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ANALYSIS AND MEASURES OF LANDFILL FIRE PREVENTION

Abstract: Large quantities of solid municipal waste containing a variety of flammable substances, that are disposed of in sanitary and non-sanitary landfills and even illegal dump sites, usually entail a high risk of fire. The level of risk is increased by the presence of methane which is released by municipal waste decomposition. The number of landfill fires varies depending on the morphological composition of the waste, ignition sources, meteorological conditions, time of year, as well as fire protection measures. The paper describes the impact of flammable waste on landfill fires, as well as causes, frequency and procedures in preventing and extinguishing landfill fires.

Key words: landfill fires, flammable waste, methane.

INTRODUCTION

In the Republic of Serbia, municipal waste is collected in an organized manner and disposed of in 164 registered municipal landfills. Each local government has its own landfill which, in most cases, is not sanitary. About 70% of municipal landfills operate without required permits and environmental impact assessments and are, therefore, categorized as unsanitary landfills. The existing landfills in most municipalities are already filled, while the majority of landfills do not meet the minimum technical requirements. The Waste Management Strategy proposes the construction of 26 regional sanitary landfills, 10 of which have been built so far. According

to statistical data, about 20% of generated municipal waste ends up in illegal dump sites, which in Serbia amount to 2170 [1].

When it comes to landfill design and the conditions of safe waste disposal with the aim to reduce the risk of fire and explosions, air, water and soil pollution, we can distinguish 5 levels of landfill protection (Table 1).

In the territory of the Republic of Serbia, the level of protection for illegal dump sites is 0, the level of protection 1, 2 and 3 is given to non-sanitary municipal landfills, while sanitary landfills have the highest level of protection - 5.

Table 1. Fire protection levels and negative environmental impacts [2]

Levels	Level of control	Management & operation	Operational facility
0	None	Uncontrolled dumping–no controls	Uncontrolled burning, lacking most “control” functions
1	Low	Site staffed; waste placed in the designated area; some site equipment	Site staffed, some containment and management of combustion process; basic operating procedures to control nuisance
2	Medium	Waste compacted using site equipment; waste covered (at least irregularly)	Emission controls to capture particulates; trained staff follow set operating procedures; equipment properly maintained; ash properly managed
3	Medium/high	Engineered landfill site: use of daily cover material; some level of leachate containment and treatment; a collection of landfill gas	High levels of engineering and process control over residence time, turbulence and temperature; emission controls to capture acid gases and capture dioxins; active management of fly ash
4	High	Fully functional sanitary landfill site: properly sited and designed; leachate containment (naturally consolidated clay on the site or constructed liner); leachate and gas collection; final cover; post-closure plan	Built to and operating in compliance with an international best practice including e.g. EU or other similarly stringent stack and Green House Gas emission criteria fly ash managed as a hazardous waste using best appropriate technology

1. Impact of flammable waste on landfill fires

About 50% to 80% of municipal waste components are flammable substances. Organic waste is the most flammable compared to other components of landfilled waste (Figure 1). Waste can be of organic and inorganic origin. Waste of organic origin decomposes faster than a waste of inorganic origin. Organic matter

disposed of in landfills are classified into two major categories:

- substances that decompose faster (from 3 months to 5 years)
- substances that decompose slowly (up to 25 years).

