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From Editor's desk

Onoga dana kada nauka počne proučavati nefizikalne (duhovne) pojave, u deset godina napredovaće više nego u ranijim vekovima svoje istorije.
Nikola Tesla

Svet je prevazišao Covid ali drugi izazovi su tu. Da li je rat kao oblik razrešenja potisnutih nesaglasnosti neophodan i da li je nametnut, naručen i ko sve profitira na ljudskoj patnji i smrti? Istraživači i naučnici u oblasti zaštite životne sredine su zabrinuti za ugrožavanje prirode i ratom izazvane katastrofe. Savremeni čovek je gladan za energijom i treba mu sve više i više, a u ovim vremenima nam se neki izvori kao ugalj, nafta i atomska energija serviraju kao obnovljivi, ekološki i poželjni. Mnogo je pitanja, a na nama je da damo odgovore i rešenja.

Novi broj časopisa *Safety Engineering* ostaje veran svom programskom okviru i u ovom broju su predstavljeni radovi iz različitih oblasti zaštite, poput zaštite pri sagorevanju drvenih materijala, zagađenja vazduha i emisije azotnih jedinjenja, ispitivanja neophodnog termalnog komfora, alternativnih izvora energije u Srbiji i državama u okruženju i sociološkim aspektima timskog rada.

The day science begins to study non-physical phenomena, it will make more progress in one decade than in all the previous centuries of its existence.
Nikola Tesla

The world has defeated Covid, but new challenges await. Is war an ordered, imposed means of resolving long-standing disputes, and if so, is it imposed, ordered, and who benefits from human suffering and death? Researchers and scientists who study environmental protection are worried about natural disasters and the threat to the environment posed by war. Modern man is constantly in need of energy, and sources such as coal, oil, and nuclear energy are now offered to us as desirable. There are many questions, and it is our responsibility to provide answers and solutions.

The new issue of the Safety Engineering magazine is faithful to its program framework, and this issue contains papers on: protection during the combustion of wood materials, air pollution and the emission of nitrogen compounds, the necessary testing of thermal comfort, alternative energy sources in Serbia and neighboring countries, and aspects of teamwork. In keeping with its conceptual framework, the latest issue of *Safety Engineering* journal includes articles on topics such as wood-burning safety, air pollution and nitrogen compound emissions, thermal comfort testing requirements, alternative energy sources in Serbia and surrounding regions and sociological aspects of teamwork.

On behalf of the editors
Prof. Dr. Dejan Krstić

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EXPLOSIVE PROPERTIES OF COMBUSTIBLE WOOD DUST

Abstract: In many industries, there are combustible industrial dust in some parts of production or processing technologies, which, when specific conditions are met simultaneously, can result in massive explosions. In order to achieve anti-explosion prevention in industrial operations, it is necessary to know the explosion properties and fire parameters of the industrial dust that occurs in the given industrial plant. The article deals with the explosive properties of wood combustible dust and with the possible solutions for explosion protection in wood processing plants.

Key words: explosion, industrial dust, explosion protection, industrial safety

INTRODUCTION

Explosions of dust mixtures are frequently underestimated in practice, despite the fact that a very small amount of stirred-up dust can cause a powerful explosion when ignited, resulting in not only property damage but also damage to human health or even death. Industrial dust explosion represents a great danger for building structures and production technologies which may contain other dangerous substances that, if released, could cause additional harm.

As a result of the constant development of production technology, new materials are created, necessitating the determination of their explosion and fire properties for safe use during production, storage and transportation. The area of explosion testing of materials and their parameters is carried out in testing facilities by experimental measurements. The goal of the work is the application of the acquired knowledge in the field of explosion protection of combustible industrial dust.

One of the most frequently occurring combustible industrial dust is the dust from the processing of almost all types of wood. The validity of such tests is also proven by the statistics, which clearly show a large number of fires and dust explosions in the area of the woodworking industry.

The minimum explosion temperature of Pinus Sylvestris (pine tree) and Larix Decidua (red spruce) were measured in The Fire – Chemical Laboratory of the Faculty of Security Engineering, University of Žilina, Slovakia. The minimum ignition temperature was observed depending on the particle size of wood dust obtained directly from a specific woodworking technology for the production of furniture and other wooden goods.

Table 1. *Fires in selected industries in 2016 – 2021 in Slovakia [1]*

Industry	Number of fires
Food and beverage producing and tobacco processing	104
Textile production	13
Publishing and printing	7
Leather processing and production of leather goods	13
Wood processing and production of wood goods	**261**
Cellulose processing and paper goods production	41
Other industrial production	70

Table 2. *Fire rate by cause in Žilina region in years 2016 - 2021, Slovakia [1]*

Year	Number of explosions	Number of injured persons	Number of people died
2016	31	22	3
2017	28	43	6
2018	37	30	2
2019	37	27	1
2020	26	23	1
2021	20	17	1
Total	**179**	**162**	**14**

PRINCIPLES OF THE DUST EXPLOSION

Physical and chemical properties of combustible industrial dust

The basic physical properties of dust include particle size and shape, settling time, humidity, electric charge, stickiness, wettability, bulk density, explosiveness, etc. The distribution of dust depending on the particle size is defined in Table 3. Due to the size of the particle, dust is divided into macro-, micro-, ultra-, and submicroscopic. [2]

Table 3. *Dividing of combustible dust according to particle size [2]*

Dust	Particle size
Macroscopic	bigger than 0,01 mm
Microscopic	0,01 mm - 0,00025 mm
Ultramicroscopic	0,00025 mm - 0,0001 mm
Submicroscopic	smaller than 0,0001 mm

Fire and explosion parameters of combustible industrial dust

In the case of flammable gases and liquids, most parameters can be found in safety data sheets or from other suitable sources. In the area of combustible dust, the situation is more complicated. In the professional literature, values are also given for flammable and explosive dust, but as intervals of a larger range, having a rather informative nature. In the case of combustible dust, the parameters always depend on the specific technology and their handling.

Because determination by calculation is not yet possible, the most reliable way to obtain the most accurate information about a substance's explosiveness or flammability is to take a specific sample and experimentally measure its properties in the laboratory.

Explosion conditions

In order for an explosion to occur, the explosive substance must have a concentration in the range of its explosiveness, which approximates Figure 1. If the substance is below the LEL – lower explosion limit (c_{min}), there is a large proportion of the oxidizing agent and a small proportion of the substance in the mixture. Such a mixture is not explosive. If the substance is above the UEL – upper explosion limit (c_{max}), the mixture contains too much explosive substance and lacks an oxidizing agent. The mixture is also not capable of explosion, but it can burn if there is sufficient air access. The substance burns explosively in the interface between LEL and UEL within the limits of the so-called explosive range. The y-axis shows the increase in pressure resulting from the explosion $P_{expl.}$ and the x-axis the concentration of the flammable substance c. [3]

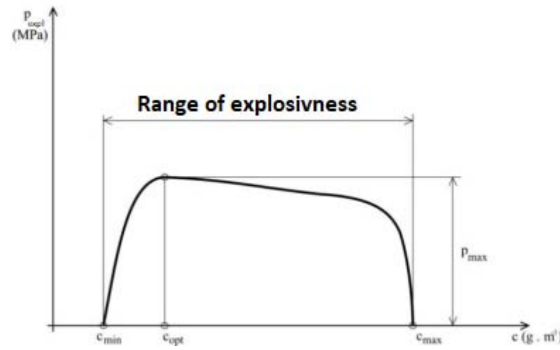

Figure 1. Explosion limits [4]

Explosion protection

The basic measure to prevent an explosion with active explosion protection is [2]:

• substitution of flammable substances for inert substances,

• limit the concentration of flammable substances to a safe level,

• eliminate the occurrence of initiation sources,

• minimize the amount of settled combustible dust by regularly removing it without stirring it into the space.

In case of impossibility or insufficient application of active protection, means of passive protection are applied in the form of protective structures in the following manner [5]:

• To be resistant to explosions.

• To relieve the explosion - it is not about preventing the explosion process, but about releasing the explosion outside the safe area (reducing the explosion pressure), most often outdoors.

• To suppress an explosion - the device, most often in the form of a container, contains a suitable extinguishing agent to prevent the initiation of an explosion. The most applied type is the HRD (high rate discharge) system.

• To prevent the transfer of flame and explosion - the transfer of flame or explosion through conveying systems, pipelines, and other elements of production systems can be prevented by using rotary feeders, quick-closing valves, dampers, relief stacks, explosion-proof barriers or gate valves.

RESEARCH METHODS

Determination of the minimum ignition temperature of selected wood dust depending on particle size was carried out in the premises of the fire-chemical laboratory of the Faculty of Security Engineering at the University of Žilina. The Slovak technical standard method was used for measurement STN EN 50281-2-1 – Electrical equipment for areas with combustible dust. Part 2-1: Test methods. Methods for determining the minimum ignition temperatures of dust. This norm states two test methods for determining the minimum dust ignition temperatures [6]:

- Method A: A layer of dust on a heated surface of constant temperature.
- Method B: Stirred powder in a constant temperature furnace.

In order to meet the objectives of the work, method B was used in the measurement.

A ceramic heating tube - furnace (2) is attached vertically to the iron frame (1). With the help of the compressor hose (3), the air is pressurized, which is admitted to the compressed air reservoir (5) through the valve (4). The pressure gauge (6) shows the air pressure in the compressed air tank. The powder is placed in the dust container (7), which, after releasing the compressed air valve (8), is sprayed into a ceramic furnace with a constant temperature, which is regulated by the connected temperature controller (9). We observe a possible ignition on the mirror (10).

Figure 2. *The testing device*

The samples were sieved through sieves with a metal insert for selection based on particle size, and then the measurement itself was carried out. The air was pressurized to 0.2 bar by a valve in the container with compressed air, and a sample weighing 0.1 g was placed in the clean dust container. During the measurement, the temperature of the furnace was regulated and the type of sample was varied. The work is dominated by the determination of the dependence of the minimum ignition temperature of stirred wood dust on the particle sizes, therefore both the constant pressure and the constant mass of the dust were used in the measurement.

After the adequate pressure was set, the sample was placed and the required temperature was reached, the compressed air valve was released with a button and the dust load was sprayed into the furnace tube.

The course of possible ignition was monitored in the space under the tube. The minimum ignition temperature was considered to be the temperature at which wood dust ignited in three successive attempts.

RESEARCH HYPOTHESIS

It is assumed that the minimum ignition temperature is reached at a lower value in the group of measured and analysed wood dust samples the finer the combustible industrial dust and, consequently, the smaller its particle size.

