same information is being transferred to a great amount of individuals or when it is needed to give some basic information to a group of people. *Experiential learning* gives the participants a chance to try out new concepts, processes or systems in a controlled environment through training, practice or internship. It is best to use experiential learning in structured environment and under the supervision of a mentor. *Games, table-tops and simulations* allow a

relaxed way of presenting the teaching content, and can be used to recreate the processes, events and circumstantial settings which help the participants in manipulating over the situation and analyzing the consequences. Their most valuable usage is for the integration and the use of complex abilities, in cases when natural tendencies of participants and feedback information are aspired; for offering realistic job-related experiences, for a better comprehension of entirety of program contents, for presenting dry material in an interesting way or for enriching the session with certain elements of competition. *Projects and writing tasks* assist the participants in reflecting about their personal understanding of concepts, information and ideas, and are realized individually or in small groups. They are applied in cases when it is needed to verify if the students understand the processed content, as well as for passing the feedback information individually. *Self-study* gives the students a chance to gain skills and knowledge through a process of self-learning led by structured materials. It is used for studying with the assistance of the computer and the Internet.

CONCLUSION

The success of the educational process lies in the respect towards the principle of individualization and in the adaption of educational content, methods, the form and the pace of the work to match the specific characteristics of students. One could say that in the education of adult students this adaptation can be seen as twofold: adult learners differentiate from the children (they own rich knowledge and experience, they have built-in habits and attitudes, they are autonomous and self-directed etc.), but also differentiate from one another, depending on the preferred style of learning. The stated determines methodical characteristics in the education of adults: firstly, it is necessary to rely on the methods that are suitable in working with adults (presentation, demonstration, debate, discussion, lecture etc.) and secondly, it is necessary to use a diversity of methods in working with adults, in order to please many of their different learning styles. Considering the fact that the appreciation of both characteristics depends on those who work with adults – teachers or instructors, we reached a conclusion that it is needed to share a great deal of attention to their methodical training, which would enrich them with the knowledge of different teaching methods, their advantages and disadvantages, as well as their abilities for accomplishing beforehand set educational goals, thus enabling them to choose the most suitable working method in regard to a concrete case, which at the same time gives the possibility to increase the quality of educational outcomes.

REFERENCES

- [1] "Effective adult learning, a toolkit for teaching adults", 2012, available at: https://humanservices.ucdavis.edu/sites/default/files/Adult-Education-Toolkit_Updated_022814.pdf (Accessed 02 Aug. 2018).
- [2] "Kako uspješno poučavati odrasle", N. Čalina, B. Dijanošić, E. Gefferth, J. Martinko, 2012, Zagreb.
- [3] A. Athanassiou, A. Baldoukas, R. Panaoura: "Handbook for adult teaching staff, basic teaching principles for adults who belong to vulnerable social groups", Frederick University Publication, 2014, Nicosia.
- [4] C. A. Clausen: "MCAEL teacher toolkit", 2009, retrieved 11 Aug. 2018 from: http://www.mcael.org/uploads/File/instructor_library/MCAEL-Teacher-Toolkit.pdf
- [5] C. M. Trivette, C. J. Dunst, D. Hamby, C. E. O'Herin: "Characteristics and consequences of adult learning methods and strategies", Research Brief, Vol. 3, 2009, pp. 1-33.
- [6] E. Farkas: "Roles, competences and training system of adult educators in Hungary, Andragoške studije, Vol. 1, 2012, pp. 63-80.
- [7] G. Giannoukos, G. Besas, C. Galiropoulos, V. Hiocour: "The andragogy, the social change and the transformative learning educational approaches in adult education", Journal of Education and Practice, Vol. 6, 2015, pp. 46-50.
- [8] H. W. Post: "Teaching adults: what every trainer needs to know about adult learning styles", 2010, retrieved 01 aug. 2018 from: <https://www.pacer.org/publications/fasttraining/Other/teachingadults-whattrainersneedtoknow.pdf>
- [9] J. C. Ihejirika: "Teaching strategies for adult learners: implications of learning characteristics for effective teaching-learning transaction", Academic Research International, Vol. 4, 2013, pp. 310-315.
- [10] J. Collins: "Education techniques for lifelong learning: principles of adult learning", Radio Graphics, Vol. 24, 2014, pp. 1483-1489.
- [11] J. Daines, C. Daines, B. Graham: "Adult learning, adult teaching", Department of Adult Education University in Nottingham, 1993, Nottingham.
- [12] J. Sørli, I. Oudenstad, M. Trantallidi, L. Jøgi, E. Perme, M. Svetina: "Adult learner: 1st module", M. Svetina, E. Perme, 2004, Ljubljana.
- [13] K. Illeris: "What is significant for adults' learning", in M. Radovan, N. Đorđević (eds.): "Current issues in adult learning and motivation" (pp. 23-32), Slovenian Institute of Adult Education, 2004, Ljubljana.
- [14] M. Kamp: "Facilitation skills and methods of adult education, a guide for civic education at grassroots level", Konrad-Adenauer-Stiftung, 2011, Kampala.
- [15] P. Freire, Pedagogy of the Oppressed New York: Continuum, 1970.
- [16] R. Florea: "Teaching methods in adult education. An appraisal of the effectiveness of methods used in training future teachers", Procedia - Social and Behavioral Sciences, Vol. 142, 2014, pp. 352-358.
- [17] S. Jelenc Krašovec: "Teacher of adults - facilitator and motivator of adult's learning and changes", in M. Radovan, N. Đorđević (eds.): "Current issues in adult learning and motivation", (pp. 53-68), Slovenian Institute of Adult Education, 2004, Ljubljana.
- [18] S. Simel: "Neformalno obrazovanje odraslih kao model obrazovanja", Andragoški glasnik, Vol. 15, 2011, pp. 47-59.
- [19] Š. Alibabić, G. Bošković, D. Popović, Z. Minić, V. Peković, N. Pejović, G. Zeković: "Elementarno funkcionalno opismenjavanje odraslih. Andragoški priručnik za nastavnike", JU centar za stručno obrazovanje, 2016, Podgorica.
- [20] Š. Alibabić, K. Popović, E. Avdagić: "Naknadno sticanje osnovnog obrazovanja. Andragoški priručnik za nastavnike", Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2012, Sarajevo.

ACKNOWLEDGEMENTS

This work is supported by Serbian Ministry of Education and Science (Project III44006, III 43014).

BIOGRAPHY of the first author

Tamara Vukić was born in Knjaževac, Serbia, in 1993.

She received her master's diploma in pedagogy from the University of Niš, Faculty of Philosophy. She is currently in her first year of doctoral studies in pedagogy at the Faculty of Philosophy in Niš.

She has a scholarship from the Serbian Ministry of Education.



METODIČKE SPECIFIČNOSTI OBRAZOVANJA ODRASLIH U SISTEMU BEZBEDNOSTI I ZAŠTITE

Tamara Vukić, Vesna Nikolić

Rezime: U radu su predstavljeni rezultati teorijskog istraživanja metodičkih specifičnosti obrazovanja odraslih u sistemu bezbednosti radne i zaštite životne sredine. Polazeći od opservacije odrasle osobe u ulozi učenika i deskripcije relevantnih didaktičko-metodičkih saznanja, na kraju rada su date preporuke i saveti za izbor odgovarajućih metoda u procesu obrazovanja i učenja odraslih.

Ključne reči: obrazovanje odraslih, metodika, bezbednost, zaštita

MILICA STOJKOVIĆ¹
MILORAD BEJATOVIĆ²

¹University Business Academy in
Novi Sad,
Faculty of Law for Commerce and
Judiciary in Novi Sad
²University Business Academy in
Novi Sad,
Faculty of Law for Commerce and
Judiciary in Novi Sad

¹mstojkovic1@yahoo.com

²bejatovic@pravni-fakultet.info

LEGAL PROTECTION FROM NOISE AND VIBRATIONS AND ECONOMY

Abstract: *The paper analyzes certain parts of judicial decisions in the field of economy, so that the conclusions point to the current situation in judicial practice. This paper aims to consider the questions of using court to protect people from noise and vibrations in business activities. Legal protection from possible effects on human health and safety is necessary, since noise and vibrations are often the cause of health damage, permanent disability and occupational illness. Civilization progress has brought innovations in technology; therefore, noise becomes is an element of everyday human activities in their occupational and private environments. The consequences of noise and vibrations are often the basis for compensation for damages in civil proceedings before the competent courts. Noise protection can be viewed from several different aspects (technical, medical, economic, legal, etc.). This paper deals with legal protection against noise and vibrations in the judicial practice. There is a need for changes in the legal protection policy against noise and vibrations. It is necessary to adopt new laws and by-laws, in order to find suitable solutions for smooth business activities.*

Key words: noise, vibrations, protection, law, practice

INTRODUCTION

The working environment is a part of the environment, that is, an open or closed space in which a person performs purposeful work and meets his needs. Pollution of human life and working environment is pollution of air, water and soil, and pollution caused by ionizing and non-ionizing radiation and pollution from noise and vibration.

Noise is every sound whose value exceeds the allowed level prescribed by law, given the time and place where it arises and the environment in which people work and stay. Vibrations represent the oscillatory movement of solid bodies or particles in the area of infrasound and partially sound frequencies. They are caused by oscillations of some matter or are a side effect of noise. Since the man began to build industrial machines, and especially since the engines became the drivers of these machines, the inevitable problems are connected with the appearance of noise and vibration, their reduction and isolation. The task of engineers is to find adequate solutions to these problems, and legislators to find adequate legal frameworks.

NOISE PROTECTION IN CASE LAW

In the unfolding of the daily economic life of the emission as the harmful effects that come from the neighboring land in the form of noise, unpleasant smells, wastewater, etc., the owners of the adjacent land must suffer to a certain extent that is usual with respect to the nature, the purpose of the immovable property, opportunities. The owner of the real estate is obliged to refrain from the actions and to eliminate the mentioned causes that arise from his immovable

property if they cross the limit of the usual tolerance and thus significantly impede the use of the neighboring real estate.

The Court will ban fattening cattle in the area (feedlot), which is only four meters from the yard of prosecutors, because of excessive harmful emissions (odors and noise from the roar of cattle at the time that the waste water that pose a contamination of drinking well water), although it's about the rural environment and what the main activity of agriculture is for the respondent. [1]

The first instance court correctly applied the substantive law when the plaintiff's claim was accepted and prohibited the defendant from stopping with further fattening of the large cattle in the object in question, since harmful emissions cannot be remedied in any other way. The noise from the work of the compressor gives the right to damage to the protection, if, by its intensity, housing in a certain environment is made more difficult by a tolerable measure. [2]

PROTECTION AGAINST NOISE AND DAMAGE COMPENSATION

Occupational diseases occur due to the adverse effects of working conditions at certain work places (noise, vibrations, etc.) and unfortunately, the inaccuracy is a consequence of the work of man in the working environment of our country. The Law on Labor Relations stipulates that if an employee suffers a violation or injury at work or in connection with work, the employer is obliged to compensate him, which in specific legal matters raises the issue of proving the cause-effect relationship between the harmful event and the violation in question. Legislation regulations do not

contain any detailed provisions on when the employee is considered to have suffered injury or injury at work, or in connection with work, nor does it contain a definition of a professional illness or conditions for compensation for damage caused by professional illness.

In one of the cases from case-law, the fact that the Prosecutor suffered from a disease characterized by a profession of illness was established in the process of exercising rights from pension and disability insurance, as well as from the findings and opinions of the expert, heard by the court. The Law on Pension and Disability Insurance determines the categories of persons who provide rights in the event of disability and physical injury caused by occupational injuries or occupational diseases. [3]

Compensation for damage caused by professional illness is exercised according to the provisions of the Articles of the Law on Obligations, which stipulate the conditions of objective responsibility. [4] The provision of Article 154 of this Law stipulates that, regardless of guilt, for damage from dangerous things or activities, which result in increased risk of environmental damage.

It was determined that the owner of the dangerous item is responsible for the damage from the dangerous thing, and the person who deals with it is responsible for the damage from the dangerous activity.

If the defendant does not prove in the proceedings that the plaintiff's disease was caused by the fault of the prosecutor himself, by the third person's guilt or by force of force, he shall be liable to compensate the plaintiff as an injured person.

The employer is obliged to organize and take measures of protection at work so that the employee can carry out work without danger to his life and health using the usual degree of attention. The failure to perform this duty entails the responsibility of the defendant for the damage caused to the prosecutor, since the employer did business contrary to the provisions of the legislation in the field of occupational safety.

The provisions of the regulations on pension and disability insurance prescribe that the employee who has suffered from an occupational disease has the same position as the employee who suffered the injury at work, and the employer is responsible for the damage caused by the occupational illness of the employee under the same conditions under which he is responsible for the damage resulting in injury at work. From this it follows that these categories of employees are equal in terms of legal treatment. An employee who has suffered from an occupational disease has the same position as an employee who has suffered an injury at work. [5]

THE LAW ON PROTECTION AGAINST NOISE IN THE ENVIRONMENT

The Law on Protection against Noise in the Environment [6] regulates environmental protection entities against noise, measures and conditions for protection against noise in the environment, noise measurement in the environment, access to noise information, monitoring and other issues of importance for environmental protection and human health.

It is interesting that the provisions of this law do not apply to the noise generated in the workplace and in the working environment, the noise generated by the means of transport, the noise arising from military activities in the army bases and activities for protection against natural disasters, natural and other disasters, noise from household activities or noise from the neighboring household, as well as the noise of those who create it.

Protection of the environment from noise is ensured by determining the conditions and undertaking protection measures related to spatial, urban and acoustic planning, sound protection, strategic assessment of the impact of plans, programs and projects on the environment, prescribing the limit values of noise indicators in the environment, acoustic zoning, development of action plans for protection against noise in the environment, assessment of harmful effects of noise on human health, etc. Environmental protection entities in the territory of the Republic of Serbia include the Republic of Serbia, the local self-government unit, legal and natural persons, scientific-professional organizations, associations and citizens. Assessment of noise levels and noise protection measures in the environment are integral elements of projects, plans and programs to which the laws governing the process of strategic environmental impact assessment are applied. Environmental Impact Assessment by Competent Persons predicts possible harmful effects of noise on the environment.

SOME LEGAL ASPECTS OF INJURE RIGHTS OF ENVIRONMENT

The Environmental Impact Assessment Study determines the conditions and measures that can prevent, reduce or eliminate harmful effects of noise. In the performance of entrusted tasks, the Ministry supervises the work of the Agency, the autonomous province, the local self-government units, as well as the authorized legal entities.

Inspection and police authorities have a special role in ensuring the effective enforcement of laws, other regulations and general acts in the legal field in question. Inspectorate authorities examine the application of laws and other regulations by direct insight into the operations and conduct of supervised subjects of inspection supervision, and state the measures for which they have the necessary powers, such as the adoption of decisions requiring the removal of identified irregularities, imposing a ban, performing

control of execution of the decision, the procedure for administrative execution of a decision in the case of a party's involuntary treatment according to the decision within the deadline, and others. Police authorities take preventive measures and apply police powers to establish and maintain the necessary order in the work environment, and provide assistance to city authorities in the execution of decisions and other responsibilities.

The Regulation on noise indicators, limit values, methods for assessing noise, disturbance and harmful effects of noise in the environment [7] prescribes environmental noise indicators, limit values, methods for assessing noise, disturbance and harmful effects of noise on human health. This bylaw prescribes minimum requirements which the employer is obliged to fulfill in ensuring the application of preventive measures with the aim of removing or minimizing the risk of injury or damage to the health of employees arising or arising from noise exposure.

The greatest risk of hearing damage occurs, and there are precise requirements that are required by legal entities with licenses to perform work testing of working environment conditions in the process of preventive and periodic testing of working environment conditions regarding the noise emission limit value and noise exposure action value.

The employer is obliged to eliminate the risk arising from the exposure of employees, or to reduce them to the minimum. As for workplaces for which it has been established that the action value of the exposure to noise is exceeded, the employer is obliged to mark it with the labels for safety and health at work, and to distinguish that area from the access of employees who do not work on the team jobs.

Compensation for damage caused by excessive noise may be required only if the noise risk cannot be eliminated or prevented by appropriate measures so that it is reduced to a level that does not exceed the normal limit. When an expert in a particular profession did not have the necessary expertise to clarify and determine some controversial fact from the other profession, then the first instance court was obliged to designate experts of the relevant profession, since it was a complex expert. [8]

It is stipulated that noise measurement can be carried out by professional organizations that have appropriate professional staff and noise measurement equipment. The Minister prescribes: the permissible level of noise in the center in which the person is staying; methodology of noise measurement. Closer conditions to be fulfilled by professional organizations are determined by professional organizations that meet the noise measurement requirements.

The obligation to monitor the environmental impact is a permanent obligation foreseen by the Environmental Protection Act, and when noise is concerned, noise sources must be used and maintained so that they do not exceed the permissible level in the environment in

which a person resides within the meaning of the Rules on Allowed Noise Level in the environment. [9]

By imposing a ban on the processing and storage of all dangerous and harmful substances on the territory of the entire municipality, the local self-government unit has exceeded its powers prescribed by the Constitution and the Law on Environmental Protection because it unauthorized the prohibition of performing certain economic activities in the municipality, although, in accordance with the Law, in certain conditions, may limit the operation of the plant and perform activities in a particular area, that is, the ministry in charge of environmental protection may prohibit the performance of certain activities, for a specific time or part of the territory of the Republic of Serbia or the autonomous province or local self-government unit prevention of endangering the environment or human health. [10]

VIBRATIONS AS A CAUSE OF PROFESSIONAL DISEASES

Of particular interest is the case from the case law of the Court of Justice of the European Union, which will be explained in more details in this paper. It is of importance for the relationship between national and supra-national law in the territory of the European Union.

Mr Salvatore Grimaldi is an Italian who worked in Belgium from 1953 to 1980. On May 17, 1983, he asked the Occupational Disease Fund to recognize "Dipitren's contracture", from which he was suffering, for a professional illness. Dipitren's contract is a neurological disease of the hand caused by mechanical vibrations that occur when using a pneumatic drill.

The Fund rejected the request of Mr. Grimaldi with the explanation that the specific disease is not on the Belgian list of occupational diseases. Mr Grimaldi sued the Labor Dispute Tribunal in Brussels, and it has been established in an expert opinion that the Prosecutor is suffering from the aforementioned illness, which, although not listed on the Belgian list of professional diseases, may be regarded as "a disease caused by an overload [...] of the tissue around the tendon".

This disease is found on the European list of professional diseases, which is an integral part of the Recommendation of July 23, 1962. Member States are encouraged to include that list in national law. In addition, in the main proceedings, the question arises whether Mr. Grimaldi can prove at all, in order to obtain compensation based on the "mixed" system envisaged by Commission Recommendation no. 66/462 of 20 July 1966 on the conditions for awarding compensation to persons suffering from professional diseases, that one disease, which is not on the national list, is of professional origin.

The Labor Tribunal in Brussels decided to adjourn the proceedings and send a motion to the EC Court for a preliminary ruling on the subject matter of the case which has an interpretation of Community law. The EC

Court was asked to answer the question of whether a measure such as the "European List of Occupational Diseases" could have direct effect in a Member State if that list is clear, unconditional, sufficiently specific and unambiguous and does not give discretion to the authorities of a Member State in terms of achieving the objective of the recommendation and if it was an integral part of the Commission's recommendation that has not been formally incorporated into national law for more than 25 years.

Unlike Article 173 of the Treaty which excludes the EC Court of Justice right to review the legality of the recommendations, Article 177 of the Treaty gives the EC Court of Jurisdiction the power to decide on a previous matter subject to the validity and interpretation of all acts of the Community institutions, without exception. [11]

Since the choice of the form of the act can not change the nature of a Community measure, the EC Court, when it is called upon to interpret the measure bearing the name of the recommendation, must determine its scope of application to determine whether such a measure, having in mind its content, produces binding effects. By this judgment, the Court found that recommendations, as acts which do not have a binding effect under the Treaty and to which individuals can not be invoked directly before a national court, may nevertheless have a certain legal effect. National courts should take them into account in the settlement of disputes, especially in cases where they interpret national law measures adopted for the purpose of implementing the recommendations, or where the purpose of the recommendation is to amend the binding provisions of Community law.

CONCLUSION

In the light of economic life, the Republic of Serbia needs significant progress in the field of environmental protection.

There are opportunities for further improvement in contrast to the problems faced by workers in the random environment on a daily basis, as well as environmental rights subjects. The legislator is aware of the importance of protecting the environment, as well as any changes that are unwilling to undertake in order to monitor the pace with the Community law of the European Union.

It is a big influence of noise and vibration on pollution of the living and working environment, with obvious effects on human health, and it is necessary to meet with the noise and vibrations and their impacts, as well as getting to know with adequate methods of control and protection against noise and vibrations of all the actors of economic life.

Our society should work on a modern, multidisciplinary approach to environmental protection, as well as to provide great activities in the field of analysis, planning, management and remediation of the endangered environment due to the negative noise and

vibration effects. In the end, should be added that it is necessary to adopt new laws and by-laws, in order to find suitable solutions in accordance with the possibilities for the smooth running of business life.

REFERENCES

- [1] Presuda Okružnog suda u Valjevu, Gž.br.1079/2008(1) od 15.12.2008. godine
- [2] Odluka Vrhovnog suda Srbije Rev. br. 1936/98 od 24.6.1998. godine
- [3] Zakon o penzijskom i invalidskom osiguranju ("Sl.glasnik RS", br. 34/2003, 64/2004- odluka USRS, 84/2004- dr.zakon, 85/2005, 101/2005-dr zakon, 63/2006-odluka USRS, 5/2009, 107/2009, 101/2010, 93/2012, 62/2013, 108/2013, 75/2014, 142/2014 i 73/2018)
- [4] Zakon o obligacionim odnosima („Sl. list SFRJ“, br.29/78, 39/85, 45/89- odluka USJ i 57/89, „Sl. list SRJ“, br.31/93 i „Sl. list SCG, br.1-2003- Ustavna povelja)
- [5] Presuda Vrhovnog suda Srbije, Rev. br. 76/1998 od 2. novembra 1998. god.
- [6] Zakon o zaštiti od buke u životnoj sredini (Sl. Glasnik RS", broj 36/2009 i 88/2010)
- [7] Uredba o indikatorima buke, graničnim vrednostima, metodama za ocenjivanje indikatora buke, uznemiravanja i štetnih efekata buke u životnoj sredini ("Sl. glasnik RS", broj 75/2010)
- [8] Rešenje Vrhovnog suda Srbije, Prev. 623/95 od 17.1.1996. godine - Sudska praksa privrednih sudova - Bilten br. 2/1996 - str. 77
- [9] Presuda Višeg trgovinskog suda, Pkž. 281/2004 od 4.11.2004. godine - Sudska praksa trgovinskih sudova - Časopis za privredno pravo, br. 4/2004 - str. 165)
- [10] Odluka Ustavnog suda, IU broj 122/2006 od 16. jula 2009. godine, objavljena u "Sl. glasniku RS", br. 60/2009 od 3. avgusta 2009. Godine
- [11] Judgment of the Court (Second Chamber) of 13 December 1989, Salvatore Grimaldi v Fonds des maladies professionnelles, Case C-322/88, ECLI:EU:C:1989:646; Opinion ECLI:EU:C:1989:366

BIOGRAPHY of the first author

Milica Stojković was born in Vranje, Serbia, in 1989. She graduated and received Master's Degree in Laws from the University of Niš, Faculty of Law. She received PhD Degree for legal science from the Faculty of Law for Commerce and Judiciary in Novi Sad.

Her main areas of research include commercial law, competition law, European Union law, etc.

She is currently working as an assistant professor at the Faculty of Law for Commerce and Judiciary in Novi Sad.



PRAVNA ZAŠTITA OD BUKE I VIBRACIJA I PRIVREDNI ŽIVOT

Milica Stojković, Milorad Bejatović

Rezime: U radu se analiziraju pojedini delovi sudskih odluka iz oblasti privrednog života, tako da određeni zaključci upućuju na postojeće stanje u sudskoj praksi. Ovaj rad ima za cilj da razmotri neka pitanja korišćenja sudske zaštite zbog buke i vibracija prisutne u privrednom poslovanju. Neophodna je pravna zaštita od mogućih uticaja na bezbednost i zdravlje ljudi, budući da su buka i vibracije često uzrok zdravstvenih oštećenja, trajne invalidnosti i profesionalne bolesti. Civilizacijski napredak je doneo različita sredstva tehnologije, te je buka prateći faktor svakodnevne aktivnosti ljudi pri upotrebi sredstava čovekovog radnog i privatnog okruženja. Posledice buke i vibracija su neretko osnov za naknadu štete u parničnim postupcima pred nadležnim sudovima. Zaštita od buke se može posmatrati sa više različitih aspekata (tehničkog, medicinskog, ekonomskog, pravnog i dr.). U ovom radu je reč o pravnoj zaštiti od buke i vibracija u sudskoj praksi. Neophodne su promene u politici pravne zaštite od buke i vibracija. Potrebno je donošenje novih zakonskih i podzakonskih akata, u cilju pronalaženja celishodnih rešenja u skladu sa mogućnostima nesmetanog odvijanja privrednog života.

Ključne reči: buka, vibracije, zaštita, zakon, praksa

SLAVENKA ELEK¹
IVAN MIJAILOVIĆ²

¹Jkp put - Novi Sad

²University of Niš,
Faculty of Occupational Safety

¹slavenka.elek@jkpput.rs

²ivan.mjailovic@znrfak.ni.ac.rs

OCCUPATIONAL SAFETY AND HEALTH EDUCATION PLAN IN A ROAD CONSTRUCTION COMPANY – EXAMPLES OF GOOD PRACTICE

Abstract: According to the article 7. which is part of the Serbian law that manages occupational safety and health, one of the preventive measure is education, upbringing and training in the field of occupational safety and health. The Law on Occupational Safety and Health of the Republic of Serbia also deals with this subject in the part called "training of employees", articles 27,28,29,30,31. The article 28 determines that training of employees for safe and healthy work is done by the employer, theoretically and practically, in accordance with the training programme. The paper will describe the training program in the field of occupational health and safety in the road construction company "JKP put" - Novi Sad, as the example of good practice.

Key words: Occupational safety and health, training program, education, preventive measures.

INTRODUCTION

Occupational safety and health legislative determines obligations of employer in sense of education and training of employees. The employer is obliged to inform the employee, during the course of training for safe and healthy work, with all types of risks in the tasks assigned to him and on concrete measures for safety and health at work in accordance with the risk assessment act.¹

Training for the safe and healthy work of an employee must be adjusted to the specifics of his workplace and is carried out according to the program, the content of which must be renewed and modified by the employer when necessary.

If the employer orders the employee to simultaneously perform more than one job, he is obliged to provide an employee with a safe and healthy work at each of the jobs.

Training of employees for safe and healthy work is done by the employer theoretically and practically, in accordance with the training program for safe and healthy work done by the employer.

Testing the theoretical and practical skills of an employee for safe and healthy work is done at the workplace.

Periodic tests of the skills for safe and healthy work of an employee working at an increased risk workplace shall be carried out no later than one year after the date of the previous examination, and in other workplaces no later than four years from the date of the previous check.

When the technological process of work requires additional training of an employee for safe and healthy work, the employer is obliged to inform the employee about performing the work process in a safe manner, by means of notifications, instructions or instructions in a written form.

The employer is obliged, as soon as possible, to alert every person, who is in the workplace area, to dangerous places or to health hazards occurring in the technological process, or to the security measures he must apply, and to pointing to safe moving zones.

The employer is obliged to visually mark and highlight the safety and / or health markings in order to inform and inform employees of risks in the technological process, directions of movement and permitted places of detention, as well as measures for preventing or eliminating risks.

The employer is obliged to ensure that access to the workplace, which is threatened with immediate danger of injury or health damage (poisoning, choking, etc.), only persons who are qualified for safe and healthy work, who have received instructions to stop working and / or immediately leave the workplace and go to a safe place, special instructions for work in such a place and which are supplied with adequate means and equipment for personal protection at work.

TRAINING PROGRAM FOR BUILDING MACHINE OPERATORS

Education and training program is subdivided in two different categories: basic and specialized program of training.

Basic part of the training program

Includes occupational safety and health organization in the company. For example, the importance and goal of safety and health at work, occupational Health and Safety Law, Ordinance on injuries at work, Instructions on the procedure for controlling employees for the presence of alcohol and / or psychoactive substances in the body, Occupational Injury Procedure, Safety and Health at Work, Rulebook on the content of the study about the arrangement of construction sites, etc.²

Organization and functioning of safety and health at work in the company as well as the organizational parts of the company, arranging and organizing health and safety measures at the workplace in the workplace, supervision of the implementation of safety and health at work, obligations and responsibilities of the employer, manager of organizational parts and direct job organizers and their role in the occupational health and safety system, rights and obligations of employees, in the field of occupational safety and health. Employer's Act and Occupational Health and Safety Documents: Labor Regulations, Rules on Safety and Health at Work, Workplace Risk Assessment Workplace, Decisions, Notices, Plans, Procedures, Minutes, etc.



Prohibition measures at work: consuming alcohol, narcotics and narcotic drugs, tobacco and the right of the employer to sanction employees who violate safety and health at work.

Rights, obligations and responsibilities of employees are rights and obligations related to the training of persons for safe and healthy work, rights and obligations regarding the use of issued means and equipment for work and prescribed means and equipment for personal protection at work, the right of a person to refuse to work, person's responsibility for safety and health at work, employee representatives and cooperation of employees in the field of safety and health at work, person for safety and health at work - cooperation and role, cooperation with occupational medicine, goals of health care of employees and cooperation with competent labor inspection.

Next part of the training deals with rights, obligations and responsibilities of responsible persons:

The responsible person for occupational safety and health in the company distributes workers to work and conditions for employment in accordance with the regulations on safety and health at work.

Getting to know the hazards and hazards in the workplace in the workplace - The Risk Assessment Act, prohibition of work of a person who does not comply with the prescribed safety and health measures at work.

Establishes measures of sanctions against offenders. The right of the employer to sanction persons who violate safety and health at work, and makes instructions for operation and maintenance of equipment and tools for work-purpose.

The basic task of training for safe and healthy work is training for safe and independent work, training for safe group work, acquisition and development of work habits and working discipline and developing proper attitude towards vehicles using tools and equipment used in the work process.

Also, training should help in developing responsibility and precision in carrying out work and performing work operations.

For employees working on this positions, it's crucial that training bring skillful and proper handling of vehicles, equipment and tools, and develop awareness of the importance of preparatory actions for efficient and safe performance of work.

Training has a goal to establish proper implementation of safety and health regulations at work, teach employees how to use personal protective equipment, as well as developing a responsible relationship towards one's own and the health of others.

Development of awareness of the importance of preserving material goods and protecting the environment is also very important.

The training program also includes getting to know the work cycles of a motor vehicle / construction machine, and how to operate it.



Recognition of the most common operating errors on the vehicle / construction machine, the person knows the causes and the methods of removal and use of the appropriate tools and equipment.

Special part of the training program

Special part of the training program includes getting operators to know operating instructions, the basis of the technology of work, the types and characteristics of the material used in the work process. Also, selection of suitable materials and tools and basic measurement techniques and working with measuring instruments are necessary. Employee learns about measures for safe work, handling machines and devices used in the work process as well as auxiliary jobs on demanding machines.



This part of the training includes learning about dangerous zones, prerequisites for handling a construction machine, general rules for safe working with construction machines. He is also informed about organization, work planning and preparation of the machine for work, introduced to construction site and working on the construction site as well as use of personal protective equipment-type, purpose. The employee is introduced to the crucial parts of Risk assessment act that includes mechanical hazards that occur using equipment for work and measures for removing identified hazards.



It includes:

Internal transport and movement of work machines or vehicles as well as movement of equipment for work. (potential danger of collision with other motor vehicles and other mechanics with which it is handled - serious injuries to operator of vehicles or construction machinery, or other participants on the construction site, as well as damages to construction machinery and vehicles (serious consequences)

Training of employees for safe work at all levels (drivers, operators, construction workers, and all those who participate in the process of work on the site), user's manual for safe work, respect all safety and operating instructions prescribed by the original manufacturer's instructions, as well as internal documents. Safe movement of workers in the workspace, outdoor transportation of machines and vehicles on marked routes with mandatory indebtedness of a person who will regulate movement

of vehicles and workers by contract signals and getting acquainted with jobs on the site

Employee needs to understand the conditions and method of work on the construction site (access road to the location of the device operation, the strength of the roadway, the elements of the road, the gauge, the distance from the edge from the edge or foot of the slope or excavation, then the passageway, passes through interference and other exploitation elements, ensure the safe movement of the device and transport means, maneuvering space of the device at the work site free from above ground, underground and ground faults, in the working position the flatness and hardness of the substrate, the necessary support surface and other conditions from the manufacturer's instructions, working position and working the track device such that the device for moving the work and to impact or by its own weight does not result in a disruption of the soil, or deformations of protective structures of neighboring buildings).



Adequate working preparedness of the driver, the operator (the driver must not drive sick, unsteady, tired) is needed likewise getting to know the work with the vehicle with the collaboration of other machines.

Adopting instructions before starting work, management by instructions during suggestions to associates during work.

Adjust the speed of the movement at the allowed speeds, as follows: Max. 20 km / h on the construction site and to apply safety and health measures at work

Practical training of all participants at the site, for safe and healthy work is necessary. He should be aware of protected movement of workers in dangerous zones of the machine (rotating blades, connections and joints, whole space below and behind the machine) and to stop every work until a person leaves the dangerous zone

Use equipment for working with gifted certificates and licenses and conduct regular technical supervision of work equipment.

He should be ensured that the load is adequately located and secured and ensured that employees are properly trained.



Next part of this training is introduction to dangers that arise in relation to the characteristics of the workplace.



Hazardous surfaces (floors, treads, touch surfaces) that have sharp edges - edges, spikes, rough surfaces, convex parts. Preventive maintenance of construction machines, (potential danger of injuries by contact with sharp edges of the body or other parts of the machine).

The machine operator by job description works on minor repairs or small preventive maintenance, for all other repairs and maintenance, the competent department of the company, that is the department of the workshop, is in charge.

Not engage in functional repairs of the machine, or major repairs, and do not exceed the authority over this. It will not work if you do not know or you are not sure what to do.

For tiny repairs it performs uses a hand-held tool. The most common causes of hand tools are:

- tool failure
- use the tool for the wrong purpose
- incorrect tool manipulation
- incorrect disposal of the tool
- accidents resulting from improper use of manuals

Tools are usually cuts, stabs, eye damage due to decay of particles which are delayed, etc. In order to reduce the risk of handling hand tools, the worker needs daily control of the correctness of the tool, and irregular put the tool out of use.

Tools and devices should be used only for the purpose for which they are intended, and for each job tools of appropriate sizes must be used. Sharp tools should be transferred in bags and toolboxes, a it is forbidden to get sharp tools to others workers

Trained employee training for minor repairs and familiarization with all security measures during this performance

Be familiar with all the technical characteristics of the machine, its purpose, possibilities, recommendations, safety measures, possible defects, the method of removing the failure, maintenance of the machine, safety instructions, etc., provided by the manufacturer and which are contained in the original instructions of the machine, which should be are in the service of mechanization

During any repairs, the vehicle must be out of operation or off and secured from unplanned start-up

During the execution of works requiring the lifting of covers of any kind, it is necessary to ensure, by placing the safety support



It was used to use unsafe items for support

Minimal attention and employee concentration

Use of personal protective equipment⁴

The vehicle is to be rolled only at the designated points, holding firmly for the handrails or parts of the machines intended for holding

Cleaning the grips from grease and dirt

Cleaning the steps of the stairs from snow, ice, mud

Cleaning shoes from snow, ice, mud

CONCLUSION

Training for the safe and healthy work of an employee must be adjusted to the specifics of his workplace and is carried out according to the program, the content of which must be renewed and modified by the employer when necessary.

Testing the theoretical and practical skills of an employee for safe and healthy work is done at the workplace.

Periodic tests of the skills for safe and healthy work of an employee working at an increased risk workplace shall be carried out no later than one year after the date of the previous examination, and in other workplaces no later than four years from the date of the previous check.

Training is carried out through theoretical and practical education. After completing the training, testing is carried out.

The education program contains the necessary elements related to knowledge of work equipment, workplace and work environment, the use of personal protective equipment, and the dangers that can occur during work. The organization and implementation of the theoretical part of training for safe and healthy work is carried out by an expert of safety and health at work in cooperation with appropriate professional institutions, in accordance with the Law on Safety and Health at Work and the Program for Training Occupied Persons in the Area of Safety and Health at work in JKP "PUT", Novi Sad.

After the theoretical part of the training, the examination of the knowledge through facial testing is carried out, testing the theoretical knowledge test for independent and safe work in JKP "Put", Novi Sad. The person was satisfied with checking the knowledge of the theoretical part of the training if he answered exactly over 80% of the questions.

If, during the examination of the knowledge, it is determined that the person is not sufficiently qualified for safe work, he / she cannot be allowed:

- to start work independently at the workplace for which he / she has been employed
- a temporary injunction is pronounced

In that case, the training continues, after which the qualification check is re-established within 30 days. If it is not established in the second repeated examination procedure that a person has been trained for safe work at a particular workplace, a person cannot perform tasks in the specified position.

The practical part of the training for safe and healthy work is carried out by the responsible manager of the organizational unit in which the person is deployed, or the appropriate professional institution.

In the course of practical training, a person is introduced to all types of risks, hazards and hazards in his workplace, as well as concrete measures for removing these risks, along with demonstration on equipment, tools, machines.

It is capable of working with all tools for the work, tools and equipment it manages, the handling and servicing procedure, the purpose and characteristics of the tools and accessories, protective devices and equipment of devices, protective blockades, STOP TASTERS, working procedures.

The responsible manager in charge of carrying out the practical part of the training appoints persons who will be in charge of conducting practical training (direct manager, older experienced colleagues, etc.) in writing. A person engaged in work may not start independent work or work without direct supervision by a person designated for carrying out a practical part of the training, until he is qualified for safe work.

Practical training includes two-week work, with control and supervision, the person in charge. Practical training can last longer than 10 working days if the competent and authorized persons assess that the person who is trained performs certain jobs in an unsafe manner.

REFERENCES

- [1] "Zakon o bezbednosti i zdravlju na radu", Službeni glasnik RS, broj 101/2005,91/2015, i 113/2017.
- [2] Program osposobljavanja zaposlenih za bezbedan i zdrav rad JKP Put - Novi Sad, 2017.
- [3] Poseban deo teorijskog osposobljavanja radno angažovanih lica u JKP „Put“ - Novi Sad za bezbedan i zdrav rad za obavljanje poslova rukovalac građevinskim mašinama.2017
- [4] Pravilnik o ličnoj zaštitnoj opremi, "Službeni glasnik Republike Srbije broj 100/2017"

BIOGRAPHY of the first author

Slavenka Elek was born in Stolac, Bosnia and Hercegovina, in 1978.

She received the diploma in Technology from the Faculty of Technical Sciences in Novi Sad. Currently, she is a person responsible for occupational safety and health at JKP Put - Novi Sad. Her main areas of research include occupational

Safety and health, road construction technology and fire protection.



PLAN OSPOSABLJAVANJA ZAPOSLENIH ZA BEZBEDNOST I ZDRAVLJE NA RADU U PREDUZEĆU ZA PUTEVE - PRIMERI DOBRE PRAKSE

Slavenka Elek, Ivan Mijalilović

Rezime: Na osnovu člana 7. Zakona koji reguliše bezbednost i zdravlje na radu u Republici Srbiji, jedna od preventivnih mera je obrazovanje i obuka u oblasti bezbednosti i zdravlja na radu. Zakon o bezbednosti i zdravlju na radu takođe definiše ovu problematiku u delu „obuka zaposlenih“, u članu 27, 28, 29, 30 i 31. Na osnovu člana 28, poslodavac je u obavezi da organizuje teoretsku i praktičnu obuku za zaposlene iz oblasti bezbednosti i zdravlja na radu, u skladu sa programom stručnog osposobljavanja zaposlenih za bezbedan rad. U radu je predstavljen primer dobre prakse programa obuke zaposlenih zaposlene iz oblasti bezbednosti i zdravlja na radu, kroz primer dobre prakse preduzeća za puteve JKP put - Novi Sad.

Key words: bezbednosti i zdravlje na radu program obuke, obrazovanje, preventivne mere.



RISK ASSESSMENT AND MANAGEMENT



MARKO CVETKOVIĆ¹
JOANA DUARTE²
EVICA STOJILJKOVIĆ³
LUTVO HAZNADAREVIĆ⁴
JOAO MANUEL ABREU DOS
SANTOS BAPTISTA⁵

^{1,2,5}University of Porto,
Faculty of Engineering, Portugal

³University of Niš,
Faculty of Occupational Safety,
Serbia

⁴Collage Mostar,
Logos Center, Bosnia and
Herzegovina

¹marko.cvetkovic.33@gmail.com

²jasduarte@fe.up.pt

³evica.stojiljkovic@znrfak.ni.ac.rs

⁴hlutvo@yahoo.com

⁵jsbap@fe.up.pt

PROFESSIONAL DRIVERS' POSTURES TRACKING - A REVIEW OF METHODOLOGIES AND APPLIED EQUIPMENT

Abstract: While performing their tasks, professional drivers are in prolonged sitting position (usually for more than 2 hours), with various static body postures which, sometimes, require the movements of lower or upper body parts. These kinds of body activities can lead to a variety of consequences, such as venous disorders, cardiovascular diseases, pain after sitting and muscles cramps. To accomplish the goal of this study, the PRISMA Statement Methodology was used. For this reason, 27 Scientific Journals and 25 Indexes/Databases were scanned, where 10750 related studies were found, of which 18 were included in this paper. Selected articles were presented in the tables that couple together the equipment and the methods used in various motion analyses. The primary conclusion shows that the method which combines the markers with cameras gives the best results and examines the movements of all body parts in case of a professional driver.

Keywords: motion tracking, movement analysis, body posture, driver.

INTRODUCTION

Despite the advancements in vehicles technology, their equipment, and the efforts to make them as safe as possible, the human factors cannot be neglected. During the steering of vehicles, professional drivers are in situations that require long-term sitting, with limited body movements, due to the restrictions caused by the controlling position; also, they need to maintain constant visual contact with the instruments and surroundings.

Thus, a driver is, most of the time, in a static position and, as such, falls within the high-risk group for the spinal column disorders, pain in the lower back and muscles, sciatica, pain in the neck, among others (Harrison, Harrison, Croft, Deed, & Troyanovich, 2000). According to data provided by the World Health Organization (World Health Organization, 2004), 1.2 million people get killed every year, and 20 million people get seriously injured in traffic accidents worldwide. So, the upper and lower limbs of drivers should be analysed in order to study the possibilities of improving the system of operation and the ergonomics of vehicles.

With the aim to reduce human error during the steering of a vehicle, one of the best-known movement analysing systems of a driver and his activities is the one using cameras (Cheng, Park, & Trivedi, n.d.; Yan, Coenen, & Zhang, 2014). However, the motion analysis using cameras cannot be easily implemented, since it requires additional lightning inside the vehicle. If suitable conditions for implementation of such systems are provided, a reliable approach would be a multi-perspective (i.e., by multiple camera views) and multi-modal (i.e., thermal, infrared and colour) (Cheng

et al., n.d.; Cheng, Park, & Trivedi, 2007), based on video analysis and real-time tracking of all body parts.

The obtained results are usually presented in 3D technology, allowing us to analyse specific body parts, such as upper extremities (as a whole), or only a hand (through a thermal camera) along with head motion and its position (Cheng et al., n.d., 2007; Alexandra Kondyli, Sisiopiku, Zhao, & Barmpoutis, 2015; Tawari, Martin, & Trivedi, 2014). A multi-perspective and multi-modal approach is very demanding since when driving, a variety of environmental conditions cause a change of light levels inside the vehicle. In addition to other challenges for applying motion analysis by cameras, there are other issues to be solved, related to the individual characteristics of each driver.

Apart from the above mentioned methods, there are also other devices which can be used to analyse body posture, such as dot sensor/markers used in combination with cameras (Bastien, Blundell, & Neal-Sturgess, 2017; Caruso, Camere, Bordegoni, & Bordegoni, 2017; Tran, Doshi, & Trivedi, 2012). A particular combination of marker/sensors, placed on defined body parts by a standard of the user guidebook, and cameras were presented by different authors (Bastien et al., 2017; Peng, Wang, & Denninger, 2017). This model examines the entire body posture, and it is very reliable, both in the motion analysis and in terms of determining the body position.

Nonetheless, it should be emphasised that the implementation of the method in real conditions is difficult for the lower limbs movements' analysis: the problem relies on the visibility of the lower extremities due to the gearbox. However, it is possible to present foot activities using the method based on the vision-based foot behaviour investigation (Tran et al., 2012).

With the purpose of data collection, the framework for driver foot behaviour analysis was created and afterwards displayed and examined by Hidden Markov Model (HMM) (Tran et al., 2012; Zhao &, 2013). There are also other methods for determining and evaluating this issue by studying the head movements, eye and facial expressions among others (Kondyli et al., 2017; Tawari et al., 2014; Yan et al., 2014).

The primary objective of this article is to investigate the equipment used to determine the driver's real-time motion tracking, in addition to which methods can be applied to analyse the movements of the lower limbs while steering a vehicle. Furthermore, the articles focused on the studying of body posture were also included. The main reason for implementing the above-mentioned method is based on the equipment and the procedures applied in the articles to monitor driver's body posture. The drivers' upper and lower limbs should be analysed in order to study the possibilities of improving ergonomics of vehicle operating system.

MATERIALS AND METHODS

For carrying out this study, the PRISMA Statement Methodology (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009) was used, which requires the application of the research methodology in four steps (search for the available literature, screening, application of the eligibility criteria, and the analysis of selected papers). The implementation of PRISMA methodology requires the usage of a well-defined research question and keywords and their combination, as well as clear-cut inclusion and exclusion criteria.