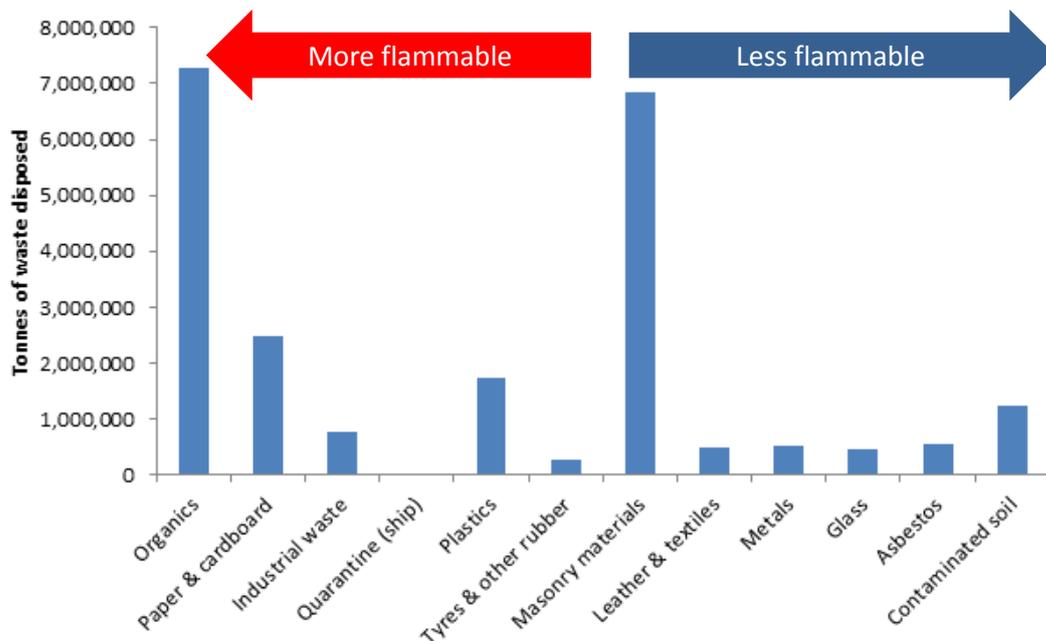


Figure 1. Flammability of different waste types [3]

Waste age influences the flammability of municipal solid waste because the ignition temperature and humidity percentage decrease as the waste age increases. Table 2 shows the values of smoldering and ignition temperature, time of smoldering and ignition,

as well as humidity percentage for waste with morphological composition as follows: organic waste, paper, textiles, plastics, waste from public areas, metal, glass, construction material.

Table 2. Smoldering and ignition temperatures depending on the age of waste deposits [4]

Waste Category	Smoldering		Ignition		Moisture Content (%)
	Temperature (°C)	Time (min)	Temperature (°C)	Time (min)	
Fresh Waste	125	32	266	47	53.75
3 Months Old Waste	120	31	227	36	36.35
6 Months Old Waste	105	26	195	30	29.84
36 Months Old Waste	102	25	181	26	5.21
60 Months Old Waste	98	23	179	27	2.63

In addition to landfilled waste, one of the main causes of fires and explosions is methane, which is the main component of landfill gas generated by waste decomposition. The risk of fire and explosion occurs within the flammability limits or explosive range from 5 to 15% vol. Based on the Decree on waste disposal in

landfills ("Official Gazette of RS", No. 92/2010), sanitary and non-sanitary landfills are monitored to record the emission of landfill gases from reservoirs for landfill degassing, and methane gas is also monitored besides to other components. [5]

Table 3. Monitoring the concentration of landfill gas components [6]

Reporting	CH ₄	O ₂	CO ₂	CO	H ₂ S	No. gas wells
2015	4.9 - 6.8%	10.9 -12.98%	13.4-15.9%	<1(mg/m ³)	<1(mg/m ³)	5
2015	5.1-11.4%	9.5-13.34%	16.1-19.5%	<1(mg/m ³)	<1(mg/m ³)	7
2016	0.1-1.9%	20.0-21.5%	0.1-1.6%	0 (ppm)	0 (ppm)	6
2017	0-16.3%	13.11-21.15%	0-6.1%	0 (ppm)	0 -11.8 (ppm)	22
2018	0-39%	1.87-21.02%	0-6.7%	0 (ppm)	0 -21.8 (ppm)	21

2. Causes and frequency of landfill fires

The most frequent types of fires are fires in the active area of the landfill (77%). The most common causes of fire on the landfill body are spontaneous combustion of landfill materials (54.6%), while the unknown causes

of fire (21.2%) include arson as well as natural phenomena due to atmospheric discharge and solar radiation. The least frequent causes of landfill fires are explosions (0.4%).