RESEARCH RESULTS

The measurement results prove the dependence of the particle size of wood dust and the minimum ignition temperature. As the particle size of wood dust decreases, the temperature required for its ignition also decreases. In the case of measuring the minimum ignition temperature of the stirred wood dust of forest pine tree, the temperature was set at 343 °C for the particle size of 0.50 mm, for the dust with the particle size of 0.315 mm at 343 °C, for the dust fraction of 0.20 mm at 338 °C C and 0.16 mm at 333 °C. In the case of measuring red spruce, an even smaller temperature difference was observed - 418 °C (0.50 mm), 416 °C (0.315 mm), 415 °C (0.20 mm) and 414 °C (0.16 mm). Even if the differences in the minimum ignition temperatures of individual fractions of wood dust are minor, it is reasonable to conclude that the finer the dust, the more dangerous it is in the event of an explosion, and the more important it is in terms of explosion prevention. The experiment proves the fact that dust in production operations is explosive.

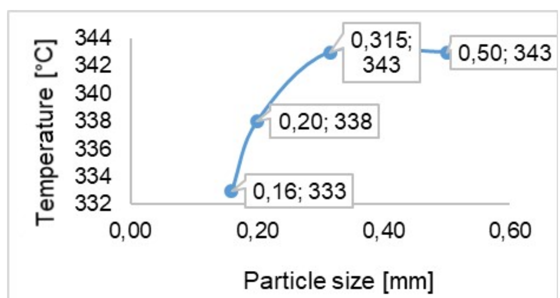

Figure 3. *Dependence of minimum ignition temperature on particle size of forest pine wood dust in a stirred state*

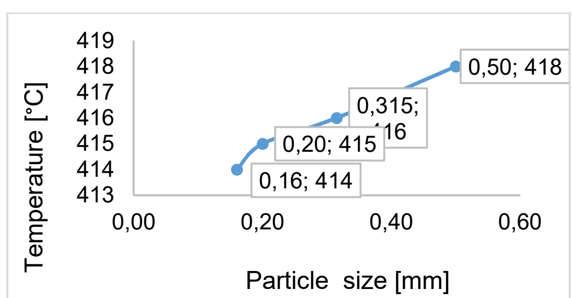

Figure 4. *Dependence of minimum ignition temperature on particle size of red spruce wood dust in a stirred state*

CONCLUSION

Homogeneous samples of Pinus Sylvestris (pine tree) and Larix Decidua (red spruce) were used for the experiment. However, if the dust collected in the bags of extraction devices in the woodworking plant is not homogeneous (it changes with the orders of customers), it is important to start with explosion protection by knowing the partial minimum ignition temperatures of selected types of combustible wood dust. Subsequently, a SWOT analysis was applied to the operation in order to reveal strengths and weaknesses (in the internal environment of the operation) and opportunities and threats (from the external environment), which result from the level of security of the operation against explosions.

In addition to active explosion protection (continuous removal of wood dust by suction, removal of potential initiation sources, etc.), opportunities for the company include the possibility of completing construction systems for protection against fires and explosions (secondary explosion protection), optimization of production processes (renewal and introduction of new technological innovations, e.g. in areas of extraction of wood waste, machines with a more efficient grinding method, etc.)

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Miroslava Vandlíčková was born in Čadca, Slovak Republic, in 1978.
She received the diploma in chemical engineering at The Slovak Technical University in Bratislava, Slovak Republic and the Ph.D. degree in physical chemistry at The Palacký University in Olomouc, Faculty of Natural Sciences, Czech Republic.
Her main areas of research include explosion protection of industrial plants with the occurrence of combustible industrial dusts, dangerous substances and CBRNE substances.
She is currently working as a lecturer of physical chemistry, explosion protection, and CBRN substances and as a vice-dean for education at the Faculty of Security Engineering, University of Žilina, Slovak Republic.

EKSPLOZIVNA SVOJSTVA ZAPALJIVE DRVNE PRAŠINE

Miroslava Vandlíčková, Soňa Stenchláková

Rezime: *U mnogim industrijama prisutna je zapaljiva industrijska prašina u pojedinim delovima proizvodnih ili prerađivačkih tehnologija, koja može izazvati velike eksplozije kada se paralelno postignu određeni uslovi. Da bi se postigla protiveksplozijska prevencija u industrijskim operacijama, neophodno je poznavati eksplozivna svojstva i požarne parametre industrijske prašine koja se javlja u datom industrijskom postrojenju. Članak se bavi eksplozivnim svojstvima drvne zapaljive prašine i mogućim rešenjima zaštite od eksplozije u postrojenjima za preradu drveta.*

Ključne reči: eksplozija, industrijska prašina, zaštita od eksplozije, industrijska bezbedno

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PRIMARY MEASURES TO REDUCE NOx EMISSIONS AND THE RESULTS OF THEIR IMPLEMENTATION ON THE ENERGY BOILER

Abstract: *The Republic of Macedonia as a signatory to the agreement for the energy community, Treaty Establishing the Energy Community, should fulfill the basic aspects of the European energy legislation, including the LCP Directive. The reduction of nitrogen oxides is one of the conditions that should be fulfilled in accordance with this Directive. This could be carried out using primary and secondary measures. Several methods for carrying out primary measures, along with their specificities and the outcomes of using each, are discussed in the paper.*

Key words: nitrogen oxides, primary measures, reduction.

INTRODUCTION

Signing the Treaty Establishing the Energy Community agreement means fulfilling the basic aspects of the European energy legislation, including the LCP Directive. This directive provides for the desulfurization and elimination of nitrogen oxides in new and existing thermal power plants. This means that reconstruction and modification activities should be undertaken at the existing energy plants in order to meet the limit values. According to the LCP Directive [1], the restrictions after 2016. are: 400 [mg/Nm^3] emissions of sulphur oxides, SOx; 200 [mg/Nm^3] emissions of nitrogen oxides NOx and up to 50 [mg/Nm^3] emissions of particles. In the case of existing buildings, during the reconstruction and revitalization of energy boilers, priority is given to measures which, in addition to reducing the emission and impact on the environment, will also improve their efficiency.
Reduction of nitrogen oxides can be achieved by applying primary and secondary measures. With the secondary measures, binding or reduction of the nitrogen oxides contained in the output gases is carried out in separate plants that are outside the boiler. However, the primary measures of preventing NOx generation are completely concentrated in the furnaces of the boilers. These methods aim to change the operating and design parameters in the combustion process, thereby reducing the formation of nitrogen oxides or transforming those that have already formed in the boiler before they are released.
The current energy crisis may have prolonged and temporarily delayed the implementation of the LCP directive, but this should not reduce the importance of protecting the human environment and clean air, as well as implementing new technologies for cleaner air.

MECHANISM OF FORMATION OF THE NITROGEN OXIDES IN THE STEAM BOILERS FURNACE

The energy boiler is a device that produces steam with a pressure greater than atmospheric, using the chemical energy of fossil fuels (liquid, solid, gas), nuclear energy, electricity, waste heat from industrial-technological processes, aggregates and plants, etc.[2]. The most common heat source for producing steam in steam boilers is the chemical energy of fossil fuels. In fossil fuel steam boilers, first of all, the fuel and oxygen from the air together with the fuel enter into a chemical reaction (combustion), creating combustion products with high heat content.
In a steam boiler furnace, nitrogen oxides can form from the molecular nitrogen in the air used to burn the fuel, as well as from the nitrogen contained in the fuel components in the following three ways [3]:
- by the reaction of nitrogen from the air and oxygen, also from the air, resulting in thermal nitrogen oxides, NOx^T;
- by the reaction of hydrocarbon radicals with molecular nitrogen from the air, resulting in rapid nitrogen oxides, NOx^B;
- by oxidation of nitrogen compounds from the fuel, which produces nitrogen oxides from fuel, NOx^G.

Thermal nitrogen oxide, $\mathbf{NOx^T}$ is formed as a result of the oxidation of molecular nitrogen and atomic oxygen and the oxidation of atomic nitrogen and molecular oxygen at temperatures higher than 1300°C, according

$$N_2 + O \rightarrow NO + N$$

$$N + O_2 \rightarrow NO + O$$

The first reaction has a major role in the formation of NO^T, but the basic condition is that high-temperature zones (t>1300°C) are formed during combustion in the furnace. In this way, it is possible to increase the concentration of oxygen and nitrogen in the atomic state. Known as the Zeldovich mechanism is the occurrence of

NO^T and it occurs in the flame zone and the zone outside the flame front after the combustion process of the combustible mixture is complete, with an excess of air higher than one. The intensity formation of thermal nitrogen oxide depends primarily on the temperature of the gases and on the time they retain in the high-temperature zones.

Fast nitrogen oxide, **NOx^B**, is the result of reactions of hydrocarbon radicals and molecular nitrogen, such as the following radical-forming reactions:

$$CH + N2 \rightarrow HCN + N$$

$$CH2 + N2 \rightarrow HCN + HN$$

The radicals formed during the above reactions containing nitrogen (HCN, HN, N) enable the formation of nitrogen monoxide in further reactions with oxygen radicals. So, for example, the reaction of atomic nitrogen with the hydroxyl group OH

$$N + OH \rightarrow H + NO$$

In the initial combustion zone of the fuels, these reactions occur very quickly, because the content of combustible substances is high, and the temperatures are higher than 730ºC. The formation of NOx^B, in real conditions ends at temperatures lower than 1200 to 1300°C. The conditions for the formation of NOx^B are influenced by: the local coefficient of excess air in the reaction zone, the temperature, and the rate of flame heating. As the temperature increases, the NOx^B content increases exponentially.

Fuel nitrogen oxide, NO^G, is formed by oxidation of part of the nitrogen contained in the organic mass of the solid and liquid fuels, at temperatures higher than 630°C. In solid fuels, the content of bound nitrogen is the highest, 0,5 to 3,5% of the combustible mass, it is significantly lower in liquid fuels, and in natural gas, there is no bound nitrogen.

Most of the nitrogen (about 75%), during the combustion of solid fuels, passes into a gaseous state and forms combustible nitrogen monoxide. However, a smaller part remains in the composition of various compounds of coke residue and does not participate in the NO^G formation process. In the phase of ignition and combustion of volatile substances, i.e. in the initial part of the flame, the fuel nitrogen oxide is formed. Its achieved content at this stage includes 15 to 20% of the nitrogen contained in the fuel and does not change along the length of the flame, despite the fact that active coal particle combustion continues. It was determined that in the formation zone of fuel nitrogen oxide, its concentration significantly depends on the nitrogen content in the fuel, on the concentration of O_2 and on the temperature in the interval from 680 to 1130°C [3]. With a further increase in the flame temperature, its influence on the formation of fuel nitrogen monoxide decreases, and only the dependence on the concentration of O_2 remains.

According to the mechanism of formation of nitrogen oxides described above, it can be noted that the processes occur and end completely in the zones of active combustion of fossil fuels.

The final concentration of the nitrogen oxides formed in the furnace of steam boilers depends on the conditions in the combustion zone: the concentration of O2, the temperatures and the retention time of the gases in the reaction zones, and the nitrogen content in the fuels.

MEASURES TO REDUCE THE EMISSION OF NITROGEN OXIDES IN STEAM BOILERS

Reducing the emission of nitrogen oxides in the exhaust gases of steam boilers can be done by applying:

• Primary measures, which disrupt the conditions under which NOx formation occurs,

• Secondary measures, with the implementation of additional systems to reduce already formed NOx.