This research included 30 Scientific Journal editors: ACM Digital Library, ACS Journals, AHA Journals, AIP Journals, AMA Journals, Annual Reviews, ASME Digital Library, BioMed Central Journals, Cambridge Journals Online, Cambridge Journals Online, CE Database (ASCE), Directory of Open Access Journals, Emerald Fulltext, Geological Society of America, Highwire Press, IEEE Xplore, Informaworld, Ingenta, IOP Journals, MetaPress, nature.com, Oxford Journals, Royal Society of Chemistry, SAGE Journals Online, SciELO, Science Magazine, ScienceDirect, Scitation, SFX A-Z, SIAM, Sociology: A SAGE Full-Text Collection, SpringerLink, The Chronicle of Higher Education, Wiley Online Library and 25 Index – Database: Academic Search Complete, AGRICOLA Articles, Beilstein, Business Source Complete, CiteSeerX, Compendex, Criminal Justice Periodicals, Current Contents, Energy Citations, ERIC, Inspec, Library, MEDLINE, PsycArticles, PsycCRITIQUES, PubMed, ScienceDirect, SCOPUS, Social Sciences & Humanities Proceedings, SourceOECD, TRIS Online, Web of Science, Zentralblatt MATH.

The keywords combinations used were: "body posture" AND (driver OR driving); "body posture" AND (driver OR driving) AND ("motion capture" OR video OR camera); ("movement analysis" or "Motion analysis") AND (driver OR driving); ("movement analysis" or

"motion analysis") AND (driver OR driving) AND ("motion capture" OR video OR camera); "motion tracking" AND (driver OR driving); "motion tracking" AND (driver OR driving) AND ("motion capture" OR video OR camera); "body movement" AND (driver OR driving); "body movement" AND (driver OR driving) AND ("motion capture" OR video OR camera); kinematics AND (driver OR driving) AND ("motion capture" OR video OR camera).

After limiting the research period to five years (from January 2013 until September 2017), exclusion criteria were defined, and all articles had to meet the following requirements: 1) the papers should be written in English, 2) title and abstract should be in accordance with the primary goal of the study, 3), the content of the paper should be accessible 4) the articles must be related to the analysis of the drivers' movement inside the vehicle, 5) preference is given to the papers that contain also the motion analysis of the lower limbs.

All the works accepted after the application of the eligibility criteria were analysed in detail, with the objective of extracting the results that allowed a complete analysis, or would make available information, of drivers' movements during the driving activity. This study also included the works that examined drivers' posture in order to have a complete understanding of the working environment and work-related behaviours during the trip. One of the limitations of this article lies in the fact that not many articles on the analysis of the lower limbs were found, making a complete methodological conception difficult on this subject.

RESULTS

After the analysis and application of the exclusion criteria, 49 papers were considered eligible, 11 of which (Figure 1) were included in the conception of this study (Table 1 and Table 2).

The distance between sensors levels and displayed objects (an analysis of movement recorded by the cameras) is presented in a two-dimensional series of depth values (Dozza & Pa, 2013; Alexandra Kondyli et al., 2015; Tran & Trivedi, 2012; Yan et al., 2014; Zhao & Zhang, 2013). The presentation of the obtained data in a three-dimensional series requires adding the number of frames recorded, as well as the number of pixels in the width and height of each frame separately. A three-dimensional segment is required for the analysis of human activities. The process of image segmentation as a computer vision problem has been studied, as suggested by Kondyli et al. (2015). The obtained results must be performed in a real-time condition. As an example, the above-mentioned example uses the Prime Sense TM depth sensor, contained in the Microsoft Kinect TM device. Nevertheless, before the beginning of the information analysis, it is necessary to maintain a similar quality in each image. Depending on the parts of the body being studied, it is necessary to eliminate certain disturbances (image intermittence caused by the devices, while

observing the eye movement of the driver (Dozza & Pa, 2013), changes of lighting levels inside the vehicle, and so forth).

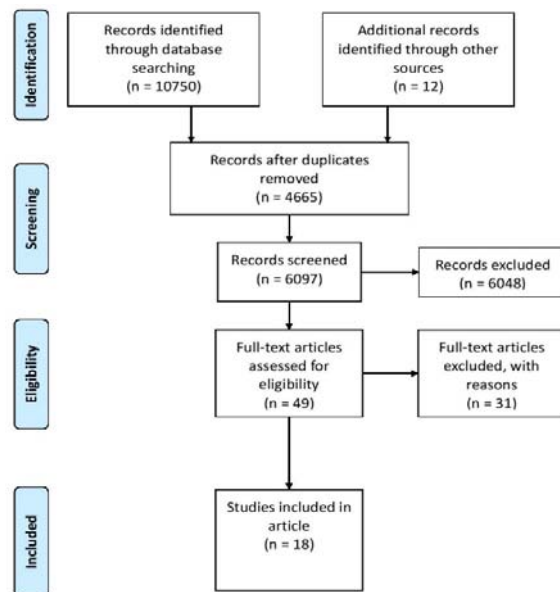


Figure 1. PRISMA Flow Diagram (Moher et al., 2009)

Databases such as Naturalistic Driving Studies (NDS) (Dozza & Pa, 2013), A Southeast University Driving Posture Database (SEU-DP Database) (Zhao & Zhang, 2013), Driver's Motion Depth DataBase (DMDDb) (A Kondyli et al., 2017) need to be created, in order to collect the necessary data to be used in the future and to analyse the drivers' behaviour in different situations. It is necessary to programme the algorithms for data processing, as well as storage, and the analysis of the achieved results.

Dozza (2013) presented a comparison of different types of processing algorithms based on two criteria: specificity and sensitivity. Because of the large number of data, this comparison is of great importance since the algorithms can, within a specified period, execute the whole processing. By comparing the results (Dozza & Pa, 2013), it can be concluded that the Harmonic mean algorithm achieves 100% both in sensitivity and specificity, while GLCM props have the lower score of 64% for both criteria.

Table 1. Equipment and Software

Author	Methodology	Additional equipment	Software	Algorithm
Kondyli (2015)	Single camera	N.A.	SDK	Skeleton tracking algorithm
Dozza (2013)	4 cameras	N.A	N.A	Harmonic mean, Optical flow, Mean GLCM props
Zhao (2013)	Single camera	N.A	HOMOF, HOG	Canny edge detection, MLP
Chao Yan (2014)	Single camera	N.A	PHOG	The random forest, <i>k</i> -Nearest Neighbor Classifier, Support vector machine, MLP
Kondyli (2014)	2 cameras	The Mobile Eye-XG eye-tracking equipment	KinectM by Microsoft	learning algorithm – self-developed
Cuong (2010)	2 cameras	Head pose tracking with HyHOPE	XMOB - Extremity Movement Observation	RVM
Shinko (2007)	4 cameras	4 cameras multi-modal	N.A	Hidden Markov Model
Tawari (2014)	Single camera	CoHMEt	POS	MPS, CLM, ICP
Caruso (2016)	Abstract Prototyping technique with Motion Capture technology	6 cameras	NURBS	N.A
Bastien (2017)	Motion-tracking system	8 camera	3D motion capturing system	N.A
Cuong (2012)	Single camera	Illumination flashlight	N.A	Optical flow

HyHOPE - (Hybrid Head Orientation and Pose Estimation); CoHMEt - Continuous head movement estimator; SDK - Microsoft Kinect Software Development Kit; HOMOF - homomorphic filter, HOG - Histogram of Oriented Gradients; PHOG - pyramid histogram of oriented gradients; POS - pose from orthography and scaling; MLP - The multilayer perceptron; RVM - Relevance Vector Machine; MPS - Mixture of Pictorial Structures; CLM - constrained local model; ICP - iterative closest point; SAFER - Vehicle and Traffic Safety Centre at Chalmers; SEU-DP - A Southeast University Driving Posture Database; Fps - frames per second

Table 2. Data treatment and body parts

Author	Data treatment	Real-time	Body parts
Kondyli (2015)	N.A	N.A	Upper body
Dozza (2013)	SAFER	5–10 fps	Upper body
Zhao (2013)	SEU-DP	N.A	Upper body
Chao Yan (2014)	N.A	24 fps	Upper body
Kondyli (2014)	Eligibility-screening questionnaire	30 fps	Upper body
Cuong (2010)	LISA	15 fps	Upper body and head
Shinko (2007)	Probabilistic Data Association	N.A	Upper body and head
Tawari (2014)	LISA-A	30 fps	head movement
Caruso (2016)	NURBS	16 fps	All body
Bastien (2017)	N.A.	N.A	All body
Cuong (2012)	Hidden Markov Model	30 fps	Drivers foot

The Motion History Image (MHI) approach (Yan et al., 2014) uses the most straightforward motion representation, motion analysis or other corresponding actions. Using MHI, it can be demonstrated how a specific object is triggered, using image segment technology. Another methodology, called Motion Energy Image (MEI) (Yan et al., 2014) can show the presence of any motion or spatial pattern, in the sequence of images. Using these two approaches to the analysis of the driver's movement can be advantageous because the obtained results are construed in black and white images. Motions during the driver's activity are represented in white colour with traces of displacement, and, based on that, the direction of the upper limbs motion can be detected, in this case (Yan et al., 2014). Based on this method, Kondyli (2017) developed an algorithm that uses the image segmentation technique to recognise the position of the hands, while steering a vehicle. The obtained depth frames were based on the principle presented in the paper of Kondyli (2015).

Optical flow is a well-known computer vision technique for assessing movement, and it has been applied in the monitoring of facial expression, movement of the upper extremities, head movements, among others. Tran (2012) found the benefit of this method in the analysis of the driver's foot movement while steering the vehicle. As a conclusion, after the method implementation, the collected results represented the position and speed of the foot movement in each frame.

As an advanced technical system, the method of cameras, and sensor/markers placed on the driver's body parts, in terms of motion tracking is more demanding regarding the data processing duration. Every single frame provides a large number of data (body parts position, as well as angles, movement of the upper or lower extremities direction, accelerations, among other parameters), which need to be elaborated and processed. Standardised NURBS-based modelling software (Caruso et al., 2017) provides support for this method and, as a final result, describes three-dimensional space, including all related information. Examining the data provided by the standardised software, all the important ergonomic characteristics and the conditions that a vehicle requires can be achieved (required workspace, position of the driver body, and others). Moreover, by combining the

suggested technique, a variety of applications have been found, such as testing the reaction of the driver in a vehicle accident (Bastien et al., 2017), defining the angles of the body posture while steering a vehicle, among others (Demirdjian, 2009; Jeong & Park, 2017; Peng et al., 2017).

DISCUSSION

The primary purpose of this work was to analyse and present the methods and the equipment being applied in driver's motion tracking while steering a vehicle.

Data processing techniques were also taken into consideration and were both compared and analysed, with the aim of obtaining the best way of determining driver's adopted posture and movements in real working conditions. Thus, the methods for static postural analysis were further included in this study (Demirdjian, 2009; Jeong & Park, 2017; Peng et al., 2017).

The significant majority of the works applies the multi-perspective and/or multi-modal technique of motion tracking analysis requiring two or more cameras (Cheng et al., n.d., 2007; Tran & Trivedi, 2010, 2012; Zhao & Zhang, 2013). As a proper approach for achieving the results of the drivers' static body posture, a combination of cameras and sensor/markers has been presented. This process reveals the data of driver's static body postures, the angles of both upper and lower extremities, as well as three-dimensional movement analysis with the accurately plotted body movement paths (Bastien et al., 2017; Caruso et al., 2017; Tran et al., 2012).

The methodology of analysing drivers' motions requires the proper positioning of the cameras (there should be a placement of 45° between them), considering which parts of the body need to be examined (Alexandra Kondyli et al., 2015; Zhao & Zhang, 2013). This methodology applies to the capturing of upper extremities analysis. Concerning the lower extremities, the situation is different: the main problem is the variety of the interference in the visibility (gearbox, changing of the light level, and unsuitable space for the camera installation, among others). Moreover, the camera's operating mode defines the data analysis system. For example, using thermal cameras (Cheng et al., n.d., 2007) the driver's hands

can be analysed, due to thermal radiation differences between that body part and the rest (arm, for instance). The codebook-based background subtraction method (Cheng et al., n.d.; A Kondyli et al., 2017) is a useful tool to recognize the driver's body posture and separate it from the background recorded colour video. Besides the methodology presented above - of using two or more cameras -, it applies to vision-based driving position recognition method, to use one camera mounted on the side of the driver (Dozza & Pa, 2013; Yan et al., 2014). As a support of this method, the received data from one camera can be manifested as a silhouette of the motion history image and create a driver's movement reaction, using the Application of the Pyramid Histogram of Oriented Gradients (PHOG) software (Yan et al., 2014).

What is more, advanced methodologies using developed software based on the eye movement analysis can be applied in the drivers working environment (Alexandra Kondyli et al., 2015; Tawari et al., 2014; Tran & Trivedi, 2012).

Regarding outcomes, the combination of the Abstract Prototyping technique with Motion Capture technology (Caruso et al., 2017) gives a possibility to define the required drivers' working space and/or to establish what kind of posture the driver adopts while operating. Furthermore, applying the basic knowledge of biomechanics, the dynamic performing movements can be observed and studied. Markers are placed in different, previously defined, parts of the drivers' body (head, chest, abdomen, upper and lower extremities) (Caruso et al., 2017). Afterwards, standardised NURBS-based modelling software (Caruso et al., 2017) is needed to process and analyse the obtained data.

Due to the conditions above that do not allow the use of cameras in the analysis of the lower limb movements, the application of this method is suitable for testing (seating posture, ergonomic characteristics of a vehicle, and others) in laboratory conditions. As such, it can also be used in real-world conditions, if the collected data presents the driver in a software animation mode (avatar).

CONCLUSIONS

In the drivers'/operators' working environment, there can be a variety of hazards that can have a negative impact on the drivers' health. It is well-known that prolonged static, and awkward posture linked with the vibration caused by the engine, can induce a variety of musculoskeletal disorders. In addition to this, the combination of the hazards, as well as vehicle ergonomic characteristics can be of the highest importance. Studying drivers' static body posture and the biomechanics of the movements regarding their health is a critical matter. Observing the motion tracking in a vehicle, using different equipment and methods, creates a new approach to understanding human/operator movements.

The most typical method to analyse the drivers' movements is using one or more cameras and

presenting footage (black and white or in colours) in frame segments. Merging all of these data into one image, taking into consideration that black colour represents the static position and white colour movement, the overall motion can be represented.

Furthermore, adding makers/sensors and subsequent analysis of the movements gives a meaningful diversity of the results to be used (posture, angles, motion tracking, body parts accelerations, etc.). Another level of data treatment and display uses a three-dimensional model and examines both the movement and the postures. Creating a three-dimensional model with the necessary parameters gives a better approach to understanding drivers' operating behaviours. Opposite to these positive factors, there may be certain undesirable issues such as interfacing between the data collection and the database. In addition to this, the connection between the markers/sensors and the computer is wireless, meaning that the signal can be easily disturbed (an object blocking the signal, someone passing between the markers/sensors and the computer, electromagnetic interference of the vehicle itself, among others). It is of great importance to check all the adverse factors and to establish a work environment without any disturbances for the data collection.

REFERENCES

- [1] Bastien, C., Blundell, M. ., & Neal-Sturgess, C. (2017). A study into the kinematic response for unbelted human occupants during emergency braking. *International Journal of Crashworthiness*, 8265(July), 1–15. <https://doi.org/10.1080/13588265.2017.1301080>.
- [2] Caruso, G., Camere, S., Bordegoni, M., & Bordegoni, M. (2017). System based on abstract prototyping and motion capture to support car interior design, 4360(July). <https://doi.org/10.1080/16864360.2015.1084194>
- [3] Cheng, S. Y., Park, S., & Trivedi, M. M. (n.d.). Multiperspective Thermal IR and Video Arrays for 3D Body Tracking and Driver Activity Analysis 2 . Analysis of Thermal Video.
- [4] Cheng, S. Y., Park, S., & Trivedi, M. M. (2007). Multi-spectral and multi-perspective video arrays for driver body tracking and activity analysis. *Computer Vision and Image Understanding*, 106(2–3), 245–257. <https://doi.org/10.1016/j.cviu.2006.08.010>.
- [5] Demirdjian, D. (2009). Driver Pose Estimation with 3D Time-of-Flight Sensor.
- [6] Dozza, M., & Pa, N. (2013). Recognising safety critical events: Can automatic video processing improve naturalistic data analyses?, 60, 298–304. <https://doi.org/10.1016/j.aap.2013.02.014>.
- [7] Harrison, D. D., Harrison, S. O., Croft, A. C., Deed, E., & Troyanovich, S. J. (2000). Sitting Biomechanics , Part II: Optimal Car Driver ' s Seat and Optimal Driver ' s Spinal Model, 23(1), 37–47.
- [8] Jeong, Y., & Park, W. (2017). Differences between obese and non-obese drivers in preferred vehicle interior components setting and driving posture. *Ergonomics*, 139(July), 1–12. <https://doi.org/10.1080/00140139.2016.1211322>.

- [9] Kondyli, A., Barmpoutis, A., Sisiopiku, V. P., Zhang, L., Zhao, L., Islam, M. M., Zhao, L. (2017). A 3D body posture analysis framework during merging and lane-changing maneuvers. *Journal of Transportation Safety & Security*, 0(0), 1-18. <https://doi.org/10.1080/19439962.2017.1294226>.
- [10] Kondyli, A., Sisiopiku, V. P., Zhao, L., & Barmpoutis, A. (2015). Computer Assisted Analysis of Drivers' Body Activity Using a Range Camera. *IEEE Intelligent Transportation Systems Magazine*, 7(3), 18-28. <https://doi.org/10.1109/ITS.2015.2439179>.
- [11] Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *Annals of Internal Medicine*, 6(7), 264-269. <https://doi.org/10.7326/0003-4819-151-4-200908180-00135>.
- [12] Peng, J., Wang, X., & Denninger, L. (2017). Ranges of the least uncomfortable joint angles for assessing automotive driving posture. *Applied Ergonomics*, 61, 12-21. <https://doi.org/10.1016/j.apergo.2016.12.021>.
- [13] Tawari, A., Martin, S., & Trivedi, M. M. (2014). Continuous head movement estimator for driver assistance: Issues, algorithms, and on-road evaluations. *IEEE Transactions on Intelligent Transportation Systems*, 15(2), 818-830. <https://doi.org/10.1109/TITS.2014.2300870>.
- [14] Tran, C., Doshi, A., & Trivedi, M. M. (2012). Modeling and prediction of driver behavior by foot gesture analysis. *Computer Vision and Image Understanding*, 116(3), 435-445. <https://doi.org/10.1016/j.cviu.2011.09.008>.
- [15] Tran, C., & Trivedi, M. M. (2010). Towards a vision-based system exploring 3D driver posture dynamics for driver assistance: Issues and possibilities. *IEEE Intelligent Vehicles Symposium, Proceedings*, (i), 179-184. <https://doi.org/10.1109/IVS.2010.5547957>.
- [16] Tran, C., & Trivedi, M. M. (2012). 3-D posture and gesture recognition for interactivity in smart spaces. *IEEE Transactions on Industrial Informatics*, 8(1), 178-187. <https://doi.org/10.1109/TII.2011.2172450>.
- [17] World Health Organization. (2004). World report on road traffic injury prevention.
- [18] Yan, C., Coenen, F., & Zhang, B. (2014). Driving posture recognition by joint application of motion history image and pyramid histogram of oriented gradients. *International Journal of Vehicular Technology*, 2014. <https://doi.org/10.1155/2014/719413>.
- [19] Zhao, C. H., & Zhang, B. L. (2013). Recognition of driving postures by combined features and random subspace ensemble of multilayer perceptron classifiers, 22. <https://doi.org/10.1007/s00521-012-1057-4>.

ACKNOWLEDGEMENTS

This systematic review was supported by Laboratory of the Prevention of Occupational and Environmental Risks (PROA) at the Faculty of Engineering at the University of Porto.

BIOGRAPHY of the first author

Marko Cvetković was born in Gnjilane, Serbia, in 1990. He received the diploma in environmental engineering and the MS degree in occupational safety from the University of Nis, Faculty of Occupational Safety.



As a PhD student at the University of Porto, Faculty of Engineering, his main area of research include ergonomics, biomechanics, among others.

PRAĆENJE POKRETA TELA PROFESIONALNIH VOZAČA - PREGLED METODOLOGIJE I PRIMENJENE OPREME

*Marko Cvetković, Joana Duarte, Evica Stojiljković, Lutvo Haznadarević,
Joao Manuel Abreu Dos Santos Baptista*

Rezime: Tokom obavljanja zadataka, profesionalni vozači su u stalnom sedećem položaju (obično više od 2 sata), zauzimaju različite statične položaje tela koji ponekad zahtevaju kretanje donjih ili gornjih ekstremiteta. Takve aktivnosti mogu dovesti do posledica, kao što su venski poremećaji, kardiovaskularne bolesti, bol nakon sedenja i grčevi mišića. Da bi se ostvario cilj istraživanja, korišćena je metodologija izjave PRISMA. Pregledano je 27 naučnih časopisa i 25 indeksnih baza podataka; od ukupno 10750 studija na ovu temu, 18 je uključeno u ovaj rad. Izabrani članci (radovi) su predstavljani kroz tabelarni prikaz opreme i metoda korišćenih u različitim analizama kretanja tela vozača. Primarni zaključak je da metod u kome se koriste markeri u kombinaciji sa kamerama daje najbolje rezultate jer prati pokrete svih delova tela profesionalnog vozača.

Ključne reči: praćenje pokreta, analiza kretanja, držanje tela, vozač.

MUČENSKI VLADIMIR¹
PEŠKO IGOR²
BIBIĆ DRAGANA³
SENJAK MILENA⁴
DUŠICA SAVIĆ⁵
MIODRAG HADŽISTEVIĆ⁶

ANALYSIS OF FALLS TO THE LEVEL BELOW IN CONSTRUCTION INDUSTRY OF SERBIA

Abstract: Construction is a branch of industry which is characterized by a large number of injuries and fatalities at work. Only in the past year, 39 percent of all work-related injuries occurred in the field of construction industry. This research presents the analysis of injuries and fatal injuries that occurred on construction sites in the Republic of Serbia due to the fall to the level below. Data from the Labour Inspectorate of the Ministry of Labour, Employment, Veteran and Social Affairs, were collected from 2013 to 2017. 54 injuries occurred due to the fall to the level below, which was the half of the all injuries on construction sites which occurred over a five-year period.

Key words: construction, occupational safety, non fatal and fatal injuries, falls.

¹University of Novi Sad, Faculty of Technical Sciences

²University of Novi Sad, Faculty of Technical Sciences

³University of Novi Sad, Faculty of Technical Sciences

⁴University of Novi Sad, Faculty of Technical Sciences

⁵NIS Gazprom Neft

⁶University of Novi Sad, Faculty of Technical Sciences

¹mucenskiv@uns.ac.rs

²igorbp@uns.ac.rs

³draganabibic@uns.ac.rs

⁴senjakm@uns.ac.rs

⁵Dusica.N.Savic@nis.eu

⁶miodrags@uns.ac.rs

INTRODUCTION

Construction is a branch of industry where work-related injuries are almost happened every day and unfortunately are more and more frequent. In this branch of industry, the highest number of deaths is the main consequence of non-compliance with basic occupational safety and health regulations. OSHA [1] claims that more than 50% of deaths from falls are in construction and approximately 15% of all occupational deaths are falls.

That is why occupational health and safety in the construction sector is the primary research area. In order to ensure that the quality of work safety is satisfactory, it is necessary to abide by the legal regulations and the defined rules. Workers, as well as their managers, need to be aware of the dangers and potential losses and the importance of respecting the safety in the construction industry.

Comparison with other industry branches shows that construction industry is characterized by a large number of injuries at work and deaths. Last year, 39 percent of all fatal injuries happened in construction industry. Also, 14 percent of serious occupational injuries and 22 percent of collective injuries were in construction [2]. Due to this, health and safety risks are one of the most important risks in construction projects and represent the great challenge for contractors. Observing the work process itself, analysis of all elements of the process and their interrelationships is

the basic precondition for managing the occupational safety.

Mučenski et. al [2] in their research of the occurrence of injuries and fatal injuries on construction sites in the past five years, have shown that half of all work-related injuries have occurred due to the falls to a level below. They collected 113 reports of mostly heavy and death injuries of which 54 were related with falls. **Figure 1.** shows that the highest number of deaths occurred due to falls to level below.

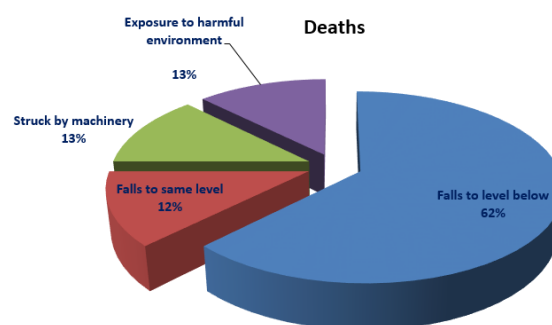


Figure 1. Number of deaths occurred due to falls on level below in construction industry of Serbia

Due to the large number of injuries and deaths, this research deals with the analysis of indirect and essential causes that led to the appearance of falls to level below and results are shown in the next chapter.

METODOLOGY AND THE DATABASE

In order to identify causes of the risks, it is necessary to collect historical data about injuries. It is also very important to determine the causes of the injuries. For the research purpose, the database of construction work-related injuries was created. Database was created with the aim of defining potential sources of risk, their connection with different types of works (ground work, concrete work, carpentry, etc.), materials, tools, machinery and labor characteristics. In addition, the injuries data provide information on the significance of these parameters and facilitate the quantification of risk parameters (probability and magnitude of consequences). Database was obtained from the Ministry of Labor, Employment, Veterans' Affairs and Social Affairs. The data refer to construction companies of the Republic of Serbia and include information about injuries that occurred in the period from 2013 to 2017. The total number of analyzed injuries is 54.

The fall to the level below is by Rees and Eidson [4] is a fall to the surface below in relation to the surface on which a person stands or works. Fall to the level below according to Mučenski [5] covers the injuries caused by workers falling on the surface that is beneath the surface at which the fall began.

DATA ANALYSIS

In the first phase of data analysis, it was concluded that the type of work significantly affected the occurrence of injuries due to falls. As it can be seen in **Figure 2**, most of the injuries occurred during the execution of formwork, installation work and painting works, as much as 46%, which are works that are dominantly performed at a height. An interesting fact is that 13% of all injuries due to the falls occurred in the handling of machinery.

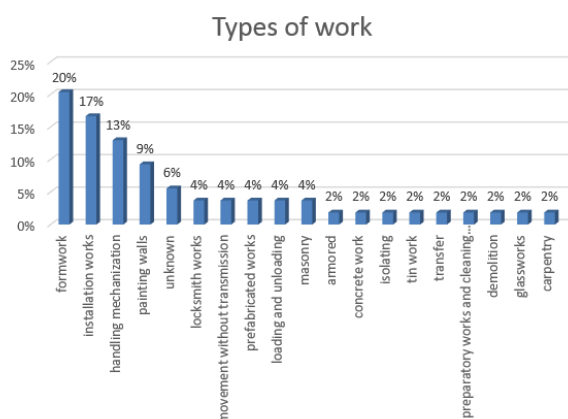


Figure 2. Injuries occurred due to the fall on level below when performing various types of work on the construction site

The next phase shows which mechanization or equipment were mostly used in the injuries events. As

it can be seen in the **Figure 3**, the missing of the safety equipment is predominant of falls. Ladders, unsecured edges and work at height without adequate personal protective equipment (PPE) resulted in the appearance of 67% of all falls related injuries.

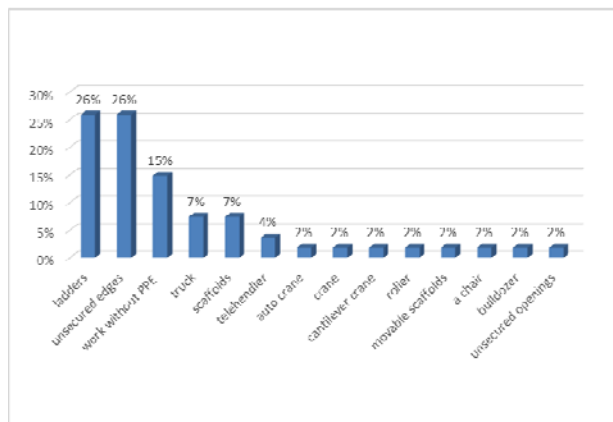


Figure 3. Falls to level below in relation to the mechanization, equipment and surroundings

Third phase of analysis included affected body parts due to falls. More than a half of all injuries resulted with multiple injuries, more precise 58% of them (**Figure 4**).

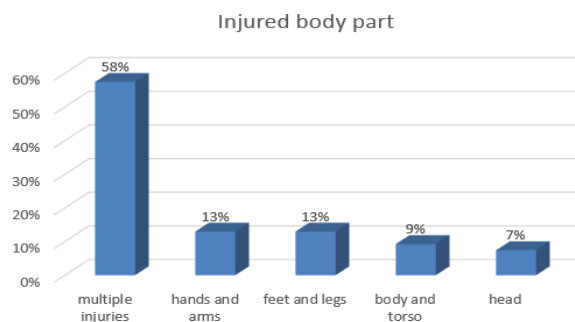


Figure 4. Injured body part due to the falls on the level below

Observing the characteristics of process, it can be concluded that the causes of injuries can be observed in two levels. The first level of injuries is related to the characteristics of realization of a particular work operation (work methods, tool used, working conditions, etc.) that caused injuries. The first level is called an indirect cause of injuries. The second level examines the essence of the injuries (basic causes). The partition into two levels of causes was adopted on the basis of research according to Reese and Eidson [4] and Mučenski [5].

Further results will be related with determination the most common basic and indirect causes of injuries.

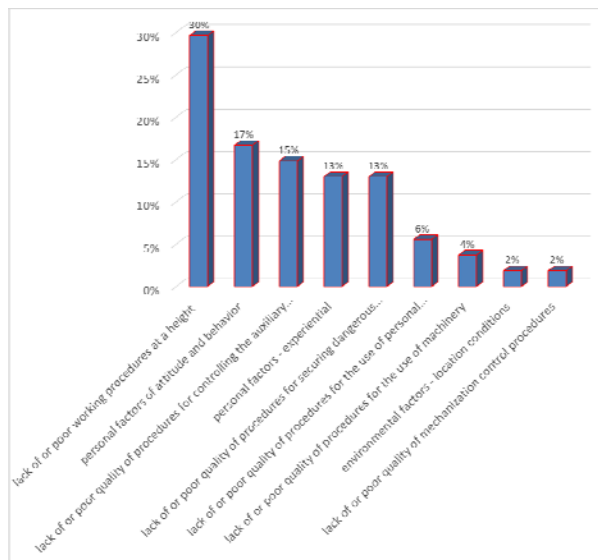


Figure 5. Basic causes that led to the injuries due to the falls to level below

According to analysis of basic causes (**Figure 5**), lack of, or poor working procedures at height is the most common cause of injuries occurrence at work, even 30%. Further more, personal factors of attitude and behavior, lack of or poor quality of procedures for controlling the auxiliary equipment, personal factors – experiential and lack of or poor quality of procedures for securing dangerous zones are causes of 57% occurrence of the rest injuries.

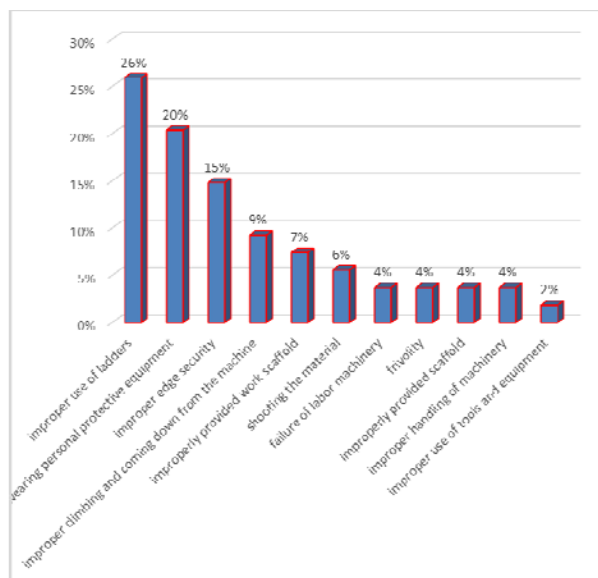


Figure 6. Indirect causes that led to the injuries due to the falls to level below

Based on the analysis of indirect causes of injuries at work, it was concluded that 63% of falls occurred due to the improper use of ladders, non-wearing personal protective equipment and improper edge security. All of that injuries are multiple, 65% of injuries are

characterized as major injuries, 24% as a small injuries and 12% as fatal injuries.

Analysing the injuries and reports it was detected that several basic terms that are regulatory defined were missing in several cases of injuries. These terms are shown in the **Table 1**.

Table 1. Parameters related to workers and workspace

	Unknown or no	yes
Was there a risk assessment act	30%	
Was the workers trained for professional work according the law	22%	
Was the workers trained for safe work according the law	7%	
Was the workplace with increased risk		70%
Did worker have medical certificate	26%	

Based on the perception of the parameters related to the workers themselves and the workspace, all based on the most common causes that induced the injuries, it was concluded that 33% of the companies in which the employees worked did not have a risk assessment act. Also, 22% of workers did not have professional competence for the job, 7% of them did not have qualification for safe work. 26% of workers did not have medical certificate and 70% of workplaces in which injuries occurred were workplaces with increased risk.

CONCLUSION

The interest of the society as well as every individual is to achieve the highest level of occupational safety and health, to minimize adverse effects such as occupational injuries, occupational illnesses and illnesses related to work, and to achieve the working conditions in which the employee would have a sense of satisfaction when performing his professional tasks. In order to achieve this goal, it is necessary to connect all participants who can affect occupational safety and promote preventive actions in order to prevent injuries at work.

This research has shown that 46% of injuries, which occurred due to the falls to level below happened while performing formworks, installation work and painting

works. 13% of all falls happened in the process of handling of machinery.

Furthermore, ladders, unsupported edges and work at height without adequate PPE resulted in 67% of injuries. More than a half of all injuries are multiple injuries, even 58% of them.

According to the last phase of analysing data, the primary basic cause of falls is related to the poor procedures for working at height (30%) and 63% of falls occurred due to improper use of ladders, non-wearing personal protective equipment and improper edge security.

Further research will be done on order to perform in debt analysis of collected data and to analyse impact of the company size on falls.

REFERENCES

- [1] https://www.osha.gov/dte/grant_materials/fy08/sh-17792-08/falls_english_r6.pdf
- [2] Labor Inspectorate Report for 2017, Republic of Serbia, Ministry of Labor, Employment, Veterans' Affairs and Social Affairs, Labor Inspectorate, Belgrade (2018), URL: <https://www.minrzs.gov.rs/lat/pres/saopstenja/izv-estaj-o-radu-inspektorata-za-rad-za-2017-godinu.html>, (7th November 2018).
- [3] V. Mučenski, D. Savić, M. Hadžistević, S. Đurović, M. Ilić: "Indicators of occupational injuries in construction industry of Serbia", Continuous education - the basis for the improving occupational safety, Vol 15, 2018, pp. 3-14.
- [4] C.D.Reese, J.V.Eidson : "Handbook of OSHA construction safety and health, Taylor&Francis group, Boca Ration, 2006, ISBN 0-8493-6546-5
- [5] V. Mučenski: "Model of semi-quantitative risk assessment for safety at work in building processes", PhD dissertation, 2013.

ACKNOWLEDGEMENTS

The work reported in this paper is a part of the investigation within the research project TR 36017 "Utilization of by-products and recycled waste materials in concrete composites in the scope of sustainable construction development in Serbia:

investigation and environmental assessment of possible applications".

The project is supported by the ministry for Science and Technology, Republic of Serbia. This support is gratefully acknowledged.

This research could not be realized without strong support of the Labour Inspectorate and Ministry of Labour, Employment, Veteran and Social Affairs. This support is gratefully acknowledged.

BIOGRAPHY of the first author

Dr. Vladimir Mučenski is assistant professor of the Faculty of Technical Sciences in Novi Sad and a consultant in the field of project management. He has 15 years of experience in construction and especially in the field of organization and technology of building and safety at work in construction. He obtained the title of doctor of technical sciences with the doctoral dissertation entitled "Model of semi-quantitative assessment of occupational safety risks for construction processes". He is a member of the council of the Faculty of Technical Sciences, president of the Executive Board of the Union of Safety at Work of Serbia, a member of the Association of Engineers and Technicians of Serbia and the Serbian Chamber of Engineers and a reviewer of the State audit commission for projects of especial importance for the Republic of Serbia.



ANALIZA PADOVA NA NIVO ISPOD U GRAĐEVINSKOJ INDUSTRIJI SRBIJE

Mučenski Vladimir, Peško Igor, Bibić Dragana, Senjak Milena

Rezime: Građevinarstvo je grana industrije koju karakteriše veliki broj povreda i smrtnih povreda na radu. Samo u protekloj godini 39 procenata svih povreda na radu desilo se u oblasti građevinske industrije. U ovom istraživanju prikazana je analiza povreda i smrtnih povreda na radu koje su se desile na gradilištima u Republici Srbiji prilikom pada na nivo ispod. Prikupljeni su podaci Ministarstva za rad, zapošljavanje, boračka i socijalna pitanja, odnosno Uprave za bezbednost i zdravlje na radu u periodu od 2013. do 2017. godine. 54 povrede su se desile usled pada na nivo ispod što je polovina ukupnih povreda na gradilištima koja se javila u periodu od pet godina.

Ključne reči: građevinarstvo, zaštita na radu, velike i smrtne povrede, padovi.

Kristina Smiljković¹,
Marko Bogdanović²,
Ivan Krstić³

¹ University of Maryland,
Department of Mathematics
² College of Applied Technical
Sciences Niš,
³ Faculty of Occupational Safety,
University of Nis

IMPLEMENTATION OF PDSA ANALYSIS IN LEONI WIRING SYSTEM SOUTHEAST D.O.O. PROKUPLJE

Abstract: *This paper represents the importance of a well-known "Plan -Do -Study- Act" method, hereinafter referred to as a PDSA analysis. The PDSA analysis represents an alternative for improvement of a system quality. The method has found widespread use in all sectors of the economy; however, but there are speculations regarding the practical use of the model. Therefore, our analysis shows the effectiveness of the theoretical base for implementation and use of PDSA analysis, as well as a detailed description of required documentation, and statistic data for comparison. The key part is the effectiveness of the production sector and the implementation of the appropriate standards. This paper provides the base for further research.*

Key words: quality, management, analysis, pdsa, product.

INTRODUCTION

The quality of the final product is the key to the realization of set goals by the company with minimal usage of spending the resources and the company's components. The quality is the level upon which a set of characteristics fulfils requirements.

A certain level of quality is the principle that is based on pre-defined and outlined goals of the company and the availability of necessary components factors; resources for their achievement.

Schematics of effectiveness are given within each industrial plant as guidelines for the company. Schematics of effectiveness indicates growth, but also a drop in the quality of industrial manufacturing for a certain sector for a given period.

Efficacy is represented within the means of a certain set of inputs and outputs that are closely related allocative and technical efficiency.

Technical efficiency represents the possibility of using fewer inputs for allocative efficiency. This represents the state of the market in which allocation of resources allow opportunity to create the more optimal combination of input/output. Therefore, allocatively effective market is one that has no imperfections, meaning there is no market errors.

PDSA circle of improvement

The Juran¹ philosophy of quality was used in all quality standards in the nineties. With the market development, as well as increasing demands, the philosophy of quality is changed and now the Deming philosophy of continuous quality improvement is in use. Meaning the PDSA circle of continuous improvement.

¹ Juran philosophy – "always do your best for the first and every time"

PDSA got the name from the first letters of the words "Plan - Do - Study - Act" and represents the model of continuous improvement of products or the production process itself.

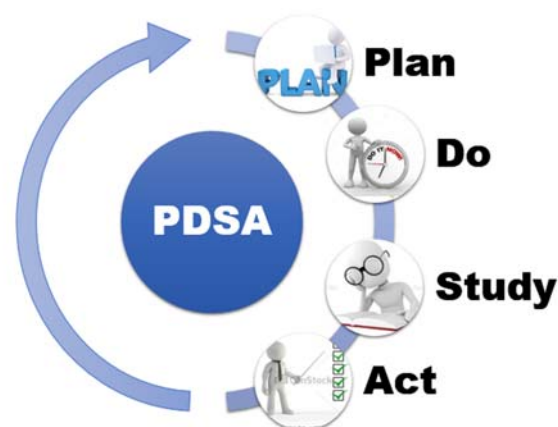


Figure 1. Deming-Shewhart PDSA circle

The model refers to the improvement of the quality of all activities in the manufacturing process. Therefore, in order to have full effect within an organization, the model must be accepted and applied by each employee of each activity in the manufacturing process. In other words, each activity in the process should be planned first, implemented, checked, and at the end measures for the improvement of the whole implemented process. This allows the organization to create a standard which all employees should adhere to in order to achieve the best possible results.

The PDSA circle of improvements always begins by making the analysis of the current situation in organization and assessment of all the problems

followed by a process of improvement that consists of four phases.

Phases of PDSA circle

Plan - This stage should be established to all elements of the production process. The system should be defined from the way actions are performed by participants in the process and their responsibilities, to the results of the production process. In other words, the quality requirements should be set in order to reach the expected goals.

Do - Implementation of activities that are set out in the previous stage.

Study - The quality of the process itself is done after completion of the quality improvement process. In this phase, the assessment of input should be done. Consideration may be carried out in two cases:

1. The results have not been achieved - then the data is collected and the causes of failure are determined. The process must be restarted.
2. Results are achieved - When the results are achieved, additional checks are performed and then the "Act" stage is the following.

Act - Once the previous improvement of the quality is defined and the certain results are achieved, the necessary decisions for the implementation of quality improvement in the production process should be made.

PDSA circle allows the process of improvement for both, small and large organizations because of its great flexibility in the sense that the user can develop his own approach method that performs a modification while maintaining the logic of the PDSA cycle.

Results of application of PDSA analysis

The research results of applicability of the model of continuous improvement were applied in Company for the production of cables LEONI Wiring System Southeast Ltd., which has the branch in Prokuplje (Serbia) for the period November - December 2016.

PDSA model is applied as basic guidelines model - planning, organizing, and controlling with feedbacks. The goal of the tool for improving quality is the improvement of products and services based on the betterment of production processes and cutting costs in order to make the high-quality product. This method provides an analysis impact and consequences of potential mistakes. The method analyzes the potential error, resulted from mistakes and the cause of those mistake.

3.1. Step one -Planning

Planning refers to the procedure that rely on statistical evaluation of the test results in order to, within a certain period of time, bring changes for continuous improvement of processes or products. The evaluation of a product or process is to assess compliance with the set of required norms. Quality Objectives

Administration are setting certain demands in order to improve the quality of a product.

The goals is related to identifying and setting a certain types of errors, which, statistically speaking, occur in a particular product. The product in the form of the sample, which is studied in this paper is the product of a brand Grundfos.



Figure 2. Grundfos KP(left) and AP (right) submersible drainage pumps

The studied sample is not the final part of the Grundfos product, but two separated parts which are shown on Figure 2, Unilift KP and AP submersible drainage pumps. These parts are the power cord and power switches. They are connected in one, vulcanized, and watertight plug, which is plugged into a socket and is hermetically isolated.

Statistical indicators of the examined product Unilift KP indicate the need for corrections, and therefore it is necessary to make changes in order to improve the quality of the product itself. Quality improvement is planned on the basis of ten types of errors that have occurred on the product. Types of errors that were examined are: the incorrect dimension of cables and wires on the cable, untested and damaged plugs, and frequent errors in relation crimping.

The plan of the organization was to set up a few essential steps which should, in a certain period of time, give a positive growth and efficiency in the actual production of the final product. Improvement of internal visual inspection was the primary goal. The secondary goal was to train new employees and proactive training of skilled workers. The third goal was to do re-training of a certain number of employees in the relevant technical personnel in order to effectively maintain machines.

3.2. Step two -Do

The analysis of measurement consists of a series of procedures which were estimated to measure the uncertainty of working conditions. The measurement of uncertainty was taken into account during data collection. The analysis of the measurement was estimated if observed sector or product meets or does not meets the desired outcome. This procedure quantified the parameter product or process.

There are several sampling techniques, but in practice, the most used is the standardized procedures. The ISO 9001 standard counts the bad elements of the sample

and the ISO 9004 standard sort nonconforming elements. The introduction of the external control diminishes the possibility of reoccurrence of frequent faults in a product. With this step, the work of internal control was improved.

Due to the increased volume of production, more employees were needed. Based on this fact, training was organized for new employees. In addition to classical training, new training which was based on visiting other branches of the company was implemented.

Statistics showed that the majority of errors were caused by the machine system and, as the solution, the model of additional training was introduced.

3.3. Step three -Study

One of the ways to present the data is the graphic presentation in the form of histogram. Of particular interest are the procedures that describe the average value. Statistical data precede all other statistical methods. Description of the process will be better if the larger number of the data is accumulated.

Data collected in this paper can be used only for academic purposes. Presented quantity and the percentage of bad pieces is shown in the form of histogram (figure 3).

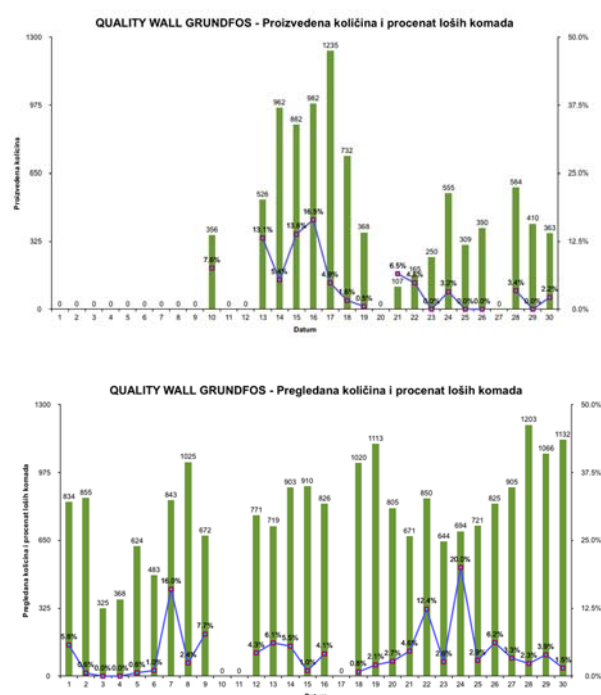


Figure 3. Histogram of the ratio of produced quantity and of the percentage of bad pieces

Histogram represents the ratio of observed sample and percentage of bad samples in a certain period of time. The period considered in the paper covers November and December of 2016. Applying PDSA model describes the changes in percentage ratio. Positive

growth as well as the increase of efficiency in terms of the quality of products is noted as the diagram in figure 4.