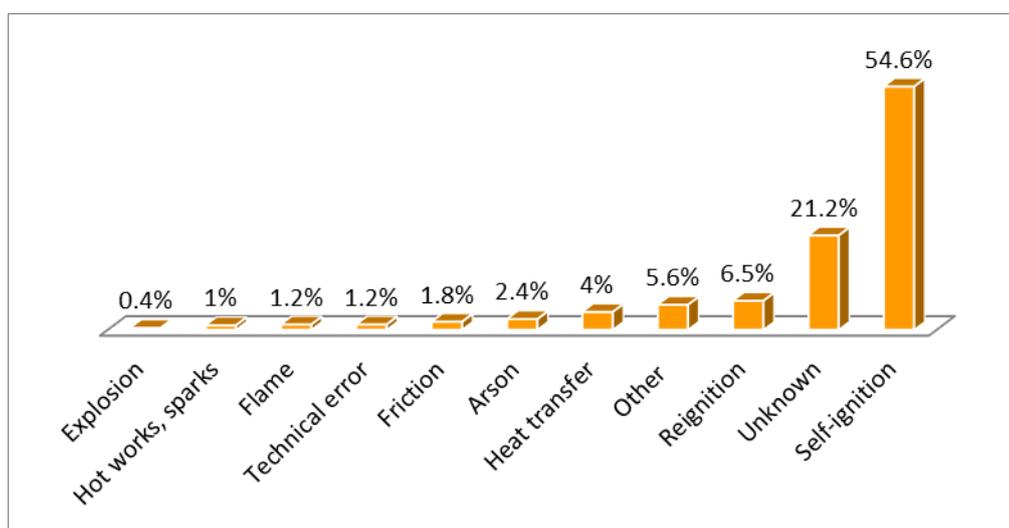


Figure 2. Landfill fires cause statistics [7]

Fires on landfill construction facilities – office and administrative buildings and other facilities (porter's lodge, weighing scales) comprise 7%. Possible causes of fires in the landfill buildings are: employee inattention, improper use of thermal devices, malfunction of electrical installations, work equipment, static electricity, emergencies (earthquakes, lightning strikes, etc.), deliberate fires, explosive devices, ignition of flammable substances near heat sources, spontaneous combustion of certain substances. Other fires at the landfill occur on refuse collection vehicles and in the green belt inside the landfill area.

Fires are categorized by the way they burn:

- flaming - burning with an open flame and
- burning fires - burning by smoldering without flame.

Flaming fires are characteristic of surface fires while burning fires are characteristic of underground fires.

In order to provide a more comprehensive insight into the frequency of landfill fires on the global level, Figure 3. shows the number of fires at the landfills in the USA and Canada for the 2016-2021 period.

From Figure 3, it can be concluded that the largest number of landfill fires occurred during the summer months. Records for the month of June indicate the greatest number of fires in 2018 and 2020; in July the largest number of fire outbreaks was reported for the years 2016 and 2017, while in August the largest number of fires was in 2019.