Since the formation processes of nitrogen oxides occur and end in the combustion zone, the primary measures to prevent their formation are completely concentrated in the furnace of the boilers. The primary measures include: lowering the maximum temperature in the furnace, reducing the oxygen concentration in high temperature zones and applying special combustion technologies.

One way to reduce the temperature and oxygen concentration in the combustion zone is shown in Fig. 1, by introducing cooled gases into the furnace [4].

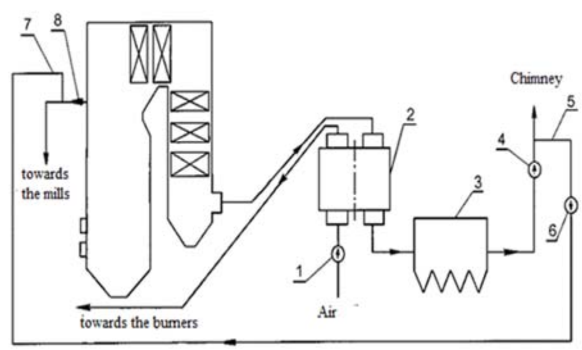

Figure 1. *Principle scheme of a system for bringing part of the cooled gases into the furnace;1.FD fan, 2. Air preheater, 3.Precipitator, 4.ID fan, 5.Recirculation gas extraction, 6.Fan for cold gas recirculation, 7.Cold recirculation gas supply, 8. Duct for gas recirculation from the furnace.*

A method that does not require additional investments, and which achieves a significant reduction in NOx emissions, is control, i.e. reduction of the coefficient of excess air in the furnace. However, this reduction is possible as long as there is no negative impact on the boiler efficiency, that is, an increase in losses due to incomplete fuel combustion (increased amount of combustible substances in the slag and fly ash).

The most efficient way to reduce NOx emission is staged combustion, where fuel and air are injected at several different levels (two or three) to the height of the furnace. At the same time, the formation is limited, and in some cases, a partial reduction of already formed NOx is carried out.

IMPLEMENTATION AND RESULTS

In the boiler, which is taken as a model in this paper, the reduction of nitrogen oxides is carried out by using staged combustion, where the fuel is injected in three levels through the low NOx burners (low nitrogen-emission burners) (fig. 2), introduction the "Over fire air" - tertiary air on two levels - OFA1 and OFA2, (Fig. 3) and reduction of the amount of primary air for temperature regulation of the mills, by introducing some kind of gas recirculation.

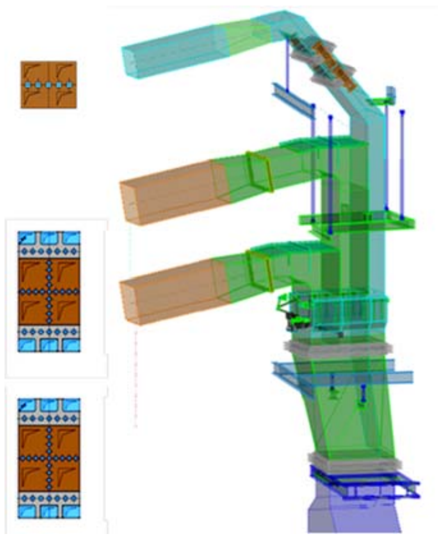

Figure 2. *Low NOx burners and ducts*

Before the implementation of the above-mentioned changes, the concentration of NOx was many times higher than allowed.

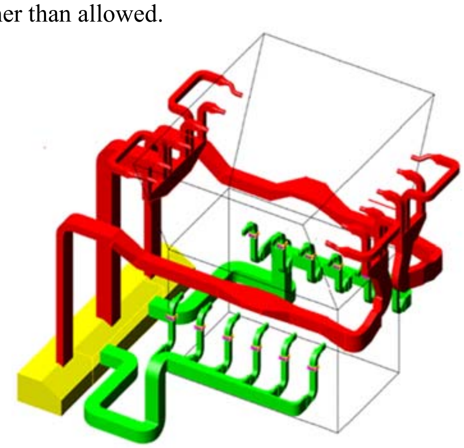

Figure 3. *Tertiary air system OFA 1 and OFA 2 for air mixture*

Figure 4 shows the results of monthly measurements before the application of primary methods for reducing NOx, in the period from 2006 to 2013.

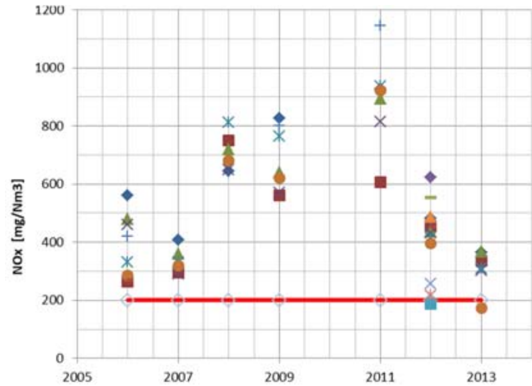

Figure 4. *NOx emission before the implementation of the primary measures for NOx reduction, m*onthly *measurements [5].*

Also in Figure 5, it can be seen that in the specified period (before the implementation of primary measures) the maximum values for NOx emissions were in the range of 400 to 1000 [mg/Nm^3].

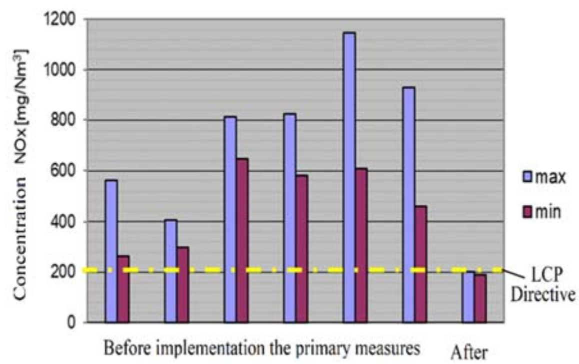

Figure 5. *NOx emission before and after the implementation of the exemplary NOx reduction measures.*

By introducing staged combustion in the boiler, which is taken as a model, the emission of nitrogen oxides is reduced below the limit value according to the directive, i.e. below 200 [mg/Nm^3] (Fig. 5).

Figure 6. *NOx emission after implementation of the primary measures for NOx reduction, monthly measurements [5].*

By applying primary measures, the organized combustion of the coal dust enables keeping the excess air coefficient lower than 1,2, and at the same time formation of thermal nitrogen oxides is eliminated. Figure 6 shows the monthly measurements after applying primary measures.

CONCLUSION

Following the application of the primary NOx reduction measures on the boiler that were used for the model, NOx emissions were lowered below the Directive's limit value, or below 200 [mg/Nm^3]. Namely, as a result of the measures taken, NOx emissions were decreased on average by nearly four times.

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Primarne mere za smanjivanje emisija azotnih oksida u energetskim kotlovima i rezultati njihove primene

Lidija Joleska Bureska, Cvetanka Mitrevska, Nevena Gruevska, Susana Zikovska

Rezime: *Republika Makedonija kao potpisnica Ugovora o osnivanju energetske zajednica (Treaty Establishing The Energy Community) bi trebalo da odgovori na osnovna načela evropskog zakonodavstva, uključujući i LCP Direktivu. Jedan od uslova koji treba biti ispunjen u skladu sa ovom direktivom je redukcija azotnih oksida. To se može postići primenom primarnih i sekundarnih mera. U radu je predstavljeno nekoliko metoda za izvođenje primarnih mera, kao i njihove specifičnosti i rezultati dobijeni njihovom primenom.*

Ključne reči: azotni oksidi, primarne mere, redukcija.

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TESTING OF THERMAL COMFORT AT WESTERN SERBIA ACADEMY OF APPLIED STUDIES

Abstract: *The paper analyzes thermal comfort conditions of Western Serbia Academy of Applied Studies' (hereinafter ASSZS) premises, using the Fanger method. Influence of individual parameters: air temperature, relative humidity, air flow rate, mean radiation temperature, noise and illumination level, as well as influence of thermal insulation of clothing and metabolism intensity assessment on the thermal comfort of employees in ASSZS has been tested. PMV and PPD indexes were measured using these data. A linear correlation between the calculated values of the PMV index and the respondent's statement about the thermal sensation has been determined, too. Statistical processing of the collected data was used to rank the facilities.*

Key words: influence microclimatic parameters, personal parameters on the thermal comfort, thermal comfort assessment, PMV/PPD Fanger*'s* index

INTRODUCTION

Thermal comfort is defined as such a state of mind, i.e. human consciousness, which expresses satisfaction with the thermal environment, ISO 7730, 2005, [1].
A person's thermal sensation is influenced by microclimatic factors, but air temperature, air humidity, air flow rate and mean radiant temperature of the surrounding surfaces are always different at different altitudes, [2,3].

The Rulebook on preventive measures for safe and healthy work at the workplace ("Official Gazette of the RS", number 21/09 and 1/19, hereinafter Rulebook) defines the permissible values of microclimate parameters in the working premises. The requirements for indoor illumination are defined by the standard SRPS EN 12464-1:2012 Light and lighting - Lighting of workplaces, while the quality of illumination as a consequence of daylight and electrical lighting is defined by the SRPS U.C9.100:1963. The limit value of noise exposure is determined by the Rulebook on preventive measures for safe and healthy work when exposed to noise, (Official Gazette of the RS, no. 96/11, 78/15 and 93/19) and the standard SRPS EN ISO 9612:2016 Acoustics - Determination of noise exposure in the working environment - Engineering method. The thermal insulation coefficient of clothing (CLO) is defined by the ISO 9920 standard, while the assessment of metabolic intensity is defined by the ISO 8996 2004 standard.

Table 1. shows the thermal comfort expressed on Fanger's scale (very cold, cold, slightly cool, neutrally pleasant, slightly warm, warm, very warm).

Table 1. *Human thermal sensation (ISO 7730 2005),* [1]

VC	C	SC	NP	SW	W	VW
-3	-2	-1	0	1	2	3

According to the ISO 7730 2005 standard, the thermal environment is considered acceptable if at least 80% of respondents are satisfied with it.

RESEARCH METHOD

Thermal comfort parameters: air temperature, relative air humidity, air flow speed, mean radiant temperature, noise and illumination level, as well as thermal insulation of clothing and assessment of metabolic intensity were measured. Using these data, PMV (Predicted Mean Vote) and PPD (Predicted Percentage Dissatisfied) indices were obtained. The PPD index has been introduced in order to anticipate the percentage of unsatisfied persons in a given thermal environment [1].
Two techniques were employed to gather the data: one involved the use of a questionnaire, while the other involved the use of measuring instruments to measure the microclimatic parameters of noise and illumination in the workplaces of the employees.