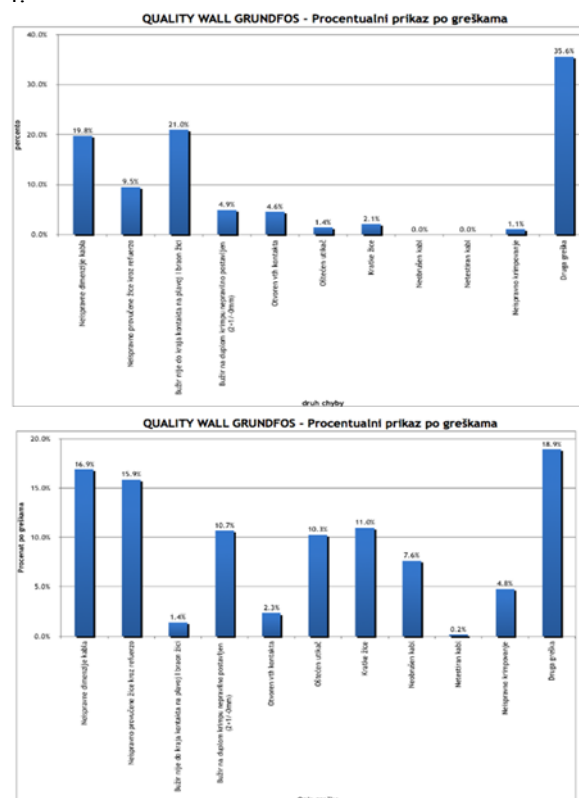


Figure 4. Defects shown by percentage of occurrence

Rate of growth is shown in a ratio between increased production and minimization of frequent errors. These clearly indicates the positive result of the application of observed analysis. Also, the planned model PDSA has indicated some negative indicators that have been manifested by increased occurrence of other types of errors on the product. Future considerations, as well as setting the next PDSA cycles, are the result of further research which will not be discuss in this analysis.

3.4. Step four -Act

The production process is statistically affected by the size of many parameters the product parameters must possess. On practical side, the requirements of a certain standards or specific technology require that the value of a particular parameter has average value. These requirements must be met to make the products interchangeable between themselves. The smaller the average value is, the greater is the quality. Indexes of process capability are expressed as dimensionless numbers. In this paper initial and final defects expectation are calculated. That expectation is referred as PPM^2 and it is shown in a form of diagram (fig. 5).

² PPM – Parts Per Million

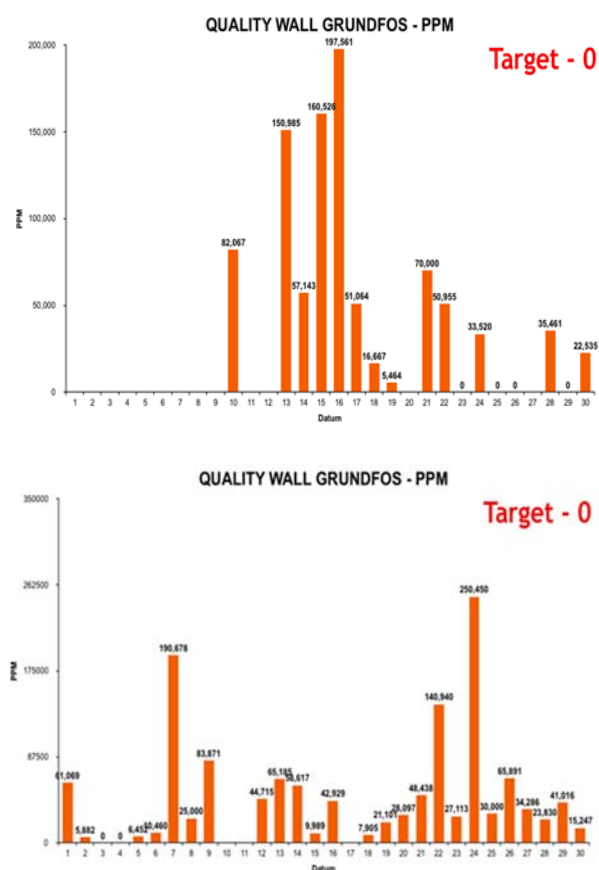


Figure 5. PPM diagram

The criteria is set on TARGET 0, which means that it is given proportion of 0:35000. In other words, cables without errors comes in 35000 products in every 5 consecutive days.

Considering practical part, whether natural or technological process, there is no 100% perfect system. Border value of 80 represents 1 defected cable in 10000 produced. PPM diagrams for the period of November and December of 2016 represent clear improvement of the product Unilift KP and AP submersible drainage pumps. However, it should be noted that the following analysis of PDSA model indicated new irregularities on the product. This newly created problem raises questions for further research.

CONCLUSION

All quality improvements were based on the achievements and proactive studies in the structure of the observed industrial sector. If during the PDSA analysis, the set plan is not fully developed, it is necessary to re-consider and review it, but from another point of view. The reiteration of PDSA cycles leads to developing of many habits such as: understanding of the problems, development and improvement, teamwork, and process diagnostics. Continuous improvements of the PDSA plan makes the production sector more robust to failure.

REFERENCES

- [1] J.M. Juran, "Juran's Message for Europe", European Quality, V1, N1, 1994., 18-25
- [2] Y. H. Cao, Y. M. Yan and A. C. He, "Application characteristics of Quality Management System in Enterprise", Coastal Enterprises and Science & Technology, Vol. 10, No. 6, 2005, pp. 56-60
- [3] G. P. Laszlo, "Project Management: A Quality Management Approach", TQM Magazine, Vol. 3, No. 3, 2003, pp. 157-160
- [4] Giorgio Giallocosta, Maria Chiara Torricelli, "Values, Quality and Effectiveness in public works production and management processes in Italy," Journal of Technology for Architecture and Environment, Vol. 6, 2013, pp.12
- [5] H.-A. Crostack, M. Höfling, J. Liangsiri, "Simulation in Quality Management – An Approach to Improve Inspection Planning", Acta Polytechnica, Vol.45, 2005
- [6] Salagean Horatiu Catalin, Ilies Radu, Gherman Mihai, Cioban Bogdan, "APPROACHES TO QUALITY MANAGEMENT AT EUROPEAN LEVEL", Annals of the University of Oradea : Economic Science, Vol.1, 2013, pp. 1654
- [7] Jiangping Wan, Ming Zeng, "Case Study on Improving Quality Management of W Company's New Product Development Project", Technology and Investment, Vol.4, 2013, pp.153,
- [8] M V Lotlikar, "QUALITY RISK MANAGEMENT (QRM): A REVIEW," Journal of Drug Delivery and Therapeutics, Vol.3, 2013,
- [9] Maria Luisa Germanà, "Demand for quality and design ideas competition: experimentation to discover good practices", Journal of Technology for Architecture and Environment, 2013, pp.81

ACKNOWLEDGEMENTS

We gratefully acknowledge the support and generosity of the management of LEONI WCS Southeast Europe d.o.o. and Mr. Vorginec Marko, the quality engineer, without whom the present study could not have been completed.

BIOGRAPHY of the first author

Kristina Smiljković was born in Aleksinac, Serbia, in 1994.

She received the bachelor with honours diploma in occupational safety engineering from the University of Niš, Faculty of Occupational Safety in Niš. She is currently performing her research

at the University of Maryland, Department of Mathematics. Her main areas of research include occupational safety, risk assessment and environmental protection.



IMPLEMENTACIJA PDSA ANALIZE U LEONI WIRING SYSTEM SOUTHEAST D.O.O. PROKUPLJE

Kristina Smiljković, Marko Bogdanović, Ivan Krstić

Rezime: U radu je predstavljen uticaj "Planiraj-deluj-razmatraj-primeni" metode, u daljem kontekstu PDSA analize. PDSA analiza predstavlja alternativu za unapređenje kvaliteta sistema. Metod je nasao široku primenu u svim privrednim sektorima, ali postoje spekulacije u vezi prakticne primene modela. Stoga, u radu je prikazana teorijska osnova za implementaciju i primenu PDSA analize, kao i detaljan opis potrebne dokumentacije, modela za testiranje zeljene promene i statistickih podataka radi poređenja. Ključni deo predstavlja efektivnost celokupnog proizvodnog sektora i implementacija odgovarajucih standarda. Rad predstavlja osnovu za dalja istrazivanja.

Ključne reči: kvalitet, menadžment, analiza, PDSA, proizvod.

NIKOLA MIŠIĆ¹
ACA BOŽILOV²
DUŠICA PEŠIĆ³
DARKO ZIGAR⁴

^{1,2,3,4}University of Niš,
Faculty of Occupational Safety in Niš

¹nikola.misic@znrfak.ni.ac.rs

²aca.bozilov@znrfak.ni.ac.rs

³dusica.pesic@znrfak.ni.ac.rs

⁴darko.zigar@znrfak.ni.ac.rs

CHECKLIST FOR FUEL TANK SAFETY ASSESSMENT

Abstract: Over the last four decades, a distinctive approach to hazards and failures that cause loss of life and property has been developed in the process industries. The modern approach to the avoidance of injuries and loss in the process industries is the outcome of various events. Central to this approach is leadership by management, starting with senior management, and creation of a safety culture that provides the appropriate environment for reduction of incidents and improvement of safety performance.

Checklists can be a very powerful tool for hazards assessment methodology to identify the major contributors to risk, to improve safety measures and to assist the analysis in these aspects. This paper presents a systematic hazards identification methodology for fuel storage tanks, by applying a checklist technique on the accident causes and the relevant protection measures.

Key words: hazards assessment, storage tanks, checklist, accident.

INTRODUCTION

Accidents at fuel tanks are relatively rare, which however, may lead unexpected consequences for the installation, the environment and the health of workers and neighbors. These accidents demonstrate not only the large-scale of destruction in the surroundings, together with the implication of potential environmental issues, but also the necessity to prevent similar accidents. Extensive study was made, by collecting reference and information through appropriate literature, with the aim to perform a statistical analysis of accident occurrence in storage tanks.

The management system is crucial to loss prevention and it is essential that this system itself be monitored. The management system may be audited in several ways. These include:

1. self-checking procedures, through checklists
2. internal audit, and
3. external audit.

In particular, there are checks on:

- Overall management attitude, policies, systems and procedures, and personnel selection;
- Plant level management, attitude, systems, training, and feedback;
- Incident reporting, investigation, and statistics.

The Qualitative Risk Analysis approach uses well known types of analysis, such as the Checklist, the Failure Mode and Effect Analysis (FMEA) and the Hazard and Operability analysis (HAZOP). Quantitative methods attempt to specify the safety level or the associated risk level of a system or an installation, through the well-established methods of Fault Tree (FTA) and Event Tree Analysis (ETA). Those methods could be lengthened with risk assessment methodologies tailor-made for offshore process facilities in seismic, for largescale oil export terminals, for fire management systems and for estimating the domino effect in petrochemical.

Checklist is the simplest tool of hazard identification in a chemical installation. It is impossible to envisage high standards in hazard control unless this experience is effectively utilized [1]. Checklists are applicable to management systems in general and to a project throughout all its stages. Obviously the checklist must be appropriate to the stage of the project, starting with checklists of basic material properties and process features, continuing on to check- lists for detailed design, and terminating with operation audit checklists.

Main types of storage tanks

Large liquid storage tanks are used in the petroleum and chemical industries for the storing of both raw material and intermediate or finished products in confined areas that are normally separated from the rest of the installation. The types of tanks for storing combustible or flammable liquid hydrocarbon fuel are classified in three main types by the Institution of Chemical Engineers (Figure 1) [2]:

1. Fixed or cone roof tanks.
2. Open top floating roof tank (simple pontoon or double deck).
3. Fixed roof tanks with internal floating roof.

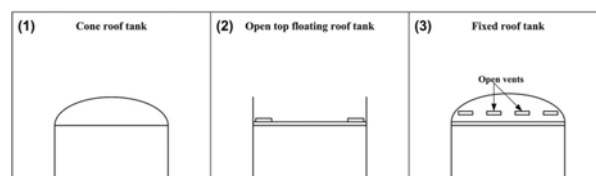


Figure 1. Types of tanks for fuel storage

A fixed or cone roof tank is made of a vertical cylinder side and a fixed cone-shaped roof that is welded to each other. This type of tank usually contains "black" heavy products, such as fuel-oils, asphalt (bitumen) and vacuum or atmospheric residue. Hence, the use of

insulation, steam or coil heating in these types of tanks is necessary for keeping of the content in a liquid state. An open top floating roof tank is made of a vertical, cylindrical above ground shell similar to the conical roof tank. However, instead of a conical roof it has a pontoon type roof, characterized by the ability of the roof to rise and fall on the stored-fuel surface, in order to prevent the large volumes emittance of fuel-vapors. Moreover, there is a rim seal that covers the space between the floating roof and the tank shell, in the form of a rubber tube filled with kerosene, where most frequently a fire may start. An internal floating roof storage tank is a combination of the above two types of tanks, as the tank consists of a conical roof with the addition of the internal floating roof or pan that floats directly on the fuel surface. Furthermore, internal floaters have the capability to decrease the potential of ignition and to prevent the initiation of tank fires.

The second and third categories of tanks are used for volatile liquid hydrocarbons such as crude oil and "white" light products (jet, diesel and gasoline).

Tank fire accidents scenarios

Potential fire scenarios that can be developed in a tank accident are (Figure 2):

1. Rim seal fire
2. Spill on roof fire
3. Full surface fire
4. Bund or Dyke fire
5. Pontoon explosion
6. Boilover

The most severe are the full surface fire and boilover. The scientific study confirms the lightning as the most frequent cause of tank accident, while fire and explosion constitute the 85% of total cases of tank accidents [3]. However, it is important to mention that sometimes a full surface fire can escalate to a boilover, even though it is accounted as a very rare incident.

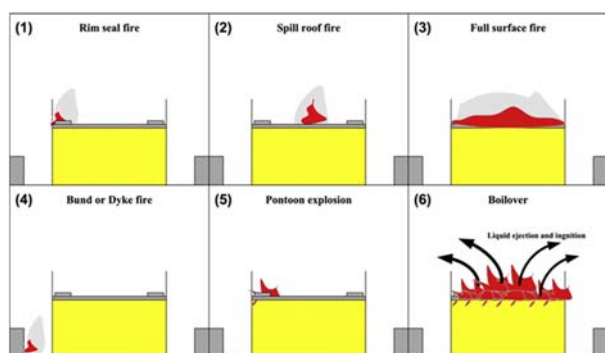


Figure 2. Potential tank fire scenarios

Vapour cloud explosion

In fact the investigation of explosion accidents in the vicinity of liquid hydrocarbon storage tanks led to significant conclusions, such as

- a) the explosion always follows a leakage of gasoline,
- b) tank overfilling is the major cause,
- c) the cloud ignition happens in nearby sites

- d) the delay of the ignition ranges from 20 to 90 min from leakage onset,
- e) almost windless conditions prevail before the accident, and
- f) there is significant recurrence of this type of accident (though not as destructive), almost every 5 years around the world.

All these make obvious that an explosion accident after the release of a hydrocarbon vapour cloud, as a result of tank overfilling has a significant occurrence probability and needs to be further investigated, especially in non-properly safeguarded commercial tank farms.

HAZARD IDENTIFICATION FOR LIQUID FUEL TANKS

General steps for hazard identification for liquid fuel tanks are based on:

- Description of the local area, including a general map;
- Sufficient knowledge of the hydrogeological, hydrographical and meteorological data of the area together with any protected environmental zones;
- Sufficient meteorological data with heavy snow and heavy rain frequencies;
- List of the hazardous installations in the surroundings;
- Ground plan of the plant and/or tank farm together with process flow diagrams;
- Description of production processes for every location of the plant;
- Characteristics of chemical substances (Material Safety Data Sheets - MSDS).

The present checklist is based on a catalogue of causes that could lead to the failure of the tank, together with a list of preventive and protection measures that can avert the occurrence of an accident in a storage tank. These two lists derive from past experience of tank operation and maintenance, and are to be considered as prerequisite conditions to avoid problems in safety. If an installation satisfies these criteria, then the accident potential is very low without banning risk totally.

The most common initiating events or failure causes for fixed/cone and floating roof tanks are grouped in the general headings presented in Table 1.

Table 1. Immediate causes of accidents

1. Operational errors
- Tank overfilling
- Drain valves left open accidentally
- Vent closed during loading/unloading
- Oil leaks due to operators' errors
- High inlet temperature
- Drainage ducts to retention basin obstructed
2. Equipment/instrument failure
- Floating roof sunk
- Level indicator
- Discharge valve rupture
- Rusted vent valve does not open
3. Lightning
- Poor grounding
- Rim seal leaks
- Flammable liquid leak from seal rim
- Direct hit
4. Static electricity
- Rubber seal cutting
- Poor grounding
- Fluid transfer
- Improper sampling procedures
5. Maintenance errors
- Welding/cutting
- Non explosion-proof motor and tools used
- Circuit shortcut
- Transformer spark
- Poor grounding of soldering equipment
- Poor maintenance of equipment both normal and blast proof
6. Tank crack/rupture
- Poor soldering
- Shell distortion/buckling
- Corrosion
7. Piping rupture/leak
- Valve leaking
- Flammable liquid leak from a gasket
- Piping failure
- Pump leak
- Cut accidentally
- Failure owing to liquid expansion
8. Miscellaneous
- Earthquake
- Extreme weather
- Vehicle impact on piping
- Open flames/smoking flame
- Escalation from another unit (domino)
- Accident caused by energy/fuel transportation lines
- Arson (intentional damage)

9. Safety supporting systems

- Electric power loss
- Insufficient tank cooling
- Firefighting water loss
- Firefighting water in piping freezing

For all the above mentioned causes there are certain protective measures aimed at limiting or preventing their occurrence and are presented in Table 2.

Table 2. Protective measures

1. Design
- Following engineering standards and regulations
- Modification of tank top design to prevent overfilling
- Site inspection
- Safe distance
- Dikes, bunds
- Defining tank capacity
2. Maintenance
- Routine inspection
- Periodic proof testing of overfill prevention system/
- Corrosion resistance
- Preventive checking of venting equipment
- Use proper equipment
- Use explosion-proof tools
- Maintenance of both normal and blast proof equipment
- Hot work permit
- Checking of successful work completion
3. Equipment
- Following engineering standards
- Handling static electricity during tank loading
- Lightning protection system
- High-integrity automatic operating overfilling prevention system
- Arrangements to ensure that the receiving agent has ultimate control of tank filling
- Remotely operated and fire-safe shut-off valves
- Protection against fluid expansion in piping
- Temperature monitoring
4. Safety supporting systems
- Fire detection and alarm system
- Firefighting network
- Foam supply and production system
- Tank cooling system
- Spare firefighting water tank/diesel driven pump
- Anti-frost protection
- Connection of gas detection with the overfilling prevention system
- CCTV equipment
- Emergency response plan

5. Miscellaneous

- Safeguarding
- Electrical supply of tanks added to critical utilities
- No smoking/good house keeping
- Protection against extreme weather phenomena
- Protection from vehicle bumping
- Protection of piping from mechanical stress
- Protection from DOMINO effects
- Protection from areal electric power lines
- Proper labelling and traffic signing
- Appropriate management of oily waste
- Appropriate management of firefighting water
- Appropriate management of rain water

CHECKLISTS ANALYSIS

Hazard identification consists of the identification of serious incidents which may result in danger to employees or the public or environment or in financial loss. Fundamental methods can be used to identify the underlying root causes which can lead to the undesired consequences, as well as to identify those incidents which could lead to problems related to operability, maintainability and other problems.

From a perspective of completeness, it is important that the most important undesired consequences have been identified and taken into account in the hazard evaluation or risk assessment. Completeness depends on how sophisticated the identification technique is and how well known the hazards are. For an existing technology, the hazards may be known from past experience and a simple identification technique will be sufficient to identify the important hazards.

A checklist analysis uses a written list of items or procedural steps to verify the status of a system. Checklists contain possible failures and causes of hazardous events. Checklists are based on operating experience and are often used in risk analyses. Traditionally, checklists vary widely in their level of detail and are frequently used to indicate compliance with standards and practices.

Checklists are limited by their author's experience; therefore, they should be developed by authors with varied backgrounds who have extensive experience with the system they are analyzing. Frequently, checklists are created by simply organizing information from currently relevant codes, standards and regulations. Checklists should be considered as living documents and should be audited and updated regularly.

The Checklist Analysis is easy to use. But it should be clear that the use of checklists depends critically on the expertise and judgement of the engineer selecting and applying the checklist. As a result, decisions taken by the engineer with regard to the checklist selected, and any additional or superfluous questions, should be fully documented and justified.

Given the availability of experience in the field of application, the use of checklists is straightforward and uncomplicated.

Checklist for tank safety assessment

This checklist has the form of Tables 1 and 2, and it is expended with additional space for "Evaluation" and "Comments" regarding the awareness of failure causes and the implementation of protection measures by tank farm owners. These remarks are filled out by the person who performs the tank inspection. More specifically, in column "Evaluation" the inspector must complete each cell of the table with the appropriate letter (A, B, C or X). The explanation of each letter is as follows:

- A: Full description (the safety study describes the specific failure cause or protective measure with full details),
- B: Insufficient description (the safety study does not describe the specific failure cause or protective measure with the appropriate detail),
- C: Inefficient (the safety study does not include or there is inefficient description of the specific failure cause or protective measure), and
- X: Inapplicable (the specific failure cause or protective measure is inapplicable to this installation).

The "Comments" column contains any comment of the inspector that is important to be referred for the specific failure cause or protective measure.

Based on issues mentioned in Tables 1 and 2, findings of the literature gave rise to some additional remarks and suggestions:

- The protection against lightning is considered vital, so the existence of a very effective grounding system is deemed indispensable for every separate tank combination with lightning conductors positioned at sufficient height and distance from the tank farm.
- A rim seal fire is considered as the most frequent fire cause for floating roof tanks containing petrol, crude oil and kerosene, as the first one burns out quickly, while the last two produce significant thermal load while burning.
- Venting devices placed on the top of fixed roof tanks should be regularly checked, as they may be easily blocked, because of a variety of reasons, such as the intrusion of birds.
- The systematic maintenance of blast proof equipment is underlined, so that its blast proofing quality is preserved.
- The sinking of the floating roof must be avoided through regular maintenance of the pontoons and the rim seal and drainage system integrity checking (easy to happen).
- Extreme weather phenomena, such as an abrupt and heavy precipitation, can cause flooding of the drains for oily residuals resulting in the spreading of hydrocarbons to the environment.

CONSLUSION

A checklist should be used for just one purpose only - as a final check that nothing has been neglected. Items on the checklist should only be inspected by individuals knowledgeable of and familiar with structure of fuel tanks. The frequency of inspections is the minimum standard recommended by the committee. Other factors affecting the frequency of inspection could include such things as monthly throughput, climatic conditions, applicable environmental rules and regulations, manufacturers' recommendations, experience with component performance, or other extenuating circumstances. Some fuel-dispensing system components must be inspected according to requirements established by environmental, fire safety, and other authorities having jurisdiction over fuel tanks.

REFERENCES

- [1] D. Brissaud, S. Tichkiewitch, and P. Zwolinski, Eds., *Innovation in Life Cycle Engineering and Sustainable Development*. Dordrecht: Springer Netherlands, 2006.
- [2] I. of C. Engineers, *Liquid hydrocarbon storage tank fires : prevention and response: a collection of booklets describing hazards and how to manage them*. 2008.
- [3] J. I. Chang and C.-C. Lin, "A study of storage tank accidents," *J. Loss Prev. Process Ind.*, vol. 19, no. 1, pp. 51–59, Jan. 2006.

ACKNOWLEDGEMENTS

This paper was supported by projects III43011, III43012 and III43014 of the Ministry of Education and Science of Republic of Serbia.

BIOGRAPHY

Nikola Mišić graduated from the Faculty of Occupational Safety in Niš, University of Niš, at the department of Fire Protection. From 2012, he works as an associate on the project funded by the Ministry of Education, Science and Technological Development of Republic of Serbia. At 2017, he became a teaching assistant. His main research interests are monitoring environmental pollution and risk analysis in the working environment.



ČEKLISTA ZA PROCENU BEZBEDNOSTI NA REZERVOARIMA ZA GORIVO

Nikola Mišić, Aca Božilov, Dušica Pešić, Darko Zigar

Rezime: Tokom protekle četiri decenije u procesnim industrijama razvijen je poseban pristup opasnostima i neuspesima koji uzrokuju gubitak života i imovine. Savremeni pristup izbegavanja povreda i gubitaka u procesnim industrijama je rezultat različitih događaja. U središtu ovog pristupa je upravljanje rukovodstvom, počev od višeg upravljanja i stvaranje bezbednosne kulture koja pruža odgovarajuće okruženje za smanjenje incidenata i poboljšanje performansi bezbednosti.

Čekliste mogu biti veoma moćan alat u metodologiji za procenu opasnosti kako bi se identifikovali glavni doprinosi riziku, poboljšati mere sigurnosti i pomoći analizi u ovim aspektima. Ovaj rad predstavlja sistematičnu metodologiju za identifikaciju opasnosti na skladišnim rezervoarima za gorivo, primenom tehnike čeklista za uzroke udesa i relativne zaštitne mere.

Ključne reči: procena opasnosti, skladišni rezervoari, čekliste, akcidenti.

MILIŠA TODOROVIĆ¹
SELMA HADŽIĆ²
SNEŽANA ŽIVKOVIĆ³

MANAGING WORK SAFETY BY ANALYSING INJURIES AT WORK

¹Logos centar of Mostar,
²Ceps, Kiseljak
³University of Niš,
Faculty of Occupational Safety in Niš

¹todor.timprotekt@gmail.com
²selmaha2010@gmail.com
³snezana.zivkovic@znrfak.ni.ac.rs

Abstract: *The process of harmonization of regulatory acts in the area of occupational safety and health with the norms of European Union is taking its course. However, there can be a long way from normative regulation of occupational safety and health to safe work environment. We observe the results of application of measures for safe work through the number of injuries at work. In the paper we will make an analysis of injuries at work in 2016 and 2017, and show the state of safety in real life. As a method of research, the secondary data analysis is used.*

Key words: injuries, work safety, occupational safety.

INTRODUCTION

Safety at work is a very important area of social life. It is clear that the man has always aspired to do his activities in a way that will provide him safety. During the development of human civilisation, safety at work went through different phases. In the first phase it wasn't of special importance because of social regulation, role of the state and development level of the workforce. With time and more active involvement of the country in the relationship between the employer and the employee, the role and importance of safety at work is gradually changing. The cognition that injuries at work make enormous costs that reflect negatively both for employer and employee and the state, is a reason enough for more important role of safety at work. In this sense, making and harmonization of normative acts in area of safety at work is a necessary condition.

Does this mean that it is a sufficient condition for creating a safe work environment? In what way can we measure the results that are being achieved in the area of safety at work? In what way are we talking about "near miss" as a form of preventive activity in the process of creating a safe work environment? What is the price of an injury at work? How much are we dealing with and analysing the injuries at work that happened in the previous period? Who is dealing with that data and who are they informing about the results of their research? What did we learn from the injuries that happened and in what way did we turn the bad experiences into an excellent base for taking preventive activities? Those are all questions and dilemmas we will be dealing with in this paper, wanting to present the real condition in the area of safety at work.

In this paper through analysing numbers and structures of injuries at work in 2016 and 2017 on the territory of Republic of Serbia, we will try to indicate some trends. We are aware that a simple comparison of acquired data has multiple traps and can lead us to some results that do not reflect the real condition. For more precise perceiving of this data we also need data for workforce, economic activity etc.

However, the goal of this paper is to define the clear frame of work from which we will draw some informations, which will motivate us to make a bigger picture when we are talking about safety at work. We will accentuate critical points when it comes to analysis of fatal injuries at work and severe injuries at work with a fatal outcome. In the first part of the paper we will become acquainted with the occurrence of safety at work in these regions, whereby we will pay special attention to normative activities in this area. After that, we will acquaint ourselves with some basic terms connected with the term of injury at work. We will display some dilemmas in terms of costs that occur as an integral part of the injuries at work as well as role and importance of safety culture in the process of making a safe work environment. After that we will engage in exact indicators about number and structure of injuries at work in the two observed years. In the last part we will try to draw attention to the importance of distinct and transparent publishing of the results of the analysis of injuries at work and their transferring to the person who is responsible for safety and health at work that, based on that, needs to correct certain protective measures to create a safe work ambient.

THE TERM INJURY AT WORK

The need for legal regulation of work relationships and safety at work is there in accordance with the development of the society itself. So, regulations like Law on Work Inspection from 1921, Law on Employee Safety from 1922, Law on Employee Social Insurance and other are created on the territory of old Yugoslavia. With introducing self-management there are two basic laws- about work relations and about public servants. Laws on work safety on the territory of Republic of Serbia in the past have been brought with numerous additions and changes. In accordance with generally accepted trend and effort for Serbia to get closer to European Union, the first Law on Safety and health at work is brought in 2005(Todorović, Živković, 2013).

Existence of legal and by-law acts is an important, but not a sufficient enough condition for creating the conditions for safe work. One of the first definitions of

injury at work dates from 1884 and is connected to the procedure of introducing insurance in case of a work accident. Health legal service of social insurance in Germany has determined an injury at work as physical or mental health damage that occurred during one work shift influenced by exogenous factors (Mihailović, 2010). In accordance with postulates of International Labour Organization (ILO), injuries at work are defined as any injury, illness or death of the person that occurred as a work accident.

Statistical office of European communities (Eurostat) quotes that in EU, almost 3 % of work-engaged people has experienced an accident at work that caused an absence longer than 3 days, i.e. 83 million sick days (Eurostat, 2010).

In time when technical systems on working tools prospered, when there is a clear obligation, both for designers and makers of the tools for work, when we are talking about safety aspects for tools for work, we have to look for new ways which will enable the reduction of the number of work injuries. We need to work much more on creating appropriate safety culture which should help in more clear understanding of the role of every individual in the process of creating a safe work environment. Without the clear perception that the employee is in great measure responsible for his safe work, we cannot expect a great shift in the process of reducing the number of deadly and heavy injuries at work. Safety and health at work are being observed from the angle of existing and potential dangers and risks to which the employees are exposed to in the process of execution of their work tasks. The risk is usually measured through determination of degree of probability and consequences of some unforeseen event. In a situation when we have low risk level, we have high safety level, and when we have high risk level, we have low safety level. However, the relation between safety and risk is much more complex for us to come to relevant solutions that would show the right way in understanding this matter based on the above mentioned form. (Živković, Todorović, 2018).

Result of the work of every engineer can be easily quantified. It is only a question of will and desire and the person for safety to acquire all necessary data which could easily point to economical aspect of injuries at work. One of the biggest problems starts from the fact that a big number of employers is not aware of size of costs that occur as results of an inappropriate work environment. Economical burden of weak safety and health at work culture is estimated at 4% GTP every year. (ILO, 2014b; Živković, Markić, Todorović, 2014). The question of cost of injury at work is the question of all questions. Whether we want it or not, a big part of our activities is being measured or is trying to be measured in money.

In order for us to come to a certain amount of money, it is necessary that we have the correct data at disposal. The basic data which we need concern the number of lost days because of injuries at work. According to our

knowledge, you cannot get this data from any institution. What is especially interesting is that the employers do not worry about this because they find that data unimportant. A question comes up: why are the employers thinking like that?

It is because the engineers of work safety do not have the necessary width in perceiving their job and they are not presenting in the right way what are the costs of injuries at work to the employers. The information about the number of lost days due to injuries at work clearly frames the cost we are talking about. When we add that to the salary of the other employees that we have to hire, and also add indirect costs that occurred because of a standstill in the work progress and a greater premium of insurance for injuries at work, we easily see how quickly that amount is growing. Those are the numbers that should be presented to the employers in the right way so that they have a clear picture about the size of costs for injuries at work. Until the employers understand that the resources invested in the area of safety at work are not an expense, but an investment, we cannot expect big changes in employer's perception of work safety. In the base of every preventing, we start from the fact that in the first phase it is necessary to invest certain financial resources for the positive benefits to show in the next phase. Until we deal with work safety as an aspiration to control the causes of injuries at work, we cannot expect a significant move in the process of creating safe work environment. Injuries at work are determined by disbalance between unfavorable work conditions, insufficient understanding of safety and health at work both of employers and employees. Unfavorable work conditions include wide spectrum of biological, mechanical and physical exposure to the environment, psychological demands that refer to concrete tasks, work environment, questions about handling and using the materials, tools and machines, organizational factors, and also management pressure to achieve designed plans and production goals. (Chau et al. 2007; Chau, 2011; Kunar et al. 2010).

How much we are dealing with injuries at work and in what way and on what level are the causes and consequences of occurrence of injuries at work observed. From the author's experience, on the employer's level, in most cases, nobody deals with analysis of the injuries at work that occurred. Employers are not interested and people for safety and health at work are not too interested to draw certain lesson about that. That is what is especially interesting, because it is them that are responsible people for safety and health at work. From the level of state, apart from simple collecting of those data, it is unclear if somebody is dealing with those injuries. Are the special programs that should become an integral part of inspection supervision in the process of controlling the application of measures for safe work in organizations made? The general impression is that nobody is dealing with that data. So how can we talk about safety and health at work as a preventive activity that should

create conditions for safe work of all employees? With an approach like that we surely can't talk about a permanent reduction of injuries at work. If we look at the trend of injuries, we see that it is not on the descending path, but that it changes from year to year. The question of consequences of injuries at work on the quality of life of an individual who experienced injuries at work is a special question. In most cases, our health system recognizes only physical work injuries. Connection of stress and conditions in which injuries occur is very hard. According to the author, since the Law on Safety and Health at Work has come into force in Republic of Serbia, no injury at work has been classified as a stress consequence. The results of the studies clearly indicate that the people who experienced injuries at work, compared to other people who got hurt someplace else, suffer from wider spectrum of consequences of mental health, including stress, anxiety and depression (Keogh et al. 2000; Mason et al. 2002; Stansfeld et al. 2000).

By individual analysis of numerous cases of big accidents, it has been confirmed that the safety culture has got a great influence on creating a safe work environment. It is a known fact that the culture changes hard and slow. Because of that we need to comprehend it as a very important factor that influences the increase of business competences of every organization and to actively control its growth and development. Appropriate safety culture creates basic preconditions for long term productivity and health protection of employees which manifests in increase of competence, both for employer and employees but also for the state itself. On the other hand, it creates conditions for safer work environment of the employee. (Živković, Todorović, 2018).

According to Todorović (2010), the process of analysis of injuries at work can be observed through a circular cycle that consists of five phases: analysis of acquired data, determination of consequences of injuries at work, analysis of spent resources, defining the measures for preventing the number and difficulty of injuries at work, tracking of applied measures and collecting the feed back.

Spasić (2003) quotes criteria for assessing the size of the injury rate i.e. the ratio of injuries at work over a certain period of time in relation to the average number of employees:

- Low rate of injury- the occurrence of injury up to 2% employees;
- Heightened rate of injury- the occurrence of injury from 2.1 to 4 % of employees;
- High rate of injuries- the occurrence of injuries from 4.1 to 6% of employees;
- Enormous rate of injuries- the occurrence of injuries with over 6.1% of employees.

Irresponsible behaviour of the employees often presents the source of injuries at work. Examples of behavior and positive feedback related to responsible behaviour

strongly influence change of behaviour in the in the field of protection against the risk of injury.

Long term, safety programs based on behaviour have the goal to apply the normal way of safety at work: "We either do it this way or don't do it." (Živković, Todorović, 2018)

RESULT OF RESEARCH AND DISCUSSION

Injuries at work occur in several ways, but generally observed injuries occur due to inadequate working conditions, defective and unsafe work tools, incompetent workers for safe work. We can look at the end result of that state in the following chart.

Table 1. Review of work injuries in the period 2013-2017

Year	Number of performed inspection supervisions in case of a deadly, sever with fatal, collective, difficult and light injuries at work					
	Total	Fatal	Severe injuries with a deadly outcome	Collective	Difficult	Light
2013.	1146	24	14	11	849	248
2014.	1100	21	17	19	904	139
2015.	947	24	14	18	780	111
2016.	900	29	13	20	774	64
2017.	919	23	16	14	817	49

For the purposes of this paper, we will put the accent on the analysis of injuries at work from 2016 and 2017. Before any analysis we must start from the fact that simple observation of official data unfortunately does not represent the real state. A large number of employers still do not report injuries at work. Fatal injuries or severe injuries at work are hard to cover, but everything else often goes unreported. It sounds incredible that in the entire year only 49 light injuries has been reported. For the purposes of this work, we will not deal with this. We just want to indicate on the fact that these statistical data shouldn't be taken at face value. It is clear that simplified looking at the data on the number of injuries at work says that there is a slight decline for **21%** when we are talking about fatal injuries. An identical situation exists with data for severe injuries with fatal outcome with **19%**. There is also a declining trend with collective injuries with fatal outcome in the amount of **30%**.

What is concerning is the negative trend when it comes to severe injuries. When we are talking about them, there is a negative trend, i.e. increase of number of injuries at work up to **6%**.

Looking at the report from the work inspection we can conclude that there is a certain positive breakthrough because it is being relatively precisely said as to what are the causes that led to injuries at work. The problem starts from what is not visible, at least not to authors, and that is who uses this data and in what way do they use the data to conclude the change of conscience and

use of undertaking corrective measures in the process of creating a safe work environment. By analysing the causes and circumstances due to which the injuries at work occurred, it has been confirmed that the most common causes of injuries in 2016 were the following: unsafe work at altitude and on improperly mounted scaffolds, not using the prescribed funds and tools for personal safety at work, primarily work without the safety helmet and safety belt, work in improperly secured excavations, non-application of the basic principles of the organisation of works, deviation from proper and established work process, improper cooperation (coordination) of participants in the works, improper work with working tools, incompetence of engaged at work for safe work, incomplete implementation of safety and health at work measures at work places, engaging a significant amount of untrained people to 'work black'. (Izveštaj Inspekcije rada za 2016).

What is not good is that the number of fatal injuries based on every of above mentioned basics is not seen. If we say, for example, that from 29 fatal injuries, 20 occurred as a consequence of unsafe work on altitude and improperly mounted scaffolds, then we can come to clear conclusions that the scaffolds are our biggest problem. In the next phase we should organize seminars for all people in safety and health work which would, as a goal, would have only education when it comes to scaffolds and work at altitude. All people for safety and health at work would have an obligation to necessarily attend to one seminar with this topic once a year. An integral part of all these activities would also be a periodic organization of work inspection at construction which would have a goal that through preventive scaffolds and work at altitude check ups influence the change of business practice in making of scaffolds and the technology of working at altitude. In such continuous work we are sure that the general ambient would change and that the number of these injuries at work would gradually decline. Of course, there shouldn't be expectations that there will be significant shifts in a relatively short period because it still depends a lot on the perception of employees and employers.

However, until we start dealing with fatal injuries in this way, we don't see a clear guide mark that will create environment for the work of all employees. In the yearly report of Work Inspection for 2017, jobs in which the injuries occurred are clearly showed. However, the basic question that comes up is related to the end users of this data, in which way do this data change the perception of safe environment and create safe working conditions.

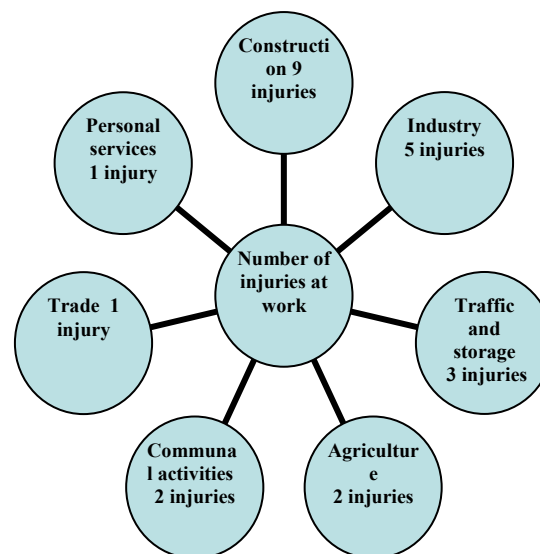


Figure 1. Structure of work injury in 2017 by activity

If we look at this data, we can see in which direction preventive activities should be organized. When analysing the official reports of the number of injuries at work for 2016 the data on injuries at certain jobs were not available, unlike those for 2017. What we want to point out is the fact that these data exist at a hardly approachable place on the site of Ministry of Labor, Employment, Veterans' Affairs and Social Affairs. The Ministry fulfilled its legal obligation and updated the public about the current situation when it comes to injuries at work and the results of work inspections. Analysing the report of work inspections, we can notice that they give clear guidelines that should help in creating conditions for reduction of the number and severity of injuries at work. Except the general measures and many nice wishes, in one policy, the urge to establish efficient national registration and collecting the data on injuries at work and professional illnesses system is defined. The first question we ask is related to the legal grounds which would obligate the employers to keep records which are connected to injuries at work and lost work days. Is there such a legal ground? No, there isn't. Then how are we supposed to make the employer keep that kind of records? Work inspection should organize its' activity in two directions when it comes to causes which led to severe and fatal injuries at work. The first direction should be related to reinforced supervision of application of safety work measures in these jobs during which the accent should be placed on observing the causes which in that job generated causes for occurrence of fatal injuries at work. The other direction of activities of the work inspection should be related to education of people for safety and health at work whereby the accent would be placed on critical points which in the most cases lead to creating the conditions for fatal injuries at work.

CONCLUSION

Based on everything aforementioned we can conclude that there is a trend of reduction of fatal deaths at work. Should we be pleased with the fact that in the previous year died 6 people less? That *only* 23 people died? Does it mean that in this ambient this year there won't be 6 more? Of course it doesn't. The current fall shouldn't and mustn't be an encouragement because human life is priceless. Without preventive observation of causes of injuries at work there is no significant breakthrough. In that sense and learning from the mistakes that happened and making the preconditions for those same mistakes not to be repeated. The causes which led to fatal injuries at work must be interpreted in seminars for people for safety and health at work with concrete explanations of what led to those injuries and in which way the conditions for prevention of these injuries. In the next phase people for safety and health at work should work on prevention of repeating of these causes as well as proactive communication with their employees with goal that through analysing the events that have almost happened, preconditions for safe work environment will be created. The role of work inspection is especially significant in that process and through various ways of education should influence a change of conscience that we should be dealing with safety at work once the injury happens.

REFERENCES

- [1] Chau, N., Gauchard, G., Dehaene, D., Benamghar, L., Touron, C., Perrin, P., & Mur, J. (2007) Contributions of occupational hazards and human factors in occupational injuries and their associations with job, age and type of injuries in railway workers. *International Archives of Occupational and Environmental Health*, Vol. 80, No.6, pp. 517-525.
- [2] Eurostat (2010). Health and safety at work in Europe (1999-2007) - A statistical portrait. Available: <http://ec.europa.eu/eurostat/documents/3217494/5718905/KS-31-09-290-EN.PDF/88eef9f7-c229-40de-b1cd-43126bc4a946> (Accessed on 4 March 2018).
- [3] Keogh, J.P., Nuwayhid, I., Gordon, J.L. & Gucer, P.W. (2000) The impact of occupational injury on injured worker and family: outcomes of upper extremity cumulative trauma disorders in Maryland workers. *American Journal of Industrial Medicine*, Vol. 38, No. 5, pp. 498-506
- [4] Mason, S., Wardrope, J., Turpin, G. & Rowlands, A. (2002) Outcomes after injury: a comparison of workplace and nonworkplace injury. *The Journal of Trauma*, Vol. 53, No. 1, pp. 98-103
- [5] Mihailović, D. (2010). Psihologija rada i organizacije, Fakultet organizacionih nauka, Beograd
- [6] Spasić, D. (2003). Ekonomika zaštite na radu. Grafika Galeb, Niš.
- [7] Todorović, M., Živković, S. (2013): *Ekonomске implikacije primene Zakona o bezbednosti i zdravlja na radu*, 16. Međunarodna konferencija „Upravljanje kvalitetom i pouzdanošću“ ICDQM-2013, Beograd, Zbornik radova, str. 357-362. ISBN 978-86-86355-14-0 COBISS.SR-ID 199082764 CIP 005.6(082) 005.6:658.58(082)
- [8] Todorović, M., Živković, S., (2017): Analysis of occupational injuries in the Republic, JEL classification: J28, UDC 613.6(497.11); ISBN: 978-86-6139-138-5, Faculty of Economics Nis
- [9] Živković, S., Markić, M., Todorović, M., (2014): Integrated security systems as an instrument of reducing the number of occupational injuries and material costs, *Actual problems of economics*, 2(152), pp. 479-491. UDK 330 ISSN 1993-6788
- [10] Živković, S., Todorović, M., (2018): Uloga ljudskih faktora u sistemu bezbednosti i zaštite, Logos centar, Mostara, Bosna i Hercegovina, ISBN 978-9958-043-17-7, COBISS.BH-ID 25981702, str. 219-247
- [11] Izveštaj Ministarstva za rad, zapošljavanja, boračka i socijalna pitanja za 2016.godinu
- [12] Izveštaj Ministarstva za rad, zapošljavanja, boračka i socijalna pitanja za 2017.godinu

BIOGRAPHY of the first author

Miliša Todorović was born in Kladanj, Bosnia. He graduated in Economics and obtained MA at the Faculty of Economics in Subotica. He is a Ph.D. student at the Faculty of Occupational Safety in Niš. Also, he is an author of several professional



papers in the field of occupational health and safety and organizational culture. He lives and works in Stara Pazova. He is a founder of the consulting company providing occupational health and safety services, where he has been working for the last ten years. His research field is organizational culture and its impact on safe work environment.

UPRAVLJANJE ZAŠTITOM NA RADU KROZ ANALIZU POVREDA NA RADU

Miliša Todorović, Selma Hadžić, Snežana Živković

Rezime: *Proces usklađivanja normativnih akata u oblasti bezbednosti i zdravlja na radu sa normativom Evropske unije ide svojim tokom. Međutim, put od normativnog regulisanja bezbednosti i zdravlja na radu do bezbednog okruženja za rad može biti veoma dug. Rezultate primene mera za bezbedan rad posmatramo kroz broj povreda na radu. U radu ćemo napraviti analizu povreda na radu u 2016 i 2017 godini i prikazati kakvo je stanje zaštite u relanom životu. Kao metoda istraživanja, primenjena je analiza sekundarnih podataka istraživanja.*

Ključne reči: povrede na radu, zaštita na radu, inspekcija rada.

ALEKSANDAR ZUNJIĆ¹
VLADIMIR SREMČEVIĆ²
SVETLANA CICEVIĆ³
ALEKSANDAR
TRIFUNOVIĆ⁴
EVICA STOJILJKOVIĆ⁵

¹University of Belgrade,
Faculty of Mechanical Engineering

²Music school Mokranjac,
Belgrade

^{3,4}University of Belgrade,
Faculty of Transport and Traffic
Engineering

⁵University of Nis,
Faculty of Occupational Safety

¹azunjic@mas.bg.ac.rs

²vladimirsremcevic1@gmail.com

³s.cicevic@sf.bg.ac.rs

⁴a.trifunovic@sf.bg.ac.rs

⁵evica.stojiljkovic@znrfak.ni.ac.rs

THE EFFECTS OF INTERIOR DESIGN OF PUBLIC TRANSPORT BUSES ON PASSENGER SAFETY

Abstract: *In large urban areas, buses for public transport are used daily by a large number of people. Due to this, the safety of passengers in public buses is of great importance. A large number of expert and scientific studies have been carried out on the safety of the construction of the buses, as it has been considered to have the greatest impact on safety. As a result, the safety aspect of the interior of the bus was neglected. This paper examines some aspects of the interior design of buses that may have an impact on passenger safety.*

Key words: city buses, safety, interior design.

INTRODUCTION

Previous research on passenger safety in urban transport buses was primarily aimed at passenger injuries caused by the collision and non-collision effects [1-11]. On the other hand, when it comes to elements that could affect the safety of passenger transport, only a few items in the questionnaires for assessing the quality of transport were possibly related to the safety aspect. In view of this, no research has been carried out previously relating to different aspects of the interior safety of the buses. For this reason, it is not possible to make a review of the literature related to this issue.

On the other hand, bearing in mind that no previous research has been carried out on the detection of potential unsafe elements of the bus interior, no methodology has been established which enables the assessment of this type. For this reason, the main objective of this paper is to form a tool to enable the research of the safety aspects of the interior of buses for urban passenger transport. After that, the aim is to carry out a research on a sample of buses of GSP Belgrade, based on the application of such a tool, which would enable the creation of a more complete insight about the safety of buses used for the transport of passengers in Belgrade.

METHOD

As mentioned above, there is no tool that would be suitable for studying the safety of different segments of the interior. In view of this, we decided to design a tool in the form of a questionnaire for this purpose. The reason for this was the assumption that this tool form

provides a comprehensive insight into different aspects of the interior, which can affect safety.

We have selected a number of constructs of the questionnaire, which are also basic areas that may have an impact on the safety of the interior of the bus for the urban transport of passengers. In this paper, the emphasis is on a construct related to the design of individual elements of the interior of the bus, with a focus on passenger safety. For this segment of the safety of the internal space of the bus intended for the accommodation of passengers, a number of issues have been created that are part of the questionnaire for assessing the safety of bus transport. The content of this questionnaire is given below.

The aim of the survey is to discover the elements in the interior of the buses that can be improved in order to make passenger transport safer. For each claim that is contained in the question, it was necessary to round off a number from 1 (meaning totally disagree with the statement) to 5 (totally agree with the statement), which best suits the situation on the buses in which passengers are most often transported.

The mentioned questionnaire was given to passengers of city bus transport in Belgrade for filling in. A total of 140 questionnaires were filled in. The age of the subjects ranged from 15 to 73 years. The sample covered both genders. The average age of the respondents was 40.4 years.

QUESTIONNAIRE ON THE SAFETY OF THE ELEMENTS OF THE BUS INTERIOR

1. There are a lot of hard or sharp parts on the bus where I can hit in case of sudden braking

totally disagree 1 2 3 4 5 totally agree

2. In some situations (rain, snow) floor becomes slippery?

totally disagree 1 2 3 4 5 totally agree

3. On the bus floor, there are a lot of uneven parts that can be hooked up and be the cause of fall down

totally disagree 1 2 3 4 5 totally agree

4. There have been cases when I fell down or was hit on the bus due to the existence of slippery surfaces and to pass without injury

totally disagree 1 2 3 4 5 totally agree

5. There have been cases when I fell down or was hit on the bus due to the existence of slippery surfaces and have received an injury

totally disagree 1 2 3 4 5 totally agree

6. There have been cases when I fell down or was hit on the bus due to the existence of rugged surfaces and to pass without injury

totally disagree 1 2 3 4 5 totally agree

7. There have been cases when I fell down or was hit on the bus due to the existence of rugged surfaces and have received an injury

totally disagree 1 2 3 4 5 totally agree

RESULTS AND ANALYSIS OF RESULTS

The analysis will be conducted for each question from the questionnaire. The following table summarizes the arithmetic means and standard deviations for the answers to the questions asked. In addition, in relation to each question from the questionnaire, a test of the normality of the distribution of the response was applied and a graphical representation of the frequency of the answers offered was given.

Table 1. Mean values and standard deviations for individual questions from the questionnaire.

Questions	Mean	Standard deviation
1	3,657	,880
2	2,786	,718
3	1,764	,706
4	1,057	,476
5	1,029	,338
6	1,029	,338
7	1,029	,338

The range of answers to question 1 "There are a lot of hard or sharp parts on the bus where I can hit in case of sudden braking" is from 2 (disagree) to 5 (completely agree). The distribution of answers to this question can not be considered normal, $W=0.872$, $p=0.000$.

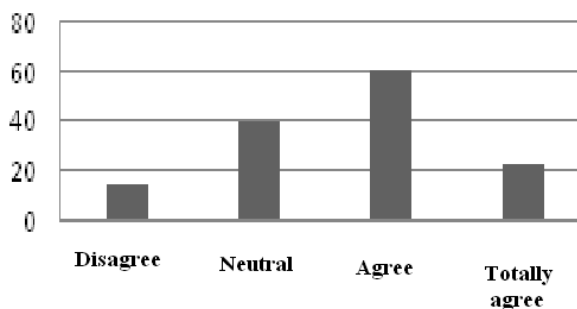


Figure 1. Frequencies of respondents' answers to the question 1 "There are a lot of hard or sharp parts on the bus where I can hit in case of sudden braking".

The range of answers to question 2 "In some situations (rain, snow) floor becomes slippery?" is from 2 (disagree) to 4 (agree). The distribution of answers to this question can not be considered normal, $W=0.793$, $p=0.000$.

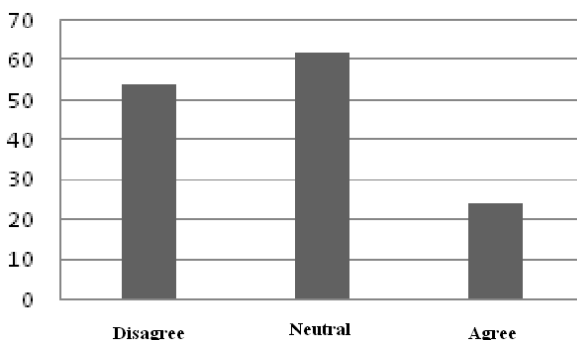


Figure 2. Frequencies of respondents' answers to the question 2 "In some situations (rain, snow) floor becomes slippery?".

The range of answers to question 3 "On the bus floor, there are a lot of uneven parts that can be hooked up and be the cause of fall down" is from 1 (totally disagree) to 3 (neutral). The distribution of answers to this question can not be considered normal, $W=0.789$, $p=0.000$.

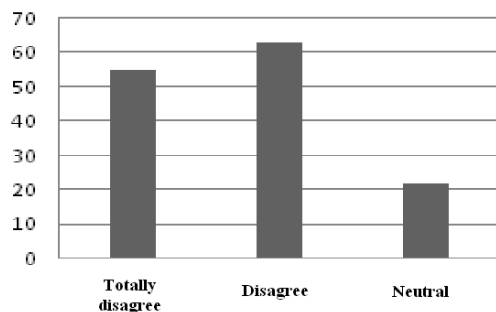


Figure 3. Frequencies of respondents' answers to the question 3 "On the bus floor, there are a lot of uneven parts that can be hooked up and be the cause of fall down".

The range of answers to question 4 "There have been cases when I fell down or was hit on the bus due to the existence of slippery surfaces and to pass without injury" is due to the nature of the question 1 (totally disagree) or 5 (completely agree). The distribution of answers to this question can not be considered normal, $W=0.096$, $p=0.000$.

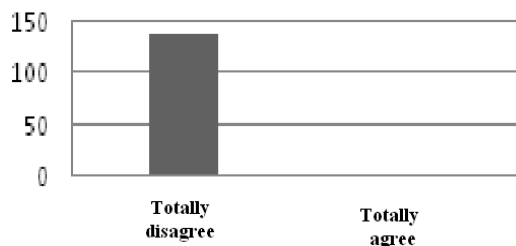


Figure 4. Frequencies of respondents' answers to the question 4 "There have been cases when I fell down or was hit on the bus due to the existence of slippery surfaces and to pass without injury".

The range of answers to question 5 "There have been cases when I fell down or was hit on the bus due to the existence of slippery surfaces and have received an injury" is due to the nature of the question 1 (totally disagree) or 5 (completely agree). The distribution of answers to this question can not be considered normal, $W=0.058$, $p=0.000$.

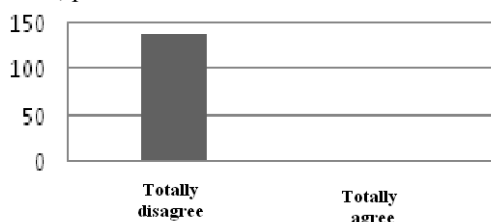


Figure 5. Frequencies of respondents' answers to the question 5 "There have been cases when I fell down or was hit on the bus due to the existence of slippery surfaces and have received an injury".

The range of answers to question 6 "There have been cases when I fell down or was hit on the bus due to the existence of rugged surfaces and to pass without injury" is due to the nature of the question 1 (totally disagree) or 5 (completely agree). The distribution of answers to this question can not be considered normal, $W=0.058$, $p=0.000$.

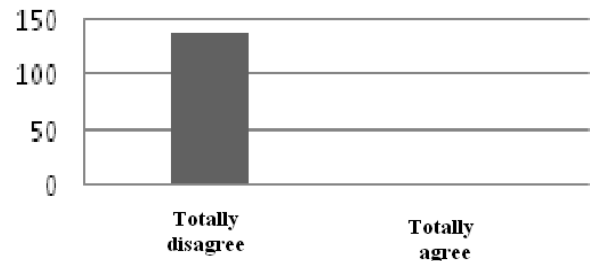


Figure 6. Frequencies of respondents' answers to the question 6 "There have been cases when I fell down or was hit on the bus due to the existence of rugged surfaces and to pass without injury".

The range of answers to question 7 "There have been cases when I fell down or was hit on the bus due to the existence of rugged surfaces and have received an injury" is due to the nature of the question 1 (totally disagree) or 5 (completely agree). The distribution of answers to this question can not be considered normal, $W=0.058$, $p=0.000$.

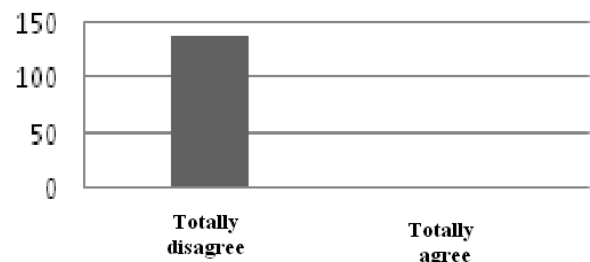


Figure 7. Frequencies of respondents' answers to the question 7 "There have been cases when I fell down or was hit on the bus due to the existence of rugged surfaces and have received an injury".

CONCLUSION

As potential factors of the interior design of the buses, which in some situations can lead to passenger injuries, sharp and hard objects of the interior, uneven and slippery surfaces were identified. The results of the study showed that although 24% of the respondents believe that in some situations, such as rain or snow in the bus, the floor becomes slippery, respondents did not have any injury due to the presence of slippery surfaces. Injuries among respondents were also not due to the possible existence of rugged surfaces. However, as the main safety threat, respondents see the existence of hard or sharp parts on the bus. For this reason, city buses designers need to pay special attention to this aspect in the future, to reduce the risk of injuring of passengers.

REFERENCES

- [1] P. Albertsson and T. Falkmer, "Is there a pattern in European bus and coach incidents? A literature analysis with special focus on injury causation and injury mechanisms", *Accident Analysis and Prevention* 37 (2005), 225-233.
- [2] U. Bjornstig, P. Albertsson, J. Bjornstig, P-O Bylund, T. Falkmer and J. Petzall, "Injury events among bus and coach occupants - non-crash injuries as important as crash injuries", *IATSS Research* 29 (2005), 79-87.
- [3] R. Grant, A. Kirk and R. Bird, "Why do passengers get hurt when buses don't crash?", in: *Contemporary ergonomics 2002*, P.T McCabe, ed., Taylor & Francis, London, 2002, pp. 465-470.
- [4] P. Halpern, M.I. Siebzeher, D. Aladgem, P. Sorkine and R. Bechar, "Non-collision injuries in public buses: a national survey of a neglected problem". *Emerg Med J* 22, 2005, 108-110
- [5] A. Kirk, R. Grant and R. Bird, "Passenger casualties in noncollision incidents on buses and coaches in Great Britain", in: *Proceedings of the 18th International Technical Conference on the Enhanced Safety of Vehicles*, US Department of Transportation, Nagoya (19-22 May).
- [6] H. Nagata and S. Lee, "Survey on accidental falls of elderly workers while commuting to and from work", in: *Contemporary ergonomics 2004*, P.T McCabe, ed., CRC Press, Boca Raton, FL., 2004, pp. 78-82.
- [7] A. Palacio, G. Tamburro, D. O'Neill and C.K. Simms, "Noncollision injuries in urban buses - strategies for prevention", *Accident analysis and prevention* 41, 2009, 1-9.
- [8] A.E. Wahlberg, "Characteristics of low speed accidents with buses in public transport", *Accident analysis and prevention* 34, 2002, 637-647.
- [9] A.E. Wahlberg, "Characteristics of low speed accidents with buses in public transport: part II", *Accident analysis and prevention*, 36, 2004, 63-71.
- [10] A. Zunjic, V. Sremcevic, V. Zeravcic Sijacki and A. Sijacki, 2012, "Research of injuries of passengers in city buses as a consequence of non-collision effects", *Work* 41, pp. 4943-4950.
- [11] A. Zunjic, V. Sremcevic, S. Cicevic, "Research of undocumented injuries of passengers in buses for city transport", *Proceedings of the 7th Symposium on Industrial Engineering*, Belgrade, 2018, pp. 99-101.

ACKNOWLEDGEMENTS

This paper is part of the projects TR35030 and 391-00-16/2017-16/39

BIOGRAPHY of the first author

Aleksandar Zunjić is a Full Professor at the University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia. Dr. Aleksandar Zunjic is the President of the Ergonomics Society of Serbia. He is a member of the Board of Directors of the International Engineering and Technology Institute (IETI). He is also the President of the IETI for the Belgrade Branch. Aleksandar Zunjic is a member of the Technical Committee of the International Ergonomics Association (IEA) - Work With Computing Systems (WWCS). He has been the editor, member of organizational boards and scientific boards of many international conferences. He is a member of the Editorial Board of an international publishing house from England, for the area of Ergonomics. Aleksandar Zunjic is a member of the Editorial Board of four international journals. In addition, Aleksandar Zunjic is also the Editor-in-Chief of two international journals: IETI Transactions on Ergonomics and Safety and IETI Transactions on Engineering Research and Practice.



UTICAJ DIZAJNA ELEMENATA ENTERIJERA AUTOBUSA ZA GRADSKI PREVOZ NA BEZBEDNOST PUTNIKA

Aleksandar Žunjić, Vladimir Sremčević, Svetlana Čičević, Aleksandar Trifunović, Evica Stojiljković

Rezime: U velikim gradskim sredinama, autobuse javnog prevoza svakodnevno koristi veliki broj ljudi. S obzirom na to, bezbednost putnika u autobusima gradskog prevoza ima ogroman značaj. Veliki broj stručnih i naučnih studija je obavljen na temu bezbednosti konstrukcije autobusa, jer se smatralo da ona najviše utiče na bezbednost. Usled toga, aspekt bezbednosti unutrašnjeg prostora autobusa je bio zanemaren. U ovom radu se razmatraju pojedini aspekti dizajna enterijera autobusa koji mogu imati uticaja na bezbednost putnika.

Ključne reči: gradski autobusi, bezbednost, dizajn enterijera.

GORAN SEKOVSKI¹
BLAGOJA BOGOEVSKI²
BILJANA STAVRESKA³

¹Institute of technical Inspection and
Safety Engineering – ITI Skopje

²GMC Skopje

³Institute of technical Inspection and
Safety Engineering – ITI Skopje

¹Goran.Sekovski@itibi.mk

²bbogoevski@yahoo.com

³Biljana.Stavreska@itibi.mk

ACCIDENTS AND SAFETY RISKS DURING INSTALLATION, MAINTENANCE AND MODERNISATION OF LIFTS

Abstract: *Vertical transportation is the safest transport compared to others; however, because of the enormous number of lift units, old lift stock especially in Europe, huge number of daily users, and significant number of employees in this sector, numerous serious harms and fatal accidents happen, especially during work on them. The situation in Macedonia, although there aren't satisfactory statistics, is similar and perhaps even worse than that shown in the global averages. Proper use of collective and personal protective equipment is essential. The subject of this paper is to underline safety risks and prevention associated with installation, maintenance and modernization divided as Fatal & Serious Accidents Prevention and Frequent Accidents Prevention according ELA Brochure – Basic Safety Practices on Lifts.*

Key words: lift safety, installation, maintenance, modernization, safety risk, accidents, personal protective equipment, protective means.

LIFTS - CURRENT STATE OF THE ART

The present number of lifts that are in use worldwide is estimated at 13.000.000 with the rate of newly installed units of over 500.000 to 550.000 per annum. Less than half of these, or around 6.140.000 with an annual increase of 140.000 units, account for Europe (The statistics of the number of lifts published by ELA for the period until 2017 inclusive was made based on incomplete data from 31 countries – Western Balkans Countries are not included). [1] The daily turnover of individual users, i.e., use of lifts – in the sense of individual trips (hereinafter referred to as “users”) in Europe is estimated at about 1.000.000.000 and almost 4.000.000.000 worldwide. Hence, there is no doubt that the lift is one of the most frequently used transportation devices in the world. [6]

It is only in EU that this economic branch employs around 157.000 people and since it is mainly based in the East, the total number of employees in this sector worldwide is multiply higher than that in Europe. The employees in this sector work in two main fields of activities: a) production and installation of new lifts and b) maintenance, repair and modernization of existing lifts. Even 60% of the employees in this field are directly involved in field activities, as are installation, maintenance and modernization of lift equipment. [3] In Macedonia, the number of employees in this economic branch is around 300.

Although vertical transport by lifts is far the safest in respect to any other transportation means, due to the large number of lifts in use, their average obsolescence, particularly in Europe, the large daily number of users and the large number of employees in this sector who are at an increased risk at most of their working places due to the nature of their work, injuries happen frequently, sometimes with serious and fatal consequences. In the Republic of Macedonia, records on injuries on and near lifts (during work on lifts and

their use) are not kept in any institution. There is no precise inventory even in respect to the number of lifts. The unofficial figure ranges between 9.000 and 11.000. Several statistical analyses of injuries at work and during use of lifts in the USA and EU could therefore be of an assistance and could serve in developing strategies for improvement of safety of lifts in general and especially safety during installation, maintenance and modernisation in our country and beyond.

ACCIDENTS - STATISTIC ANALYZES

The latest study carried out by the *Engineer Research and Development Centre in the USA* [4] and published in 2013 provides a detailed analysis of injuries and particularly fatalities during works on lifts and their use. In this study, data from the research and statistics carried out by the *Centre* were used. On the other hand, the *Centre* used, with a limited access, the data base of the U.S. Bureau of Labor Statistics referring to fatalities that happened in lifts and in their vicinity during work in the period 1992-2009 in which 263 fatalities on lifts and 8 fatalities on escalators are recorded. Data from the Consumer Product Safety Commission referring to injuries of passengers that happened during and beyond the working time in the period 1997-2010, were also used. According to the study, around 28 fatalities and 17.000 serious injuries happen in the USA annually during work on or in the vicinity of lifts, or their use during and beyond the working time. *Table 1* shows that 50% of the fatalities account for accidents during work on lifts or in their vicinity, around 20% account for users of lifts during working time and around 30% account for general users, i.e., users of lifts beyond the working time. *Figure 1* shows that almost one third of the considered fatalities account for lift installers and repairers. Other professions present in fatal accidents related to lifts can be seen on the same graph. The most frequent

reasons for the fatal outcome of the accidents suffered by professionals dealing with installation and repair of lifts as well as other professionals are given in Figure 2. Figure 3 shows the statistics of fatalities according to performed activities.

Table 1. Average annual number of fatalities 1992-2010

- a) Data on fatal accidents according to CFOI (Census of Fatal Occupational Injuries) Research File 1992-2009 in conditions of limited access to data from the reports of the U.S. Bureau of Labor Statistics.
- b) Additional data on fatal accidents obtained from CPSC - Consumer Product Safety Commission for the period 1997-2010.
- c) Number 28 has been obtained by taking into account the real values of the addends, not their rounded off values.

	Lifts	Escalators	Total
Working on/beside a lift	15 ^a	0,4 ^a	15
Users during work	5 ^b	0,2 ^b	5
Users beyond work	5 ²	2 ²	7
Total	25	3	28^c

Installation and maintenance of lifts

The analysis of this statistics shows that almost $\frac{3}{4}$ of these 110 fatalities happened during installation or repair of lifts and involve lift installers and repairers. The remaining fatalities involve specialized technicians, engineers, construction supervisors, cleaners and other technicians.

More than $\frac{1}{3}$ of the fatalities happened due to falling into lift shafts affecting lift installers and repairers. Most of these installers and repairers were neither registered nor trained for such work. Almost $\frac{1}{3}$ of these workers were trapped between (between two cabins in the same shaft, between a cabin and a counterweight, a cabin or a counterweight and the wall of the shaft), while $\frac{1}{5}$ were smashed while working in the lift shaft, most frequently by a down sliding cabin during work in the shaft pit.

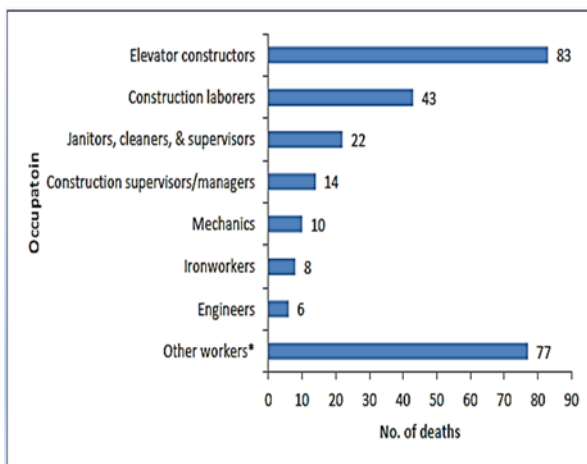


Figure 1. Fatalities in the period 1992-2009 according to profession

Work in the vicinity of a lift

Almost all of the 107 registered fatalities refer to construction workers and none lift installer or repairer. 49 of these fatal accidents (45 of these related to a fall in the lift shaft) happened due to unprotected openings of the lift shaft or due to their inappropriate fencing.

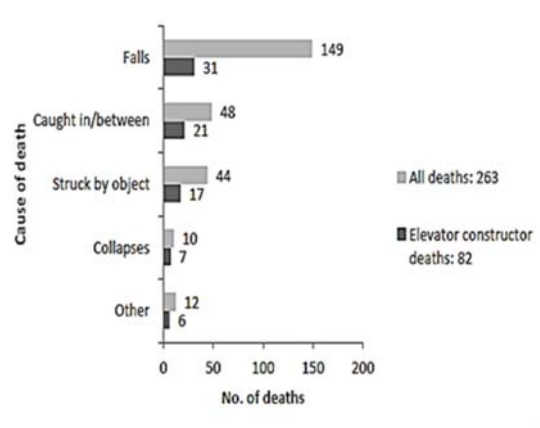


Figure 2. Reasons for injuries with a fatal outcome

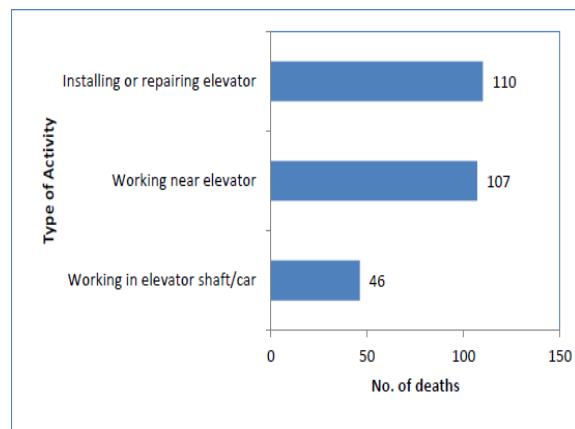


Figure 3. Fatalities according to activities performed at the critical moment

Work in the lift shaft or lift cabin

Forty six fatalities belonging to this category happened during activities such as taking keys that have fallen into the lift shaft, cleaning of the interior of the lift shaft, repair of a stuck lift, falling of a cabin or a platform into the shaft pit. [6].

On the other hand, the European national associations as is the leading European Lift Association ELA does not have the best statistics of those killed and injured in lifts. ELA has engaged an independent agency to collect information from national associations in the so-called "black box" where data on accidents are stored without information on lift producers and repairers to encourage companies to provide such data by guaranteeing their anonymity. These data are necessary for getting a complete insight into the accidents related to lifts without which one cannot make a successful analysis and successful improvement of safety. Finally, ELA, have some statistics on accidents and injuries (Figure 4), although incomplete as they allege. These

refer to the total number of accidents with slight and heavy injuries as well as fatalities according to which the most threatened are lift installers and maintainers. The reasons for these injuries are given in Figure 5 presented as pie chart with respective percentage. The reasons for the accidents are classified according to the SNEL [3] list of risks (Safety Norm for Existing Lifts is a frequently used abbreviation for standard EN 81-80:2003 [8]). According to this list, the most frequent reasons for accidents are inadequate tools and methods, especially devices for hanging/lifting of the equipment in the machine room and the shaft, than unsafe access to the machine room and the shaft pit, absence of protective fence at higher levels in the machine room, etc. According to ELA, the ratio between accidents with fatal consequences and total heavy injuries is 1/92 in the case of workers on lifts is shown as pyramid (Figure 6). [7]

Lift worker accidents



Figure 4. Incomplete data on number of injuries that happened at working place for 2015 of 26 EU countries

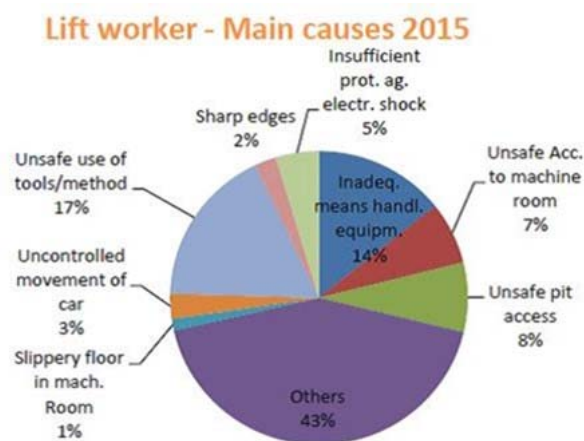


Figure 5. Main causes for injuries at working place



Figure 6. Number of heavy and slight injuries in respect to a single fatality case.

Situation in Macedonia

In Macedonia, there have continuously been recorded injuries and, unfortunately, fatalities. Within only a year, there were 4 accidents with 3 serious injuries and a fatality. The last accidents happened to lift installers, repairers and their superiors. Injuries happen each year. As is the case in world frames, the fact that the workers directly involved in installing and maintenance of lifts are the most endangered in this sector has also been confirmed in Macedonia. If the reasons for injuries and fatalities are considered, namely falling (collapse) of lift equipment and fall of employees into lift shafts, there is again agreement with the first stated reasons for accidents in the world (fall into the shaft, caught in or between the equipment, struck inflicted by equipment or tool, collapse of equipment and other reasons). However, if the number of lifts in Macedonia and the number of accidents in this period are taken into account, the probability of occurrence of an accident and hence heavier injuries and injuries with a fatal outcome is greater than that in the EU.

SAFETY RISKS

Obviously, employees in the lift industry are exposed to risks, which if not fully identified and adequately managed, may lead to a fatal or serious accident.

The present heading, as it is defined in ELA Brochure [9] and based on SNEL list of risks, aims to help any employee and company understanding what the main risks are and help them identify effective means of protection. Following list is based on lift industry experience and knowledge of serious accidents but cannot be considered as fully exhaustive.

Fatal & serious accidents

1. Accessing the site - New equipment - Control of mechanical energy
 - Risk of being hurt by a falling object can occur when walking on a construction site and a worker drops a tool or materials.
2. Access to the machine room or the pulley room - Trap access - Fall protection

Risk of falling from unsuitable access equipment if:

- Unsafe ladder (damaged, too short or can't be secured to a fixing point);
- Unsafe trap (not robust enough, too heavy, no system to prevent accidental closing etc.).

3. *Access to the machine room or the pulley room – Access to roof – Fall protection*

Risk of falling from unprotected edge if:

- Edge is within less than 3 m from the access path to the machine room or pulley room.

4. *Work in the machine room – Fall protection*

- Risk of falling through unprotected hole from an open trap / when lifting equipment through the trap.

5. *Work in the machine room – Control of electrical energy*

Risk of being electrocuted when:

- Taking measurements on electrical equipment;
- Replacing or repairing an electrical component or any equipment which can be powered with 110V DC or 50V AC and more (controller, selector, machine, main line switch, junction box, door lock...);
- Working in close proximity of the energized equipment.

6. *Work in the machine room – Work on rotating / moving equipment*

Risk of crushing or amputation when:

- Working on moving equipment such as ropes, sheave, selectors etc.;
- Working in close proximity of unprotected equipment.

7. *Work in the machine room – Work on the brake control of mechanical energy*

- When working on the brake, the movement of the sheave is free and can lead to an uncontrolled movement of the car.

8. *Work on the landing – Service & renovation – Fall protection*

- Risk of an employee or a member of the public falling through unguarded opening when the landing door is open and the car is not behind.

9. *Work on the landing – Work on moving / rotating equipment*

- Risk of crushing or amputation when working on moving equipment such as the car door operator, landing door panels or car doors.

10. *Work on the landing – New equipment – Fall protection*

- Risk of an employee or a worker of the construction site falling through the unprotected hoistway opening.

11. *Access the hoistway – Access the top of the car – Control of the elevator*

- Risk of being crushed in the hoistway when working on the top of the car.

12. *Access the hoistway – Access to the pit – Control of the elevator*

- Risk of being crushed by the car or the counterweight when accessing and working in pit.

13. *Work in the hoistway – Top of the car / inside the car – Fall protection*

- Risk of falling from the top of the car;
- Risk of falling from inside the car when exposed to a fall hazard.

14. *Work in a hoistway – Moving in the hoistway – Control of the mechanical energy*

- Risk of being crushed by an equipment when moving the car in the hoistway (counterweight);
- Risk of being crushed on top of the hoistway if insufficient space on the top of the hoistway.

15. *Work in a hoistway – Adjacent units – Control of the elevator*

- Risk of being crushed by an adjacent running unit or any other equipment which may be moving (adjacent counterweight etc.).

16. *Work in a hoistway – Work on the hydraulic lifts – Control of mechanical energy*

- When working on the hydraulic system, on the pipe or cylinder, the risk of having a free fall of the car is significant, potentially resulting in crushing hazard if the employee is working in pit.

17. *Work in a hoistway – Work on a ladder – Fall protection*

Risk of fall from the ladder in case:

- The ladder slips if not adequately secured;
- The ladder is not in good condition;
- The risk can occur typically when working on the top of the counterweight or deflection sheave on top of the hoistway in repair or renovation.

18. *Work in a hoistway – Falling objects (renovation & new equipment) – mechanical energy*

Risk of injury by a falling object can occur when:

- Working in the hoistway while an object falls through unprotected holes in the hoistway;
- Working in the hoistway while a colleague is working above in the machine room or on the top of the car and drops a tool or equipment;
- Working in the hoistway while another colleague installs a lift in the adjacent hoistway not being protected by a screen or other means.

19. *Work in a hoistway – Work on ropes (renovation & new equipment)*

When working on the suspension system e.g. replacing ropes, this can lead to:

- Free fall of the car;
- Free fall of the counterweight.

20. *Control of high risk activities – Hoisting and rigging activities*

Risk of falling equipment if hoisting practice is inadequate:

- Car or counterweight insufficiently secured;
- Damaged sling or hoisting equipment.

Risk of fall with the car if rigging practice is inadequate:

- Gravity center insufficiently identified.

21. *Control of high risk activities – Scaffold*

- Risk of fall from the scaffold;

- Risk of falling with the scaffold if inadequately built.
- 22. *Control of high risk activities – Temporary fixed working platform*
 - Risk of fall from a temporary fixed working platform;
 - Risk of falling with the temporary fixed working platform if inadequately built or inadequate guardrails.
- 23. *Work in a hoistway – Car used as a temporary moving platform – (renovation & new equipment)*
 - Risk of fall from the moving platform;
 - Risk of fall with the car if inadequately built.
- 24. *Control of high risk activities – Defeating a safety circuit*
 - Risk of being crushed when accessing/working/egressing the hoistway;
 - Similar risks exist for members of the public in the situation that the landing door safety has been disabled.
- 25. *Control of high risk activities – Asbestos*
 - Asbestos in brakes – risk of severe health effects if brake lining are removed without precautions;
 - Asbestos on hoistway walls – risk of severe health effects if put in contact or removed without precautions.

Hopefully, fatal and serious accidents represent a minor proportion of the accidents reported by the companies.

Frequent accidents

This chapter aims to present the risks that are the source of the most frequent accidents, which occur. These accidents are, most of the time, not specific to lift work. Although not usually fatal, they can still lead to painful injuries. Consequently, these risks must not be neglected and appropriate measures as suggested in the examples shall be taken. Again, this list is not exhaustive and it is the responsibility of every company and employee to conduct a proper risk assessment and to comply with the communicated rules.

1. *Access the hoistway – Access to the pit*

Risk of falling, slipping when accessing or egressing the pit if:

- There is no ladder for pit > 1 m;
- Ladder is not adequate;
- Ladder is not used;
- Floor is slippery.

2. *Slip, Trip, Fall*

- Risk of falling on stairs when there is poor lighting or stairs are in poor condition;
- Risk of falling when the ground is wet, uneven, with a small step etc.

3. *Safe use of hand tools*

- Risk of slipping of tools if the spanner, screwdriver or bolt is in poor condition.

4. *Safe use of electrical portable tools*

- Risk of dust in the eye, risk of cuts, laceration, flying particles and fire;
- Risk of cuts, laceration when using cutting tools.

5. *Safe use of chemicals*

- Risk of loss of conscious, disease or health issues in case of use of dangerous products;
- Risk of explosion if flammable product is used in close proximity to hot work or lit cigarettes.

6. *Manual handling*

- Risk of back injuries when lifting equipment;
- Risk of cuts, laceration if the load falls down;
- Risk of falls or slips when handling the equipment.

Other risks that have not been developed in this paper but which can be relevant are:

- Risk of a fire;
- Risk related to welding activities;
- Risk related to the specificity of the site (nuclear plant, chemical plant, explosive atmosphere etc.);
- Risks related to the use of vehicles.

SAFETY (PROTECTIVE) MEASURES

There are few tools as standards, technical specifications, codes of practice, and other official documents, which integrated can improve safety at work on lifts after their implementation (MKC EN ISO 14987:2013, MKC EN 13015+A1:2009, MKC EN 81-80:2008, BS 7255:2012 etc.). However, under this heading will be presented only characteristic, most important and frequently applied protective measures and equipment for listed safety risks. Two types of protective equipment and means are necessary:

- The personal protective equipment, which protects the body from an injury;
- The means of fall protection, which prevents the employee from falling from heights.

The personal protective equipment that protects the body from an injury includes: safety helmet, safety shoes (anti-slip, anti-perforating, toe protection), working clothes (protect against cuts, dirt), required gloves (heavy duty gloves when doing manual handling, cut protective when performing repairs, using tools, etc., electrical gloves for work on potential live equipment, chemical gloves when using chemical products). Primary protection means: the balustrade or guardrail. Guardrail or balustrade shall be installed if a risk of fall exists as defined in the local regulation (for example, gap>30 cm and working area >2 m):

- On top of the car;
- On top of temporary working platform;
- On a scaffold;
- On edge of a building;
- In hoistway/shaft opening.

Secondary protection means: fall arrest system or fall restrain system. Fall Arrest System: STOPS the fall and includes:

- Body harness EN 361;
- Short lanyard EN 355 with shock absorber;
- Connectors to attach the harness EN 362.

Fall Restraint System: PREVENTS a fall and includes:

- Body harness EN 361 or Belt EN 358;

- Adjustable lanyard EN 355;
- Connectors to attach to harness EN362.

All fall protection equipment:

- Is individual: every employee exposed shall be provided with one;
- Must be formally inspected yearly by a competent person (supplier or any trained person);
- Must be checked before each use.

Hooking points. The car beam is generally considered as an adequate hooking point for the fall arrest system.

When working on the car:

- Attach after accessing;
- Detach before egressing.

This is to prevent still being attached when putting the unit back in service. Other situations: the life line. The life line shall be fixed to an adequate hooking point with the right capacity as per local regulation. The life line shall be protected against sharp edge. Use life line when working on: Temporary platform; On a car when ropes have been removed; On a car partially assembled, suspended by chain or hoisting device. A ladder when working on top of counterweight.

CONCLUSION

Application of few actual tools we already have, as standards, technical specifications, codes of practice, and other official documents and recognizing safety risks in working procedures and especially proper use of adequate protective means and personal protective equipment can lead to higher level of safety for workers in lift sector.

REFERENCES

- [1] Ebru Gemici-Loukas: General Assembly ELA Annual Conference 2018 - Lifts & Escalators in a Sustainable Future, 17 April 2018, Stockholm, <http://www.ela-aisbl.eu/index.php/infodesk/library/brochures>.
- [2] ELA European Lift Association, SNEL White Paper, ELA 2013, <http://www.ela-aisbl.eu/index.php/main-themes/safety>.
- [3] Michael McCann, PhD, CIH, "Deaths and Injuries Involving Elevators and Escalators", CPRW - The Center for Construction - Research and Training, Silver Spring, MD, USA, 2013.
- [4] Goran Sekovski, B. Stavreska, K. Tanevska: "Increasing Safety of Lifts, Escalators and Conveyors" (in Serbian), Proceedings 10th National Conference with International Participation –Tara 2013, Faculty of Technical Sciences, Novi Sad, Serbia, 2013 pp. 112-122.
- [5] NEII Safety Committee: "Field Employees' Safety Handbook for Elevators Industry", Elevator World, Inc. Mobile Alabama, 2015.
- [6] European Lift Association: ELA News e-Newsletter 2012-2018, <http://www.ela-aisbl.eu/news.htm>, ELA 2009-2018.
- [7] MKC EN 81-80:2008 Safety Rules for the Construction and Installation of Lifts – Existing Lifts – Part 80: Rules on Improvement of Safety of Existing Passenger Lifts and Lifts for Transport of Goods.
- [8] ELA Editing Team: "Basic Safety Practices For Lifts", ELA 2013, <http://www.ela-aisbl.eu/index.php/infodesk/library/brochures>.
- [9] Goran Sekovski: "Safety risks during installation, maintenance and use of lifts", Mechanical Engineering – Scientific Journal, Faculty of Mechanical Engineering, Skopje, Vol. 33, No. 3, 2015, pp. 233-240;

BIOGRAPHY of the first author

Goran Sekovski was born 25.12.1966 in Skopje, Macedonia. He received the diploma in mechanical engineering from the Ss. Cyril and Methodius University in Skopje, Faculty of Mechanical Engineering and the M.Sc. degree in Earthquake Engineering from Institute of Earthquake Engineering and Engineering Seismology (IZIIS) in Skopje at the same University. Since 1992, he has worked in Institute of occupational safety, fire protection and commodity inspections - Skopje on technical inspections of machine equipment, including vertical transportation equipment, on other OHS issues as consultancy, risk assessment and inspections of work equipment. From 2003, he is Managing director at the same company and from 2016 he establish Institute of Technical Inspection and Safety Engineering–ITI Skopje, dealing with OHS, Environmental protection and Technical inspection issues and he is General manager there.



NESREĆE I BEZBEDNOSNI RIZICI PRI MONTAŽI, ODRŽAVANJU I MODERNIZACIJI LIFTOVA

Goran Sekovski, Blagoja Bogoevski, Biljana Stavreska

Rezime: Vertikalni transport je najbezbedniji transport upređen sa ostalima, međutim, zbog enormnog broja liftova, starog voznog parka, posebno kod nas i u Evropi, velikog broja dnevnih korisnika i značajnog broja zaposlenih u ovom sektoru, dešavaju se nesreće sa teškim i fatalnim posledicama na radu na liftovima. Statistika u Makedoniji je takođe nepovoljna čak, možda i nepovoljnija nego evropski proseki. Adekvatna upotreba kolektivnih i ličnih zaštitnih sredstava i opreme je suštinske prirode. Predmet rada je potenciranje bezbednosnih rizika i zaštita radnika koji rade na montaži, održavanju i modernizaciju liftova u suglasnosti sa ELA brošuram.

Ključne reči: bezbednost liftova, montaža, održavanje, modernizacija, bezbednosni rizici, nesreće, lična i kolektivna zaštitna sredstva.

**JELENA
MALENOVIĆ-NIKOLIĆ¹
MARKO NIKOLIĆ²
MILENA MANČIĆ³
DEJAN KRSTIĆ⁴
GORAN JANAČKOVIĆ⁵**

¹University of Niš,
Faculty of Occupational Safety
¹malenovicznr@gmail.com
marko8989@live.com
milena.jovanovic@znrfak.ni.ac.rs
dekikrs@gmail.com
janackovic.goran@gmail.com

OCCUPATIONAL INJURIES IN MINING AND ENERGY COMPLEXES

Abstract: Mining and energy complexes belong to a branch of economy in which occupational injuries, sometimes with a fatal outcome, are a frequent occurrence. The statistical data presented in this paper reveal the incidence of occupational injuries and indicate the necessity of implementing preventive measures in mines and thermal power stations.

Key words: mining and energy complexes, occupational safety.

INTRODUCTION

Mining and energy complexes, which deal with exploitation and transformation of primary coal energy, belong to a branch of economy that requires substantial financial investment in occupational safety. It is necessary to classify occupational injuries in order to identify the causes of injuries and threats to physical and mental integrity of employees in mines and thermal power stations.

OCCUPATIONAL INJURIES

The already difficult position of workers is additionally burdened with a lack of modern tools and basic work conditions, which leads to a variety of occupational injuries, all of which are systematized differently. Pursuant to Article 7 of the Rules on the Content and Manner of Issuing Report Forms for Occupational Injuries and Professional Diseases ("Official Gazette of the Republic of Serbia", NO. 72/06, 84/06 – corr., and 4/16), it is the duty of the employer to submit reports on injuries. The injury report provide in Table 1 shows the number of occupational injuries in 2017, listed according to severity [1].

Table 1. Number of occupational injuries in 2017 by severity [1]

Occupational injuries	Number
Fatal occupational injuries	9
Severe occupational injuries	898
Severe commuting injuries	677
Minor injuries	8.628
Total:	10.213

The data provided in the table show that minor injuries are in the majority, but there were also nine fatal injuries [1], whereas there were eight fatal injuries in 2016 [2]. This suggests that there were serious oversights in the operation of the environmental protection departments in mining and energy complexes.



Figure 1. Occupational injury of a miner [3]

The number of occupational injuries was also analyzed in terms of the type of activity of employers (Table 2)

Table 2. Number of occupational injuries in 2017 by type of activity [1]

Activity	No.	%
01 – Construction	67	7.39
02 – Agriculture, forestry, and fishing	37	4.08
03 – Mining	36	3.97
04 – Processing industry	216	23.81
05 – Healthcare and social security	94	10.36
06 – Transport and storage	79	8.71
07 – Distribution of electricity, gas, steam, and air-conditioning (except the trade of gaseous fuels via pipeline networks)	71	7.83
08 – Water supply, wastewater management, waste disposal control, and the like	34	3.75
09 – Wholesale of motor vehicles and motorcycles	94	10.36
10 – Housing and food services	14	1.54
11 – Media and communication	15	1.65

12 – Finance and insurance	17	1.87
13 – Education	30	3.31
14 – Professional, scientific, innovation, and technical activities	14	1.54
15 – Administrative and auxiliary services	22	2.43
16 – State administration and defence, mandatory social insurance	42	4.63
17 – No data	25	2.76
Total:	907	100.00

Table 2 reveals that almost 4% of injuries occur in the ore mining sector, while almost 8% of injuries in 2017 were related to the distribution of electricity, gas, steam, and air-conditioning.

The data from Table 2 are represented graphically in Figure 2.