Questionnaire

The questionnaire was modified, in accordance with international standard ISO 10551 1995. It consists of sections related to demographic data, workplace data, light perception, noise perception and thermal comfort. At the same time, the evaluation of the intensity of metabolism and the thermal insulation of the clothing was carried out, in accordance with international standards, ISO 7730 2005, ISO 8996 2004 and ISO 9920 2007. While filling out the questionnaire, the respondents did not have the opportunity to see the measured values on the measuring instruments.

Examining the physical conditions of the working environment

The tests were carried out during the month of March 2022, under different external meteorological conditions, in a closed, combination of naturally - artificially ventilated facilities.

The respondents performed their work while standing, sitting on chairs or walking slowly around the workplace. Measurements of the working environment's internal conditions, such as: air temperature, ^{0}C, relative air humidity, %, air flow speed, m/s, thermal radiation, ^{0}C, noise level, dB(A) and illumination, lux, were carried out during the day, at two different heights: 1.1 m and 1.7 m, in the period from 08:00 to 14:00, and it lasted 5 minutes at each workplace. The measurement results were read on the measuring instruments and the mean value for both heights was taken into account.

The HT–3007SD and TESTO 480 devices were used to measure air temperature, relative air humidity and air flow rate in the working environment. The black globe thermometer for measuring thermal radiation is placed at a height of 1.1 m and 1.7 m. The mean radiant temperature (t_{mr}), was calculated, according to equation 1. and the recommendations of the ISO 7726 1998 standard [3]:

$$t_{mr} = \left[\left(t_g + 273\right)^4 + 2{,}5\ 10^8\ v_a^{0{,}6}\left(t_g - t_a\right)\right]^{\frac{1}{4}} - 273 \quad (1)$$

where are:

t_g – temperature of the black globe thermometer, ^{0}C,
t_a – air temperature, ^{0}C,
v_a – air flow velocity, m/s.
A standard globe thermometer has a diameter D = 0.15m, and an emissivity $\mathcal{E}_g$ = 0.95.

The Bruel&Kjaer phonometer, type 2260, and indoor microphone type 4189 were used for noise level measurement. The instrument was placed at a height of 1.7 m, i.e. in the area of the head height of an average person. The sound level meters, microphone and associated cables, have met the requirements specified in IEC 61672-1:2002, first class 1 or class 2 instruments.

The device HD450 was used for illumination level measurement and it was placed at a height of 0.85 m, in the area of the average height of a desk [4].

For the level of metabolism, a value of 1.2 met was taken, which corresponds to moderate work in a sitting position (1 met = 58.15 of the human body surface), i.e. 70 W/m^2. Using a program PMV_cal_tanabe6.xls (live.com), the prediction of the thermal comfort as well as a comparison between these results and the results of the respondents' expression of thermal comfort on the Fanger scale were performed.
Statistical data processing such as the determination of parameters: standard deviation (S), coefficient of variation (Cv), covariance (Sxy) and Pearson's linear correlation coefficient (r) was performed in the paper [5].

RESULTS AND DISCUSSION

Description sample research

Teaching and non-teaching staff at ASSZS, working in different positions, a total of 120 respondents participated in the research. Measurements were made at 15 measuring points. The structure of employees, gender, time interval of work, time spent at the workplace, and declaration of work activities are shown. in Figures 1, 2, 3, 4 and 5.

The mean age value in the Užice Department is 48.18 years, while in the Valjevo Department it is 46.2 years. All respondents stated that there is a glass window at a distance of less than 2m from the respondent's workplace.

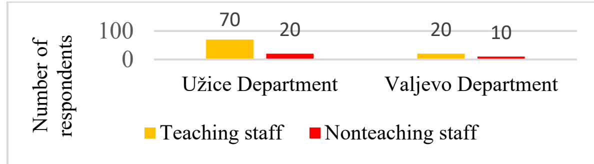

Figure 1. *Structure of employees in ASSZS*

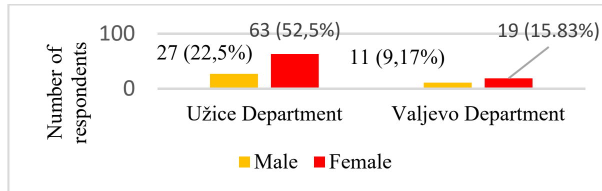

Figure 2. *Gender structure*

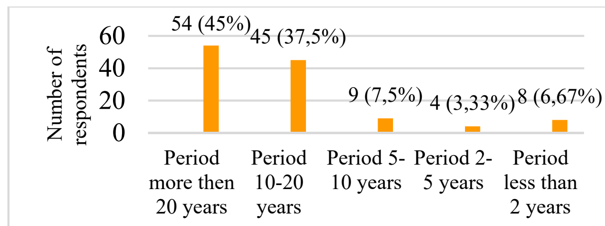

Figure 3. *Years of service*

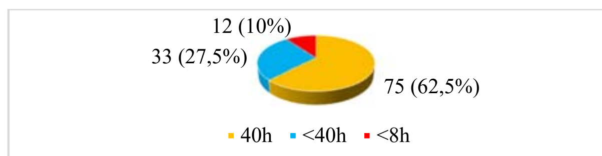

Figure 4. *Working time*

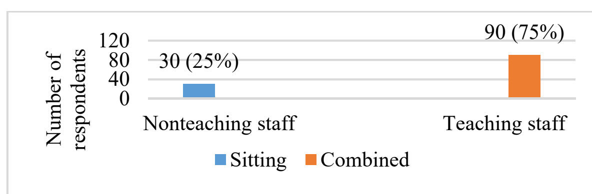

Figure 5. *Work methods of respondents*

Microclimate parameters, illumination and noise level
Information about microclimate parameters was obtained based on respondents' answers at the workplace. Of the teaching staff, only two respondents (2.66%) said that the air is excessively dry and that the humidity level should be higher. Both teachers are male and belong to the younger generation, Figure 6.

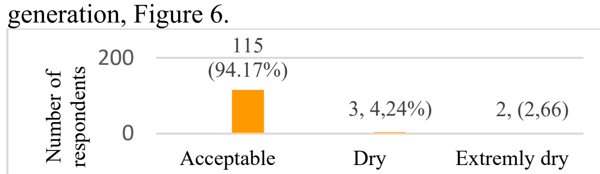

Figure 6. *Air quality*

The results of statements about the sources and illumination level at the workplace are shown in Figure 7.

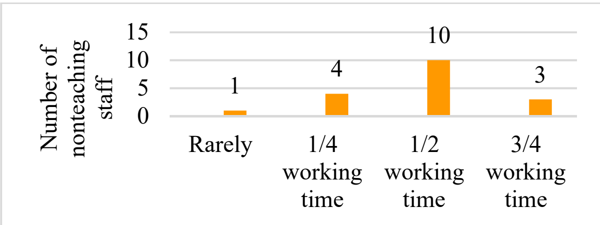

Figure 7. *Sources and illumination level*

Considering the noise level in the workplace, only 3 respondents, 2.5% of the total number of 120 respondents, who worked in the Student Service of the Užice and Valjevo Departments, stated that during $^3/_4$ of the working time they should raise their voice in conversation with colleagues.

The results of the microclimate parameters measured values show that the air temperature increases with the increase of the building floors and with the measuring height (1.1m and 1.7m), while the relative humidity values are lower Since there were no observed deviations, the mean values of air flow rate and relative air humidity were determined for both heights in this paper. The highest mean values of relative air humidity and air flow rate were measured in the amphitheaters, in the Užice Department (the largest amphitheater is located on the ground floor) and in the Valjevo Department. This is understandable given that the majority of students remain in those classrooms during lectures and they are constantly getting ventilated.

The mean value of relative humidity in the Student Service, Užice Department, is slightly lower compared to other classrooms in both Departments, which coincides with the statement of the employees of the Student Service, that they would be more comfortable if the relative humidity was higher. The lowest mean value of relative air humidity was measured in the Carpentry Workshop, which is located in the basement of the Užice Department, at 36.8%. That fact and the highest measured air temperature of 24.5^{0}C gives a sense of comfort to the employees.

When the results of the microclimate parameters obtained through the questionnaire and measurements are compared, they almost match.

The results of illumination level measuring and uniformity show that the mean illumination values and uniformity (> 0.85 in all workplaces) are higher than the permitted values, SRPS EN 12464-1:2012. Respondents who belong to non-teaching staff, 18 of them (15%) declared that they experienced eye strain during work which could be due to the previous fact or to spending more time in front of the computer due to a greater volume of work, Figure 8. In this case, there is no complete agreement between the results obtained through the questionnaire and the measurement. According to the Rulebook on preventive measures for safe and healthy work when exposed to noise (Official Gazette of RS No. 96/2011, 78/2015 and 93/2019), the results of noise level measurements show that the measured values are not above the permitted level in both Departments. It is fairly uniform, namely 63dB in the Užice Department and 62dB in the Valjevo Department, which indicates the fact that almost all respondents are exposed to approximately the same noise level in the working environment. Slightly higher noise levels were measured in the Student Services, at 12:00, 70dB, compared to the measurements at 8:00 and 14:00, considering a larger number of students staying in the Student Services at that time. Finally, the percentage of respondents who feel minor consequences due to the increased noise level at that time is small, which does not significantly affect the thermal comfort of employees.

Mean radiant temperature

The results of the mean radiant temperature calculation in Užice and Valjevo Departments, according to equation (1), are shown in Table 2.

At workplaces in the office – the 3rd floor and in the Carpentry workshop – the Užice Department, as well as in the teacher's office in the Valjevo Department, there are deviations, i.e. the values are higher at a height of 1.7m than at a height of 1,1m, but they are small. In general, the mean radiant temperatures in the Užice Department increase with the number of floors of the building, while in the Valjevo Department are fairly uniform throughout the building.

Assessment of thermal comfort

The obtained results of the PMV/PPD index, Table 3., were compared with the respondents' statements on the Fanger's scale.

It was taken that the assessment of thermal insulation of clothing for each respondent (spring clothes - pants, shirt, shoes) is 0.7 clo, i.e. 0.11 m^2K/W, (*1 clo=0.155 m^2 ºC/W), ISO 9920 2007. For the metabolism level in this work, a value of 1.2 met was taken, which corresponds to moderate work in a sitting position (1 met = 58.15 human body surfaces, i.e. 70 W/m^2).

In the Užice Department, the state of thermal comfort (0 "neutrally pleasant") was expressed by 52.5% of a total of 120 respondents, for "a little warm" (1), 9.17%, and 17.64% of respondents for "warm " (2), and for "a little cool" (- 1) on the thermal sensation scale. The mean value is 0.28, which means it ranges from "neutrally pleasant" (0) to "slightly warm"(1).

In the Valjevo Department, the state of thermal comfort (0 "neutrally pleasant") was reported by 18.33% of respondents, 5% of respondents for "warm" (2) and 1.66% of respondents for "a little cool" (-1), on the thermal sensation scale.