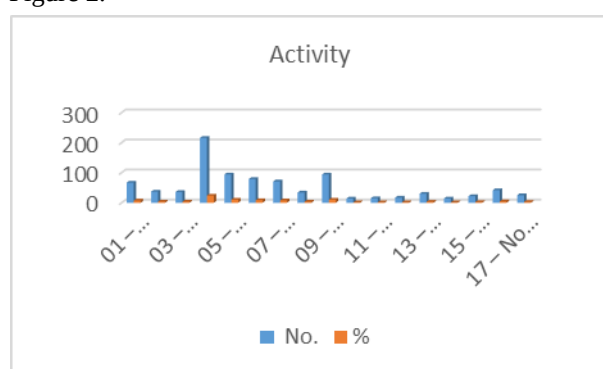


Figure 2. Number of occupational injuries in 2017 by type of activity

The graph in Figure 2 clearly shows that the activity pertaining to the distribution of electricity, gas, steam, and air-conditioning is in the fifth place overall regarding occupational injuries in 2017.

The number of occupational injuries in 2016 by type of activity is shown in Figure 3.

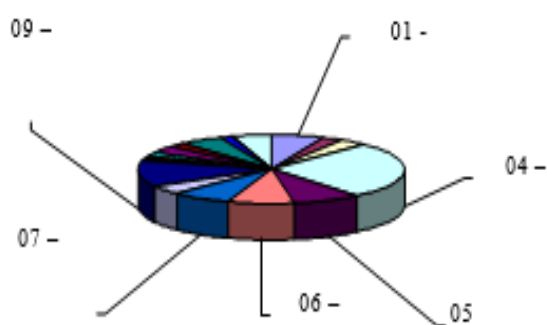


Figure 3. Number of occupational injuries in 2016 by type of activity

01-Construction 6,36, 04- Processing industry 26,59%, 05 – Processing and social security 8,43, , 06- Transport and storage 7,91%, 09-Distribution of electricity...7.26%, 09- Wholesale and repair of motor vehicleless 11,80%

The data show that the distribution of electricity, gas, steam, and air-conditioning also ranked fifth in 2016.



Figure 4. Electricity distribution as a cause of higher risk [3]

Table 3 provides the data for occupational injuries in 2017 according to the type of injury.

Table 3. Number of occupational injuries in 2017 by type of injury [1]

Injury type	No.	%
1. Fracture	539	59.43
2. Dislocation	34	3.75
3. Sprain	17	1.87
4. Other wounds	84	9.26
5. Superficial injury	32	3.53
6. Contusion and crush	29	3.20
7. Burn	13	1.43
8. Death, burns, or shock caused by electricity	9	0.99
9. Multiple types of injury	20	2.21
10. Damage due to a foreign object in the eye, nose, etc.	4	0.44
11. Internal injuries	3	0.33
12. Other	88	9.70
13. No data	35	3.86
Total	907	100.00

Table 3 reveals that electric shocks and electricity-related burns or deaths occurred in 0.99% of the cases in 2017. This piece of data does not refer solely to occupational injuries in mining and energy complexes. A previous analysis revealed that another ca. 8% of injuries were related to ore mining and energy transformation.



Figure 5. Fatal mining occupational injury [3]

The number of occupational injuries in 2017 by type of injury is represented graphically in Figure 6.

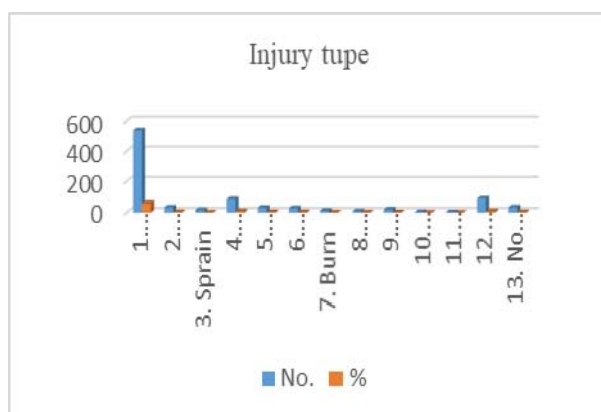


Figure 6. Number of occupational injuries in 2017 by type of injury

The graph above shows that injuries related to electric shock are not prevalent but are rather among the three least frequent occurrences in 2017.

An operations report [1] also includes data on the sources of injuries, as shown in Table 4.

Table 4. Number of occupational injuries in 2017 by source [1]

Injury source	No.	%
1. Facilities	25	2.76
1.1 Energy facilities	15	1.65
1.2 Technological facilities	1	0.11
1.3 Facilities for chemical and technological processes	8	0.88
1.4 Facilities and installations for storing materials	1	0.11
2. Machinery and devices	153	16.87

The data shown in Table 4 lead to a conclusion that energy facilities are ranked third according to the number of injuries for which they were the source, which amounts to 1.65% of the total number of injuries in 2017.

Table 5. Number of occupational injuries in 2016 by source [1]

Injury source	No.	%
1. Facilities	13	1.69
1.1 Energy facilities	9	1.17
1.2 Technological facilities	2	0.26
1.3 Facilities for chemical and technological processes	2	0.26
1.4 Facilities and installations for storing materials	79	10.25
2. Machinery and devices	13	1.69

In 2016 (Table 5), there were even fewer occupational injuries where the source was the operation of energy facilities.



Figure 6. Machines as the cause of injury [3]

Energy facilities and mines in Serbia mostly rely on outdated machinery and equipment, which makes them hazardous work environments.

CONCLUSION

Statistical data presented in the paper suggest the necessity of resolving issues in the field of coal energy exploitation and transformation and electricity distribution. A large number of mining accidents, worn-out equipment, lack of financing, spontaneous combustion of coal, and a lack of trained emergency response crews have resulted in an alarming situation.

REFERENCES

- [1] Annual Operations Report for 2017, Ministry of Labour, Employment, Veteran and Social Policy of the Republic of Serbia, Occupational Safety and Health Directorate, Belgrade, 2018
- [2] Annual Operations Report for 2016, Ministry of Labour, Employment, Veteran and Social Policy of the Republic of Serbia, Occupational Safety and Health Directorate, Belgrade, 2017
- [3] <https://www.srbijadanas.com/clanak/poginuo-rudar-urudniku-belo-brdo-kod-leposavica-18-11-2015>
- [4] <http://archive.almanar.com.lb/english/article.php?id=196887>

BIOGRAPHY of the first author

Jelena Malenović Nikolić was born in Knjaževac, Serbia, in 1974. She received a degree in environmental protection engineering and a Magister of technical sciences degree in the same field from the Faculty of Occupational Safety in Niš.



Doctoral dissertation: Environmental Management System Modelling in Mining and Energy Complexes, University of Belgrade, Faculty of Mining and Geology, Scientific field: Mining Engineering, Special Scientific field: Occupational Safety and Environmental Protection. Her main areas of research include energy, environmental protection and management, air quality, and environmental security. She works as an assistant professor at the Faculty of Occupational Safety in Niš, University of Niš.

POVREDE NA RADU U RUDARSKO-ENERGETSKIM KOMPLEKSIMA

Jelena Malenović-Nikolić, Marko Nikolić, Milena Mančić, Dejan Krstić, Goran Janačković

Rezime: Rudarsko-energetski kompleksi predstavljaju granu privrede koja dovodi do čestih povreda na radu, a nekad i do povreda na radu sa smrtnim ishodom. Predstavljeni statistički podaci ukazuju na dinamiku pojave povreda na radu i neophodnost primene preventivnih mera zaštite, u rudnicima i termoelektranama.

Ključne reči: rudarsko-energetski kompleksi, zaštita na radu.

SANDRA STANKOVIĆ¹
DEJAN VASOVIĆ²
LJILJANA TAKIĆ³

¹ Innovation Center of University of Niš

² University of Niš,
Faculty of Occupational Safety in Niš

³ University of Niš,
Faculty of Technology in Leskovac

¹sandra.stankovic.op@gmail.com

²dejan.vasovic@znrfak.ni.ac.rs

ljilja_t@yahoo.com

ECOSYSTEM SERVICES MANAGEMENT IN THE CONDITIONS OF EXTREME HYDROLOGICAL EVENTS

Abstract: *Services of nature, or ecosystem services are defined as benefits that ecosystems provide to people. They have a direct or indirect impact on the survival of the people as well as on the quality of working and living environment. There are four main groups of ecosystem services: supporting, provisioning, regulating and cultural. Due to the evident impact of extreme hydrological events on ecosystem services, the subject of this paper is aimed towards the analysis of links between ecosystem services management and extreme hydrological events.*

Key words: ecosystem services, extreme hydrological events, management, processes

INTRODUCTION

Hydrological, ecological and anthropogenic linkages represent the subject of contemporary scientific concerns. Hydrological and environmental risks are more pronounced in recent years which are confirmed by events such as the destructive cyclones, extreme drought and heavy rainfall. In these conditions, a specific problem is the management of ecosystem services, i.e. those components of ecosystems which have the character of resources that support the development of communities that use them, modify, or ultimately discard. This indicates that one of the greatest challenges of the 21st century, faced by the scientific community, is the management of primary ecosystem services, or distribution, quality and allocation of water resources, as well as the implementation of measures to adapt to new challenges. Everyone in the world depends completely on natural resources and the services that they provide, such as potable water, food, climate regulation, disease management, spiritual fulfilment, and aesthetic enjoyment.

Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, in order to meet their own needs. For the purposes of this paperwork, ecosystem represents living elements which interact with each other and their non-living environments – providing benefits, or services, to the world while the ecosystem services make human life possible by, for example, providing nutritious food and potable water, regulating disease and climate, supporting the pollination of crops and soil formation, and providing recreational, cultural and spiritual benefits. Despite an estimated value of \$125 trillion, these assets are not adequately accounted for in political and economic policy, which means there is insufficient investment in their protection and management [1]. There are four main groups of ecosystem services in relation to their importance for the people (Tab. 1).

Table 1. Main groups of ecosystem services [1]

Ecosystem services		
Supporting - nutrient cycling - soil formation - primary production	Provisioning	food
		fresh water
		biofuels
	Regulating	climate
		water cycle
		pollination
	Cultural	aesthetic
		spiritual
		recreational

These ecosystem services have a direct or indirect impact on the survival of the people and the quality of living and working environment.

LINKAGES BETWEEN ECOSYSTEM SERVICES AND EXTREME EVENTS

Due to the evident impact of global climate mechanisms on hydrological extremes, it is increasingly expecting phenomena such as an increase in the frequency of extremely high rainfall, the occurrence of severe storms, floods, droughts and other hydro-meteorological extremes, with special impact on both the environment and on the ability to meet the needs of society, in the future [2]. Most terrestrial and coastal ecosystems are associated with water, including groundwater. Ecosystems play a vital role in ensuring the flow and storage of fresh water. That is why it is essential to investigate the management of primary ecosystem services at the river basin level, especially during extreme hydrological phenomena [3]. In general, two major approaches can be distinguished:

1. Adjusting hydrological events such as drought, flood and climate change,

2. Qualitative and quantitative conservation of water resources, which optimizes the water consumption.

Extreme hydrological disaster beside to natural disaster can cause the disruption in the provision of ecosystem services, such as water supply [4,5]. In addition, periods of low and high water occurring in the zone of sanitary protection, or water intake can lead to interruptions in irrigation, but also worsen working conditions i.e. affects the procedures for the operation because in the process of obtaining drinking water needed to meet certain conditions in plants for water treatment [6]. These operating conditions can change significantly in the case of large and small water, where there is an increased risk (increased hazards at the water intake and at the sides, and for treatment of water) because it requires for example increased coagulant dosage.

The figure 2 depicts the strength of linkages between categories of ecosystem services and components of human well-being, and includes indications of the extent to which it is possible for socioeconomic factors to mediate the linkage.

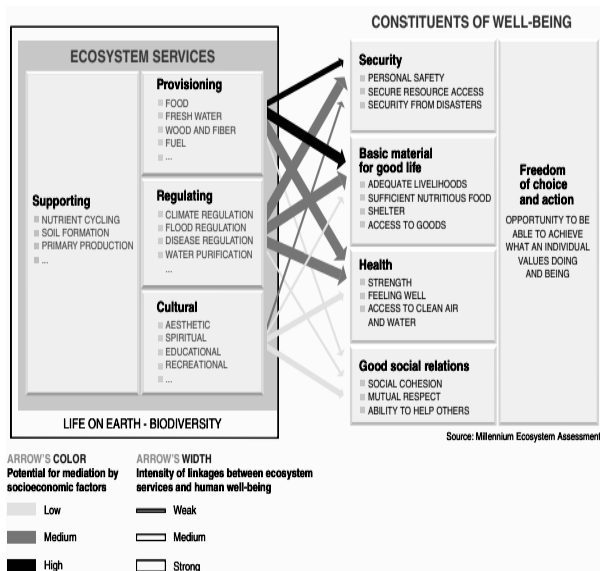


Figure 2. Illustration of linkages between ecosystem services and human well-being [7]

In addition to the influence of ecosystem services on human well-being depicted here, other factors including other environmental factors as well as economic, social, technological, and cultural factors influence human well-being, and ecosystems are in turn affected by changes in human well-being [8].

CONCEPTUAL FRAMEWORKS, STRATEGIES AND TOOLS

The sustainable use of ecosystem services is becoming increasingly important and prominent in the legislative agenda worldwide. At the international scale, first activities concerning hydrological extremes and their influence at the ecosystem services were derived at the global conference on disaster risk reduction held on

January, 2005. in the province of Hyogo, Japan. After this successful conference was adopted Hyogo Framework for Action 2005-2015: Developing Resilience of Nations and Communities to Disasters (HFA - Hyogo Framework for Action). This framework concludes that the losses caused by disasters increasing, with serious consequences for the survival, dignity and source of income of individuals, especially the poor, as well as hard earned development goals. The risk of disasters is increasingly global problem and its impact and actions in one region can affect the occurrence of risk in another region and vice versa. The risk of disaster is caused by the interaction of hazards with sensitive to physical, social, economic and ecological factors. This report clearly states the fact that events of hydro-meteorological origin constitute the vast majority of natural disaster [9].

The current framework for disaster risk reduction after 2015 was adopted at the Third World Conference on Disaster Risk Reduction, held in March 2015 in Sendai, Miyagi province, Japan (SFDRR - Sendai Framework for Disaster Risk Reduction). Since the adoption of the Hyogo Framework for action in 2005, as documented in national and regional reports on the progress of its implementation in practice, as well as other global reports, the Parties and relevant stakeholders have made progress in terms of reducing the risk of disasters at local, national and global levels, which led to a reduction in mortality in case of any emergency. Effective disaster risk management contributes to sustainable management of ecosystem services. The international mechanisms for strategic advice, coordination and development of disaster risk reduction partners, such as the Global Disaster Risk Reduction Platform and Regional Disaster Reduction Platforms, and other relevant international and regional forums for cooperation, have been helpful in the development policy of action, strategy, knowledge and learning together. The previous Hyogo Framework for Action was an important instrument for raising public awareness and institutions, encouraging the take-up of political obligations, as well as the focus and action of a large number of stakeholders at all levels [10].

At the national scale, first activities concerning ecosystem services were presented within the National strategy for sustainable use of natural resources and goods. This document promotes an integral environmental management system that ensures the realization of the human right to life and development in a healthy environment and a balanced relationship of economic and environmental development in the Republic of Serbia, as the management activities of natural values which are to be realized by planning sustainable usage and preserving their quality and diversity. Observed from the perspective of the process affecting the basic components of ecosystem services (in sense of time), or in relation to service determinants (in a spatial sense), the Strategy clearly defines the role and location of majority renewable natural resources and goods as ecosystem services. The Strategy

recognizes the fact that the use of natural resources is influenced by the elements of different sectoral policies that encompass several sectors:

- water-related policy,
- biodiversity policy,
- land protection policy,
- urban environment policy,
- economic policy,
- fiscal policy,
- transport policy,
- agricultural policy,
- energy and minerals policy, etc.

and thus emphasizes the interactivity of the relationship within the framework of the ecosystem services. By applying the Strategy for the sustainable use of natural resources and goods, a long-term framework of resource management policies within multiple sectors is formed, i.e. sustainable use of natural resources (an essential component of ecosystem services). It analyzes the current basis of natural resources of the Republic of Serbia, the ways of managing natural resources, and a set of goals and instruments of practical policy for implementation in the coming years, bearing in mind also the positions of the Republic of Serbia regarding European Union accession process. The strategy also focuses on increasing the efficiency of resource utilization (thus reducing the intensity of their use) and reducing the impact on the environment of economic resource use (the intensity of using environmental resources has been thoroughly analyzed as one of the determinants of ecosystem services). The Strategy recognizes natural resources as state property, the use of which is carried out under the conditions and in the manner provided by law. Managing natural resources requires making decisions and using tools that necessarily have a political dimension. The ability to accurately assess the capacity of an individual resource, the most efficient way of allocating it, and the willingness to take measures in case of deterioration in resource quality or exhaustion are essential for resource management efficiency and should be followed (in the case of non-renewable sources) by determining the optimum level of exploitation, allocation of the corresponding part of the yield from the exploitation of natural resources to other forms of capital in order to prevent a total reduction in capital and appropriate measures to prevent or compensate the negative external effects, especially those related to the negative impact on the environment [11].

At the other hand, first activities concerning hydrological extremes and their influence at the ecosystem services were presented within the National strategy for protection and rescue in emergency situations. Interactions in the environment - society system mostly has a stable character, whether it is a load that is continuously delivered by the ecosystem (ecosystem services - regulatory services), that is, supply services that have a life support role in the first place - life support services. Exception to regular

interactions are extraordinary - emergency circumstances, i.e. the situations where due to a certain incident (accident, catastrophe, extreme hydrological events...) a certain component of the environment or society and the created value in it is threatened. In such situations, in a short period of time, the disproportionately high burden in the sphere of the environment or society, which exceeds the capacities of the line organizations, results in the generation of disproportionately large loads. Strategic directions, specificity of response in such situations, as well as the roles of competent institutions are given in the National strategy for emergency response and rescue in emergency situations. The purpose of this strategy is to protect the life, health and property of citizens, the environment and the cultural heritage of the Republic of Serbia. The national strategy defines national coordination mechanisms and guidelines for disaster reduction programs caused by extreme natural phenomena and the protection, response and rehabilitation measures of consequences. The National strategy provides basis for the fulfillment of the recommendations of the European Union for the development of the national protection and rescue system. Reducing the risk of disasters requires a strong institutional base, which can be achieved through capacity building, good governance, promotion of appropriate program policies and legislation, facilitated information flow and effective coordination mechanisms. The National strategy should provide an efficient and effective system of protection and rescue through strategic areas that are aligned with abovementioned Hyogo and Sendai operating frameworks [12].

CONCLUSION

Extreme hydro-meteorological events affect all sectors of the economy and the environment, impacting people where they live and work. The deepening of our understanding about the nature of extreme and catastrophic natural and man-induced events, in particular hydrologic, becomes very topical. The challenge of reversing the degradation of ecosystems while meeting increasing demands for their services can be partially met under some scenarios, but these involve significant changes in policies, institutions, and practices that are not currently under way. There are many options which exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.

REFERENCES

- [1] Food and Agriculture Organization of the United Nations, Ecosystem Services & Biodiversity unit. Available at: <http://www.fao.org/ecosystem-services-biodiversity/en/>
- [2] D. Vasović, J. Malenović Nikolić, G. Janačković: "Evaluation and Assessment Model for Environmental Management under the Seveso III, IPPC/IED and Water Framework Directive", Journal of Environmental Protection and Ecology, 17 (1), 2016, pp. 356-365.
- [3] S. Stanković, D. Vasović, G. Janačković: „Modelling the Impact of Extreme Hydrological Phenomena on the Environmental Service Functions“, In the Book of abstracts of the 1st International Student Conference "Water for Sustainable Development", 2018, ISBN 978-606-598-663-3, pp. 102.
- [4] Law on Environmental Protection, "Official Gazette of the RS", No 135/2004, 36/2009, 36/2009, 72/2009, 43/2011, 14/2016 and 76/2018. In Serbian
- [5] Law on Water, "Official Gazette of the RS", No 30/2010, 93/2012 and 101/2016. In Serbian
- [6] Regulation on the drinking water quality, "Official Gazette of the RS", No. 44/99. In Serbian
- [7] Millennium Ecosystem Assessment "Ecosystems and Human Well-being", Synthesis report (Eds. José Sarukhán and Anne Whyte), World Resources Institute, 2005, Washington. ISBN 1-59726-040-1.
- [8] U.S. Global Change Research Program, U.S. Climate Resilience Toolkit. Available at: <https://toolkit.climate.gov/>
- [9] Hyogo Framework for Action (HFA) 2005-2015: Building the Resilience of Nations and Communities to Disasters. United Nations International Strategy for Disaster Reduction. 2005. Available at: <https://www.unisdr.org/we/coordinate/hfa>
- [10] Sendai Framework for Disaster Risk Reduction 2015-2030: Making the Difference for Poverty, Health and Resilience. United Nations International Strategy for Disaster Reduction. 2015. Available at: <https://www.unisdr.org/we/coordinate/sendai-framework>
- [11] National strategy for sustainable use of natural resources and goods, "Official Gazette of the RS", No 33/2012. In Serbian
- [12] National strategy for emergency response and rescue in emergency situations, "Official Gazette of the RS", No 86/2011. In Serbian

ACKNOWLEDGEMENTS

The presented research is a part of the projects "Development of new information and communication technologies, based on advances mathematical methods, with applications in medicine, telecommunications, power systems, protection of natural heritage and education" (III 44006) and "Research and development of energy efficient and environment friendly polygeneration systems based on renewable energy sources utilization" (III 42006), under the auspices of the Ministry of Education, Science and Technological Development, Republic of Serbia.

BIOGRAPHY of the first author

Sandra Stanković was born in Niš, Serbia, in 1991.

She received master diploma in environmental protection engineering, department for Communal System Management and he is currently enrolled on a third year of PhD studies in environmental engineering at the University of Nis, Faculty of Occupational Safety in Niš. Her main areas of research include, but not limited to smart water resources management, measures to climate change adaptations, extreme hydrological events, water security etc. She is working as a project assistant at the Innovation Center of University of Niš.



UPRAVLJANJE EKOSISTEMSKIM USLUGAMA U USLOVIMA EKSTREMNIH HIDROLOŠKIH POJAVA

Sandra Stanković, Dejan Vasović, Ljiljana Takić

Rezime: Usluge prirode, ili ekosistemske usluge su definisane kao pogodnosti koje ekosistemi pružaju ljudima. One imaju direktan ili indirektan uticaj na opstanak ljudi, kao i na kvalitet radne i životne sredine. Postoje četiri osnovne grupe ekosistemskih usluga: podržavajuće, uskuge snabdevanja, regulišuće i usluge od kulturnog značaja. Zbog činjenice da ekstremni hidrološki događaji imaju evidentan uticaj na ekosistemske usluge, cilj ovog rada je analiza veza između procesa upravljanja ekosistemskim uslugama i ekstremnih hidroloških pojava.

Ključne reči: ekosistemske usluge, ekstremni hidrološki događaji, upravljanje, procesi

BOJAN BIJELIĆ¹
MILENA STANKOVIĆ²
MIROLJUB GROZDANOVIĆ³

^{1,2,3}University of Niš,
Faculty of Occupational Safety

¹bojan.bijelic@znrfak.ni.ac.rs
²milena.stankovic@znrfak.ni.ac.rs
³mirko@junis.ni.ac.rs

THE IMPORTANCE OF HUMAN RELIABILITY ANALYSIS IN RISK ASSESSMENT PROCESS

Abstract: Human factor has significant effects on risks that can occur in any system. Better understanding of these effects is of a great importance for system's safety. The main purpose of this paper is to emphasize the role and importance of human reliability analysis in the risk assessment process. By giving an overview of historical development of human reliability analysis methods, with advantages and shortcoming for each generation of methods, this paper points out the need for further research in this area.

Key words: human factor, human error, human reliability analysis, risk assessment.

INTRODUCTION

Most of existing systems are to some degree influenced by a human factor. Humans are directly or indirectly involved either in creation, development, maintenance or work of systems, so they have a significant influence on systems' reliability. Reliability of technical systems shows a constant and steady growth in recent year due to technological progress and has reached a very high level. Due to this, the focus of reliability research has changed and the human reliability is now getting more and more attention. Therefore it's necessary to properly understand the influence of human factor on systems and determine the best ways to assess that influence. Involvement of human factor always brings a possibility of human errors; this issue can be dealt with either by fully eliminating the human factor, which is hardly achievable, or by reducing the possibility of human error [1]. The concept of human error may look, at first glance, as unnecessary to define, but it's exactly the opposite. There are some difficulties in explaining this concept and even some authors avoid giving an exact definition of this term. Some of the existing definitions are:

- "departure from acceptable or desirable practice on the part of an individual that can result in unacceptable or undesirable results" [2];
- "the failure to perform a stated task (or the performance of a forbidden action) that could result in disruption of scheduled operations or damage to property and equipment" [3];
- "human error as any member of a set of human actions that exceeds some limit of acceptability" [4];
- "an action that fails to meet some implicit or explicit criterion, but that definition begs the question of what is the criterion" [5];
- "any member of a set of human actions or activities that exceeds some limit of acceptability, i.e. an out of tolerance action [or failure to act] where the limits of performance are defined by the system" [6].

Risk can be defined as an effect of uncertainty of objectives [7]. Risk cannot be avoided and ignoring it can have serious consequences, therefore it is necessary to properly assess the risk and determine ways to manage it. Risk management represents a process in which organization based on the assessed risks takes appropriate measures to reduce potential hazards and their consequences as much as possible.

Very important tool for human reliability analysis are methods used in human error analysis. Historically, these methods have developed in three directions, according to which they are grouped into three generations. Practically, the development of each new generation of methods was an attempt to overcome observed deficiencies of the previous generation.

The primary goal of this is emphasizing the role and importance of human reliability analysis in the risk assessment process. By giving an overview of historical development of human reliability analysis methods, with advantages and shortcoming for each generation of methods, this paper emphasizes the need for further research in this area.

DEVELOPMENT OF HUMAN RELIABILITY ANALYSIS METHODS

Serious industrial accidents happening worldwide, that had a serious number of casualties and for which human factor has been determined as a significant contributor, expedited the development of human reliability analysis methods. The need for creating good quality tools and methods for thorough analysis of human factors lead to a development of significant number of different methods and each of those methods gave a certain contribution. Development of human reliability analysis methods started at the beginning of 1970s, most of the methods were developed in the mid-1980s, for so called first generation methods, and in the mid-1990s, for second generation methods (Figure 1). A large number of methods were developed primarily for use in nuclear power plants and then later modified for use in other industrial areas.

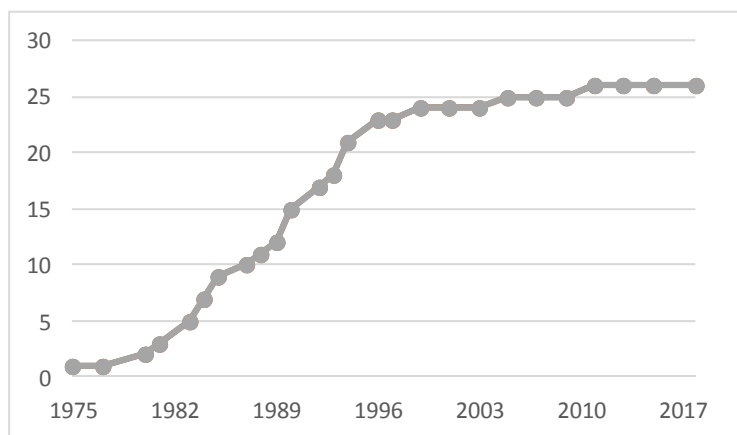


Figure 1. Cumulated number of HRA methods (modified by [8])

First generation of human reliability analysis methods were developed under the great influence of probabilistic risk assessment and these methods viewed humans simply as mechanical components of systems - they used the so called mechanistic approach. The majority of existing methods belong to this generation and are representing one of the first attempts to involve the human factor in the risk assessment process. Some of the most important methods of first generation are [1, 8, 15, 16, 17]:

- Technique for Human Error Rate Prediction (THERP),
- Human Error Assessment and Reduction Technique (HEART),
- Accident Sequence Evaluation Program Human Reliability Analysis Procedure (ASEP),
- Simplified Plant Analysis Risk Human Reliability Assessment (SPAR-H),
- Human Reliability Management System (HRMS),
- Justification of Human Error data Information (JHEDI),
- Paired Comparison (PC),
- Absolute Probability Judgment (APJ),
- Success Likelihood Index Method/Multi-Attribute Utility Decomposition (SLIM/MAUD),
- Human Cognitive Reliability (HCR), etc.

The main purpose of first generation methods is to identify human error and quantify the probability of human error by focusing on the behavioural aspect of the human performance. The main disadvantages are neglecting the impact of the environment, organizational factors and cognitive processes in which human error occurs. Although methods of this generation have been criticized for their view on human error, they are also most applied and validated in practice thanks to their simplicity and quantitative aspect.

Attempts to overcome the shortcomings of first generation methods lead to the development of second generation methods in the beginning of the 1990s. The second generation deviates from the mechanistic approach in an effort to better understand the context in

which human error occurs. Methods of this generation go from a quantitative approach, typical for probabilistic risk assessment, to a qualitative approach for the estimation of human error [9]. Taking into account the cognitive aspect and the cause of the error, instead of focusing on frequency of human error like first generation methods, helps us to better understand the background behind a human error. Second generation methods are [1, 8, 15, 16, 17]:

- A Technique for Human Event Analysis (ATHEANA),
- Cognitive Reliability and Error Analysis Method (CREAM),
- Connectionism Assessment of Human Reliability (CAHR),
- Méthode d'Evaluation de la Réalisation des Missions Opérateur pour la Sécurité (Assessment method for the performance of safety operation (MERMOS)), etc.

The main characteristic of second generation methods is focusing on context in which task is performed. The main disadvantages are lack of better inclusion of human cognition and heavy reliance on expert judgment [10]. Most of the second generation methods are still not validated in practice.

The development of third generation of human reliability analysis methods starts at the early 2000s. These methods are basically modified methods of first generation based on experience gathered from methods of first and second generation. Currently there are only two methods belonging to this generation: Nuclear Action Reliability Assessment (NARA) and Railway Action Reliability Assessment (RARA). NARA is an improved version of HEART, a first generation method, created especially for application in nuclear power plants, while RARA is modified version of NARA for application in railways transportation.

HUMAN ERROR ASSESSMENT AS AN ELEMENT OF RISK ASSESSMENT

Industrial accidents, such as Bhopal, Three Mile Island and Chernobyl, lead to increased interest in research of impact of human error, i.e. impact of human reliability on systems.

Simple framework for understanding human error (Figure 2) consists of three parts as follows:

- context in which human error happens;
- human fallibility;
- barriers that can prevent human error [11].

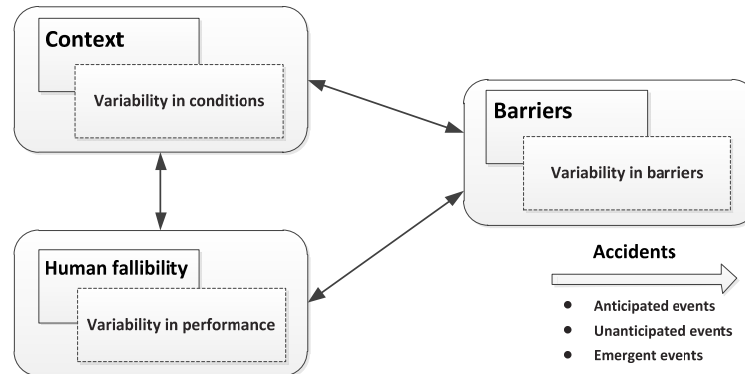


Figure 2. Framework for understanding human error and its potential for adverse consequences [11]

Since human factor is often found as the cause for a vast number of accidents, it is clear that it must be included in the risk assessment process [8]. Risk assessment is a process that consists of identifying and analysing hazards while determining the severity of possible consequences and the probability of occurrence of an unwanted event [12]. Risk assessment is an essential part of any risk management process and cannot be complete without considering the human

factor. This whole concept called human reliability analysis aims to analyse the influence that humans have on system's functionality and easily fits into the framework of risk assessment (Figure 3). Risk assessment that includes a human reliability analysis allows analysts to have an overview of all risks in the system and to determine the role that human factor plays in the emergence of risks [13].

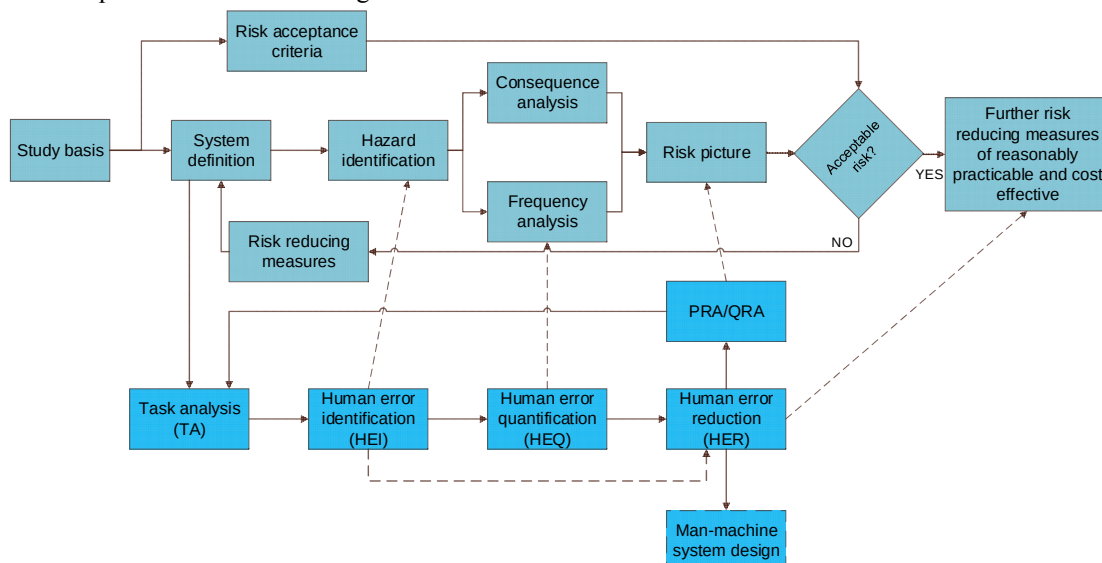


Figure 3. The Human Reliability Analysis Procedure in Risk Analysis [14]

Human reliability analysis was created for use in probabilistic risk analysis and has found its purpose for both assessing the risk of human error and as a tool for reducing the system's vulnerability [8]. In order to incorporate the result of human reliability analysis in risk analysis it is necessary to present those results in a quantitative form, and for this it is the best to calculate the probability of human error – HEP.

CONCLUSION

Research of human factor is a necessity especially in the light of increasing automation of production systems. Human error is not something that can be simply eliminated. Therefore it's necessary to find way to manage risks brought by the human factor, as an inevitable part of any system. Risk assessment is the first step toward the successful risk management. Unfortunately most current views on human reliability

are oversimplified. Human reliability cannot be properly analysed without fully understanding the context in which work is performed. Inadequate analysis of human factor in process of risk assessment is often caused by assessor's ignorance i.e. his lack of knowledge in area of human reliability analysis. Slowdown in the development of human reliability analysis methods is evident in recent years. Clear indication of this is the existence of only two methods of third generation that emerged in the 21st century, which are actually modifications of first generation methods and do not represent significant innovations. There is plenty of room for new research in this area and for development of new methods that will assess the analysis of human reliability not only from the engineering aspect, but also from the aspect of psychology and ergonomics.

REFERENCES

- [1] Kirwan, B. (1994). *A guide to practical human reliability assessment*. CRC press. London.
- [2] Bea, R. G. (1998). Human and organization factors: engineering operating safety into offshore structures. *Reliability Engineering & System Safety*, 61.1-2, pp. 109-126.
- [3] Dhillon, B. S. (2012). *Safety and human error in engineering systems*. CRC Press, London.
- [4] Swain A. D. and Guttman H. E. (1983). *Handbook of human reliability analysis with emphasis on nuclear power plant applications*. US Nuclear Regulatory Commission, Washington, D.C., Tech. Rep.
- [5] Sheridan, T. B. (2008). Risk, human error, and system resilience: fundamental ideas. *Human factors* 50.3, pp. 418-426.
- [6] Swain, A. D. (1989). *Comparative evaluation of methods for human reliability analysis*. No. GRS--71. Gesellschaft fuer Reaktorsicherheit mbH (GRS).
- [7] International Organization for Standardization. (2009). *ISO 31000: Risk Management: Principles and Guidelines*.
- [8] Hollnagel, E. (2005). Human reliability assessment in context. *Nuclear Engineering and Technology*, 37.2, pp. 159-166.
- [9] Baziuk P. A., Rivera S.S., and McLeod J. N. (2016). *Fuzzy Human Reliability Analysis: Applications and Contributions Review*. Advances in Fuzzy Systems.
- [10] Griffith, C. D. and Sankaran M. (2011). Inclusion of fatigue effects in human reliability analysis. *Reliability Engineering & System Safety*, 96.11, pp. 1437-1447.
- [11] Sharit, J. (2012). *Human error and human reliability analysis*. Handbook of human factors and ergonomics, pp. 734-800.
- [12] American Society of Safety Engineers (2011). *ANSI/ASSE Z590.3-2011 - Prevention through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes*. Des Plaines, IL.
- [13] Gertman, D. et al. (2005). *The SPAR-H human reliability analysis method*. US Nuclear Regulatory Commission.
- [14] Stojiljkovic, E., Glisovic, S., Golubovic, T. (2014). Risk Assessment of Industrial and Environmental Monitoring Systems – The Significance of Human Reliability Analysis. *Facta Universitatis, Series: Working and Living Environmental Protection*, 11 (2), 145 – 152.
- [15] Stojiljkovic, E., Bijelic, B., Grozdanovic, M., Radovanovic, M., Djokic, I. (2018). "Pilot Error In Process Of Helicopter Starting". *Aircraft Engineering and Aerospace Technology*, 90 (1), 158-165.
- [16] Stojiljkovic, E., Glisovic, S., Grozdanovic, M. (2015). The Role of Human Error Analysis in Occupational and Environmental Risk Assessment: A Serbian Experience. *Human and Ecological Risk Assessment: An International Journal*, 21 (4), 1081-1093.
- [17] Stojiljkovic, E., Janackovic, G., Grozdanovic, M., Savic, S., & Zunjic, S. (2016). Development and Application of a Decision Support System for Human Reliability Assessment – A Case Study of an Electric Power Company. *Quality and Reliability Engineering International*, 32 (4), 1581-1590.

BIOGRAPHY

Bojan Bijelić was born in Skopje, R. Macedonia, in 1985. He graduated in the field of Occupational Safety from University of Nis and currently is on Ph.D. studies in the area of Occupational Safety Engineering. He is currently working as a teaching assistant at Faculty of Occupational Safety in Nis.



ZNAČAJ ANALIZE LJUDSKE POUZDANOSTI U PROCESU PROCENE RIZIKA

Bojan Bijelić, Milena Stanković, Miroljub Grozdanović

Rezime: Ljudski faktor ima značajan uticaj na rizike koji mogu da se jave u sistemu. Bolje razumevanje ovih uticaja je od izuzetne važnosti za bezbednost sistema. Osnovni cilj ovog rada je da istakne ulogu i značaj analize ljudske pouzdanosti u procesu procene rizika. Davanjem pregleda istorijskog razvoja metoda za analizu ljudske pouzdanosti, sa prednostima i nedostacima svake generacije metoda, ovaj rad ukazuje na potrebu za daljim istraživanjem u ovoj oblasti.

Ključne reči: ljudski faktor, ljudska greška, analiza ljudske pouzdanosti, procena rizika.

DEJAN RISTIĆ¹
MILAN BLAGOJEVIĆ²
LUTVO HAZNADAREVIĆ³

^{1,2}University of Niš,
Faculty of Occupational Safety,
Serbia

³Logos Center, College Mostar,
Bosnia and Herzegovina

¹dejan.ristic@znrfak.ni.ac.rs

²milan.blagojevic@znrfak.ni.ac.rs

³hlutvo@yahoo.com

RELIABILITY ANALYSIS OF FIRE DETECTION AND ALARM SYSTEMS

Abstract: *The aim of this paper is to determine the reliability of fire detection and alarm systems using fault tree quantitative analysis. The analysis is performed using analytical and matrix procedures for determining minimal cut sets and minimal path sets. The quantitative analysis focuses on a system installed in a production hall, which contains a heat detector, a smoke detector, and a manual fire alarm. The top event analyzed was the event "the fire detection and alarm system has not detected a fire". Based on the analysis and the evaluation of importance of the minimal cut sets, we were able to conclude that events such as line interruption, manual fire alarm push-button failure, and short circuits are the most significant events as they are the biggest contributors to fire detection and alarm system failure.*

Key words: reliability, fault tree analysis, minimal cut set, minimal path set, fire detection and alarm system.

INTRODUCTION

According to SRPS A.A2.005 (1986), reliability is the ability of a product to perform its required function under specified conditions over a specified time period. It is expressed through probability of faultless operation. A system failure refers to the incompatibility of a specific system's function with the function it provides to the user. In terms of reliability, failure refers to the inability of a product (a part, an assembly, a subsystem, a system, or a device) to perform its required function; alternatively, it refers to situations when specific product features fall outside a specified domain that constitutes satisfactory functioning of a product (SRPS A.A2.005:1986).

With regard to safety systems, as specific technical systems that maintain the safety of another system, there are no differences in the definition of failure in terms of reliability and safety. Namely, any disturbance of safety system functioning (failure in terms of reliability) implies the loss of ability to reduce risk of the system being protected (failure in terms of safety). This is why reliability is understood as a fundamental performance of any safety system.

The chief advantage of predicting reliability of complex systems does not lie in the absolute predicted numerical value but in the possibility to repeat the assessment for different maintenance time, different design redundancies, and different values of component failure frequency. This became feasible with the appearance of computers, e.g. with fault tree analysis software, which allows fast repetition of predictions. Thus, it is possible to make an assessment based on relative predictions with a higher degree of certainty compared to absolute values. In addition, the complexity of modern design products and systems results in the system failure not always being a consequence of simple failures of components and the system. The factors influencing system unreliability are the following: failure due to software elements, failure due to human factor or operative documents, failure

due to weather conditions, standard manners of failure, and the like.

Fire detection and alarm systems are fairly efficient with regard to warning people about a fire. The primary purpose of fire detection and alarm systems is to warn the user as soon and as reliably as possible about a fire breakout in order to avoid human casualties and protect property. Fire detection and alarm systems are supposed to detect fires in their earliest stage of development, immediately after the process of uncontrolled combustion is initiated (Blagojević, 2015).

Manual fire alarms are a necessary part of a fixed fire alarm installation, regardless of whether the system contains an automatic fire alarm or not. Since manual alarms are activated by people, the signal originating from such alarms is considered as a reliable notification of the occurrence of a fire and is not additionally verified by the system (Blagojević, 2015).

Constant increase of heat release is characteristic of the early stages of fire development, which is accompanied by temperature increase in the room. Heat detection in fire alarm systems can be performed with or without measuring, and due to simplicity of construction, heat detectors can be either point detectors or linear detectors, depending on the area they cover. With any detector type, only two conditions for generating the alarm signal are used: the predefined temperature value is exceeded or the temperature change rate is exceeded (Blagojević, 2015).

The fact that most fires are preceded by smoke, and that flames and temperature change occur later, is responsible for the extensive use of smoke detectors in fire alarm systems. Smoke detectors are the most efficient in situations where the composition of combustible material is such as to create smaller or bigger quantities of smoke at the very beginning of a fire. Their construction is based on two principles of smoke detection – radioactive and optical, only the detectors with a radioactive element are not in use anymore. They are produced as point or linear

detectors, but there are special smoke detector types for special purposes (Blagojević, 2015).

METHODS OF SYSTEM RELIABILITY ANALYSIS

Literature provides numerous examples of methods for system reliability analysis, which mostly pertain to systems with a simple topology. One such example is the network reduction method and the fault tree method (Billinton, Allan, 1992). The essence of network reduction lies in the reduction of the whole system to a single equivalent element, by systematically combining appropriate series and parallel branches of the reliability network. Finally, reliability of the remaining equivalent element is equal to the reliability of the original system.

One of the most important methods of determining the reliability of complex networks is based on minimal cut and path sets (Hoyland и Rausand, 1994).

The network in Figure 1 represents the use of minimal cut and path sets for system reliability evaluation. The system will function if there is one of the minimal paths (A, C) or (B, D) or (A, E, D) or (B, E, C).

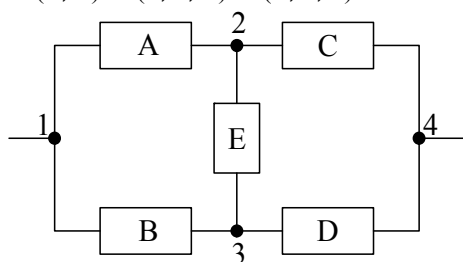


Figure 1. Bridge structure reliability network

Reliability network is widely used to determine the reliability of fire detection and alarm systems as well as fire suppression systems.

Qualitative analysis is the determination of minimal cut sets and minimal path sets. Minimal cut sets and minimal path sets represent two equivalent sources of information on the state of the system.

Minimal cut sets are those sets of events that are necessary for the occurrence of the top event. A cut is minimal when it does not contain any other cuts itself.

A minimal path set is the smallest set of events, which must not occur if the top event is to be avoided, i.e. minimal path sets are the smallest sets of events, on which reliable functioning of the system (absence of the top event) is dependent. A path is minimal when it does not contain any other paths itself.

Initial derivation can be non-minimal or minimal, so that each cut set containing a minimal cut set is not minimal. Table 1 shows these differences: minimal sets can only include sets 1, 3, and 6, because they do not contain other cut sets. Set 2 is non-minimal because it contains set 3. Set 5 is also non-minimal, because it contains sets 1, 3, and 6 (Savić, Grozdanović, Stojiljković, 2014).

Table 1. Minimal cut sets

Set	Cut set	Minimal cut set
1	AB	Yes
2	ACD	No
3	AD	Yes
4	CDE	No
5	ABDE	No
6	DE	Yes

Cut sets shown in Table 1 can be represented as causes of system failure by means of Boolean *OR* operator, whereby Boolean algebra theorems and axioms are used (Table 2):

$$AB + ACD + AD + CDE + ABDE + DE = \\ AB(1 + DE) + DE(1 + C) + AD(1 + C) = \\ AB + DE + AD(1)$$

Table 2. Boolean algebra theorems and axioms

Boolean algebra theorems	
$a + 0 = a$	$a \cdot \bar{a} = 0$
$a + 1 = 1$	$a + \bar{a} = 1$
$a \cdot 0 = 0$	$a + ab = a$
$a \cdot 1 = a$	$a(a + b) = a$
$a \cdot a = a$	$a + \bar{a}b = a + b$
$a + a = a$	
Boolean algebra axioms	
$a \cdot b = b \cdot a$	Commutative law
$a + b = b + a$	
$(a + b) + c = a + (b + c)$	Associative law
$= a + b + c$	
$(ab)c = a \cdot (bc) = a \cdot b \cdot c$	Distributive law
$a(b + c) = ab + ac$	

When creating a minimal cut set using a matrix procedure, the following steps should be taken:

- Ignore all tree elements except the basic ones;
- Begin immediately below the top event, assign a unique letter and/or number to each event;
- Proceed downward 'step by step';
- Create a matrix using letters and/or numbers. The letter representing the top event gate becomes the initial matrix input. Subsequent steps include:
 - replacing the letter of every *AND* gate with a letter/number for all gates/events serving as its inputs and representing this horizontally in matrix rows;
 - replacing the letter of every *OR* gate with a letter/number for all gates/events serving as its inputs and representing this vertically in matrix columns. Each newly-formed row has to contain all other inputs as in the initial row.
- The final matrix contains only the numbers representing initial events. Each row of this matrix is a cut set. Eliminate by verification every row containing all elements from a lower-row set. Also, delete redundant (repeated) elements in rows and

repeating rows. The remaining rows constitute a minimal cut set.

Based on the created minimal cut set, it is possible to create an equivalent fault tree, as shown in Figure 2. Fault trees have two event levels: the primary event level connected by *AND* gates and the event level directly leading to the top event, connected by an *OR* gate.

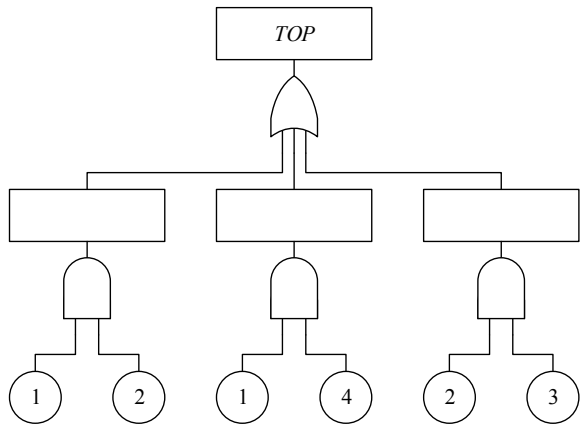


Figure 2. Equivalent fault tree created based on minimal cut sets (Clemens, 1993)

Cut sets can be used to establish the vulnerability to shared causes and for qualitative evaluation of the importance of minimal cut sets and events.

The procedure for creating a minimal path set involves the following steps (Savić, Grozdanović, Stojiljković, 2014):

- Replace all *AND* gates with *OR* gates and all *OR* gates with *AND* gates.
- Replace all events with opposite events.
- Apply same procedure as in creating the cut set matrix.
- The procedure yields path sets, specifically minimal path sets.

QUALITATIVE FAULT TREE ANALYSIS OF A FIRE DETECTION AND ALARM SYSTEM

A fire detection and alarm system comprises the following components: monitoring and control device, signalling and alarm elements, manual and automatic detectors and alarms, and auxiliary devices. The performed qualitative fault tree analysis of a fire detection and alarm system is represented using minimal cut sets and minimal path sets.

The analysis was performed for a fire detection and alarm system installed in a production hall, comprising heat and smoke detectors and a manual fire alarm. The top event (T) is “the fire detection and alarm system has not detected a fire”. The top event is preceded by event A (no signal from automatic detectors) and event B (no signal from manual alarms), which can be the result of human error (1) or push-button failure (2). Event A is caused by heat detector (C) and smoke detector (D) failure. Heat detector failure (C) can be

caused by an interruption in the switch signal (E) (due to line interruption (3) or inertness (4)), central signal interruption (F), and signal interruption through the installation (G). Central signal interruption (F) occurs due to central software failure (7), central hardware failure (8), and power supply failure (I), which can be caused by the interruption of the main (9) and auxiliary (10) power supply. Signal interruption through the installation (G) is due to line interruption (3) and a short circuit (6). Smoke detector failure (D) can be due to central signal interruption (F), signal interruption through the installation (G), and signal interruption from the detectors and alarms (H), which in turn can be due to line interruption (3) and poor calibration (5) (Ristić, Blagojević, Krstić, Krstić).

Figure 3 shows a fault tree of a fire detection and alarm system, where all events are represented by numbers or letters, depending on whether they are primary or intermediate events.

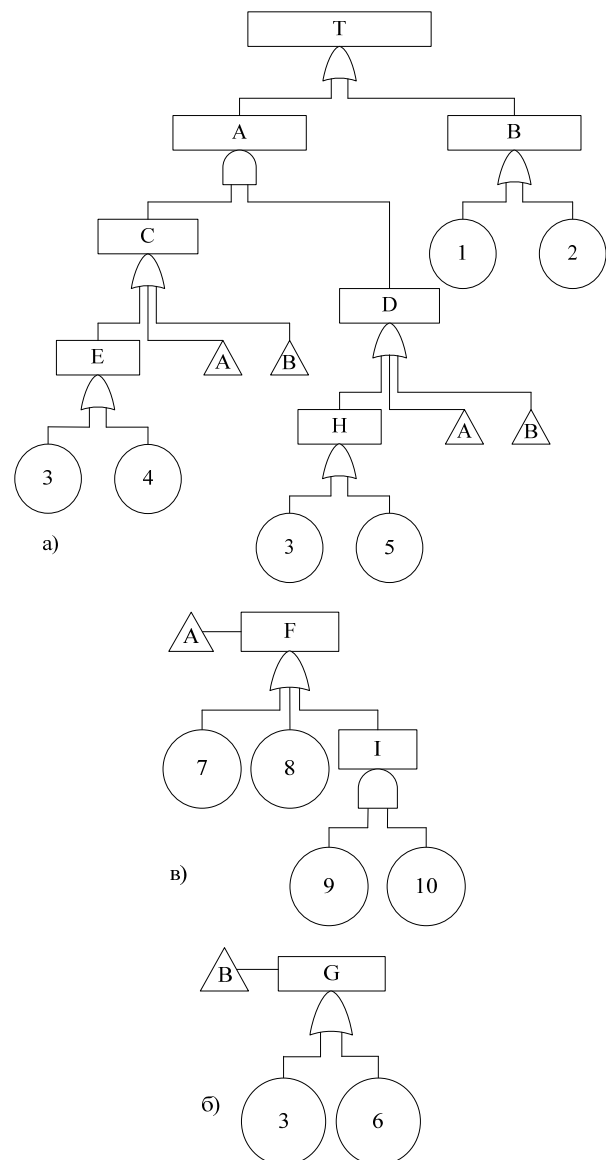


Figure 3. Fault tree of a fire detection and alarm system for qualitative analysis

Figure 4 shows the creation of minimal cut sets using a matrix procedure for a portion of the fault tree of a fire detection and alarm system.

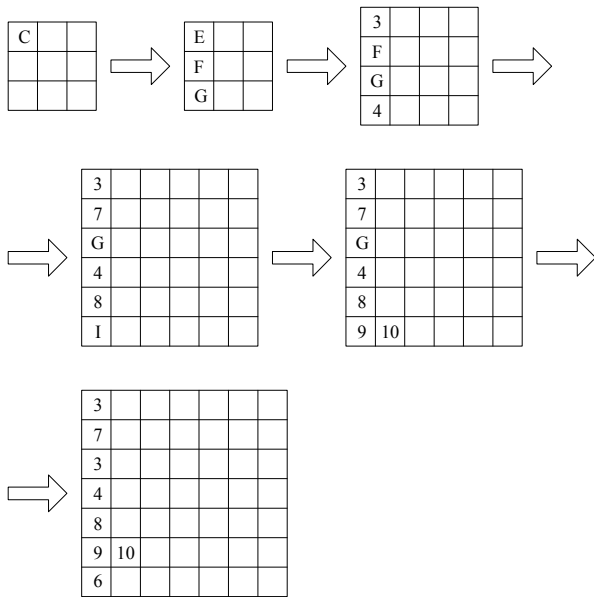


Figure 4. Creation of minimal cut sets using a matrix procedure

Creation of a minimal cut set using Boolean algebra demonstrates that the failure of specific elements, or specific individual events (“line interruption”, “inertness”, “human error”, “push-button failure”, “poor calibration”, “short circuit”, “central software failure”, “central hardware failure”), can cause overall system failure.

$$T = A + B$$

$$A = C \cdot D$$

$$B = 1 + 2$$

$$C = E + F + G$$

$$D = H + F + G$$

$$E = 3 + 4$$

$$H = 3 + 5$$

$$F = 7 + 8 + I$$

$$G = 3 + 6$$

$$I = 9 \cdot 10$$

$$F = 7 + 8 + 9 \cdot 10$$

$$D = 3 + 5 + 7 + 8 + 9 \cdot 10 + 3 + 6$$

$$C = 3 + 4 + 7 + 8 + 9 \cdot 10 + 3 + 6$$

$$A = (3 + 4 + 7 + 8 + 9 \cdot 10 + 3 + 6) \cdot (3 + 5 + 7 + 8 + 9 \cdot 10 + 3 + 6)$$

$$A = 3 \cdot 3 + 3 \cdot 5 + 3 \cdot 7 + 3 \cdot 8 + 3 \cdot 9 \cdot 10 + 3 \cdot 3 + 3 \cdot 6 + 4 \cdot 3 + 4 \cdot 5 + 4 \cdot 7 + 4 \cdot 8 + 4 \cdot 9 \cdot 1 + 4 \cdot 3 + 4 \cdot 6 + 7 \cdot 3 + 7 \cdot 5 + 7 \cdot 7 + 7 \cdot 8 + 7 \cdot 9 \cdot 10 + 7 \cdot 3 + 7 \cdot 6 + 8 \cdot 3 + 8 \cdot 5 + 8 \cdot 7 + 8 \cdot 8 + 8 \cdot 9 \cdot 10 + 8 \cdot 3 + 8 \cdot 6 + 9 \cdot 10 \cdot 3 + 9 \cdot 10 \cdot 5 + 9 \cdot 10 \cdot 7 + 9 \cdot 10 \cdot 8 + 9 \cdot 10 \cdot 9 \cdot 10 + 9 \cdot 10 \cdot 3 + 9 \cdot 10 \cdot 6 + 3 \cdot 3 + 3 \cdot 5 + 3 \cdot 7 + 3 \cdot 8 + 3 \cdot 9 \cdot 10 + 3 \cdot 3 + 3 \cdot 6 + 6 \cdot 3 + 6 \cdot 5 + 6 \cdot 7 +$$

$$+ 6 \cdot 8 + 6 \cdot 9 \cdot 10 + 6 \cdot 3 + 6 \cdot 6$$

$$A = 3 + 3 \cdot 5 + 3 \cdot 7 + 3 \cdot 8 + 3 \cdot 9 \cdot 10 + 3 \cdot 6 + 4 \cdot 3 + 4 \cdot 5 + 4 \cdot 7 + 4 \cdot 8 + 4 \cdot 9 \cdot 10 + 4 \cdot 6 + 7 \cdot 3 + 7 \cdot 5 + 7 \cdot 7 + 7 \cdot 8 + 7 \cdot 9 \cdot 10 + 7 \cdot 6 + 8 \cdot 3 + 8 \cdot 5 + 8 \cdot 7 + 8 \cdot 8 + 8 \cdot 9 \cdot 10 + 8 \cdot 6 + 9 \cdot 10 \cdot 3 + 9 \cdot 10 \cdot 5 + 9 \cdot 10 \cdot 7 + 9 \cdot 10 \cdot 8 + 9 \cdot 10 + 9 \cdot 10 \cdot 6 + 3 + 3 \cdot 5 + 3 \cdot 7 + 3 \cdot 8 + 3 \cdot 9 \cdot 10 + 3 \cdot 6 + 6 \cdot 3 + 6 \cdot 5 + 6 \cdot 7 + 6 \cdot 8 + 6 \cdot 9 \cdot 10 + 6$$

$$A = 3 + 3 \cdot 5 + 3 \cdot 7 + 3 \cdot 8 + 3 \cdot 9 \cdot 10 + 3 \cdot 6 + 4 \cdot 3 + 4 \cdot 5 + 4 \cdot 7 + 4 \cdot 8 + 4 \cdot 9 \cdot 10 + 4 \cdot 6 + 7 \cdot 5 + 7 \cdot 7 + 7 \cdot 8 + 7 \cdot 9 \cdot 10 + 7 \cdot 6 + 8 \cdot 5 + 8 \cdot 7 + 8 \cdot 9 \cdot 10 + 8 \cdot 6 + 9 \cdot 10 \cdot 5 + 9 \cdot 10 + 9 \cdot 10 \cdot 6 + 6 \cdot 5 + 6$$

$$A = 3 + 3 \cdot 4 + 3 \cdot 5 + 3 \cdot 7 + 3 \cdot 8 + 3 \cdot 9 \cdot 10 + 3 \cdot 6 + 4 \cdot 5 + 7 \cdot 4 + 7 \cdot 5 + 7 \cdot 7 + 7 \cdot 8 + 7 \cdot 9 \cdot 10 + 7 \cdot 6 + 8 \cdot 4 + 8 \cdot 5 + 8 \cdot 7 + 8 \cdot 9 \cdot 10 + 8 \cdot 6 + 9 \cdot 10 \cdot 4 + 9 \cdot 10 \cdot 5 + 9 \cdot 10 + 9 \cdot 10 \cdot 6 + 6 \cdot 4 + 6 \cdot 5 + 6$$

$$A = 3 \cdot (1 + 4 + 5 + 7 + 8 + 9 + 10 + 6) + 4 \cdot 5 + 7 \cdot (4 + 5 + 1 + 8 + 9 + 10 + 6) + 8 \cdot (4 + 5 + 1 + 9 + 10 + 6) + 9 \cdot 10 \cdot (4 + 5 + 1 + 6) + 6 \cdot (4 + 5 + 1)$$

$$A = 3 + 4 \cdot 5 + 6 + 7 + 8 + 9 \cdot 10$$

$$T = 3 + 4 \cdot 5 + 6 + 7 + 8 + 9 \cdot 10 + 1 + 2$$

$$T = 1 + 2 + 3 + 4 \cdot 5 + 6 + 7 + 8 + 9 \cdot 10$$

Analytical determination of minimal path sets for a fire detection and alarm system is provided below.

$$T = A \cdot B$$

$$A = C + D$$

$$B = 1 \cdot 2$$

$$C = E \cdot F \cdot G$$

$$D = H \cdot F \cdot G$$

$$E = 3 \cdot 4$$

$$H = 3 \cdot 5$$

$$F = 7 \cdot 8 \cdot I$$

$$G = 3 \cdot 6$$

$$I = 9 + 10$$

$$F = 7 \cdot 8 \cdot (9 + 10) = 7 \cdot 8 \cdot 9 + 7 \cdot 8 \cdot 10$$

$$D = 3 \cdot 5 \cdot (7 \cdot 8 \cdot 9 + 7 \cdot 8 \cdot 10) \cdot 3 \cdot 6$$

$$C = 3 \cdot 4 \cdot (7 \cdot 8 \cdot 9 + 7 \cdot 8 \cdot 10) \cdot 3 \cdot 6$$

$$A = 3 \cdot 4 \cdot (7 \cdot 8 \cdot 9 + 7 \cdot 8 \cdot 10) \cdot 3 \cdot 6 + 3 \cdot 5 \cdot (7 \cdot 8 \cdot 9 + 7 \cdot 8 \cdot 10) \cdot 3 \cdot 6$$

$$A = 3 \cdot 4 \cdot 6 \cdot 7 \cdot 8 \cdot 9 + 3 \cdot 4 \cdot 6 \cdot 7 \cdot 8 \cdot 10 + 3 \cdot 5 \cdot 6 \cdot 7 \cdot 8 \cdot 9 + 3 \cdot 5 \cdot 6 \cdot 7 \cdot 8 \cdot 10$$

$$T = (3 \cdot 4 \cdot 6 \cdot 7 \cdot 8 \cdot 9 + 3 \cdot 4 \cdot 6 \cdot 7 \cdot 8 \cdot 10 + 3 \cdot 5 \cdot 6 \cdot 7 \cdot 8 \cdot 9 + 3 \cdot 5 \cdot 6 \cdot 7 \cdot 8 \cdot 10) \cdot 1 \cdot 2$$

$$T = 1 \cdot 2 \cdot 3 \cdot 4 \cdot 6 \cdot 7 \cdot 8 \cdot 9 + 1 \cdot 2 \cdot 3 \cdot 4 \cdot 6 \cdot 7 \cdot 8 \cdot 10 + 1 \cdot 2 \cdot 3 \cdot 5 \cdot 6 \cdot 7 \cdot 8 \cdot 9 + 1 \cdot 2 \cdot 3 \cdot 5 \cdot 6 \cdot 7 \cdot 8 \cdot 10$$

Figure 5 shows the reliability network for a fire detection and alarm system created based on the fault tree of a fire detection and alarm system.

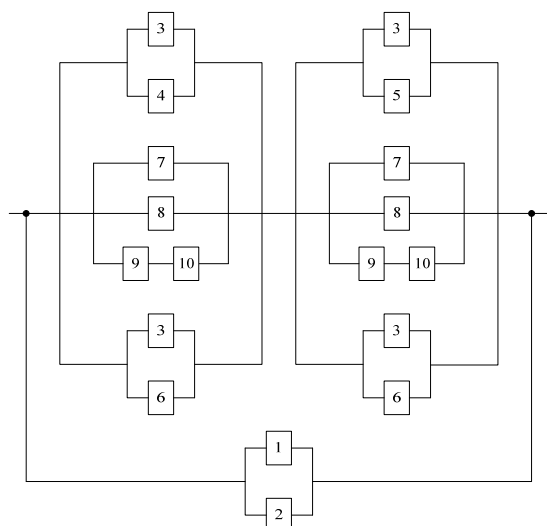


Figure 5. Reliability network for a fire detection and alarm system

Based on the performed analysis and evaluation of the importance of minimal cut sets, it can be concluded that events such as line interruption, manual fire alarm push-button failure, and short circuit are the most important events and they contribute the most to fire detection and alarm system failure.

CONCLUSION

Fault tree analysis is one the most frequently used methods for system reliability analysis. Fault tree analysis can be used to calculate the probability of an unwanted top event as a probability function of failing components. The advantage of fault tree analysis is that it can be applied to any system, regardless of its complexity. On the other hand, the drawback of this approach is that it does not consider the interactions between system components.

The paper presented a qualitative analysis of a fault tree of a fire detection and alarm system using minimal cut sets and minimal path sets. Creation of a minimal cut set using Boolean algebra revealed that the failure

of specific system components, or individual system events, can lead to the overall system failure and that some events are the greatest contributors to overall system failure.

REFERENCES

- [1] Blagojević, M. (2015), "Alarm Systems" (in serbian), University of Niš, Faculty of occupational safety, Niš, Serbia
- [2] Billinton, R. and Allan, R.N. 1992, "Reliability evaluation of engineering systems, concepts and techniques", Plenum Press, New York
- [3] Clemens, L. P. (1993). "Fault Tree Analysis" (4th Edition). Retrieved from <http://www.fault-tree.net/papers/clemens-fta-tutorial.pdf>
- [4] Hoyland, A. and Rausand, M. 1994. "System reliability theory", Wiley, New York
- [5] Ristić, D., Blagojević, M., Krstić, I., Krstić, D., 2011., "Fault tree of fire safety systems", Sbornik prednášek XX. Ročníku mezinárodní konference „Požární ochrana 2011“, pp. 305-307, Ostrava, Czech Republic
- [6] Savić, S., Grozdanović, M., Stojiljković, E. (2014). "System Reliability and Safety" (in serbian), University of Niš, Faculty of occupational safety, Niš, Serbia
- [7] SRPSA.A2.005:1986. (1986). „Reliability-Basic Terminology and Definitions“ (in serbian)

BIOGRAPHY of the first author

Dejan Ristić was born in Zemun, Serbia, in 1975. He received a bachelor's degree in fire protection and a master's degree in occupational safety from the University of Niš, Faculty of Occupational Safety in Niš.



Currently, he is a PhD student at the Faculty of Occupational Safety in Niš, where he is also employed as a laboratory expert associate.

ANALIZA POUZDANOSTI SISTEMA ZA OTKRIVANJE I DOJAVU POŽARA

Dejan Ristić, Milan Blagojević, Lutvo Haznadarević

Rezime: Cilj rada je utvrđivanje pouzdanosti sistema za otkrivanje i dojavu požara korišćenjem kvalitativne analize stabla otkaza. Kvalitativna analiza stabla otkaza sistema za otkrivanje i dojavu požara je prikazana korišćenjem analitičkog i matričnog postupka za održavanje minimalnih skupova preseka i minimalnih skupova staza. Za kvalitativnu analizu stabla otkaza sistema za otkrivanje i dojavu požara posmatrali smo sistem koji je instaliran u jednoj proizvodnoj hali i koji se sastoji od javljača toplote, javljača dima i od ručnog javljača požara. Kao glavni „top“ događaj analizirali smo „sistem za otkrivanje i dojavu požara nije detektovao požar“. Na osnovu sprovedene analize i evaluacije važnosti minimalnih skupova preseka možemo zaključiti da događaji kao što su: prekid linije, otkaz tastera ručnog javljača požara i kratak spoj su najznačajniji događaji i oni najviše doprinose otkazu sistema za otkrivanje i dojavu požara.

Key words: pouzdanost, analiza stabla otkaza, minimalni skup preseka, minimalni skup staza, sistem za otkrivanje i dojavu požara.

NATALIJA TOŠIĆ¹
DEJAN VASOVIĆ²

¹ College of Applied Technical
Sciences Niš

² University of Niš,
Faculty of Occupational Safety

¹natalija.tosic@vtsnis.edu.rs

²dejan.vasovic@znrfak.ni.ac.rs

EMAS STANDARD APPLICATION EXPERIENCES IN THE REPUBLIC OF SERBIA

Abstract: *This paper presents the importance of applying EMAS standard, which allows voluntary participation in the environmental management system for organizations operating in the European Union and the European Economic Area, but also for organizations potentially able to access the European Union. The paper also presents the chronology of EMAS development over the years, its elements, the modes of implementation and the conditions required for registering organizations. Case studies on the application of EMAS standards were presented in EU countries as well as in the Republic of Serbia. The aim of this paper is to give an insight into the current state of EMAS implementation, and to identify the potential for future structuring of EMAS.*

Key words: environment, EMAS, management, standard.

INTRODUCTION

The legal regulations of the Republic of Serbia define the use of EMS standard (Environmental Management Systems) through the Environmental Protection Law: "Legal entities, entrepreneurs and organizations can certify their environmental management system in accordance with the SRPS ISO 14001 standard. All persons and organizations that have established a system for managing the environmental protection, can also be included in the environmental management and verification system, which is called EMAS " [1].

The Eco-Management and Audit Scheme (EMAS) enables voluntary participation in the environmental management system for organizations operating in the European Union and the European Economic Area. The EMS originally proposed the European Commission, led by ISO, as a series of assets that enable the company to simultaneously pursue environmental goals and competitive goals in a synthetic way [2]. EMAS, unlike other EMS standards, emphasizes the fact that, in order for the organization to register and introduce EMAS, it must manage and improve not only direct environmental aspects, but also those "indirect" [3]. The EMAS Regulation defines the aspect of the indirect environment as an element of an activity or product of an organization that has or may have an environmental impact that may be the result of an organization's interaction with third parties [4].

CHRONOLOGY OF EMAS DEVELOPMENT

The implementation of the system started in April 1995 and promoted continuous evaluation and improvement of the environmental protection and environmental impact of organizations, which decided to establish, implement and develop the system.

The Eco-Management and Audit Scheme (EMAS) is a management tool for organizations to evaluate,

communicate and improve their environmental performance. The system has been open to businesses since 1995, under the Council of Europe (EEC) No. 1836/93 of 29 June 1993, that organizations have been given the opportunity to apply EMAS on a voluntary basis, but the participation was restricted to the branches operating in industry domain. Then introduced EMAS, is known as EMAS I.

After one year, in 1996, EN ISO 14001 - an international standard for the environmental management system was published, which was an additional step towards achieving EMAS. It was also noted that all sectors had a significant impact on the environment, and that good management in all sectors would have a positive impact on the environment. Article 14 allows Member States to extend the system to other economic sectors which led to the development of EMAS, whereby EMAS II was created. Several Member States have used this opportunity and successfully introduced EMAS into those other sectors.

According to the European Parliament and Council of Europe Regulation (EC) No. 761/2001 of 19 March 2001, a new provision was adopted that allows the application of EMAS in all economic activities, to the private and public sectors. In this way, EMAS III was created, which is now in use. The provision consists of 18 members and 8 annexes. Unlike other standards of the management system, the annexes are part of the provision. In other words, the annexes have not only an informative character and the requirements stated in them must be fulfilled.

IMPLEMENTATION OF EMAS

Over the past years, it has become clear that responsibility to the community is one of the criteria of good management, and care for the environment is a positive and logical extension of this responsibility. EMAS is designed to help organizations to contribute

and support the highest environmental management. In order for an organization to register, it is necessary to adopt an environmental policy through which it undertakes to operate in accordance with the relevant environmental legislation, and that it will continuously improve its environmental activities [5].

Involvement in EMAS

The main stages for obtaining EMAS registration are [6]:

1. Examine the organization's interaction with the environment through a review of the environmental protection system
2. Establishing an effective EMS based on a review, which leads to an improvement in the environmental impact of an organization
3. Publication of environmental impact information through a press release. This announcement is verified by a third party to provide external credibility for this performance and information element.

When a verifier issues an accreditation for a statement, the organization will be registered after receiving a registration fee. Then the organization obtains the right to use the EMAS logo (figure 1).



Figure 1. EMAS logo [5]

EMAS represents the modernization of management that influences the formation and development of public awareness and market development. Today, EMAS is a voluntary character, but it is expected to take on a mandatory character. Modern companies will have to respond adequately to consumer demands that become more aware of environmental protection issues. This can best be achieved by communicating and respecting the defined environmental protection policies and policies.

Three basic characteristics that are key to the success of EMAS standards are [7]:

1. Performance- EMAS is an environmental management tool of a voluntary type, harmonized throughout the European Union, with the aim of improving the environmental impact of organizations that are committed to reducing their negative impact on the environment.
2. Transparency-Informing the public about the environmental impact of an organization is an important aspect of the overall goal of the system.

EMAS requires the Quality and Environmental Report to be publicly available and provide information on the environmental impact and environmental effect of the organization. EMAS process increases transparency within the organization, which is ensured by the active participation of employees in the implementation of the system.

3. Credibility - EMAS logo, which can be used on the memorandum, releases and reports on environmental protection and quality and advertising for products, activities and services, is an attractive visual tool for demonstrating the organization's commitment to improving its environmental performance.

The EMAS standard is implemented through the management cycle. This toolkit is organized according to the classic management cycle: Planning - Implementation - Check - Action (Plan - Do - Check - Act or PDCA cycle) to help organizations develop and implement environmental management system in accordance with EN ISO 14001. The control cycle is illustrated in Figure 2.

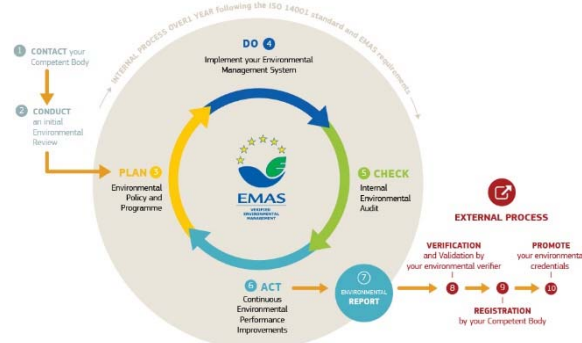


Figure 2. PDCA cycle [8]

P = planning and organizational structure of EMS

D = implementation of the program

C = control and evaluation of the environmental impact

A = operation, work on continuous improvement and, equally important, on communication and verification.

Participation in EMAS should enable all organizations to gain market advantage through improved stakeholder relationships, to feel the financial benefit through better control over operations and to provide assistance in accordance with future and current laws.

Advantages and benefits of EMAS standard

EMAS helps to create a wider range of thinking and integrates the principles of environmental protection that are already in the early stages of design and creative thinking. EMAS is an extremely useful instrument for sustainable development. It is easier to manage an organization that has an EMAS registration, because EMAS is modernizing the organization's management. EMAS enables efficient control of data and environmental impacts, providing the organization with

all the necessary information for communication with internal and external stakeholders.

Based on the stated advantages and benefits, the following are distinguished [6]:

1. General benefits

- Compliance with laws in the field of environmental protection
- Prevention of accidents in the environment

2. Internal benefits

- Reducing energy and resource consumption
- An additional reduction in costs
- Improved employee morale
- Better internal communication
- Modernizing the management system

3. External benefits

- Better communication with government authorities
- Increased recognition by banks and insurance companies
- Improving the image of the organization in public
- Priority in obtaining future public contracts

EMAS can enrich the process of innovation in environmental protection. Internal operation and return to the environmental impact can bring new feedback and positive outcomes. New insights can lead to the creation of better products and services.

EMAS STANDARD IN EUROPEAN UNION COUNTRIES

EMAS regulations are applied in all 25 Member States of the European Union, and to 3 Member States of the European Economic Area, i.e. Norway, Iceland, and Liechtenstein, but also all candidate countries already apply this system in preparation for accession to the European Union.

Table 1. Number of organizations that passed the EMAS registration [9]

Countries	Organizations
Austria	290
Germany	1239
Spain	816
Italy	983
Cyprus	94
Belgium	75

The table 1 shows that the largest number of organizations that have passed the EMAS registration are in the first place in Germany with 1239 organizations, then elsewhere in Italy, and the third in Spain. Austria is the fourth-ranked, while all other countries with less than 100 organizations per country. There are currently 3866 registered organizations in the

European Union, and of all members only Croatia and Latvia do not have any organization that has passed the EMAS registration [9].

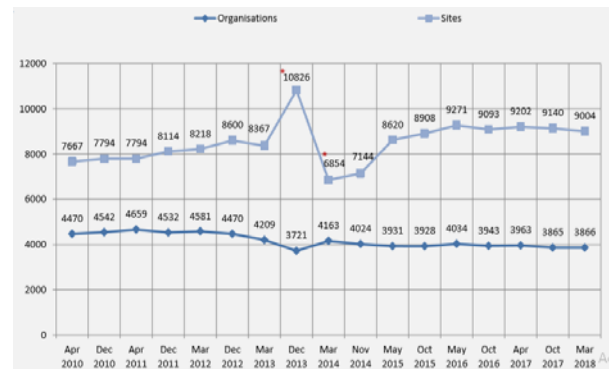


Figure 3. Development of organizations and locations from 2010-2018. [9]

Figure 3 shows the movement of the number of organizations and locations where EMAS is applied. On a monthly basis from 2010 to 2018, the number of organizations has a declining trend that. The maximum number of organizations in this period was recorded in April 2011 (4659 organizations), while in October 2017 the smallest number of organizations were recorded (3865). The number of locations in which EMAS is conducted shows the opposite trend from the number of organizations. In the entire period, it can be concluded that there is a continuous increase in the number of locations, with the exception of the period from March 2013 to May 2015, when the eccentric values of this graph are recorded, while the data for the observed period are not complete.

EMAS IN REPUBLIC OF SERBIA

In the period from the 1950s to the 1990s, environmental issues were treated as public health issues in Serbia, incorporated into the body of laws in the field of health and sanitary control. With the adoption and entry into force of the Environmental Protection Law in 1991, a period of the environment allocation is created as a separate legal entity [10].

Some of EMAS elements, which are often not directly covered through established environmental management systems in accordance with the ISO 14001 standard, which are particularly important to accentuate in the context of tools for improving the system and increasing competitiveness, are [11]:

- More attention to the energy aspects of the organization
- More active involvement of employees
- Reporting on environmental performance
- Benchmarking and compliance with regulations

Successful implementation of EMAS standard in the Republic of Serbia

The beginning of motivation in the Republic of Serbia for inclusion in the EMAS program started through the relevant national legislation in Serbia, by directly integrating the EMAS criteria, primarily through the Rulebook on the manner and procedure for managing spent batteries and accumulators (Official Gazette of RS, No. 86/2010) in which under Article 13 it is defined that the transfer of the obligation of treatment to a person who carries out the treatment of spent batteries and accumulators is preferred to a plant that is included in the certified environmental protection system - EMAS [8].

In 2014, a project titled "Implementation of laws in the field of industrial pollution control, prevention of chemical accidents and the establishment of an EMAS system" was initiated by the EU. The project was implemented by the Ministry of Agriculture and Environmental Protection, and in cooperation with the Ministry of Environmental Protection of Austria. Work on the project included meetings and workshops on various topics with foreign and domestic consultants. As part of the project, a study visit to Austria was organized in March, where a great opportunity to see EMAS in different types of organizations appeared, which confirmed the width of the requirements of this regulation.

The goal of the project was to establish the EMAS system in accordance with the requirements of EU Regulation 1221/2009 in three selected companies from Serbia [8]:

1. Galenika Fitofarmacija a.d.
2. TRS Europe d.o.o.
3. Gorenje Valjevo

For Serbian companies, the implementation of this standard could facilitate exports to the European Union market, as it proves that products are manufactured in compliance with EU environmental regulations. Also it's important for all organizations that want to be part of the EMAS system, that the EMAS standard refers to the organization, not to the product, and it is not a guarantee that one product is better than other products, but it shows that the company takes care of sustainable development and enhances its reputation, which is a great advantage in market economies.

EMAS in Galenika Fitofarmacija a.d.

For more than half a century, this company has been working to meet the needs of agricultural producers. The professionalism and commitment of employees and the high quality of their products are the basis for the success of the company that has completely adjusted its product line to specific market needs, as well as the requirements of protecting human health and environmental protection [12]. It continuously adapts to the requirements and needs of users, as well as to the standards and legal regulations governing the modern production, trade and use of plant protection products.

For many years, the development of the production program is based on active substances that are on the list allowed in the EU and on other input components that are used in European countries. High quality products and their compliance with environmental requirements and the establishment of optimum working conditions in production processes are ensured by the development and application of modern formulation technologies.

Within this company, verification and registration in the EMAS register is done in cooperation with a foreign verifier and the competent registration authority. The role of the ministry responsible for environmental protection is also important, which will be formalized through amendments to the Environmental Protection Law.

Improving the system of the company by implementing EMAS

The main goal of this company was the establishment of a sustainable system for collecting and disposing of packaging waste from plant protection products and promotion of proper treatment. Emptied packaging represented a potential environmental risk by the company. Initially, there were 6 collection points, and already in 2012 the system was developed, so now there are 88 locations from which the waste packaging is organized [12].

As part of achieving the company's goal, Envipack - an operator with an integrated permit for the collection and transport of hazardous and non-hazardous waste, organized 35 circular transport routes and collected 165 tons of waste in total, and almost 86 tons was hazardous waste [8].

EMAS in Gorenje Valjevo

The Gorenje Group has implemented an environmental protection system in accordance with ISO 14001 and EMAS. Companies that have implemented EMAS are acting responsibly to lead their business in line with sustainable development.

In the course of 2014, an analysis (table 2) of all Gorenje companies throughout Europe was certified (or are in the process of certification) ISO 14001 and EMAS [8].

Tabel 2. Certification of the company Gorenje in 2014 [8]

	ISO 14001	EMAS
Gorenje, d.d.- Velenje	Yes	Yes
Gorenje, d.d. - Šoštanj	Yes	Yes
Gorenje, d.d. - Rogatec	Yes	Yes
Gorenje, IPC, d.o.o. - Velenje	Yes	Yes

Gorenje, IPC, d.o.o.- Šoštanj	Yes	Yes
Gorenje Orodjarna, d.o.o.	Yes	No
Gorenje GAIO, d.o.o.	Yes	No
Gorenje, Valjevo, d.o.o.	Yes	No
Kemis, d.o.o.	Yes	No
Gorenje Surovina, d.o.o.	Yes	No
Asko Vara	Yes	No

Environmental Management System at Gorenje Company in Valjevo

The factory in Valjevo operates in accordance with [8]:

- Environmental policy
- ISO 14001 standard from 2011
- Rules of Environmental Protection
- Waste Management Plan 2013
- Road safety plan 2014
- Requirements of the EMAS III Directive - in 2014 registration was still expected

Improving the system of the company by implementing EMAS

The system improves through [8]:

- better selection of raw materials and energy sources
- less impact on the environment
- better utilization of raw materials
- less generous hazardous and non-hazardous waste
- controlled use of chemicals
- Cleaner energy

EMAS in TRS Europe

This is a company that produces a cartridge for laser printers. This company is an excellent example of establishing EMAS registration as the products they manage are hazardous waste, which makes the company can have a very negative impact on the environment.

Within the framework of the implementation of EMAS certification, the company's direct and indirect impacts on the environment were analyzed.

Direct impacts on the environment are:

- High consumption of el. Energy
- High gas consumption
- High consumption of chemicals
- High paper consumption due to a large number of tests

- Large quantity of waste toner powder
- Large amount of metal and plastic waste

The indirect impact on the environment is:

- Transport - gas emission and resource consumption

Improving the system of the company by implementing EMAS

System improvements in terms of reducing harmful effects, from the point of direct impact on the environment:

- Changing the heating and cooling system
- New bottle design for chemicals
- Using both sides of the test paper
- Separating toner powder by types and selling waste toner
- Separation of waste by type and sale to authorized operators
- Re-use toner cartridge parts

System improvements in terms of reducing harmful effects, from the point of view of indirect impact on the environment:

- Selection of the conveyor
- Eco-brochure for driving cars

The most significant positive impact of TRS EUROPE is the accumulation of empty toner cartridges around the world-reduction of waste. A single reprocessed cartridge typically saves 1.5 liters of crude oil, which means that TRS EUROPE saves more than 62 million liters of oil a year [8].

CONCLUSION

EMAS is one of the most demanding but also the most trusted environmental protection management system in practice. EMAS can serve as an inspiration and idea for improving competitiveness and to help each individual organization to fundamentally address its ability to further improve its management system and use it as a basis for sustainable business and achieving greater competitiveness.

The fact is that at this moment a relatively large number of organizations are simply not ready for EU EMAS registration. However, what EMAS provides to all organizations is an inexhaustible source of inspiration to improve the existing environmental management system in a particular organization. International and EU standards and regulations are a tool that can be successfully used, and which are especially important for dealing with clients from the EU. By applying EMAS standards, good practices and values in everyday business, organizations are essentially becoming part of the EU community, regardless of whether they may formally with a physical location are in a country that is not yet a member of the EU.

REFERENCES

- [1] V. R. Srbije, *Zakon o zaštiti životne sredine*, Beograd, Beograd: Sl. glasnik RS, 2016.
- [2] I. Fabio, T. Francesco and M. Frey, "Is an environmental management system able to influence environmental and competitive performance? The case of the eco-management and audit scheme (EMAS) in the European union," *Journal of Cleaner Production*, vol. 17, p. 1444–1452, 2009.
- [3] R. Handfield, S. Walton, R. Sroufe and S. Melnyk, "Applying environmental criteria to supplier assessment: a study in the application of the analytical hierarchy process," *European Journal of Operational Research*, vol. 141, p. 70–87, 2002.
- [4] E. Commission, *Proposal for a regulation of the European Parliament and of the council on the voluntary participation by organizations in a community eco-management and audit scheme (EMAS)*, Brussels: European Community, 2008..
- [5] E. Commission, "Legislation," *Official Journal of the European Union*, vol. 56, no. L76, 2013..
- [6] E. Commission, "EMAS Toolkit for small organisations," [Online]. Available: <http://ec.europa.eu/environment/archives/emas/toolkit/>. [Accessed 2 July 2018].
- [7] E. Commission, *Study on the Costs and Benefits of EMAS to Registered Organisations*, Brussels: European Commission, 2011.
- [8] V. Consulting, "EMAS Srbija," wDesign Studio, [Online]. Available: www.emas.rs. [Accessed 2 July 2018].
- [9] E. E. Register, *Official statistics of the European EMAS Helpdesk*, Brussels: EU EMAS Register, 2018..
- [10] A. S. Theresa Steyrer, "EMAS in Germany Evaluation 2012," Federal Environment Agency (UBA) , Dessau, 2013.
- [11] D. Petrović and S. Milovanović, "EMAS kao podrška na putu ka EU- naša priča," in *Zbornik radova 11. regionalne konferencije "Životna sredina ka Evropi"*, Beograd, 2015.
- [12] G. F. a.d., "Galenika Fitofarmacija a.d.," MASSVision, [Online]. Available: <http://www.fitofarmacija.rs>. [Accessed 2 July 2018].
- [13] E. Commission, "Environment," [Online]. Available: http://ec.europa.eu/environment/emas/index_en.htm. [Accessed 11 November 2018].
- [14] E. Commission, "ENVIRONMENT Eco-Management and Audit Scheme," [Online]. Available: http://ec.europa.eu/environment/emas/join_emas/how_does_it_work_step0_en.htm. [Accessed 11 November 2018].
- [15] J. Aleksic, "Primenjena Ekologija," Ministarstvo poljoprivrede i zaštite životne sredine RS, Beograd, 2014.

BIOGRAPHY of the first author

Natalija Tošić was born in Niš, Serbia, in 1993.

She received master diploma in Environmental safety at Faculty of Occupational Safety in Nis, University of Niš. Now she is at PhD study programme of Environmental Safety Engineering at the Faculty of Occupational Safety in Niš, University of Niš. Her main areas of research include environmental protection, environmental management and water protection. She is currently working as an assistant at the College of Applied Technical Sciences Niš.



ISKUSTVA U PRIMENI EMAS STANDARDA U REPUBLICI SRBIJI

Natalija Tošić, Dejan Vasović

Rezime: U ovom radu predstavljen je značaj primene EMAS standarda koji omogućava dobrovoljno učešće u sistemu menadžmenta zaštitom životne sredine za organizacije koje posluju u Evropskoj Uniji i Evropskom ekonomskom prostoru, ali i za organizacije koje bi potencijalno mogle da pristupe Evropskoj Uniji. U radu je prikazana i hronologija razvoja EMAS-a tokom godina, njegovi elementi, načini implementacije i uslovi potrebni za registrovanje organizacija. Rad prikazuje studije slučaja o primeni EMAS standarda u zemljama EU, kao i u Republici Srbiji. Cilj ovog rada je davanje uvida u trenutno stanje EMAS implementacije i identifikovanje potencijala za buduće EMAS strukturiranje.

Ključne reči: životna sredina, EMAS, menadžment, standard.

SVETA CVETANOVIĆ¹
DEJAN KRSTIĆ²
GORAN ĐORĐEVIĆ³
SRĐAN NIKOLIĆ⁴

RISK MANAGEMENT IN PREVENTIVE FOREST FIRE PROTECTION WITH A MODEL PLAN DEVELOPMENT FOR FOREST FIRE PREVENTION

^{1,2}Faculty of Occupational Safety in
Niš

³Emergency Management Sector,
Ministry of Interior of the
Republic of Serbia

⁴Niš Fire and Rescue Brigade,
Ministry of Interior of the
Republic of Serbia

¹sveta.cvetanovic@znrfak.ni.ac.rs

Abstract: *This paper discusses risk management in preventive forest fire protection and specific methods and models used for forest fire prevention. It covers all preventive methods, actions, and means pertaining to preventive measures that prevent the occurrence of forest fires and help reduce the risk of forest fires. Another relevant topic covered in the paper is the design of risk management plans for forest fire protection.*

Key words: risk management, preventive protection, forest fire, risk management plans.

INTRODUCTION

Preventive forest fire protection involves an entire complex of measures and activities to be taken before any fire breaks out or, in case a fire does break out, to aid with the organized firefighting activities. Preventive forest fire protection measures are one of the most important elements in risk management for forest fire protection. The purpose of using these measures is to reduce the risk of forest fires, reduce the number of actual fires, and mitigate the damage caused by forest fires.

There is a variety of preventive measures against forest fires and the level of forest fire protection depends on their proper implementation. Preventive forest fire protection in Serbia varies depending on the ownership status of forests; thus, forest fire protection is at a much higher level in forests owned by the state, specifically the state public companies, than in privately-owned forests, as indicated by the number of fires in state-owned as opposed to privately-owned forests.

Forest fire prevention measures are provided in forest fire protection plans, which need to define the following: efficient forest fire prevention and, in case of a fire, methods and procedures for fast detection and extinguishment during its initial stages.

GENERAL FOREST FIRE PROTECTION PLAN

The general forest fire protection plan is commonly developed for a period of five years. It contains the relevant data and measures to be taken for the purpose of prevention or extinguishment of forest fires within a region or area.

The plan contains a textual and a graphic portion with maps of the area.

The textual portion is made as a project design and it encompasses the following parts:

1. overview of forested areas according to their vulnerability level;

2. planning of measures against potential forest fire causes;
3. planning of biotechnical forest fire protection measures;
4. forest fire danger forecast;
5. forest fire detection methods;
6. construction and maintenance of fire roads;
7. methods of water supply for firefighting;
8. protection of picnic areas; and
9. planning of firefighting equipment and agents, personnel organization, and command of firefighting operations.

Overview of forested areas according to vulnerability level

Inspection and detailed knowledge of forested areas are of paramount importance for preventive forest fire protection. Forest fire vulnerability depends on the prevalent tree species and the type of forest combustibles. Not all tree species have the same ignition and combustion properties, so specific tree species and forest combustibles are more easily ignited and burn more intensely than other species, which are not as easily ignited and burn with less intensity. Due to their structure and composition, coniferous forests are more susceptible to ignition and burn more intensely than deciduous forests. For the purpose of simplifying forest fire vulnerability, the vulnerability is classified into the following six levels according to the prevalent tree species:

- level 1 vulnerability (areas under pines and larches);
- level 2 vulnerability (areas under spruces, firs, and other conifers);
- level 3 vulnerability (mixed areas under broadleaf trees and conifers);
- level 4 vulnerability (areas under oaks and hornbeams);
- level 5 vulnerability (areas under beeches and other broadleaf trees); and

- level 6 vulnerability (areas under shrubbery and clear areas).