Table 2. *Mean radiant temperature values in Departments*

Užice Department	Mean radiant temperature, t_{mr} 1,1m	1,7m
Office – business secretary	22,4624	22,4160
Student service	22,5376	22,5070
Amphitheatre – I floor	22,2226	22,2226
Teacher's office	23,8166	23,6780
Server room – IT service	24,0205	23,9904
Library	23,6588	23,6191
Classroom – II floor	24,2906	24,0582
Laboratory OSH	24,3033	24,1291
Chemical laboratory	24,2452	24,1581
Office – III floor	24,5754	24,6785
Amphitheatar – III floor	24,5045	24,3227
Carpentry workshop - basement	24,4227	24,6454
Valjevo Department	Mean radiation temperature, t_{mr} 1,1m	1,7m
Amphitheatre – ground level	22,4026	22,2820
Administrative tasks – II floor	22,3073	22,2766
Teacher's office	22,5351	22,7701

Table 3. *PMV and PPD values in Departments*

Užice Department	PMV	PPD %
Office – business secretary	-0,39	8,2
Student service	-0,40	8,4
Amphitheatre – First floor	-0,49	10,1
Teacher's office	-0,13	5,4
Server room – IT service	0,02	5,0
Library	-0,04	5,0
Classroom – Second floor	0,08	5,1
Laboratory OSH	0,11	5,3
Chemical Laboratory	0,10	5,2
Office – Third floor	0,11	5,3
Amphitheatar – Third floor	0,16	5,5
Carpentry workshop - basement	0,19	5,8
Mean values	- *0,0567*	*6,19*
Valjevo Department	PMV	PPD %
Amphitheatre – ground level	- 0,48	9,8
Administrative tasks – Second floor	- 0,43	8,8
Teacher's office	- 0,27	6,6
Mean values	- *0,3933*	*8,4*

According to the subjective feeling of the respondents, results indicate that the mean value of the thermal sensation respondents, in the Valjevo Department is -0.3933 on the thermal sensation scale, i.e. in the interval from "neutrally pleasant" (0) to "a little warm" (1), Table 3. Generally, the PMV index, in Užice and Valjevo Departments predicts lower values on the thermal scale (colder feeling), than the results of respondents' statements. Using the PMV index it is not possible to accurately predict human thermal comfort in these buildings. Women have lower skin temperatures than men, so the thermal sensation in women is more pronounced in the same thermal environment, and women express a desire for higher air temperatures than men in the same thermal environment [6]. As the basal metabolic rate decreases in men and women, older people in the same thermal environment feel colder than younger people [7]. The fact, that 52.5% of women participated in the Užice Department, i.e. 15.83% in the Valjevo Department and the age structure of the respondents, is not supported by this disagreement between the calculated results of the PMV index and the results of the thermal sensation, because the opposite should be expected. According to [1], the differences in the results between the PMV index and the respondent's statement about thermal comfort may arise due to "bad data entry", i.e. the measured microclimatic parameters of the working environment and the estimated personal parameters of the person [1]. The authors [8] state that the cause may arise due to the psychological and cultural differences of the respondents. The presented results do not confirm the results of the author [9], that the respondents feel colder than predicted by the results of the PMV index.

The ranking of the thermal environment in the Užice and Valjevo Departments, according to [1], indicates that they are in the "B" category. The highest values of the PPD index do not exceed 10%, so the thermal environment is acceptable in both the Užice and Valjevo Departments.

Statistical analysis

Table 4. *Results of the measured air temperature statistical analysis in the working environment*

Location of measurement	t_{sr}, ^0C	S	Cv
Užice	23,00	1,06	0,04606
Valjevo	21,75	0,64	0,02935

The working places can be described as "light work - without physical strain", which means that the measured air temperature values are in accordance with the recommendations of the Rulebook. The higher value of the standard deviation is in the Užice Department. The values of the variation coefficients, 4.606% and 2.935%, indicate very small oscillations of the air temperature around the mean value, in both Departments, which may have a slight, negative impact on the respondents in terms of thermal feeling and thermal comfort, Table 4.

The mean values of relative air humidity are within the recommended values according to the Rulebook.

Table 5. *Results of the measured relative air humidity statistical analysis in the working environment*

Location of measurement	Rv	S	Cv
Užice	41,6	2,57	0,06188
Valjevo	43,6	1,71	0,03913

The standard deviation and the coefficient of variation of the relative air humidity indicate greater deviations from the mean values in the Užice Department. The higher value of the coefficient of variation, 6.188%, indicates slightly larger oscillations of relative humidity around the mean values in the Užice Department and it can have a smaller effect on thermal sensation and thermal comfort, especially at low and high air temperatures, Table 5.

Table 6. *Results of the measured air flow rate statistical analysis in the working environment*

Location of measurement	V, m/s	S	Cv
Užice	0,029	0,014	0,4728
Valjevo	0,033	0,021	0,6245

The mean values of air flow rate in both Departments are within the recommended intervals according to the Rulebook. However, high correlation coefficient values, 47.28% in the Užice Department and 62.45% in the Valjevo Department, indicate greater deviations from the average values of air flow rate, which can have a negative impact on the local thermal sensation and local thermal comfort, as shown in Table 6. In this regard, attention should be paid to the height at which the measurement was made [10].

Table 7. *Results of the measured illumination level statistical analysis in the working environment*

Location of measurement	Lux	S	Cv
Užice	420,54	131,66	0,3131
Valjevo	426,67	195.02	0.4571

The mean values of the measured illumination level, in both Departments, are slightly higher compared to the prescribed illumination requirements for workplaces in closed spaces. This is confirmed by the higher values of the correlation coefficient, in the Užice Department, 31.31% and the Valjevo Department, 45.71%, which indicates that the illumination level is higher than provided by the standard, which can have a negative impact on the thermal comfort of employees, Table 7.

Table 8. *Results of the calculated mean radiant temperature statistical analysis in the working environment*

Location of measurement		t_{mr}, ^{0}C	S	Cv
Užice	1,1m	23,755	0,8578	0,03611
	1,7m	23,702	0,8585	0,03622
Valjevo	1,1m	22,415	0,1144	0,0051
	1,7m	22,443	0,2833	0,01262

Considering the impact of thermal radiation on the thermal comfort, in accordance with the international standard, it is necessary to take into account the air flow rate, ISO 7726 1998. Deviations depending on the temperature measurement height and the calculated radiant temperature exist, but they are insignificant. The mean value of the air flow rate was taken into account, for both measurement heights and the values of the coefficient of variation differ slightly, which cannot be a true indicator of whether there is an impact on the thermal comfort in the working environment, Table 8.

Including this results, there are large deviations, which is confirmed by the fact that the respondents declared differently about thermal comfort in relation to the measured values of the parameters, Table 9.

Table 9. *Results of the calculated PMV index statistical analysis*

Location of measurement	PMV	S	Cv
Užice	-0,057	0,23	-4,7564
Valjevo	-0,393	0,11	-0,2789

Table 10. *Results of correlation analysis*

		Mean value	S	Sxy	r
Užice	P	- 0,05	0.24	0,238	0,41
	M				
	V	0,28	0.99		
		Mean value	S	Sxy	r
Valjevo	P	- 0,39	0.10	0,097	0,99
	M				
	V	0,33	0.88		

The results of the correlation analysis, Table 10., indicate that in the Užice Department there is a relatively strong correlation, ($0.2 \leq |r| < 0.5$), between the PMV index and the respondent's statement, the correlation coefficient is r=0.41. In Valjevo Department there is a strong correlation ($0.8 \leq |r| < 1$), and the correlation coefficient is |r|=0.99. This result shows that only 16.81% (r^2) of the total variation in the thermal sensation of respondents in the Užice Department is explained by the PMV index, and the rest, 83.19%, by the other influences. In the Valjevo Department, as much as 98% (r^2) of the variation in thermal sensation can be explained by the PMV index.

CONCLUSION

The physical conditions of the work environment can have a direct impact on human health, comfort and productivity [11]. The most important personal parameters are the intensity of metabolism and the thermal insulation of clothing.

The test results show that the microclimatic parameters obtained by the questionnaire and by measuring the appropriate devices almost match, that the mean illumination values are higher than the permitted values, that the thermal radiation is higher than the air temperature in the working environment (questionnaire carried out during the heating season), that noise have no a great impact on thermal comfort in the working environment and that there is no agreement between the PMV index and the respondent's statements on the thermal feeling scale when assessing thermal comfort using the PMV index.

The ranking of the thermal environment in the Užice and Valjevo Departments, [1], based on the results of the respondents' statements, indicates that they are in category "B". The highest values of the PPD index do not exceed 10%, so the thermal environment is acceptable in both Departments. However, the results obtained through a questionnaire-based test that measured four microclimate parameters and two personal parameters show that it is not possible to completely quarantee the thermal comfort of a person in the working environment.

The statistical analysis of the PMV index calculation shows large deviations in the value of the correlation factor and confirms that the respondents made different statements regarding thermal comfort in relation to the measured values of the parameters, which is in agreement with the linear correlation calculation in the Užice Department. The results in the Valjevo Department showed that the respondents felt "colder" compared to the calculated values of the PMV index, it can be seen that there is an agreement, except for 2% of the variations in the thermal sensation which includes an explaination of other factors.

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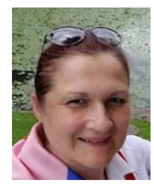

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Ispitivanja toplotnog komfora u Akademiji zapadna Srbija

Nataša Ćirović, Ivana Bojović, Nenad Milutinović

Rezime: U radu su analizirani uslovi toplotnog komfora prostorija u Akademiji strukovnih studija Zapadna Srbija (dalje ASSZS), Fangerovom metodom. Izvršeno je ispitivanje uticaja pojedinačnih parametara: temperature vazduha, relativne vlažnosti vazduha, brzine strujanja vazduha, srednje temperature zračenja, nivoa buke i osvetljenosti, kao i toplotne izolacije odeće i procene inteziteta metabolizma na toplotni komfor zaposlenih u ASSZS. Pomoću ovih podataka izmereni su Fangerovi indeksi PMV i PPD. Izvršen je proračun linearne korelacije između proračunatih vrednosti PMV indeksa i izjašnjavanja ispitanika o toplotnom osećaju. Statističkom obradom prikupljenih podataka izvršeno je rangiranje objekata.

Ključne reči: uticaj mikroklimatskih parametara i ličnih parametara na toplotni komfor, procena toplotnog komfora, PMV/PPD Fangerovi indeksi

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ALTERNATIVE SOURCES OF ENERGY AND SUSTAINABLE DEVELOPMENT IN NEIGHBOURING COUNTRIES OF SERBIA

Abstract: *The need for energy resources is constantly growing, on a global level. The effects of energy transformations degrade soil, water, and air quality. For this reason, it is necessary to increase investments in the development of alternative energy sources and increase the level of energy efficiency. A common issue in the Balkan countries is the excessive use of fossil fuels. This paper presents a comparative analysis of renewable energy source usage in Serbia, Bulgaria, Romania, Hungary, Croatia, Bosnia and Herzegovina, Montenegro, and North Macedonia. Based on the analysis, the paper concludes that the energy sectors of Croatia and Romania are making significant progress towards sustainable energy development in their respective energy sectors.*

Key words: alternative sources of energy, energy sector, sustainable development

INTRODUCTION

The contemporary issues of climate change and the energy crisis have led to the emergence of various environmental problems that require new approaches to energy development. Overcoming these significant challenges requires the application of alternative energy sources, improving energy technologies, increasing the level of energy efficiency and mitigating the consequences of energy transformations. The basic elements of the national energy policy are primarily a rational energy strategy and energy sustainable development based on available resources.