The classification of forested areas according to their vulnerability level is used to determine the preventive protection measures within the risk management system in forest fire protection. The majority of preventive measures need to be taken in forested areas with level 1 and level 2 vulnerability, which is not to say that other areas with lower vulnerability levels should be neglected.

Planning of measures against potential forest fire causes

Humans are the most common instigators of forest fires. Statistics show that over 94% of forest fires are caused by people, usually due to ignorance and negligence but sometimes even intentionally. The remaining 6% are caused by natural phenomena or other causes.

Table 1 shows the causes of forest fires in the Braničevo District in Serbia for the 1998-2008 period.

Table 1. Causes of forest fires in the Braničevo District in Serbia from 1998 to 2008 [1]

Total number of fires	Fires caused by humans	Fires caused by natural phenomena or other causes	Fires with undetermined cause
2,220	2,087	44	89
100%	94.01	1.98	4.01

Measures involving education, propaganda, or warnings require the engagement of the following institutions and media: schools, local press, local radio stations, television, warning and prohibition signs, educational billboards, etc.

Planning of biotechnical measures of forest fire protection

Biotechnical measures play a very important role in forest fire prevention. These include measures that increase the self-regulatory defence mechanisms of forests and help reduce their fire vulnerability. This is particularly relevant for level 1 and level 2 vulnerability forests, such as coniferous forests, but it is recommended that these measures be taken for other forest types as well.

The measures are implemented by growing mixed forests, splitting larger complexes into smaller parts by using biotechnical trails, building fire roads, expanding the existing firebreaks, and cleaning and maintaining fire trails and firebreaks.

The following aspects need to be considered when planning to plant mixed forests:

- soil composition, depth, and fertility, climate conditions, wind intensity, exposure, and altitude;
- topography, i.e. degree of terrain uniformity;
- selection of appropriate tree species; and
- the most favourable planting conditions, including soil preparation, planting pit depth, planting density, and the distance between conifers and broadleaf trees.

Figure 1 shows the model of building biological fire trails.

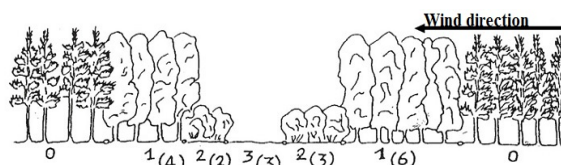


Figure 1. Model 1 (conifers). Characteristics: flat terrain, biological fire trail width 18 m. Description 0 – conifers, 1 – broadleaf trees, 2 – broadleaf shrubs, 3 – trail [2]

Flame height and propagation rate of the fire depending on wind speed are very important when building firebreaks and determining their width.

Figure 2 shows the relationship between fire propagation rate and flame height depending on wind speed.

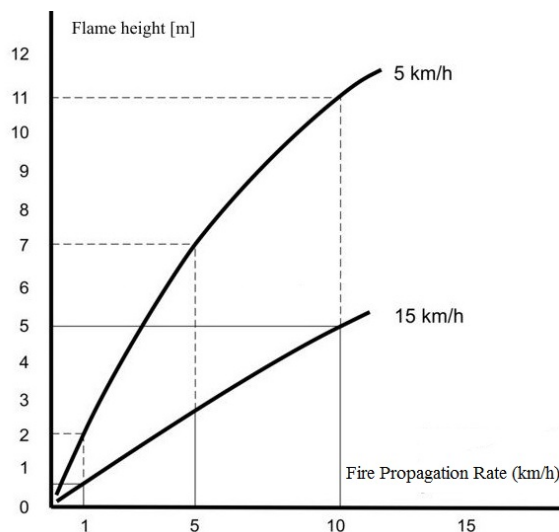


Figure 2. Fire propagation rate and flame height depending on wind speed [3]

Over time, firebreaks become covered with grass and shrubbery, which dries up during low-precipitation periods and is able to transfer a fire, so it requires occasional removal.

Removal and cleaning is performed after thawing of the snow and, if necessary, even in July or August, when most grass species complete their vegetation period and begin to dry up. The removal can be manual, which is

slower and more difficult, or using various herbicides during the plant development period.

To achieve efficient risk management in preventive forest fire protection, all biotechnical measures need to be covered by forest fire protection plans and the dynamics and financial means for the design and maintenance of biotechnical measures need to be covered by the general medium-term plan.

The role of meteorology in preventive forest fire protection

Meteorology is the study of all physical phenomena in the atmosphere, so it can be regarded as physics of the atmosphere. Therefore, in order to improve forest fire protection, it is necessary to plan the construction of a larger number of weather stations in forests, especially in forests with tree species highly vulnerable to fires (e.g. large complexes of conifers on sandy soil). The sooner the weather stations are placed in forests, the sooner the databases will be created to be used for statistical indicators and climatological research for more efficient forest fire protection.

Forest fire danger forecast

Forest fire danger forecast is one of the most important tasks performed in forest fire prevention. Since it can be used to minimize forest fire damage, a detection system, fire season preparations, and adequate mobility and readiness will prevent forest fires in most cases. The general structure of the systems for fire danger assessment that are in use in different countries corresponds to a greater or lesser extent to the system structure shown in Figure 3.

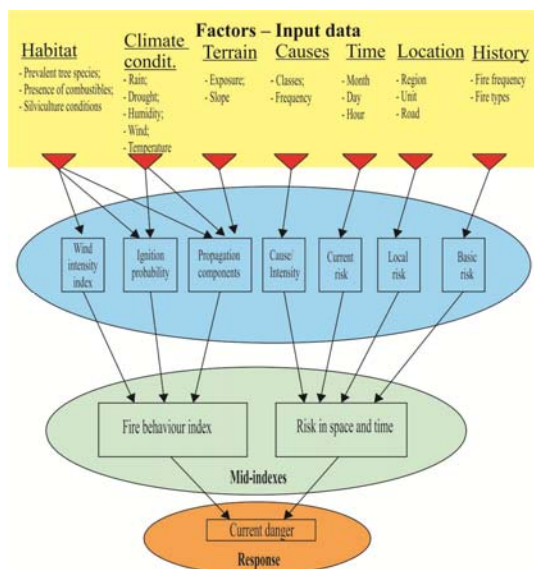


Figure 3. General structure of a forest fire danger assessment system [4]

Such an assessment system provides three tiers of information with one input tier.

The first data tier includes mid-indexes, which provide all the necessary preventive measures and firefighting equipment and agents after data analysis.

The second data tier, or the end index, determines the fire risk and fire behaviour according to the fuel state.

The third data tier provides the final response to the present threat.

Forest fire detection methods

Early fire detection greatly facilitates fire suppression and containment by making these actions as efficient as possible.

This is why forest lookouts during fire seasons need to be conducted in a planned and organized manner, because the assets and efforts invested for this purpose will always be exceeded in value by the material and environmental damage caused by untimely detected fires.

Organized fire detection methods can be classified into four groups:

1. fire detection by land lookout;
2. fire detection by aerial lookout;
3. combined fire detection method; and
4. other fire detection methods.

Figure 2 shows the block diagram of the fire lookout component.

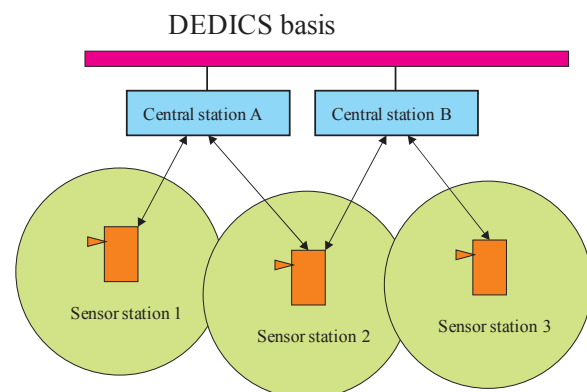


Figure 4. Block diagram of the lookout component in "DEDICS" network [5]

The data collected by meteorological sensors, such as wind speed and direction, humidity, and temperature are highly significant and are used for forest fire forecasting.

Planning of the forest fire lookout and notification system

Forest fire detection provides early observation of some of the visible fire elements, such as light from the flame or smoke, which enables extinguishment in the initial stage, before the fire engulfs a larger area. Fire detection time is essential as it impacts the efficiency of all forest fire suppression operations. The detection time in turn depends on how well-equipped and efficient the operating forces are, on fuel properties,

and the level of fire danger. The time of notification and the time required to initiate the firefighting operation are relatively constant and depend on the quality of the fire detection system. The forest fire lookout and notification system contains the following variables:

- the time required to detect a fire;
- the time required for the operating forces to reach a fire.

The time from the fire notification to the on-site arrival of the operational forces has to be as short as possible. This time can be expressed by the following formula:

$$T = T_p + T_m,$$

where:

T – time from the notification to the on-site arrival;

T_p – duration of the fire notification;

T_m – time required for on-site arrival.

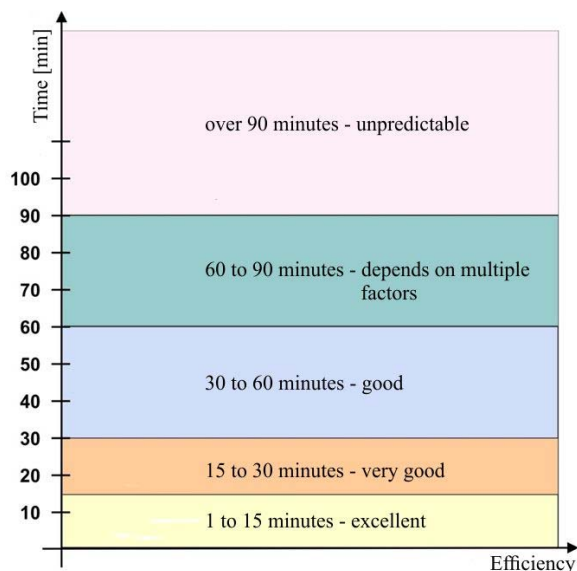


Figure 5. Firefighting efficiency in relation to the time required for on-site arrival

Figure 5 shows that the longer the time between the notification and the on-site arrival, the lower the efficiency of firefighting, as prolonged time implies more personnel required for firefighting, heavier use of firefighting equipment and agents, and higher damage from fire.

Fire road construction and maintenance

One of the crucial factors for successful extinguishment is the construction and maintenance of fire roads in forests, which are intended to allow the people involved in firefighting to reach the fire as quickly as possible and to put it out before it spreads any further. Regardless of the efforts to build as many fire roads as possible and make forests more accessible for firefighting crews and equipment, it is objectively impossible to build roads to such an extent that every part of forested areas can become accessible. Accordingly, it is necessary to plan for the use of aerial

lookout and firefighting equipment (airplanes and helicopters) in inaccessible parts of forests.

Water supply for firefighting

All firefighting water supply locations have to be clearly marked in fire maps together with access roads for wildland fire tenders, fire engines, tractors pulling tanks, and the like. Additionally, wherever airplanes and helicopters are planned for firefighting, the areas from which water is taken need to be safe enough for airplane or helicopter manoeuvres when collecting water.

Picnic area protection and maintenance

Many parts of a forest, especially near large cities or residential areas, summer resorts, beaches, etc. are often visited by hikers, picnickers, and tourists.

Forests in such locations are gravely threatened by fires, which can be caused by visitors due to negligence or ignorance, e.g. by throwing away unextinguished cigarette butts and matches or by starting a fire in an open space.

Therefore, such locations should be protected using various means, such as warning and prohibition signs, designated fireplaces for open fire, and safety barrels filled with water.

All these locations need to be controlled and monitored by foot patrols, who should also warn visitors of the hazards.

Planning of forest firefighting equipment and agents, organization of personnel, and command of firefighting operations

Forest firefighting equipment is an integral part of the firefighting organization and it has to be included in the plan. Planning of forest firefighting equipment is an important element of any plan directly influencing firefighting efficiency. The choice of forest firefighting equipment depends on the following: fire type, vegetation type, condition of combustibles, topography, number of firefighting personnel, and water availability in the field.

Forest fires are generally suppressed using land firefighting equipment and aerial firefighting equipment.

DETAILED OPERATIONAL FIREFIGHTING PLAN

The detail operational plan for forest firefighting is an integral of the general plan. The detailed plan further elaborates the general plan by dividing it into specific segments and addressing the lower organizational levels. In addition to forest fire prevention measures, the detailed operational plan elaborates down to the smallest detail the requirements, methods, tactics, and techniques of firefighting that need to be used under specified conditions in every area in case of a fire. the detailed plan also covers tasks, duties, and performance methods for all firefighting personnel.

Every operational plan should be updated annually before the fire season begins (January or February) with all the changes that affected the forest or the organizational aspects.

FIRE MAP DESIGN

Fire maps are an integral and necessary part of any forest fire protection plan. They are designed for each individual forested area based on the data from the general forest fire protection plan and the detailed operational plan.

Fire maps with a spatial representation of all these data are intended to be used by all commanding officers and participants in firefighting operations as adequate guidance and aid in selecting the proper tactics and using the most efficient firefighting methods. They can also be used by fire lookouts, pilots, as well as any other persons involved in the planning of measures and command of firefighting operations.

CONCLUSION

Preventive forest fire protection refers to the implementation of a series of measures aimed at reducing forest fire risk. This paper discussed the potentially dangerous factors that can lead to forest fires. Forest fire prevention measures include the analysis and classification of forest vegetation and combustibles, designation of forest fire vulnerability level, construction and maintenance of fire trails and firebreaks, use of biotechnical protection measures, construction and maintenance of vehicle access roads, construction and maintenance of forest water catchments and sources, removal of possible ignition sources, maintenance of picnic and recreational areas, fight against forest fire causes, construction and maintenance of lookout towers, organization of a lookout and notification service, organization of an adequate information system, development of forest fire protection plans, and other measures. This operational mode also includes forest fire forecasting,

which is an essential element of any forest fire risk management system.

REFERENCES

- [1] Online data and data from state institutions and public companies
- [2] Vasić Miodrag: *Šumski požari* [Forest Fires], JP "Srbijašume" Beograd, 1992
- [3] Dimitrov Tomislav: *Sistem ocenjivanja opasnosti od šumskih požara sa pogledom na sledećih deset godina* [Forest Fire Hazard Assessment System with Prospects for the Next Ten Years], Vatrogasni savez Srbije, 1990
- [4] Bertović Stepen, Dimitrov Tomislav: *Osnovi zaštite šuma od požara* [Basics of Forest Fire Protection], Centar za informisanje, Zagreb, 1987
- [5] Presentation of IPNAS and DEDIKS systems
- [6] Kurbacki N.P.: *Tehnika i taktika gašenja šumskih požara* [Forest Fire Suppression Techniques and Tactics], Vatrogasni savez Jugoslavije, 1996
- [7] Kistač I.F.: *Taktika gašenja požara* [Firefighting Tactics], Stroizdat, Moskva, 1990
- [8] Koylowski T.T. and C.E. Ahgren: *Fire and Ecosystems*, New York, Academic Press, 1974

BIOGRAPHY of the first author

Sveta Cvetanović was born in Donje Dragovlje, Serbia, in 1961. He graduated from the Faculty of Occupational Safety in Niš. He was employed in the occupational safety and fire safety sector at AIK Bank in Šabac. He has been working at the Faculty of Occupational Safety in Niš since 1990.

His research interests include risk management, fire and explosion risk assessment, fire safety systems, and accident recovery.



UPRAVLJANJE RIZIKOM U PREVENTIVNOJ ZAŠTITI ŠUMA OD POŽARA SA MODELOM IZRADE PLANOVA ZA SPREČAVANJE NASTANKA ŠUMSKIH POŽARA

Sveta cvetanović, Dejan Krstić, Goran Đorđević, Srđan Nikolić

Rezime: U radu upravljanjem rizikom u preventivnoj zaštiti šuma od požara su obrađene metode i modeli koje sprečavaju pojavu šumskih požara. Obrađene su sve preventivne metode i radnje kao i načini preventivnih aktivnosti koji sprečavaju mogućnost nastanka šumskih požara i koji omogućuju smanjenje rizika od nastanka šumskih požara. Izrada planova za upravljanje rizikom u zaštiti šuma od požara zauzima važno mesto u ovom radu.

Ključne reči: upravljanje rizikom, preventivna zaštita, šumski požar, planovi za upravljanje rizikom.

MILE MITIĆ¹
VELJKO RADOSAVLJEVIĆ²

²Elektromehanika DOO, Niš

¹miticmile@yahoo.com

²veljko.radosavljevic994@gmail.com

ARAMIS METHODOLOGY: RISK ASSESSMENT IN CHEMICAL INDUSTRY

Abstract: ARAMIS methodology is used to assess risk at chemical plants following SEVESO II Directive. The main objective of the ARAMIS project is to create a new integrated risk assessment methodology by combining the strengths of both probabilistic and consequence-based approaches. The first part of ARAMIS methodology is (MIMAH) Methodology for the Identification of Major Accident Hazards. MIMAH is used to assess the worst accidents likely to occur without taking any safety systems in consideration. The second part of ARAMIS methodology is (MIRAS) Methodology for the Identification of Reference Accident Scenarios, which takes into account safety systems. The ARAMIS method enables ranking the hazards only in terms of severity with the calculation of the severity index *S* for each scenario. It also enables taking into account the efforts (preventive measures) made by the company and calculating the realistic risk levels.

Key words: ARAMIS, MIMAH, MIRAS, bow-tie, dangerous phenomena, safety systems, severity, vulnerability, risk level.

INTRODUCTION

The ARAMIS project was accepted for funding in February 2001 by the European Commission, in the 5th Framework Programme for Research and Technological Development. The ARAMIS methodology is used to assess risk at chemical plants following SEVESO II Directive. The most significant EU Directive to help protect people and the environment from major accident hazards is the SEVESO II Directive.

The first part of ARAMIS methodology is (MIMAH) Methodology for the Identification of Major Accident Hazards. Using MIMAH methodology we can define the maximum hazardous potential of an installation. MIMAH is used to assess the worst accidents likely to occur without taking any safety systems in consideration, and that presents Major Accident Hazards.

The second part of ARAMIS methodology is (MIRAS) Methodology for the Identification of Reference Accident Scenarios. MIRAS takes into consideration all safety systems (devices and policies) and implement it on scenarios identified by the MIMAH methodology.

THE OBJECTIVES

The main objective of the ARAMIS project is to create a new integrated risk assessment methodology by combining the strengths of both probabilistic and consequence-based approaches. Accordingly, the method should be flexible enough to account eventually for the different national cultures, in order to become a recommended tool used by risk experts and endorsed by risk decision makers in the whole EU. [1]

Identification of possible accident scenarios is an essence in risk assessment of chemical industries. The

worst cases scenarios without taking into account safety systems, are mainly considered in risk assessments, and results of that can be overvalue of the risk.

One of the aims of the ARAMIS project is to develop a methodology able to face this problem. This report describes methods and tools to identify major accidents (without considering safety systems), then to study deeply safety systems, causes of accidents and (qualitative) probabilities, in order to be able to identify Reference Accident Scenarios, which take into account safety systems. [2]

- In first part of ARAMIS methodology, a method to identify major accident hazards will be developed.
- In the second part of ARAMIS methodology, a method will be developed to identify reference accident scenarios.
- At the end, there will be more realistic risk estimation and possible accident scenarios in chemical industry.

MIMAH (Methodology for the Identification of Major Accident Hazards)

MIMAH means "Methodology for the Identification of Major Accident Hazard". The objective of MIMAH is to identify all the potential major accident scenarios which can occur in a process industry. The main tool on which the MIMAH methodology is based is the bow-tie (Figure 1). [2]

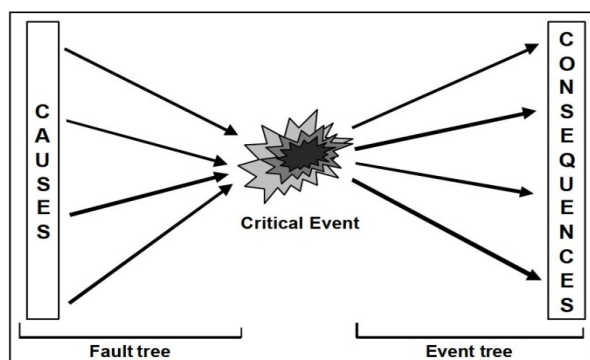


Figure 1. General scheme of the bow-tie

Critical event is in center of a bow-tie. A Critical Event is defined as a Loss of Containment (LOC) or a Loss of Physical Integrity (LPI).

Causes which lead to a critical event are on the left part of the bow tie, named fault tree.

Consequences of a critical event are on the right part of the bow tie, named event tree.

MIMAH contains 7 steps which must be followed:

- Step 1: Collect needed information
- Step 2: Identify potentially hazardous equipment in the plant
- Step 3: Select relevant hazardous equipment
- Step 4: For each selected equipment, associate critical events
- Step 5: For each critical event, build a fault tree
- Step 6: For each critical event, build an event tree
- Step 7: For each selected equipment, build the complete bow-ties

A general overview of the steps involved in MIMAH is shown in (Figure 2). [3]

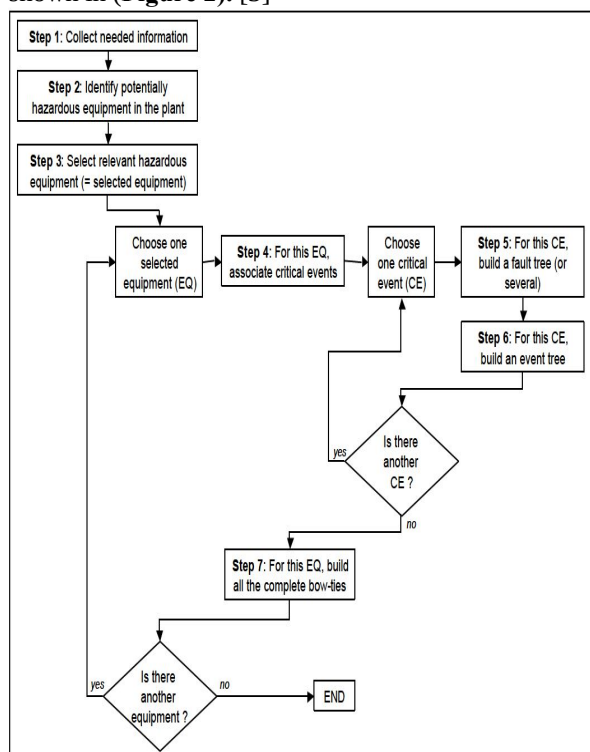


Figure 2. General overview of the MIMAH steps

MIMAH proposes 14 generic fault trees, where some critical events have several possible fault trees. MIMAH considers 12 different critical events. They can be found in details in appendix 4. For the critical events for which several fault trees have been generated, only one event tree will be built per critical event. [5]

It will be necessary to visit plant site, maybe several times, it depends on user who can choose to collect all the data at the same time, or to collect data progressively, over several visit to the chemical plant site, when they are needed, during implementation of MIMAH steps. This will give better information and prevent any oversight. Each step of MIMAH must be followed thoroughly, for precise construction of bow-ties.

The MIMAH methodology ends with the construction of complete bow-ties for each selected equipment. Each bow-tie is obtained by the association of a critical event, its corresponding fault tree on the left and its corresponding event tree on the right. For each selected equipment, the number of bow-ties is equal to the number of fault trees developed. This number can be higher than the number of critical events because, for some critical events, more than one fault tree has to be built. [2]

The bow-ties, result of the whole MIMAH method, are major accident hazards, associated to each relevant hazardous equipment, and it must be assumed that no safety systems are installed or that they are ineffective. This is essential so that (MIRAS) Methodology for the Identification of Reference Accident Scenarios, may be applied.

MIRAS (Methodology for the identification of reference accident scenarios)

MIRAS have main objective and that is to choose Reference Accident Scenarios among the Major Accident Hazards identified with MIMAH. It will be needed to model Reference Accident Scenarios so that Severity can be calculated.

MIRAS will take into account: [2]

- the safety systems installed on and around the equipment
- the safety management system
- the frequency of occurrence of the accident
- the possible consequences of the accident

MIRAS contains 8 steps which must be followed, and it must be done for every bow-tie constructed with MIMAH:

- Step 1: Collect needed data
- Step 2: Make a choice between step 3 or step 4
- Step 3: Calculate the frequency of the critical event by means of the analysis of the fault tree
 - a. Step 3.A: Estimate initiating events frequencies (or probabilities)
 - b. Step 3.B: Identify safety functions and safety barriers on the fault tree

- c. Step 3.C: Assessment of the performances of safety barriers
 - d. Step 3.D: Calculate the frequency of the critical event
- or Step 4: Estimate the frequency of the critical event by means of generic critical events frequencies
- Step 5: Calculate the frequencies of Dangerous Phenomena
- Step 6: Estimate the class of consequences of Dangerous Phenomena
- Step 7: Use the risk matrix to select Reference Accident Scenarios
- Step 8: Prepare information for the calculation of the Severity

The succession of the steps of MIRAS is shown in (Figure 3). [3]

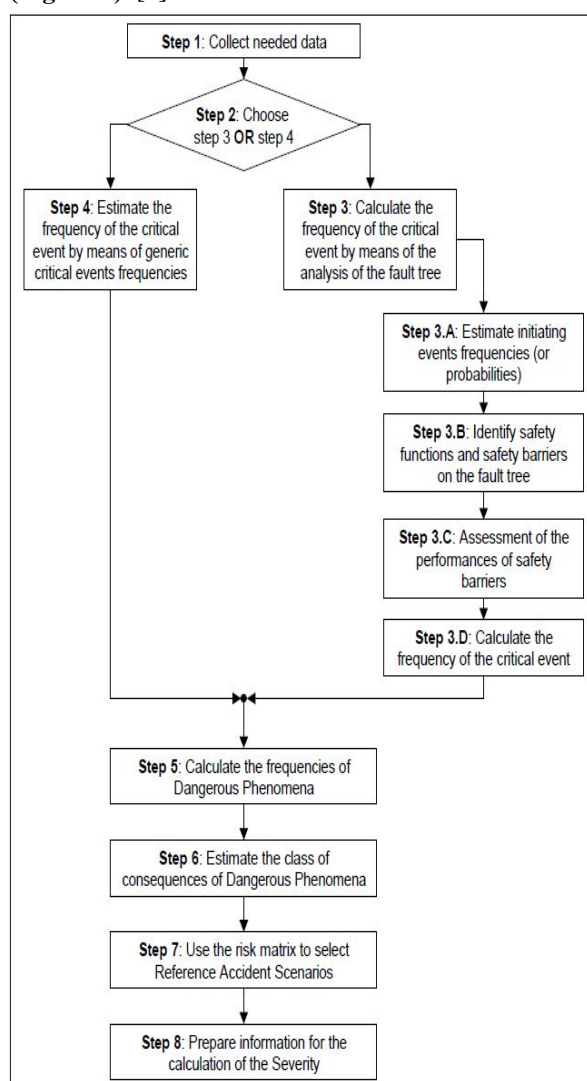


Figure 3: General overview of MIRAS steps (steps to be applied for each bow-tie built with MIMAH)

MIRAS uses for fault tree the gate-by-gate method, which starts with the initiating events of the fault tree and proceeds toward the critical event. And before calculating the output of the gate, the evaluation must

be done of all inputs to a gate. This is done by taking into consideration of all safety systems.

The frequency of each dangerous phenomenon is obtained by proceeding step by step in the event tree. For that, safety systems must be taken into account and also AND/OR gates that are not explicitly drawn in MIMAH phase of creating event tree. Potential consequences must be evaluated qualitatively for each dangerous phenomenon.

The selection of Reference Accident Scenarios is obtained thanks to a tool, called "Risk Matrix" crossing the frequency and the potential consequences of accidents. Three zones are defined in the risk matrix: the lower green zone ("Negligible effects" zone), the intermediate yellow zone ("Medium effects" zone) and the upper red zone ("High effects" zone) (see Figure 4). [3]

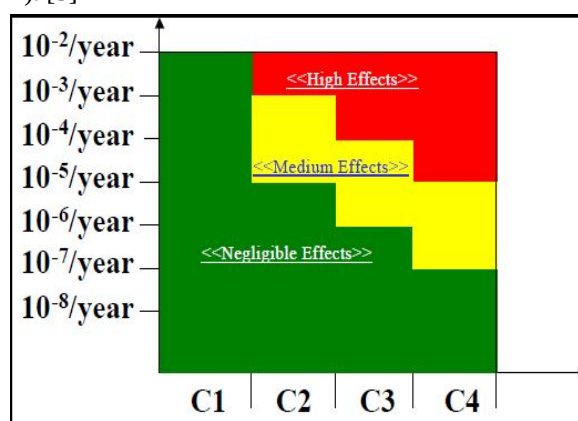


Figure 4: Risk matrix

For the severity calculations, dangerous phenomena which are located in the "yellow" or "red" zones will have to be modelled.

Risk Level (RL)

For industrial installations, the Major Accident Hazards will be first identified with MIMAH. Then, the Reference Accident Scenarios will be determined from the Major Accident Hazards. Reference Accident Scenarios define realistic scenarios, considering an installation operated at that moment. They will be used to evaluate the effects (severity) of the major accident and describe the hazard potential. Severity index S depending only on physical parameters and characterising the possible effects of scenarios. Index V characterising the spatial vulnerability of the environment of an hazardous establishment by characterising potential targets (population, natural and man-made environment). The ARAMIS method enables ranking the hazards only in terms of severity with the calculation of the severity index S for each scenario. It also enables taking into account the efforts (preventive measures) made by the company with the estimation of the prevention management effectiveness M . The severity index S can be combined with the management effectiveness index M and the vulnerability index V to define a risk level RL index of an installation in its environment (See Figure 5). [4]

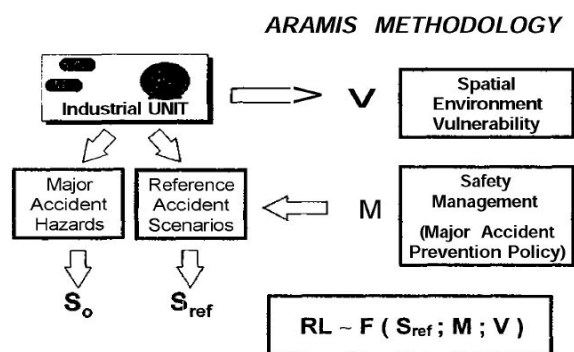


Figure 5. ARAMIS methodology representation.

CONCLUSION

ARAMIS project supports the European Research Area concerning knowledge improvement, harmonisation in decision-making process related to hazardous establishments. This method provides more realistic risk levels through risk assessment procedure, because it takes into consideration safety systems on site. It will be a great improvement for Industry and Authorities to use such a harmonised risk assessment procedure.

REFERENCES

- [1] David Hourtolou, Olivier Salvi. ARAMIS Project: development of an integrated Accidental Risk Assessment Methodology for IndustrieS in the framework of SEVESO II directive. 1. World Congress on Risk, Jun 2003, Bruxelles, Belgium.
- [2] Prof. C. Delvosalle, Ir C. Fiévez, Ir A. Pipart., "ARAMIS, Deliverable D.1.C". Faculté Polytechnique de Mons, Major Risk Research Centre, 2004, (Belgium).
- [3] H.Andersen, J.Casal, A.Dandrieux, B. Debray, V.De Dianous, N.J.Duijm, C.Delvosalle, C.Fievez, L.Goossens, R.T.Gowland, A.J.Hale, D.Hourtolou, B.Mazzarotta, A.Pipart, E.Planas, F.Prats, O.Salvi, J.Tixier.: "ARAMIS, USER GUIDE", (2004).
- [4] David Hourtolou, Olivier Salvi. ARAMIS project : Accidental Risk Assessment Methodology for IndustrieS in the framework of SEVESO II directive. LANNON, A.; COJAZZI, G.G.M. 23. ESReDA seminar "Decision analysis : methodology and applications for safety of transportation and process industries", Nov 2002, Delft, Netherlands. pp.159-170.
- [5] Debray B., Piatyszek E., Cauffet F., Londiche H., "ARAMIS DIC – APPENDIX 4, Generic fault trees". Armines, Ecole Nationale Supérieure de Mines de Saint Etienne, 2004, (France).

BIOGRAPHY of the first author

Mile Mitić was born in Niš, Serbia, in 1988. He received the bachelor with honours diploma in Environmental Safety from the University of Niš, Faculty of Occupational Safety in Niš. His main areas of research



include environmental protection, risk assessment and occupational safety in mines.

ARAMIS METODOLOGIJA: PROCENA RIZIKA U HEMIJSKOJ INDUSTRIJI

Mile Mitić, Veljko Radosavljević

Rezime: ARAMIS metodologija se koristi za procenu rizika u hemijskoj industriji pridržavajući se SEVESO II Direktive. Glavni cilj ARAMIS projekta je da kreira novu, integrisanu metodologiju za procenu rizika kombinacijom prednosti verovatnoća i pristupa baziranim na posledicama. Prvi deo ARAMIS metodologije je (MIMAH) metodologija za identifikaciju opasnosti od velikih nesreća. MIMAH se koristi za procenu najgorih nesreća koje mogu da se dese, bez razmatranja bezbednosnih sistema. Drugi deo ARAMIS metodologije je (MIRAS) metodologija za identifikaciju scenarija referentnih nesreća, koja uzima u obzir bezbednosne sisteme. ARAMIS metoda omogućava rangiranje opasnosti samo u pogledu težina, kroz proračun indeksa težine S za svaki scenario. Takođe omogućava uzimanje u obzir napora (preventivne mere) postrojenja i izračunavanje realnih nivoa rizika.

Ključne reči: ARAMIS, MIMAH, MIRAS, leptir mašina, opasan fenomen, sistemi bezbednosti, težina, ranjivost, nivo rizika.

MARIJOLA BOŽOVIĆ¹
EMINA MIHAJLOVIĆ²
SNEŽANA ŽIVKOVIĆ³
UROŠ JAKŠIĆ⁴
SANJA MARKOVIĆ⁵

INITIATIVES AND INSTITUTIONAL FRAMEWORK FOR ACCIDENT MANAGEMENT - ACCIDENT PROTECTION PLAN

¹⁴⁵Higher Technical Professional
School in Zvečan
²³University of Niš
Faculty of occupational safety in Niš,

m.bozovic@vts-zvecan.edu.rs

***Abstract:** Managing the risk of accidents for the purpose of ensuring occupational and environmental safety involves a number of activities, measures, and programs to be taken before, during, and after an accident in order to avoid it, reduce its impact, and mitigate its effects, respectively. This paper discusses the legal framework for accident management, specifically for companies and other legal entities that manufacture, store, and transport hazardous materials. Depending on its primary activity, the type and quantity of hazardous materials and the buildings it uses, a company or another legal entity is obligated to devise an accident protection plan and to adhere to it when taking measures of accident prevention and minimization of the impact on human life and health, property, and the environment. The structure of such a plan is presented, encompassing the following elements: hazard assessment; accident response measures (engaging authorized bodies in accident response; safety and rescue measures; recovery measures), and informing of the public.*

Key words: hazardous materials, accident, accident protection plan.

INTRODUCTION

Hazardous materials in production, use, transport, marketing, storage, and disposal are handled in a certain way so as not to endanger human life and health or pollute the environment, which requires the implementation of accident protection measures and other measures established by the law. Accident protection includes planning, organization, and implementation of preventive and other measures of hazardous material management based on hazard analysis, all for the purpose of reducing the risk of accidents. The consequences of accidents may include substantial losses, damage, and other negative factors for people, property, and the environment. Accident management goals are to reduce or avoid potential hazard losses, to provide prompt and proper aid for victims of a disaster, and to achieve a fast and effective recovery. The accomplishment of the first of these goals requires measures of prevention, mitigation, and minimization of the accident effects.

INTERNATIONAL FRAMEWORKS OF ACCIDENT MANAGEMENT INITIATIVE

To increase protection against major accidents, a series of documents were enacted in the EU in the mid-1990s and early 2000s, whose requirements were considerably different when compared to the previously prevalent understanding of risk management. For instance, the Convention on the Transboundary Effects

of Industrial Accidents (UN/ECE, Helsinki 1992) governs the procedures of the convention signees in cases of 'transboundary effects'. It is more detailed than the Seveso I Directive regarding the development of procedures for chemical accident control, which are acceptable as the basic methodology for risk assessment.

Directive 96/82/EC is aimed toward prevention of major accidents involving hazardous materials and toward mitigation of human and environmental impact by providing high levels of protection in a consistent and efficient manner.

APELL - Awareness and Preparedness for Emergencies at Local Level – is a publication of a program by the UNEP IE/PAC. The strategic approach of APELL is to identify and raise awareness of the presence of risk in industrialized communities, to initiate measures for risk reduction and mitigation, and to create a coordinative development of preparedness between the industry, the local government, and the population.

TransAPELL - Guidance for Dangerous Goods Transport Emergency Planning in a Local Community, a publication of a program by the UNEP IE/PAC expands the APELL instructions for risks pertaining to stationary facilities with the risks originating from the transport and distribution of hazardous merchandise. Planning in terms of transport risks is as necessary as the planning in terms of risks in

stationary facilities, but even more complex. The program has two main goals: (1) to create and/or raise the awareness of a community about the potential hazards related to hazardous material manufacture, handling, and use, and about the steps taken by the authorities and the industry to protect the community against such hazards; (2) to develop hazard response plans in conjunction with the local communities.

NATIONAL ACCIDENT MANAGEMENT FRAMEWORK

Definition of elements for risk management in Serbia began in 1994, with the introduction of Hazard Assessment Methodology, provided within the document *Rules on the Methodology for Assessing Chemical Accident and Environmental Pollution Hazards, and Preparation and Recovery Measures*. The Rules were adopted according to the Directive 82/501/EEC (Seveso I), so it clearly does not include Directive 96/82/EC, Directive 96/61/EC, UN/ECE Convention on the Transboundary Effects of Industrial Accidents, UN/ECE Convention on Environmental Impact Assessment in a Transboundary Context, and the Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context. The enactment of the Law on Environmental Protection, the Law on Integrated Prevention and Control of Environmental Pollution, and the Law on Environmental Impact Assessment has initiated a new phase in the development of risk assessment methodology.

According to the Law on Environmental Protection, “an **accident** is a sudden and uncontrolled event or a series of events resulting from uncontrolled release, discharge, or spillage of hazardous materials during their manufacture, marketing, use, transport, processing, storage, disposal, and inadequate long-term preservation”.

According to the EU Seveso II Directive, a **major accident** is an occurrence such as a major pollutant emission into the environment, fire, or explosion resulting from uncontrolled developments in the course of an industrial activity, and leading to serious danger to human health and/or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances.

Based on the Law on Emergencies, a *Regulation on the Content and the Manner of Devising Emergency Safety and Rescue Plans* was enacted. The Regulation governs the content and the procedure of creating the Emergency Safety and Rescue Plan on the national level, the level of state administration, autonomous provinces, local self-government units, companies and other legal entities, and other organizations.

Companies and other legal entities dealing in manufacture, storage, and transport of hazardous materials and the management of buildings potentially exposed to terrorist attacks are obligated to create a document Accident Protection Plan, which is an

integral part of the Safety and Rescue Plan. The Accident Protection Plan is devised according to the *Rules on the Manner of Devising and the Content of Accident Protection Plans*.

Pursuant to the Law on Emergencies, the Accident Protection Plan governs the following aspects: organisation and procedures of notification and engagement of accident response authorities; situational assessment and decision making; risk reduction measures for employees at high-risk workplaces involved in accidents; early warning and notification of state authorities and local self-government units about the accident, followed by public announcements, including the aid measures employed by those authorities during their protection plan implementation; organization of authorities and employees in the implementation of safety and rescue measures and environmental protection in the event of accident; organization of informing the public; organization of work continuation and accident recovery.

STRUCTURE OF THE ACCIDENT PROTECTION PLAN

The structure of the Accident Protection Plan is the following:

1. hazard assessment;
2. accident response measures;
 - engagement of accident response authorities;
 - safety and rescue measures;
 - accident recovery measures;
3. informing the public.

1. Hazard assessment

Hazard assessment is performed to establish the danger to human life and health and the vulnerability of buildings and the environment from the effects of accidents caused by activities involving hazardous materials or by terrorist activities. It contains the general information about the company or another legal entity, hazard identification, prevention measures, and assets.

1.1. General information about the company or another legal entity is obtained through data collection and it includes the following: name and location of legal entity; data on responsible person(s); data on hazardous materials; properties of hazardous materials generated during accidents; listing of hazardous materials; used technologies; data on the characteristics of facilities, devices, and equipment; data on the characteristics of buildings, devices, and equipment in terms of vulnerability to terrorist activity; and characteristics of the location and its surrounding.

1.2. Hazard identification involves the identification of buildings and critical points, i.e. locations in a process or a facility that constitute the weakest points or potential sources of accident hazards. The identification stage is particularly focused on analyzing the human factor as a potential cause of accident.

Representation of a possible turn of events, or a scenario, involves the analysis of potential causes, the scope, and the effects on humans, animals, the environment, and property. A scenario has to acknowledge the complexity and purpose of buildings or facilities, the complexity and danger of manufacturing processes, the level of hazardous activities by the company or another legal entity, and the possible consequences.

A vulnerability analysis is aimed at identifying and listing the following parameters: the total number of employees in a facility or a complex; jobs and the number of employees currently performing their job tasks in a facility or a complex; the number of people who are expected to be in a facility/building in predicted accident areas (it is necessary to represent the distribution of employees graphically over a layout plan of the facility/complex/building); the number of people at least 1 km away from the complex/building. The possible accident level is determined based on the predicted scenario and vulnerability analysis, and is expressed by a five-point scale.

1.3. Preventive measures are taken in order to prevent or reduce the probability of an accident and to mitigate its effects. Preventive measures comprise the following: measures planned or implemented by spatial planning, design, and construction of the facility or complex building; measures planned or implemented by the selection of manufacturing technology, technological equipment, process management equipment, and other technical equipment; measures planned by the selection of technical and technological solutions that provide safer transport of hazardous materials; measures providing quality and timely maintenance of the technical and technological aspects of a building/facility, the level of knowledge, and the level of work and technological discipline; measures intended to maintain passageways and hallways in buildings/facilities; measures planned for the safety system: supervision, security and safety system management, and hazard detection and identification; measures planned by the organization of training and education of human resources for accident response; measures planned by the creation and verification of planning documentation for accident response.

1.4. Assets for safety and rescue and for mitigation and elimination of accident effects

This portion pertains to assets, their capacities, and the need to implement safety and rescue measures and accident effect mitigation and elimination. It comprises the available human resources, available material assets and safety and rescue equipment, and assessment of the suitability of human resources and material assets to provide assistance.

2. Accident response measures

Accident response measures comprise the following:

(1) engagement of accident response authorities defines the procedures and measures that elaborate the activities and procedures of authorized

bodies and organizations (human and material resources) and their preparedness to perform safety and rescue tasks;

(2) safety and rescue measures define the procedures and measures to be taken in order to mitigate the effects of accidents;

(3) accident recovery measures are aimed at mitigating the effects, organizing post-accident monitoring and recovery, and creating conditions for restoring life and work at the location of the accident.

3. Informing the public

This involves defining and elaborating procedures of notifying and informing the public about the hazards, measures taken to prevent the accident from spreading, safety and rescue measures, and accident recovery measures, or more specifically: general information about the nature of the hazard from hazardous materials (with an emphasis on the main hazardous properties) potentially affecting humans, animals, the environment, and property; measures and manner of timely notification of employees and the general population about the accident location and effects; a person responsible for communicating with the public; measures and activities taken within the company or another legal entity in order to prevent the accident effects from spreading further or to eliminate them.

CONCLUSION

Planning and implementation of activities and investments on all levels, which are based on the knowledge of risk and which provide the highest possible degree of protection of people and property from potential future accidents, represents a systemic response of the society to this kind of danger and enables the reduction of the risk of accident and potential major consequences. The goal of society as a whole is to use efficient methods to minimize the impact of harmful effects due to potential or real hazards, to provide timely and efficiently organized emergency response, which can proceed even after the primary effects of an accident have waned, and to work at unifying and coordinating the activities directed toward protecting human health and property.

REFERENCES

- [1] Savić, S., Anđelković, B., Stanković, M., Borota, P. (2002). Specifičnosti sistema upravljanja rizikom [Particularities of the Risk Management System]. Proceedings from the 1st professional counselling session: *Engineering risk and hazards in the urban system of Belgrade*. Beograd: Skupština grada Beograda, pp. 227-234.
- [2] Nikolić V., Živković. N. (2010). Bezbednost radne i životne sredine, vanredne situacije i obrazovanje [Occupational and Environmental Safety, Emergencies and Education]. University

of Niš, Faculty of Occupational Safety in Niš, 2010. ISBN 978-86-60093-021-9, 335.

- [3] APELL – UNEP IE/PAC, 1988.
- [4] TransAPELL – UNEP IE/PAC, 2000.
- [5] European Directive 82/501/CEE – *Seveso I*
- [6] European Directive 96/82/CE – *Seveso II*
- [7] UN/ECE EIA, Espoo Convention, 1991.
- [8] UN/ECE, Helsinki Convention, 1992.
- [9] *Law on Emergencies*, (“Official Gazette of the Republic of Serbia”, No. 111/09, 92/2011, 93/2012).
- [10] *Law on Environmental Protection*, (“Official Gazette of the Republic of Serbia”, No. 135/04, 36/2009, 72/2009, 43/2011-decis. US, 14/2016, 76/2018).
- [11] *Law on Integrated Prevention and Control of Environmental Pollution*, (“Official Gazette of the Republic of Serbia”, No. 135/04, 25/2015).
- [12] *Law on Environmental Impact Assessment*, (“Official Gazette of the Republic of Serbia”, No. 135/04, 36/2009).
- [13] Rules on the Methodology for Assessing Chemical Accident and Environmental Pollution Hazards, and Preparation and Recovery Measures, (“Official Gazette of the Republic of Serbia”, No. 60/94).
- [14] Rules on the Manner of Devising and the Content of Accident Protection Plans, (“Official Gazette of the Republic of Serbia”, No. 82/2012).

BIOGRAPHY of the first author

Mariola Božović graduated from the Faculty of Occupational Safety. She currently works as an Instructor at High Technical School of Professional Studies in Zvecane at the study programme fire safety. From 2014, she is a PhD



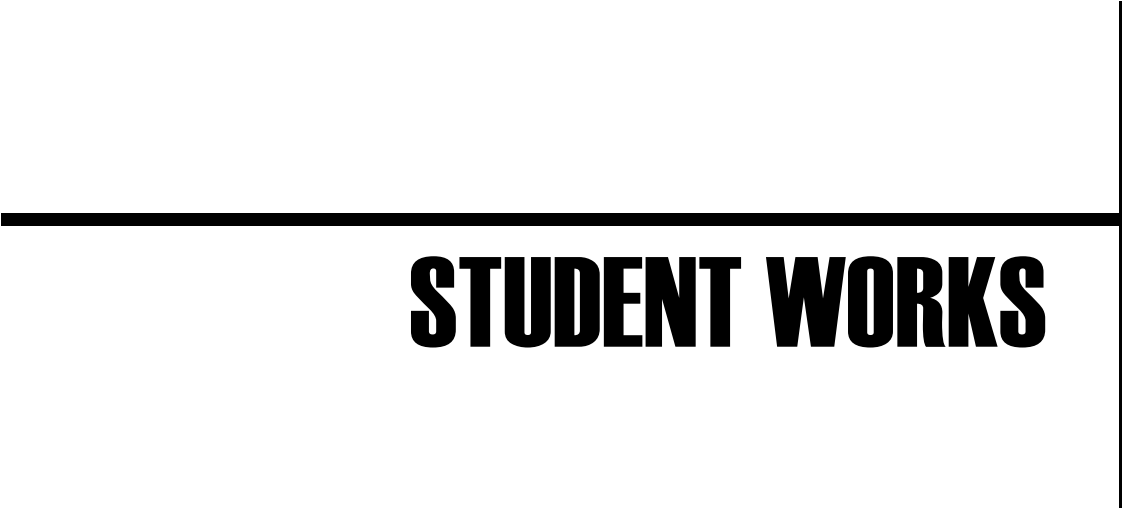
student at the Faculty of Occupational Safety in Nis, the study programme Environmental Safety Engineering. She lives and works in Kosovo.

INICIJATIVE I INSTITUCIONALNI OKVIR UPRAVLJANJA UDESIMA - PLAN ZAŠTITE OD UDESA

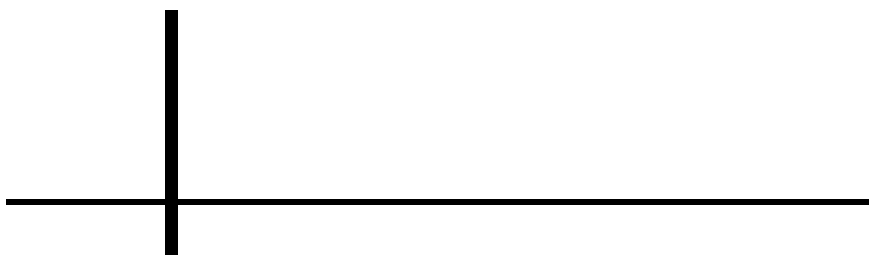
Marijola Božović, Emina Mihajlović, Snežana Živković, Uroš Jakšić, Sanja Marković

Rezime: Upravljanje udesnim rizicima u cilju ostvarivanja bezbednosti radne i životne sredine podrazumeva niz aktivnosti, mera i programa koji se preduzimaju pre, u toku i nakon udesa u cilju izbegavanja udesa, smanjenja njegovog uticaja i oporavljanja od pretrpljene štete. U radu će biti prikazan zakonodavni okvir za upravljanje udesima, konkretno za Privredna društva i druga pravna lica koja proizvode, skladište i transportuju opasne materije. Uzimajući u obzir delatnost kojom se bavi, vrstu i količinu opasnih materija i objekte koje koristi, Privredno društvo i drugo pravno lice ima obavezu da sačini i Plan zaštite od udesa i da u skladu sa tim dokumentom, preduzme mere za sprečavanje udesa i ograničavanje uticaja udesa na život i zdravlje ljudi, materijalna dobra i životnu sredinu. Biće prikazana struktura Plana zaštite od udesa, koja sadrži sledeće elemente: procena opasnosti; mere odgovora na udes (aktiviranje organa i struktura za reagovanje u slučaju udesa; mere zaštite i spasavanja; mere otklanjanja posledica udesa), i informisanje javnosti.

Ključne reči: opasne materije, udes, Plan zaštite od udesa.



STUDENT WORKS



ANICA RANDELOVIĆ¹
ŽELJKO MILIĆ²

MENTOR:
JELENA
MALENOVIĆ-NIKOLIĆ

^{1,2} University of Niš,
Faculty of Occupational Safety

¹anicarandelovic18150@eunet.rs
²zeljkomilic18094@gmail.com

BIOLOGICAL HAZARDS AS A RISK FACTOR FOR HEALTH PROFESSIONALS

Abstract: *This paper discusses types of biological hazards that affect the safety and health of health professionals. The aim of the paper is to highlight the importance of risk assessment pertaining to the safety and health of health professionals affected by biological hazards and the necessity of implementing the prescribed safety measures for employees exposed to biological agents.*

Key words: biological hazards, risk assessment, safety measures.

INTRODUCTION

It is general knowledge that health professionals are exposed to a number of risks of occupational injury or disease. Employees in medical centres, hospitals, infirmaries, emergency services, and other healthcare institutions are exposed to biological, chemical, and physical hazards, stress, and other physical and mental hazards.

This paper analyses some of the most common hazards that directly or indirectly lead to health issues of health professionals, thus potentially shortening their life. Biological hazards require special attention, as they can be the biggest risk factor for health professionals. Therefore, the organization of occupational safety and preservation of occupational health in medical institutions is a highly complex and responsible job.

The aim of the paper is to highlight the risk factors and the ways of exposure to risk, safety and health issues of health professionals due to biological hazards, and the role of the occupational medicine department in the implementation of employee safety measures related to biological agents.

BIOLOGICAL HAZARDS

Biological hazards are caused by biohazardous organisms and biological agents that produce hazardous materials, which have a negative impact on human and environmental health. Biohazardous organisms include: bacteria, viruses, parasites, fungi, prions, and microorganisms related to bioterrorism. Biohazardous organisms are found in laboratories (medical, veterinary, diagnostic, clinical, or research), in healthcare institutions, in food manufacturing facilities, in waste recycling facilities, in sewage treatment facilities, and numerous other places.

Biological hazards include [1]:

- biological agents - microorganisms and genetically modified microorganisms, cell cultures, and human endoparasites capable of causing infections, allergic reactions, or toxic effects;
- microorganisms - cellular and non-cellular microbiological entities capable of reproduction or transfer of genetic material;

- cell cultures - in vitro bred cells originating from multicellular organisms.

Biological agents are classified into four risk groups [2]:

- Risk group 1 - biological agent unlikely to cause a disease in humans;
- Risk group 2 - biological agent likely to cause a disease in humans and potentially hazardous to employees, but unlikely to spread into the environment; quality prophylaxis or treatment readily available;
- Risk group 3 - biological agent likely to cause a serious disease in humans and posing a serious threat to employees; likely to spread into the environment; quality prophylaxis or treatment readily available;
- Risk group 4 - biological agent causing a serious disease in humans and posing a serious threat to employees; high risk of spreading into the environment; quality prophylaxis or treatment not readily available.

RISK TO HEALTH PROFESSIONALS

The risk of infection is present with all health professionals working directly with blood, urine, faeces, various secretions, and tissue parts or providing care, treatment, or diagnostics for patients suffering from infectious diseases. The jobs with increased risk include surgeons, gynaecologists, orthopaedists, pathologists, dentists, laboratory technicians, nurses, and many others.

During their job performance, health professionals can suffer from [1]:

- mild infections (colds, respiratory infections, staphylococcal skin infections);
- severe infections (viral hepatitis, tuberculosis, measles, chickenpox, salmonellosis, meningitis, and other);
- lethal infections (AIDS, SARS);

Figure 1 shows an image of a skin condition due to staphylococcal bacteria.



Figure 1. *Staphylococcal bacteria skin condition* [3]

Figure 2 shows the rod-shaped *mycobacterium tuberculosis*, the bacterium that causes tuberculosis.



Figure 2. *Tuberculosis-causing bacteria* [4]

Figure 3 shows the human immunodeficiency virus (HIV), which is responsible for the acquired immunodeficiency syndrome (AIDS). It considerably differs in shape from other viruses.

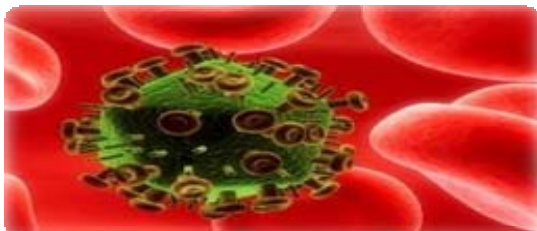


Figure 3. *Human immunodeficiency virus (HIV)* [5]

Viral hepatitis B and C, AIDS, and tuberculosis are the biggest threats to health professionals.

There are diseases caused by biological factors that can be regarded as professional diseases, provided certain conditions. These diseases include [1]:

- Imported tropical diseases, diseases caused by viruses and bacteria;
- Anthroponoses;
- Viral hepatitis;
- HIV infection;
- Tuberculosis.

Even though health professionals are well-educated and trained, they still suffer the consequences of biological hazard exposure because they occasionally fail to adhere to the prescribed measures for risk prevention, reduction, and elimination.

The Kinney method

The Kinney method is used to assess the level of risk of biological hazards in medical institutions. All job positions with an estimated risk of over 200 are considered high-risk jobs. Risk assessment is performed within medical institutions and includes jobs in which health professionals are exposed to biological

hazards. The assessment is performed by a licensed organization for risk assessment, pursuant to the Occupational Safety and Health Law, but the process also involves the occupational medicine department within the Institute for Occupational Health Protection.

Table 1. *Risk ranking according to biological hazards* [6]

A	Acceptable	$R < 20$
L	Low	$20 < R < 70$
M	Moderate	$70 < R < 200$
H	High	$200 < R < 400$
V	Very high	> 400

Table 1 shows the ranking of risk acceptability based on the Kinney method:

- A (acceptable) and L (low) risks are considered acceptable;
- M (moderate) risk is the limit value and it is allowed only if proposed occupational safety and health measures can make it acceptable;
- H (high) and V (very high) risks are unacceptable.

Requirements and conditions

There are certain requirements and conditions that health professional have to meet in order to avoid any diseases due to biological hazards.

The requirements include [1]:

- Preserved ability to fulfil job requirements;
- Preserved ability of perception;
- Preserved hand and finger dexterity and general physical competence;
- Preserved ability of spatial assessment;
- Preserved oculomotor coordination;
- General intellectual capability;
- Ability to concentrate and to focus one's attention and to memorize written and spoken orders;
- Emotional stability;
- Responsibility (conscientiousness);
- Social adaptiveness;
- Cooperativity;
- Resourcefulness (problem-solving efficiency);
- Initiative and independent thinking (making the right decisions);
- Work organization.

The conditions include [1]:

- Preserved and functioning sense of sight;
- Preserved and functioning sense of hearing;
- Preserved sense of balance;
- Preserved tactile sensation;
- Preserved function of the cardiovascular system;

- Preserved function of the respiratory system;
- Preserved muscular strength and mobility and spinal and joint function;
- Preserved function of the nervous system;
- Preserved function of the endocrine system;
- Preserved function of the gastrointestinal system;
- Preserved function of the haematopoietic system;
- Preserved function of the urogenital system;
- Undamaged (intact) skin.

The measures for risk prevention, reduction, and elimination include [1]:

- Careful handling of sharp objects;
- Regular and proper disposal of used materials;
- Maintenance of instrument hygiene;
- Maintenance of personal hygiene;
- Disinfection of work surfaces;
- Use of personal protection equipment;
- Checking if personal hygiene items are adequate;
- Concentration during work;
- Efficient work organization;
- Training and periodical knowledge testing;
- Provision of proper work uniform, safety headwear, safety mask, sterile disposable, safety shoe covers, and safety goggles.

Risk of biological hazards for health professionals can be reduced through:

- Employee training for safe and healthy work;
- Devising instructions for safe and healthy work;
- Proper disposal of used medical substances and instruments;
- Good hygiene;
- Regular swabbing of work surfaces;
- Use of adequate personal protection equipment during contact with potential irritants;
- Employee immunization against diseases caused by biological agents for which a vaccine is available;
- Medical examinations by the department of occupational medicine;
- Prevention and containment of health care-associated infections.

All previously discussed jobs entail higher risk according to occupational safety and health regulations.

CONCLUSION

The increased risk is due to biological hazards. Workplaces in medical institutions are often ridden with airborne biological hazards, such as bacteria, viruses, and fungi. There are also biological hazards

transmitted via contaminated instruments resulting from punctures or from blood contact of an infected patient with damaged skin or mucous membrane of health professionals. In all domestic medical institutions, it is necessary to adhere to the health requirements imposed by the occupational medicine department, to organize continuous education and training of employees, and to properly implement preventive occupational safety and health measures.

REFERENCES

- [1] Unapređenje sistema zaštite na radu, Zbornik radova [Improvement of the Occupational Safety System, Conference proceedings], Tara, 27-30 October 2016.
- [2] Analiza pokazatelja za procenu profesionalnog rizika [Analysis of Indicators for Professional Risk Assessment], Ivan Krstić, Dejan Krstić, Ana Kusalo, available at: <http://www.znrfak.ni.ac.rs/SE-Journal/Archive/2011-12/Safety%20Engineering%201/PDF/10%20%20-%20S2011.1.01.08%20Ivan%20Krstic.pdf>
- [3] Bakterija iz grupe stafilokoka [Staphylococcal bacteria], available at: https://www.google.rs/search?q=staphylococcie+cutan%C3%A9+photos&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjui4WH9oPeAhURzKQKHYYFCksQ_AUIDigB&biw=1242&bih=525#img=9nBylYUozl7MQM
- [4] Izazivač tuberkuloze [Causative agent of tuberculosis], available at: https://www.google.rs/search?q=bacteria+of+tuberculosis+photo&rlz=1C1GCEA_enRS812RS812&source=lnms&tbm=isch&sa=X&ved=0ahUKEWjr5vLC94PeAhVvMewKHQ1-CpwQ_AUIDigB&biw=1242&bih=569#img=U9J-2Xoeryv5PM
- [5] Izazivač Side [Cause of AIDS], available at: https://www.google.rs/search?q=virus+aids+photos&tbm=isch&tbs=rimg:CWXCUhIX2v3fjh51RkPaOMEOWVUq2c n3kD5h4wnJZaa1As8UuWmvAx2mBr5uVQAk0d2tP PLEExGwwXXNiCStYUBCoSCXnVGQ9o74wQEVkq 93pFQaQTKhIJ7BVSrZyfeQMRMjpS0DL6g_1wqEgn mHjCellpr8BEDH6c3uNgjdyoSCSzxS5aa8DHaEQO
- [6] Stepenovanje rizika prema biološkim štetnostima, Zbornik radova – Unapređenje sistema zaštite na radu [Risk ranking according to biological hazards, Improvement of the Occupational Safety System, Conference proceedings], Tara, 27-30 October 2016.

BIOGRAPHY

Anica Randelović was born in Prokuplje, Serbia, in 1999. She finished the Secondary School of Medicine “Aleksa Savić” in Prokuplje with highest grades. She is currently a first year student at the Faculty of Occupational Safety in Niš, University of Niš.



BIOLOŠKE ŠTETNOSTI KAO FAKTOR RIZIKA ZDRAVSTVENIH RADNIKA

Anica Randelović, Željko Milić

Rezime: U izloženom tekstu prikazane su definicije i vrste bioloških štetnosti koje utiču na zdravlje i bezbednost zdravstvenih radnika. Cilj rada je da se ukaže na načine procene rizika po bezbednost i zdravlje zdravstvenih radnika kod uticaja bioloških štetnosti i da se prikažu mere zaštite zaposlenih koji su izloženi biološkim agensima.

Ključne reči: biološke štetnosti, procena rizika, mere zaštite.

TANJA RISTIĆ¹
MARKO PETROVIĆ²

NOISE AS AN OCCUPATIONAL RISK FACTOR

MENTOR:
JELENA
MALENOVIĆ-NIKOLIĆ

¹University of Niš,
Faculty occupational safety,

¹tanjaristic1804@gmail.com
²mare94petrovic@gmail.com

Abstract: With the development of production tools and transport, and the resulting increase in energy consumption, in both larger and smaller cities the levels of noise and vibration are increasing every year in both the occupational and the natural environment.

Key words: noise, work environment.

INTRODUCTION

Research of environmental pollution factors in developed industrial countries has shown that noise and vibration are ranked third, as a serious factor affecting the environment. Over 40% of adult population in developed countries experience difficulties caused by noise and vibration [1].

THE ISSUE OF OCUPATIONAL NOISE

In the second half of the 20th century, particularly during the 1970s, when the issue came into focus of scientific circles, the noise level in large cities, including Belgrade [1], reached the values of 80 dBA in specific zone, and even higher during certain time periods.



Figure 1. Noise sources [1]

Significant international measures are already being taken in order to reduce the noise from traffic, industrial machinery, and industrial plants, which generate specific levels of noise, which is then emitted into the work environment, reaching every workplace [1].

The impact of noise on humans (Figure 1) depends on the noise intensity level, from the level allowing people to function normally without any unwanted effects to the level resulting in irritating sounds that disturb people's lives.



Figure 2. Impact of noise on humans [1]

Noise is any unwanted sound [2]. This means that every phenomenon such as buzzing, alarms, or loud sounds create a disturbance in people's lives. These occurrences can reflect negatively on human health.

CONSEQUENCES OF NOISE EXPOSURE

Nowadays, hearing damage commonly occurs due to exposure to excessive noise, and if the exposure occurs on a daily basis for several hours, it can result in permanent hearing damage that cannot be cured by any medical treatment.

Noise does not cause only hearing damage but also other physical, mental, and social pressures. Noise can [3]:

- Interfere with communication;
- Make the reception of auditory alarm signals difficult;
- Induce fatigue;

- Reduce occupational safety (reduced concentration);
- Cause disorientedness and neurovegetative reactions (pallor, perspiration, elevated heart rate, sickness, vomiting, dizziness, etc.).



Figure 3. Hearing damage [1]

Hearing damage (Figure 3) is very common nowadays, occurring among both the older and the younger populations, due to multiple reasons, including long periods of work with noisy machines without proper safety equipment.

The allowed noise levels in workplaces and in work environments are established according to the following parameters [5]:

- Not interfering with the performance of specific activities and tasks;
- Not interfering with direct speech communication;
- Not interfering with direct communication by other means;
- Not damaging to hearing - the overall maximum allowed noise level is 90 dBA;
- Allowed time of noise exposure in relation to the total noise level in the workplace.

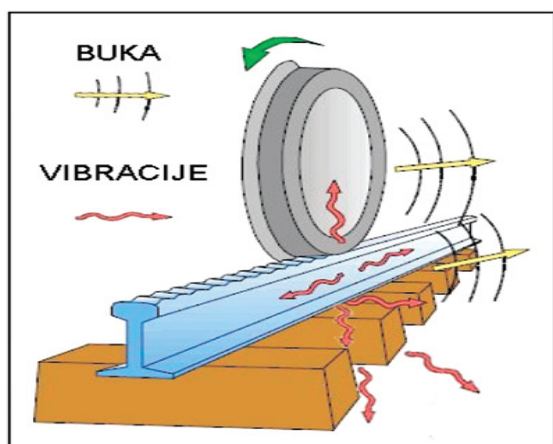


Figure 4. Noise and vibration [1]

Figure 4 shows how noise (yellow arrows) waves and vibrations (red arrows) are propagate in a work environment.

The fact is that one out of six persons over the age of 50 suffers from hearing difficulties and needs hearing aids. Hearing loss severity ranges from mild and moderate to severe and profound. Mild hearing loss reduces a person's ability to understand speech, while profound hearing makes it impossible to understand spoken communication. Regardless of the hearing loss level, many sounds are difficult or impossible to hear – sounds like birds chirping, whispering, and devices such as the telephone. If noise exposure occurs for several hours a day, hearing loss can become permanent and incurable [5].

Noise can occur both indoors and outdoors. It is especially dangerous for workers working with noisy machinery in factories or construction sites.

The maximum allowed noise level in construction sites is 65 dB during the day regardless of the urban zone the site belongs to. During the period between 8 am and 6 pm, it is allowed for additional 5 dB to be exceeded [6].



Figure 5. Construction site noise [1]

Construction sites (Figure 5) are perhaps some of the noisiest locations accompanied by vibrations, because of the heavy machinery used.



Figure 6. Occupational noise [3]

In order to reduce this phenomenon, one needs to analyze and understand it at a proficient level.

Human protection against occupational noise requires that workers wear and utilize protective work equipment, which includes ear protectors, ear plugs, or cotton wool.



Figure 7. Noise protection [1]

Ear protectors (Figure 7) are a piece of equipment that aid workers in protecting their hearing against noise from loud machines and work tools. They are to be used in all noisy work environments, whether they are in the form of over-the-ear or in-ear protectors.

Construction solutions of buildings (walls, roofs, windows, ventilation openings, foundations) have the most impact on the transfer of noise and vibration to open industrial spaces outside the facility, from where noise propagates further through the environment [1].

The main cause of noise and vibrations can be classified as follows [1]:

- Construction parameters;
- Manufacture technology;
- Work process.



Figure 8. industrial production - source of noise [1]

Methods of controlling noise sources during development, construction, manufacture, or maintenance, which are aimed at eliminating or minimizing the effects of the said causes of noise.

CONCLUSION

Standards and regulations that regulate the field of protection of humans against noise cover the entire audible area between the hearing threshold and the pain threshold, which is the result of a wide noise frequency spectrum to which humans can become exposed.

Since noise is any unwanted sound, any sound event (buzzing, alarm, murmur, clamour, banging, speech) that interferes with work or rest is considered as noise.

Noise is one of the primary causes of complex human health problems, especially in densely populated cities.

Noise protection measures have to be predicted as early as the main project design and during the planning of room layout in buildings.

REFERENCES

- [1] Ratko Uzunović, „Menadžment kvalitetom i okolinom zaštita od buke i vibracija“ [Quality and Environmental Management – Protection against Noise and Vibration], LOLA institut Beograd, 1997.
- [2] Radosavljević Lj. „Teorija oscilacija“ [Oscillation Theory], Mašinski fakultet, Beograd, 1972.
- [3] <https://repozitorij.unin.hr/islandora/object/unin%3A74/datastream/PDF/view>
- [4] Petrov Brigita, Stevanović-Pišteljić Smiljka, Paunović Katica, Biologija [Biology], Zavod za udžbenike, Beograd, 2015.
- [5] <https://www.audiovox.rs/Audiovox/131/Tipovi-ostecenja-sluha.shtml>
- [6] <https://multifizika.hr/baza-znanja/buka/buka-gradilista/>
- [7] <http://www.zrenjanin.rs/1-295-294-0/Monitoring>
- [8] <https://pharmanetwork.rs/upala-uha-i-ostecenje-sluha/>
- [9] <http://www.novolist.hr/Vijesti/Rijeka/ZIVOT-UZ-GRADILISTE-U-RIJECI-Buka-prasina-i-ruski-rulet-pri-prelasku-ceste>
- [10] http://alat.manal.hr/product.php?id_product=1070

BIOGRAPHY

Tanja Ristić was born in Leskovac, Serbia, in 1999. She finished a secondary school of economics in Bojnik, Serbia.

She is currently a freshman-year student at the Faculty of Occupational Safety in Niš.



BUKA KAO FAKTOR RIZIKA U RADNOJ SREDINI

Tanja Ristić, Marko Petrović

Rezime: Sa razvojem sredstva za proizvodnju, saobraćaja i potrošnje energije u industriju kao u većim, tako i u manjim gradovima nekim delom, iz godine u godinu beleži se porast nivoa buke i vibracije u čovekovoj radnoj i životnoj sredini..

Ključne reči: buka, radna sredina.

ŽELJKO MILIĆ¹
ANICA RANĐELOVIĆ²

MENTOR:
JELENA
MALENOVIĆ-NIKOLIĆ

¹University of Niš
Faculty of Occupational Safety

¹zeljkomilic18094@gmail.com

²anicarandelovic18150@eunet.rs

IMPACT OF EMERGENCIES ON HUMAN PSYCHOLOGICAL STATE

Abstract: Work environment refers to the totality of material factors and social relations in which people perform their work and other activities. Material factors include physical and technical work environment conditions and social relations include relations between people at work. The industrial revolution, especially the scientific and technological revolution, induced substantial changes in the work environment. As opposed to the “natural work environment” in the post-industrial production, modern times gave rise to the creation of “technical environment”, which is considerably different, particularly during emergencies, which can have a negative impact on the psychological state of workers.

Key words: emergencies, work environment.

INTRODUCTION

A large number of machines in a specific enclosed space, as well as the process of technical division of labour, have enabled serial production. The position of workers in the production process has changed, as well as their relation to other workers. By working, people establish connections and relations with other workers and with their superiors. Relations of production cause certain consequences for the workers as the social relations in the work environment. This paper primarily discusses the impact of work environment on people during emergencies. The topic of psychological state of humans in distress and fire and rescue crews during fires, technical interventions, and other emergencies requires a detailed analysis, as well as understanding of what essentially causes the issues.

Hazards threatening personnel during emergencies

The public learns about most of the hazards in difficult work conditions from general sources of everyday information, such as television, radio, the Internet, newspapers, and others. It is also very well known that these information sources are sometimes unable to represent a given situation or the hazards therein as they are, usually due to personal reasons or sheer uninformedness.

Unfortunately, events such as fires, traffic accidents, explosions, earthquakes, floods [1], and the like are reported by the mass media on a daily basis. The reports frequently comment on specific preventive measures that would help avoid such events in the future. It is well known that fires entail a hazard of building collapse, fast combustion of easily ignitable buildings, smoke poisoning, and high temperatures. With regard to explosions and earthquakes, collapses are fairly common, and there is risk of fires [2, 3] and release of highly damaging gases into the atmosphere. Floods are responsible for numerous destroyed

households and fertile soil, and they even cause landslides.

The information obtained from the abovementioned sources are not always completely true and are sometimes based on incomplete data or information used solely for the purpose of publicity. The issue that receives little or no media attention is the psychological state of people stricken by any of the aforementioned emergencies and people who selflessly risk their own lives trying to save the former group of people.



Figure 1. Fixed fire suppression system [4]

Fires entail the hazard of collapse, high temperatures, smoke inhalation, and the like. These are all true but there are many more details pertaining to these events. Collapses are very dangerous and, regardless of how a building was constructed, there is always some risk of collapse and the firefighters are aware of that risk.

In everyday circumstances, most buildings are not in full compliance with regulations and standards, which automatically considerably increases the risk of collapse, even of “unplanned” collapse, as much as such situations can be planned or calculated. The main reason for this state is the lower standard of living and the lack of sufficient material conditions for prescribed construction measures and materials. The majority of houses do not have regulation-compliant (strong enough) foundations in relation to the size of the building they support. Likewise, there are not enough load-bearing columns and beams, which are the most

important parts of a building in terms of its durability; buildings are usually built with partition walls, hollow pot slabs, slabs, or solid bricks, which is sometimes unsafe even in regular conditions, let alone during emergencies. Some of the other problems include the introduction of highly flammable and toxic materials in construction work, increased number of electric devices in everyday life, and the lack of general informedness among people. When burning, some materials release hazardous gases; for instance, many buildings contain doors and windows made of PVC, which is essentially plastic, releasing polyvinyl chloride gas $[-(\text{CH}_2-\text{CHCl})_n-]$, a highly toxic chemical compound, when on fire. Even in small amounts, it can cause tumours, skin conditions, endocrine gland disorders, lower immunity, diabetes, and other serious health issues. It is manifested later and cannot be registered instantly. The same applies to other materials used in everyday life, as most of them change their phase into gaseous when exposed to high temperatures or fire and evaporate into the atmosphere. This trend of building construction has considerably reduced the time of evacuation from burning buildings. The situation is the same with earthquakes and floods in terms of construction hazards.



Figure 2. Forest fire suppression [4]

Buildings constructed inadequately and against regulation are always at risk of collapsing and they constitute a high-risk work environment.

Psychological state of civilians (afflicted persons) during emergencies

In modern times, people are not fully aware of how hazardous their own actions are and how much their lives are at risk. Of course, when considered theoretically, these situations appear fairly simple. In the event of any accident, there are procedures in place that need to be followed. Even when people have the opportunity to participate in an exercise (simulation), e.g. fire in a residential building, the events unfold in a much simpler manner than they would in an actual fire event. First of all, people are subconsciously aware that they are witnessing a simulation and that there is no real risk, which means that there is time and room for

mistakes, as it is an exercise and there are professionals monitoring and controlling the situation at all times. Finally, after the simulation everyone returns to their daily activities.



Figure 3. Work activities of firefighters [4]

In real-life situations, things are completely different. In most cases, homeowners are initially unaware of a fire, a malfunctioning installation, a stove that is left on, a cigarette butt, etc. Fires are most easily suppressed in the earliest stages. After only several minutes, a fire transitions into a blazing stage, becoming a medium-size or a large fire, in technical terms. Specifically, after one or two minutes, the situation can drastically worsen, minimizing the chances for fast response. In such situation, civilians (afflicted persons) most often do not know how to respond and experience panic attacks, anxiety, sometimes even temporary paralysis, or chaotic and absent-minded motion. When all of this is accumulated, the afflicted persons are unable either to compose themselves and call the fire and rescue units or to ventilate the room, reduce the temperature, and lower the risk of a flashover. Other necessary actions include closing the doors, thus preventively creating fire sectors, alarming the neighbours, collecting important items (documents or valuables), turning off power sources, and shutting off the gas valve if present. Fire and rescue units arrive at the scene in 7 minutes on average, they assess the scene, assess the risk, the first-due engine company engages the fire inside, performs rescue, desmoking, and extinguishment, while the second-due and third-due companies simultaneously engage the fire externally and form an evacuation corridor, all of which requires around 10 minutes from the fire alert. Depending on the fire, suppression takes about 15-20 minutes from the arrival of firefighters, sometimes even less, but the complete extinguishment can last several hours. The entire process would be much shorter and with significantly smaller material damage if the residents themselves acted appropriately.

More vulnerable populations (senior citizens with special needs, some adults, and children) pose certain challenges to the fire and rescue units during the rescue itself. Senior citizens with special needs require additional care during rescue, which involves the

coordination of more members of engine companies and even coordination of several engine companies, thus increasing the rescue time, and consequently, the overall risk for the operation. Adults, especially males (physically superior than females) are prone to interfere with the intervention (even the extinguishment) in moments of temporary mental collapse, panic attack, or other types of mental distractions. Depending on the situation, during deep-water rescues, diving units always approach the drowning persons from the back, as the latter often tend to push their rescuers downward out of fear for their life.



Figure 4. *Extraction of injured people from a vehicle* [4]

During fires, there are numerous instances of the afflicted persons trying to remove the breathing mask from their rescuers after inhaling smoke; their inability to think clearly is explained by their fear and survival instinct. In addition to going through special training, rescuers are allowed to do specific unorthodox things during a rescue. For instance, in a water rescue or a flaming building rescue, the rescuer is allowed to use physical force if the rescued person attempts to grab hold of the rescuer's breathing apparatus, even if that means rendering that person unconscious, which can sometimes even facilitate the rescue operation. As far as children are concerned, they are the most critical group and thus the highest priority in a rescue operation. Above all, they are prone to trauma the most, and depending on their age, they can be prone to a variety of health issues in such situations; furthermore, they are smaller, shorter, less noticeable, and more difficult to physically locate in a room filled with smoke, where rescuers are forced to rely only on their sense of touch and try to feel their surrounding using their hands. In addition, children sometimes fail to respond when being called out due to fear. Fear also makes them hide under beds or tables, inside closets, or in any locations fit for hiding, in which they feel safer. This means that rescuers need to perform a thorough inspection of every room, which in turn puts them at greater risk.

Firefighters during emergencies

The psychological state of fire and rescue members is somewhat more complex than that of civilians. First of all, it should be borne in mind that firefighters and rescuers are people just like everybody else, with emotions and fears, they are able to feel pain and to

make mistakes. Therefore, when applying to become members of such units, potential candidates go through a plethora of psychological and physical tests. Naturally, they have to be exquisitely physically prepared as the job is physically very demanding, but their mental state is perhaps even more important, because work under immense amounts of pressure is a constant for them. Over the course of a single day, the fire and rescue unit can receive multiple alerts, whether for small fires, false alarms, wildfires, floods, or technical interventions (which some of them consider to be the most difficult of all). Sometimes they spend days and even weeks in the field during cold winters or hot summers.



Figure 5. *Transport of the afflicted* [4]

All of this affects the overall physical health, but recovery is quick provided a good rest, adequate sleep, and proper diet. On the other hand, psychological consequences can sometimes be felt for the rest of their lives. All of the situations mentioned above in relation to civilians apply to professional firefighters, as well. However, firefighters additionally need to be composed and unemotional, efficient, fast, professional, and willing to selflessly put their lives on the line for a successful rescue operation. Even if firefighters meet all the physical and psychological requirements before and during training, there are no guarantees that they will not experience a psychological issue any time over their career. The issues from which most fire and rescue members suffer include PTSD (Post-Traumatic Stress Disorder) and PDSI (Post-Traumatic Stress Injury).

CONCLUSION

Disorder and injury symptoms are too complex, and most members of not only fire and rescue units but also of the military, the police, and medical units are not aware that an operation or intervention can change their life forever. Specific issues have a delayed effect, including insomnia, reliving of memories, anxiety, depression, and sometimes even types of schizophrenia, but their later onset often prevents the sufferers from consulting a physician in time. They are constantly aware that their line of work involves higher risk. Unfortunately, when these symptoms become pronounced, it may already be too late career-wise, because most people go into early retirement for

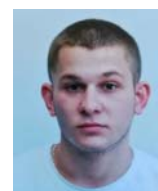
exactly that reason. Of course, this does not mean that they are unable to function within a society; they are just no longer able to perform their professional duties.

REFERENCES

- [1] Slobodan Spsić, Radovan Jovanov, Aleksandar Pavlović, Požar eksplozija provala, Inženjersko-tehnički priručnik, Vatrogasni savez Srbije, Beograd, 1998
- [2] Radovan Jovanov, Pristup projektovanju uređaja, AGM knjiga, Beograd, 2014
- [3] Slobodan Spsić, Radovan Jovanov, Aleksandar Pavlović, Preventivna zaštita od eksplozija i požara, Priručnik, Viša škola unutrašnjih poslova, Beograd, 2000
- [4] [<http://www.minpolj.gov.rs/galerija/foto-galerija/?Lang=lat>]

BIOGRAPHY

Milić Željko was born on 16 Jan 1996. He has a secondary-school vocational degree as a retail trade merchandise arranger. He passed the professional fire protection exam in 2017.



He was a student at the Faculty of Civil Engineering and Architecture in Niš in the academic year 2016-2017. From 2018, he is a student at the Faculty of Occupational Safety in Niš.

UTICAJ VANREDNIH SITUACIJA NA PSIHOLOŠKO STANJE ČOVEKA

Željko Milić, Anica Randelović

Rezime: Pod radnom sredinom prodradujemo celokupnost materijalnih faktora i društvenih odnosa u kojima ljudi ostavljaju radne i ostale aktivnosti. Materijalni faktori obuhvataju fizičke i tehničke uslove radne sredine, a društvene odnose između ljudi na radu. Sa industrijskom, a posebno sa naučno-tehnološkom revolucijom nastale su krupne promene u radnoj sredini. Nasuprot njoj „prirodnoj sredini“ rada u postindustrijskoj proizvodnji, sada se više formira „tehnička sredina“. Ona se bitno razlikuje od predhodne.

Ključne reči: vanredne situacije, radna sredina.

MARKO PETROVIĆ¹
NIKOLA GOLUBOVIĆ²
TANJA RISTIĆ³

MENTOR:
JELENA
MALENOVIĆ-NIKOLIĆ

^{1, 2, 3} University of Niš,
Faculty of Occupational Safety

¹ mare94petrovic@gmail.com

² nikola.golubovic44@gmail.com

³ tanjaristic1804@gmail.com

OCCUPATIONAL HAZARDS OF ELECTRICIANS

Abstract: *Even when all the necessary occupational safety and health precautions are taken, specific situations increase the risk and often lead to incidents, often due to the human factor. In order to minimize the risk, special attention should be given to the causes leading to risk, incidents, and occupational injuries, since safety is of paramount importance in every line of work. Occupational safety is a set of technical, health-related, legal, psychological, pedagogical, and other activities that serve to help identify and eliminate risks or risk-related phenomena such as hazards, damage, or exertion, which can threaten the safety and health of workers.*

Key words: electrician, occupational safety.

INTRODUCTION

The purpose of occupational safety is the creation of a safe work environment in order to enable regular work or to prevent halts and slowdowns of technological, production, service, or other activities. Therefore, it has to be borne in mind that occupational safety is very important for the job of an electrician, which involves hazards to a large extent. All of this needs to be considered constantly, as the work with elements of the power distribution network is quite serious and requires additional caution.

THE JOB OF AN ELECTRICIAN

In the broadest sense, an electrician is a vocation pertaining to transformation and distribution of electric power. Generally, this involves electrical wiring installation, servicing and repair of domestic appliances and devices, as well as installation of all electrical equipment.

Electrical installation work includes:

- Installation of lighting wiring;
- Installation of fire extinguishers;
- Installation of a computer network wiring;
- Distribution of household wiring;
- Installation of telecommunication networks;
- Distribution of electrical installations;
- Placement of fuses and assemblies;
- Placement of lighting; and
- Repairs of the electric power network.

The said activities are performed by electricians according to the design specifications in the development stage. After completing the job, electricians are required to test what they have done and, if necessary, to correct any mistakes or make additional repairs. This job is considered one of the most hazardous. It requires strict adherence to all the safety precautions. To provide maximum protection, there are prescribed procedures to be followed, and the

proper equipment and tools to be used, including, but not limited to, the following:

- Power shut-off by means of a fuse;
- Insulated tools;
- Rubber insulating gloves and boots;
- Safety helmet.



Figure 1. Working at height

Having completed the required education, electricians still need plenty of professional experience to attain the adequate level of practical knowledge. By working, they gain new knowledge and establish routines, which are essential for this, as well as any other job.

OCCUPATIONAL INJURIES DUE TO ELECTRIC SHOCK

Direct and alternating currents affect living organisms in different ways. Direct current passes through a conductor unidirectionally from the positive to the negative pole. In general, it is considered to be four times less harmful to humans than alternating current.

The harmful effect of electric current on humans depends on a number of factors, such as voltage, intensity, frequency, resistance of human body, exposure duration, place and manner of human contact with the electric circuit, physical state of the human body, and external conditions.

Electric shock usually occurs due to carelessness and mistakes. The shock can be caused by faulty installations or electric power lines.

The points of current entry into and exit from the body are left with injuries similar to severe burns. These locations on the body experience substantial skin and tissue loss in the shape of a funnel. In addition to producing burns, the current also has an electrolytic effect, i.e. it dissolves cells and tissue.

The current travels through the body following the path of least resistance, so the direction of the current is not a straight line. The current moves towards the moisture of the body surface, because moist surface offer less resistance.

In addition to local injuries caused by electric current, there are also general harmful effects. At the moment of electric shock, people instantly lose consciousness, which often lasts shortly and causes shorter or longer paralyses or spasms. Mental issues, such as fear, insomnia, and pronounced anxiety can also occur and last for prolonged periods. More intense electric shocks can cause small haemorrhage points in the brain, leading to permanent brain damage and sometimes even to momentary death.

An electric shock stops the breathing, causes loss of consciousness, stops the heart, creates burns at points of contact, causes tonic and clonic spasms, and ultimately leads to death. The shock sometimes throws the person away from the circuit, which can cause additional injuries. High-intensity current can produce severe burns and charred skin.

A lightning strike has the same effects as an electric shock. The person first loses consciousness and cannot remember what happened after coming to. This is followed by muscle spasms throughout the body, slurred speech, and paralysis of some parts of the body. If the lightning strike is intensive, it instantly kills a person due to breathing muscle spasms. This causes small brain haemorrhages and brain cell damage.

In the event of such injuries, if an uninjured person is nearby, they need to respond by immediately shutting off the power or using a dry piece of wood to slow or stop the flow of electricity. With high voltages, the danger exists at a minimal distance of 10 m until the power has been shut off.

Working at heights refers to work performed at the heights of 3 m and above, whereby the space is not secure.

Fall from a height is one of the most common causes of death among electricians (50%).

In this case, fall protection includes the following:

- Use of safety equipment in order to prevent the falling hazard when working at heights cannot be avoided;
- Use of corrective measures (nets, a soft landing system, safety belt and harness, etc.);
- Use of proper equipment when weather conditions make safe work impossible;
- Use of specialized equipment (power line work).



Figure 2. *Electrician job performance*

Falls from a height can cause various internal and external injuries. External injuries are visible (bleeding, scratches, open fractures, swellings, and the like), while internal injuries are not visible to the eye but only using a specialized device (ultrasound, X-ray, or a scanner).

The equipment used needs to be handled properly.

Use of proper equipment can lower the risk of injuries (bleeding, scratches, or lacerations), but the main form of protection is to perform the job as carefully as possible. The job of an electrician requires the highest level of carefulness, which largely depends on the worker's experience.



Figure 3. *Injured worker transport*

An example of an accident involving an electrician is given below:

- An employee of the Belgrade-based company “Elektroistok izgradnja, LLC”, dealing with electrical construction and maintenance, died in the village of Drainac, near the town of Svrlijig, when a 29 m pylon for the overhead power line on which he was working collapsed. The accident happened 5 km from the Knjaževac-Svrlijig main road. The metal pylon construction crushed the young employee and resulted in a fatal occupational injury.

Injuries frequently occur after a fall and, in case of a fracture, they present with pain, swelling, inability or reduced ability to move, potential deformation of the affected body part, loss of sensation, skin colour change, and loss of pulse. Dislocated joints affect the normal anatomic relation, which leads to sharp pain and deformity, whereby every movement only increases the pain (most often in the shoulders or the knees).

Sprains are accompanied by pain and smaller or larger swellings. Ankle sprains are the most common (where RICE (rest, ice, compression, and elevation) treatment is usually advised), followed by neck sprains (usually caused by whiplash injuries in traffic accidents). After receiving primary care, the injured person is transported to the nearest medical facility.

To protect themselves against electric shock, the elements, objects falling on their head, and other potential harms, employees working on construction, operation, and maintenance of high- and low-voltage electric power facilities use the equipment and tools for personal and collective occupational safety.



Figure 4. Electrician's tools

Similarly, when the implementation of technical occupational safety measures cannot provide complete safety, personal and collective occupational safety equipment and tools have to be used. According to the level of safety it provides, occupational safety equipment is divided into basic and auxiliary. Basic equipment is the one providing sufficient protection

during job performance when used according to the regulations. It is designed based on the nominal voltage of a facility. For facilities with a nominal voltage to ground above 1000 V, the mandatory protective equipment includes the following: insulating helmet, insulated rod with a test lamp to test for the absence of voltage, and insulating tongs for removing high-voltage fuse cartridges. Auxiliary equipment is used to complement the individual pieces of basic equipment or to ensure adherence to other technical measures of occupational safety (e.g. rubber insulation gloves for electricians). Auxiliary safety equipment is designed according to the nominal voltage of the basic equipment that they complement. They include rubber insulation gloves, rubber insulation footwear, and rubber insulation sheets.

CONCLUSION

There are numerous occupational hazards of electricians, and some of them may even result in death. It is necessary to use personal protection equipment and tools according to the instructions for proper use and maintenance. To minimize the occupational hazards, it is important to periodically test the equipment and ensure that it is up to code, i.e. reliable and able to provide sufficient protection to workers, and that it is properly maintained and stored. Use of personal protection equipment that is up to code increases occupational safety.

REFERENCES

- [1] <https://resenjazardileme.wordpress.com/2017/04/18/ci-me-se-bave-elektriciari/>
- [2] <https://mirtabob15.wordpress.com/2013/11/13/posao-elektri-cara-i-zastita-na-radu/>
- [3] <https://mirtabob15.wordpress.com/2013/11/26/zastita-na-radu-je-postigla-veliki-napredak/>
- [4] <http://www.stetoskop.info/Udar-elektricne-struje-393-c9-content.htm>
- [5] <https://www.ekapija.com/business-advice/271290/kako-da-prepoznate-povredu-i-kako-da-uspostavite-prvu-pomoc-kod-povreda>
- [6] <https://www.kurir.rs/crna-hronika/1895103/poginuo-radnik-24-dalekovod-od-29-metara-pao-na-mladica>
- [7] <http://www.stetoskop.info/Udar-elektricne-struje-393-c9-content.htm>

BIOGRAPHY of the first author

Marko Petrović started studying at the Faculty of Occupational Safety in Niš, study programme Environmental Protection, in 2013. He completed his primary and secondary education in Svrlijig, with a secondary school degree *economic technician*.

He is the chairman of the Youth Office Svrlijig. He is currently a freshman at the Faculty of Occupational Safety in Niš, study programme Occupational Safety.



NEGATIVNE POSLEDICE RADA ELEKTRIČARA

Marko Petrović, Nikola Golubović, Tanja Ristić

Rezime: *I pored preduzetih mera koje su vezane za bezbednost i zdravlje na radu, sprovođenjem tih mera, u pojedinim situacijama dolazi do povećanja rizika i često do incidenta, ne retko zbog ljudskog faktora. Kako bi smanjili rizik na najmanji mogući nivo moramo posvetiti pažnju na posledice koje dovode do rizika, incidenta i povrede na radu jer je sigurnost vrlo važna u svakom poslu. Zaštita na radu je skup tehničkih, zdravstvenih, pravnih, psiholoških, pedagoških i drugih delatnosti pomoću kojih se otkrivaju i otklanjaju rizici ili rizične pojave kao što su opasnost, stete, naponi koji mogu da ugrožavaju život i zdravlje ljudi na radu.*

Ključne reči: električar, zaštita na radu.