Energy indicators play a crucial role in addressing energy-related challenges. They are a fundamental component in implementing measures to enhance energy efficiency and are utilized for systematic identification and monitoring of the state and development of the energy sector. The main objective of employing energy indicators in environmental protection management is to achieve optimal energy efficiency by minimizing primary energy consumption and promoting more rational energy usage.

Energy indicators, which refer to energy consumption, alone without any connection to economic variables, do not provide sufficient information [4]. Therefore, linking economic and energy policy measures is necessary to implement an overall economic policy that enables the optimal use and consumption of energy in an economically and energetically efficient manner.

The significance of energy indicators lies in the fact that by comparing actual values obtained from collected data with common or standard values, it becomes evident which sectors can reduce energy consumption and which users are energy-efficient. This analysis provides valuable insights for organizations to effectively implement energy efficiency programs and make informed decisions pertaining to energy consumption and associated costs.

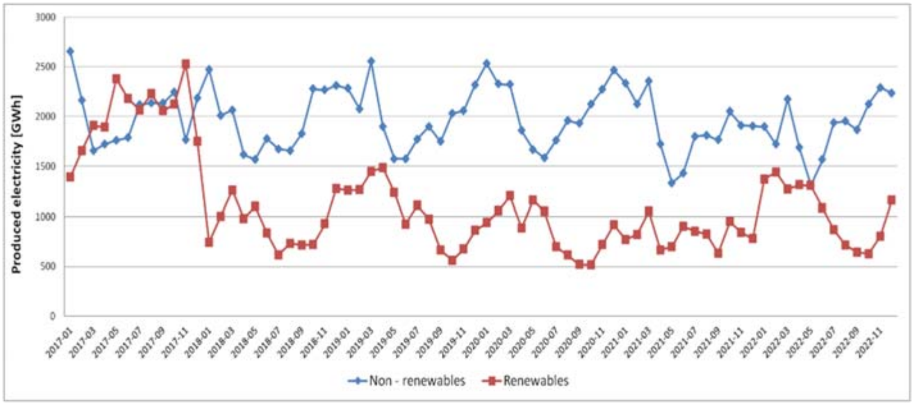
REPRESENTATION OF ENERGY SOURCES AS AN INDICATOR OF ENERGY DEVELOPMENT

Modern civilization, as well as the modern way of life, is based on the use of electricity, which is obtained from various energy sources. One of the indicators of greater significance for energy development is the energy consumption from renewable and non–renewable energy sources. This paper aims to analyze the significance of diverse energy sources in enhancing the state of the environment [2]. It conducts a comparative analysis of the approach to electricity generation and the associated expenses in Serbia and other countries from the region, namely Bulgaria, North Macedonia, Croatia, Montenegro, Bosnia and Herzegovina, Hungary, and Romania from 2017 to 2022.

Application of energy sources in the energy sector of Serbia

In Serbia, the main problem lies in the fact that the majority of energy production heavily relies on non-renewable sources such as fossil fuels, instead of renewable energy sources. This leads to high levels of pollution and environmental degradation. By shifting towards renewable energy sources, the country can significantly reduce its carbon footprint. Graph 1 illustrates the proportion of electricity generated from renewable and non-renewable sources.

The graph shows that in March 2017, 1958.00 GWh of electricity was obtained from renewable sources and 1656.00 GWh of electricity from non–renewable sources. In the same period of 2018, that number was 1304.00 GWh from renewable sources and 2064.00 GWh of electricity from non–renewable sources. In 2019, 1522.00 GWh of electricity was produced from renewable energy sources and 2552.00 GWh from non–renewable sources.

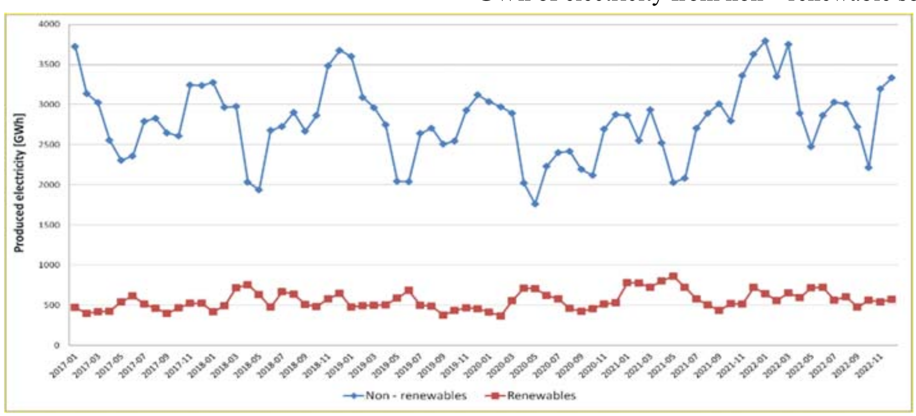


Graph 1. *Application of renewable and non–renewable energy sources in Serbia, from 2017 – 2022.[5]*

During 2020, 1277.00 GWh of electricity was generated from renewable sources and 2322.00 GWh of electricity from non–renewable sources. In 2021, 1045.00 GWh of electricity was obtained from renewable sources and 2355.00 GWh from non–renewable sources. In the last year, 2022, 1251.00 GWh of electricity was obtained from renewable energy sources and 2174.00 GWh from non–renewable sources. Based on these data, it can be concluded that electricity obtained from renewable sources gradually has been decreasing over the years, on the other hand, the production of electricity from non-renewable sources continues to grow from year to year.

Application of energy sources in the energy sector of Bulgaria

In Bulgaria the amount of electricity produced from renewable sources is– renewable very low, as shown in the following Graph 2. According to the graph data, in March 2017, 418.00 GWh of electricity was obtained from renewable sources and 3026.00 GWh of electricity from non – renewable sources. In the same period of 2018, that number was 752.00 GWh from renewable sources and 2978.00 GWh of eletricity from non sources. In 2019, 532.00 GWh of electricity was obtained from renewable energy sources and 2961.00 GWh of electricity from non – renewable sources.



Graph 2. *Application of renewable and non–renewable energy sources in Bulgaria, from 2017 – 2022.[7]*

In 2019, 532.00 GWh of electricity was obtained from renewable energy sources and 2961.00 GWh of electricity from non–renewable sources. During 2020, 519.00 GWh of electricity was generated from renewable sources and 2891.00 GWh from non–renewable sources. In 2021, 782.00 GWh of electricity was obtained from renewable sources and 2936.00 GWh from non–renewable sources. In the last year, 2022, 643.00 GWh of electricity was produced from renewable energy sources and 3751.00 GWh from non–renewable sources.

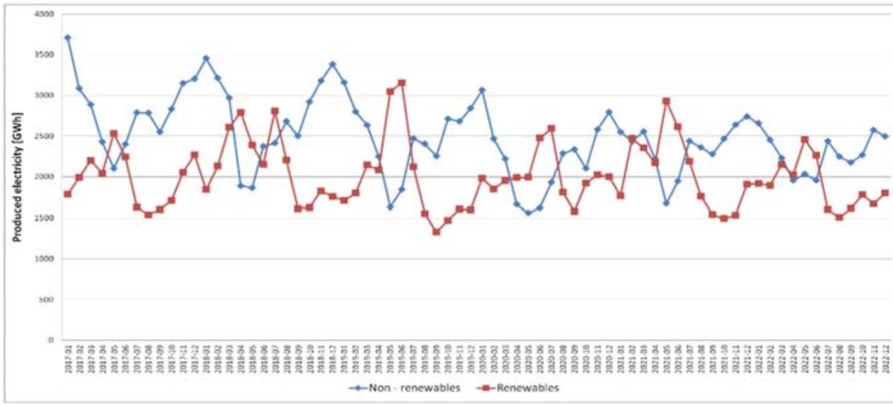
It can be concluded that in Bulgaria the use of renewable energy sources does not vary, generally it has approximate values and is used very low. It follows from this that the use of non-renewable sources should be reduced while the use of renewable sources should be increased in order to achieve sustainable development and decrease the amount of environmental pollution.

Application of energy sources in the energy sector of Romania

Romania employs renewable energy sources at nearly the same rate as non-renewable sources, according to the data in Graph 3. This indicates the country's commitment to a sustainable energy future

The graph shows that in March 2017, 2200.00 GWh of electricity was obtained from renewable sources and

2887.00 GWh of electricity from non – renewable sources. In the same period of 2018, that number was 2607.00 GWh from renewable sources and 2971.00 GWh of eletricity from non – renewable sources. In 2019, 2148.00 GWh of electricity was obtained from renewable energy sources and 2633.00 GWh from non – renewable sources.



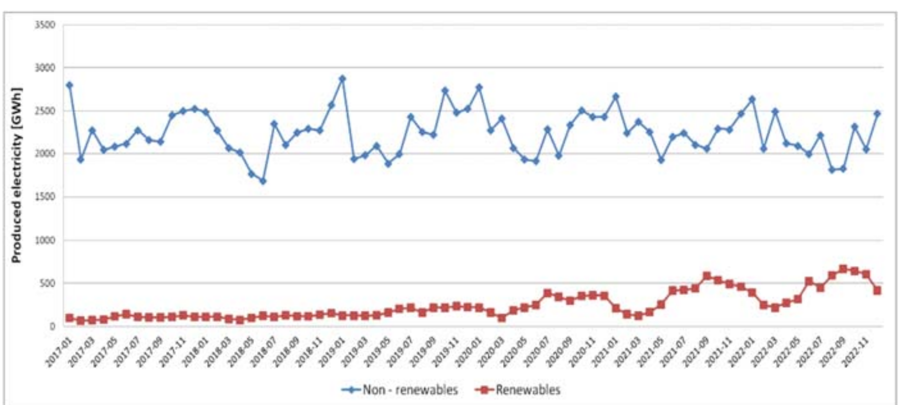
Graph 3. *Application of renewable and non–renewable energy sources in Romania, from 2017 – 2022.[7]*

During 2020, 1951.00 GWh of electricity was produced from renewable sources and 2221.00 GWh from non – renewable sources. In 2021, 2353.00 GWh of electricity was obtained from renewable sources and 2557300 GWh from non – renewable sources. In the last year, 2022, 2153.00 GWh of electricity was produced from renewable energy sources, and 3230.00 GWh of energy from non – renewable sources.

Based on the graph, it can be concluded that Romania has a good renewable capacity, due to the fact that a large amount of electricity is obtained from renewable sources, which causes less environmental pollution.

Application of energy sources in the energy sector of Hungary

Hungary has very low electricity production from renewable resources as shown in Graph 4. In March 2017, it received 92.00 GWh of electricity from renewable sources and 2275.00 GWh of electricity from non–renewable sources. In 2019, 143.00 GWh of electricity was obtained from renewable energy sources and 1982.00 GWh from non–renewable sources. In the same period of 2018, that number was 106.00 GWh from renewable sources and 2065.00 GWh of electricity from non–renewable sources. During 2020, 2410.00 GWh of electricity was generated from renewable sources and 231.00 GWh of electricity from non–renewable sources. In 2021, 322.00 GWh of electricity was obtained from renewable sources and 2370.00 GWh from non–renewable sources. In the last year, 2022, 2493.00 GWh was obtained from renewable energy sources and 457.00 GWh from non–renewable sources.



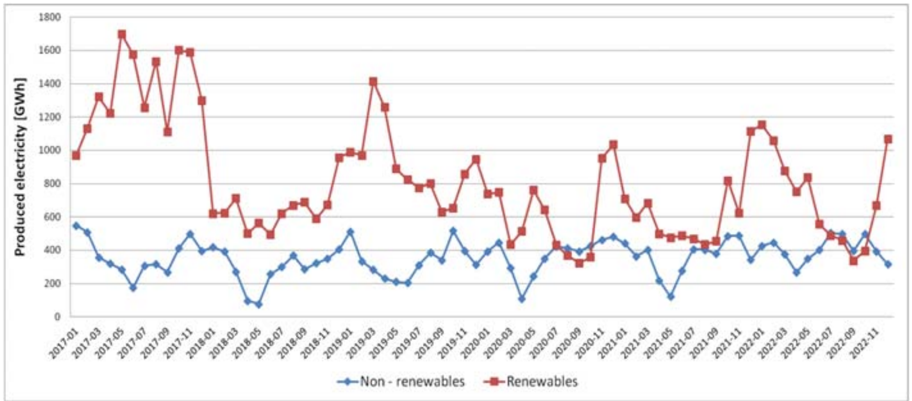
Graph 4. *Application of renewable and non–renewable energy sources in Hungary, from 2017 – 2022.[7]*

Based on the data one can come to the conclusion that Hungary does not invest enough in reducing the amount of pollution, due to the fact that it mainly uses non–renewable energy sources while using renewable ones in minimal quantities

Application of energy sources in the energy sector of Croatia

Croatia represents a country that mainly uses renewable energy sources and takes care of environmental pollution, which can be seen from Graph 5.

The graph shows that in March 2017, 1215.00 GWh of electricity was produced from renewable sources and 357.00 GWh of electricity from non-renewable sources.

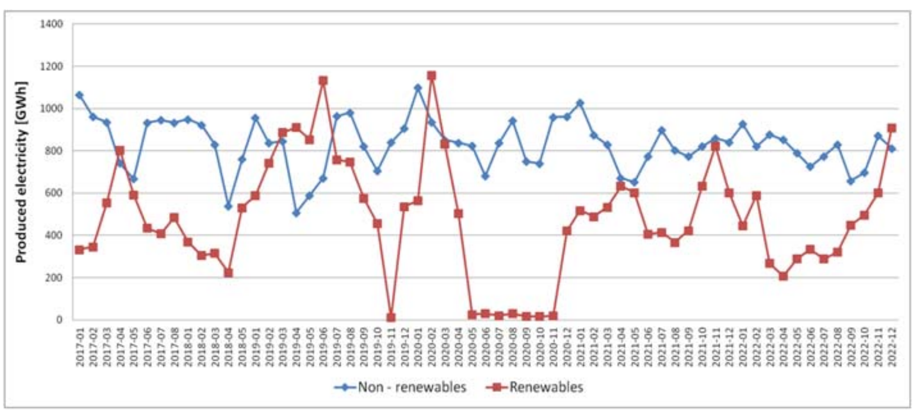


Graph 5. *Application of renewable and non–renewable energy sources in Croatia, from 2017 – 2022.[7]*

In the same period of 2018, that number was 758.00 GWh of electricity from renewable sources and 271.00 GWh from non-renewable sources. In 2019, 1250.00 GWh of electricity was obtained from renewable energy sources and 284.00 GWh from non-renewable sources. During 2020, 556.00 GWh of electricity was obtained from renewable sources, and 294.00 GWh of electricity from non-renewable sources. In 2021, 645.00 GWh of electricity was obtained from renewable sources and 401.00 GWh from non-renewable sources. In the following year, 2022, we received 842.00 GWh of electricity produced from renewable energy sources and 375.00 GWh from non-renewable sources.

Application of energy sources in the energy sector of Bosnia and Herzegovina

In recent years, Bosnia and Herzegovina has been fluctuating between relying on renewable and non-renewable energy sources, as illustrated in Graph 6. Based on the use of these sources, it can be concluded that Bosnia and Herzegovina is established around the average in terms of pollution and that the values are, according to the use of renewable and non-renewable energy sources, approximate.

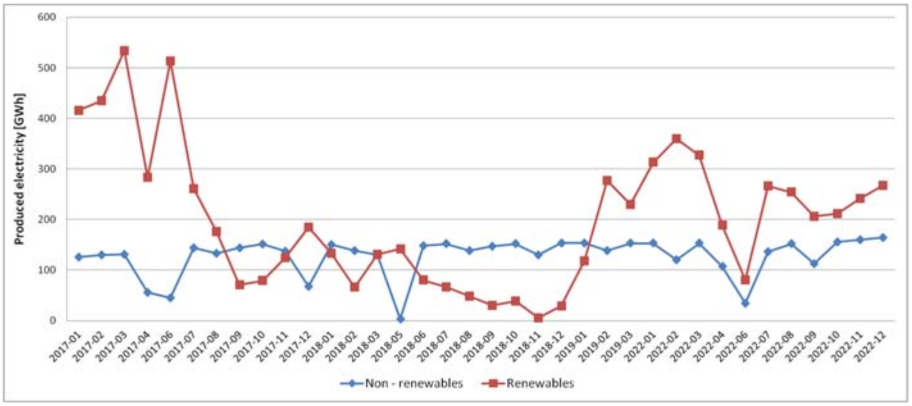


Graph 6. *Application of renewable and non–renewable energy sources in Bosnia and Herzegovina, from 2017 – 2022.[7]*

From the graph, it can be seen that in March 2017, From the graph, it can be seen that in March 2017, 467.00 GWh of electricity was produced from renewable sources and 936.00 GWh of electricity from non-renewable sources. In the same period of 2018, that number was 325.00 GWh of electricity from renewable sources and 830.00 GW from non-renewable sources. In 2019, 888.00 GWh of electricity was obtained from renewable energy sources and 846.00 GWh from non-renewable sources. During 2020, 800.00 GWh of electricity was generated from renewable sources, and 851.00 GWh of electricity from non-renewable sources. In 2021, 529.00 GWh of electricity was obtained from renewable sources and 828.00 GWh from non-renewable sources. In the following year, 2022, it produced 236.00 GWh of electricity from renewable energy sources and 876.00 GWh from non-renewable sources.

Application of energy sources in the energy sector of Montenegro

Montenegro has made significant strides in transitioning to renewable energy sources in recent years, which has led to a reduction in pollution levels. As of the latest available data, Montenegro has been predominantly using renewable energy sources to meet its energy needs. However, it is worth noting that there is currently no data available for 2020 and 2021, which can be analyzed from Graph 7. Continued use of renewable energy sources in Montenegro would be a significant step towards a cleaner and more sustainable environment.

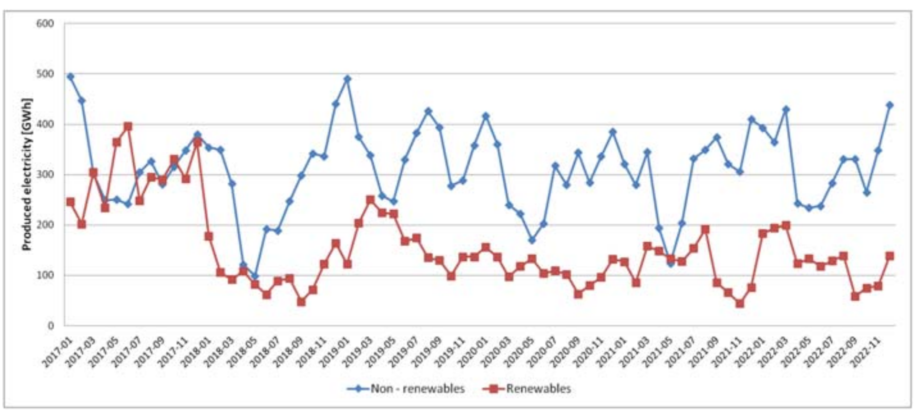


Graph 7. *Application of renewable and non–renewable energy sources in Montenegro, from 2017 – 2022.[7]*

From the graph, it can be concluded that in March 2017, 610.00 GWh of electricity was obtained from renewable sources and 131.00 GWh of electricity from non-renewable sources. In the same period of 2018, that number was 233.00 GWh of electricity from renewable sources and 130.00 GWh from non-renewable sources. In 2019, 230.00 GWh of electricity was obtained from renewable energy sources, and 153.00 GWh from non-renewable sources. We do not have data for the years 2020 and 2021.

Application of energy sources in the energy sector of North Macedonia

North Macedonia primarily relies on non-renewable sources, leading to significant pollution levels as presented in Graph 8. In 2019, 236.00 GWh of electricity was obtained from renewable energy sources and 338.00 GWh of electricity from non-renewable sources. During 2020, 98.00 GWh of electircity was produced from renewable sources and 240.00 GWh of electricity from non-renewable sources.



Graph 8. *Application of renewable and non–renewable energy sources in North Macedonia, from 2017 – 2022.[7]*

In 2021, 156.00 GWh of electricity was obtained from renewable sources and 345.00 GWh from non-renewable sources. In the following year, 2022, it produced 193.00 GWh of electricity from renewable energy sources and 430.00 GWh from non-renewable sources. Considering the data, it can be stated that North Macedonia uses mainly non-renewable energy sources and therefore has a large amount of pollution.

CONCLUSION

The consequences of climate change have significantly
The consequences of climate change have significantly increased the importance of energy efficiency as a crucial component of sustainable living and economic development. The primary objective of energy indicators, in general, is to enhance energy efficiency and mitigate energy consumption, which ensures the optimal use of energy resources.

Total energy consumption at the global level is increasing year by year. At the global level, non-renewable energy sources are mostly used for energy production; however, in recent decades, the most developed countries of the world have plans to reduce the consumption of primary forms of energy and to increase the use of renewable energy sources.

As for the situation in the Republic of Serbia, although fossil fuels are still the dominant source of energy in total consumption, the share of renewable energy sources has grown significantly in recent years. The use of renewable energy sources is extremely important because it reduces the amount of pollution, which is important from the aspect of environmental protection. On the other hand, the use of non-renewable energy sources, besides shortening the period of their future use, affects the growth of global warming, with very serious consequences for human health and the environment.

Observed within the situation in the region, Croatia and Romania can serve as good examples of how renewable energy sources should be used, given that these two countries get most of their electricity from renewable sources.

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Milan Lukić was born in Prokuplje, Serbia, in 2000.
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His main areas of research include fire protection, occupational safety and health, environmental protection, etc.

ALTERNATIVNI IZVORI ENERGIJE I ODRŽIVI RAZVOJ

Milan Lukić

Rezime: *Potreba za energetskim resursima je u stalnom porastu, na globalnom nivou. Posledice energetskih transformacija narušavaju kvalitet vazduha, vode i zemljišta. Neophodno je povećati ulaganja u razvoj alternativnih izvora energije i povećati nivo energetske efikasnosti. Karakterističan problem balkanskih zemalja je visok nivo upotrebe fosilnih goriva. U radu je izvršena uporedna analiza primene obnovljivih izvora energije u Srbiji, Bugarskoj, Rumuniji, Mađarskoj, Hrvatskoj, Bosni i Hercegovini, Crnoj Gori i Severnoj Makedoniji. Na osnovu analize u radu se zaključuje da energetski sektori Hrvatske i Rumunije ostvaruju značajan napredak ka održivom energetskom razvoju u svojim energetskim sektorima.*

Ključne reči: alternativni izvori energije, energetski sektor, održivi razvoj.

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PSYCHOLOGICAL SECURITY AS A SIGNIFICANT PERSONAL RESOURCE FOR TEAMS UNDER STRESS

Abstract: *This study aims to show that prior to making new connections with those who are necessary to create a psychologically secure team, people must feel secure. The article shows the linkage between security and attachment. The role of psychological security in ontogeny is analyzed. The authors demonstrate that the state of security has a beneficial effect on the regulation of emotions, mental health, social adaptation, social relations and values, and maintaining a background sense of personal well-being, competence and mastery. People who are in a state of security have higher self-esteem, regard themselves as capable and efficient, describe themselves in a positive way, have small discrepancies between their real and ideal selves, and have a wide range of mechanisms to deal with stress. As a result, the need for psychological defenses that distort perception, limit maneuverability, and generate interpersonal conflicts decreases. The paper indicates that before people can create a psychologically safe environment and team., they need to satisfy their basic need for attachment.*

Key words: psychological security, attachment, ideas, need for security, defense mechanisms, team.

INTRODUCTION

A new level of technological advancement creates a new type of technological risks, one that is distinguished by its invisibility. The fact that one only starts looking for security when their life, health, or well-being is in danger demonstrates the latent nature of security.

There are increasing risks associated with people worrying about whether their plans will work, whether they can perform their jobs effectively, and whether they will get along with the new team during periods of major organizational change [1]. Workplace psychological security is closely tied up with the health, resilience, and well-being of each individual and team [2]. Lakhan with a group of researchers [3] found that anxiety, stress, and psychological disorders tend to intensify during periods of uncertainty, which leads to the need to invest in ways of supporting a company's employees in times of increased stress. According to Hebles et al. [4], without being exposed to interpersonal risks and feeling secure in the work environment, employees are likely to experience less stress, which lowers emotional and cognitive consequences. Psychological security, in particular, can become a valuable mechanism to reduce stress by establishing an atmosphere of trust and secure communication. Vast research has proven the impact of psychological security on team performance as well as the obvious need for psychological security when changing jobs [5]. Psychological security is connected with task completion, information exchange, commitment, loyalty to one's organization, and creative activity. Although there have been plenty of studies looking into the advantages of psychological security and reasons why it is necessary, little is known about the specific features of its formation. This study aims to show that prior to making new connections with those who are necessary to create a psychologically secure team, people must feel secure.

The need for security is a basic human need – an anthropological constant of human existence. It emerges with the appearance of the person himself and accompanies him throughout his life. That is why a person needs to feel his connection with the outside world, with other people, belonging to certain social groups and social structures.

The research using the Adult Attachment Interview [6; 7] allowed scholars to expand on John Bowlby's theory and Mary Ainsworth's ideas. The data obtained by the authors made it possible to suggest that psychological security may be equivalent to a feeling of "invulnerability". Of course, a person who is in a state of safety is not a bulletproof superman, however, such a person can cope with difficulties and disappointments more effectively, and he is sure that other people are able to help him and support him in a situation of danger.

The state of security makes people more open, they rely less on defensive mechanisms in order to maintain self-esteem.

Attachment theory, which is partly based on observations of primates, suggests that infants are born with a strong need for attachment and use various innate behavioral procedures to realize it (crying, grabbing, clinging, following a person with their eyes, etc.). This can be seen as an innate set of “rules” related to intimacy and the search for safety. Thus, during infancy, caregivers (usually one or both parents, grandmothers, older siblings, and kindergarten workers) can serve as a source of attachment.

Research has shown that when a child is unwell, he will seek closeness from a caregiver [8], whose presence noticeably comforts him [9]. In later childhood, adolescence, and adulthood, a wider variety of relationships with partners can serve as sources of attachment (relatives, familiar co-workers, teachers and coaches, close friends, and romantic partners). “The focus on informal ties allows them to build up more flexible strategies and a of security” [10, p. 108].

In addition, groups, organizations, and symbolic characters (such as God) can also be a source of security. There is evidence that many young children have imaginary friends [11]; that some adults who suffer from the death of a spouse continue to experience their presence and seek their help and support when needed [12]; and that many adults believe they can receive protection and comfort from gods, angels, saints, and the spirits of dead ancestors [13]. Thus, according to Alan Srouf and Everett Waters [14], the feeling of security is especially relevant when faced with actual or symbolic threats. When security is achieved, the desire for intimacy fades, and the person calmly returns to another type of activity.

In young children, the desire for safety can be expressed in the desire for closeness, in crying, as well as in active behaviors aimed at restoring and maintaining closeness, such as moving towards the caregiver and acts of “clinging” [15]. In adulthood, the need for security does not necessarily entail a search for physical intimacy. Instead, a sense of security can be achieved by activating mental representations of loved ones that provide care and protection [16]. Cognitive representations help people successfully cope with threats and enable them to continue their activities without having to interrupt them to maintain a sense of security. However, during illness, injury, or in the midst of traumatic events, these strategies are not sufficient.

When the need for safety is not realized, defense mechanisms associated with anxiety and avoidance can be used [17]. Avoidance reflects the degree of distrust towards a partner, the desire to maintain independence of behavior and emotional distance from him. Anxiety is associated with a person's concern that their partner will not be available if necessary.

The state of security can be fairly stable over time and is typically the result of realized attachment with primary caregivers in early childhood [18], however, John Bowlby [19] has argued that lifelong interactions with others can change systems of operation. In fact, the state of security is rooted in a complex of cognitive and affective components that include multiple contexts [20]. Many studies show that security status can change quite rapidly depending on context and recent experience [21].

Research findings over the past decades have demonstrated that the state of security has a beneficial effect on the regulation of emotions, mental health, social adaptation, as well as social attitudes and values that play a central role in behavior. A sense of security softens suffering and causes positive emotions (joy, satisfaction, gratitude).

Representations play a central role in maintaining emotional stability and psychological security. Two types of representations can be distinguished: the first type of representation concerns the perception of life's problems as easily manageable, which helps a person maintain optimism and hope for a successful outcome in critical situations. These representations are the result of a positive interaction in which people learn that distress is manageable, external obstacles can be overcome, and the course and outcome of most dangerous events are at least partially controllable. In particular, people who are in a state of psychological safety have a wider range of interpretations of stressful events and more optimistic expectations about their own ability to overcome obstacles [22].

The second kind concerns positive ideas about other people's intentions and traits. Thus, securely attached people have a relatively positive view of human nature [23]. When describing relationships with partners, such people use mostly positive terms [24], perceive partners as support [25], and feel trust in partners [23]. In addition, securely attached people have positive expectations about their partner's behavior [21] and tend to explain negative partner behavior in relatively positive terms [26].

Also, the state of security maintains an underlying sense of personal well-being, competence, and mastery. People see themselves as active, strong and competent individuals because they can effectively mobilize partner support and overcome threats.

Thus, people who are in a state of security have higher self-esteem [27], perceive themselves as competent and efficient [28], describe themselves in a positive way, and have little discrepancy between the real self and the self-ideal [29].

In general, the presence of psychological security can mitigate the emotional damage from traumatic experiences such as wars, terrorist attacks, rape, etc. Security also plays an important role in determining the extent to which PTSD symptoms develop after exposure to trauma.

CONCLUSION

Compared to previous research in the field of psychological security, this study has an added value since it considers psychological security in ontogeny. We assume that before people can create a psychologically secure environment and team, they need to satisfy their basic need for attachment.

Individuals use their coping resources when faced with a threat or situation of uncertainty, but the leader and organization are also responsible for creating an environment in which people can meet those needs, research suggests. In practice, the main focus in shaping psychological security has so far been on dyadic and group relationships. The study implies that this approach can be successfully complemented with an additional, individualistic view. It is a valuable supplement that can contribute to organizational training and coaching. It also clarifies the role of the organization in how it should provide an environment in which people have sufficient opportunities to meet their basic needs. All this broadens the scope of attention when developing measures aimed at eliminating the lack of psychological security in the organization.

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PSIHOLOŠKA SIGURNOST KAO ZNAČAJNI LIČNI RESURS ZA TIMOVE POD STRESOM

Olga Zotova, Elena Zlateva

Rezime: *Ova studija ima za cilj da pokaže da pre uspostavljanja novih veza sa onima koji su neophodni za stvaranje psihološki bezbednog tima, ljudi moraju da se osećaju sigurno. Članak pokazuje vezu između sigurnosti i vezanosti. Analizirana je uloga psihološke sigurnosti u ontogenezi. Autori pokazuju da stanje bezbednosti blagotvorno utiče na regulaciju emocija, mentalno zdravlje, socijalnu adaptaciju, društvene odnose i vrednosti, održava pozadinski osećaj ličnog blagostanja, kompetentnosti i majstorstva. Ljudi koji su u stanju sigurnosti imaju veće samopoštovanje, sebe smatraju kompetentnim i efikasnim, opisuju se na pozitivan način, imaju male razlike između svog stvarnog i idealnog ja, imaju bogat repertoar resursa za suočavanje sa stresom, što dovodi do smanjenja potrebe za psihološkom odbranom koja iskrivljuje percepciju, ograničava manevrisanje i generiše međuljudske sukobe. U radu se ukazuje da pre nego što ljudi mogu da stvore psihološki bezbedno okruženje i tim, moraju da zadovolje svoju osnovnu potrebu za privrženošću.*

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