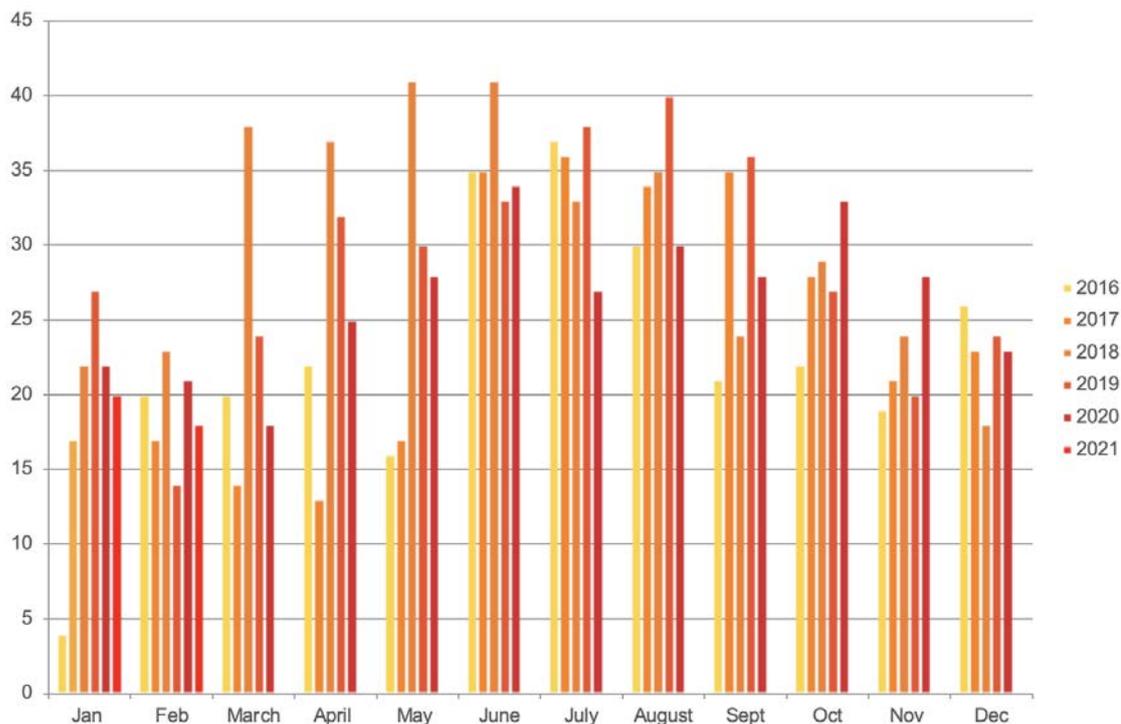


Figure 3. Landfill fire outbreaks in the USA and Canada for the 2016-2021 period [8]

3. Procedures for preventing and extinguishing landfill fires

To prevent the risk of fire outbreak and spread of a fire, as well as to mitigate its consequences, it is necessary to carry out the following:

- Proper construction of sanitary landfills implies selecting a proper location for landfill construction, Strategic Assessment and Environmental Impact Assessment Study, approved Main Technological Project, Environmental Impact Assessment Study, issued Decision on approval for construction of sanitary municipal solid waste landfill for the working area, Decision on the use permit for constructed sanitary municipal solid waste landfill for work area as well as the Decision on issuing hazardous waste disposal permit at the operator's location.

- Proper functioning and development of fire protection plans implies the following - According to the Law on Fire Protection, sanitary landfill belongs to the third category with a certain risk of fire and is obliged to organize the implementation of preventive fire protection measures with the necessary number of persons professionally trained to implement protection measures, as well as to provide adequate firefighting equipment and devices. In this regard, the following documentation is required:

- Fire protection rules
- Recovery plan for eliminating consequences of fire outbreak
- Accident protection plan

- Basic employee training in the field of fire protection
- Fire emergency evacuation plan

- Waste collection implies the transfer of waste from the point of use and disposal to the landfill, control of waste collected and classifying waste components for recycling. Waste residues are transported to the active area of the landfill by landfill roads. Disposal of municipal waste is done in stages, and afterward, waste is compacted in layers across the waste cells.

- Proper waste handling and storage are done on the active waste disposal area. Inert waste material is used as a layer to compress municipal waste. At the landfill site, there is always enough landfill cover material for the whole month. At sanitary landfills in the Republic of Serbia, there are passive degasification systems for collecting landfill gas from the landfill body. Daily covering by a layer of inert material on the deposited waste provides protection against wind-blown litter in and around the waste, birds, rodents and insects. The specialized service performs regular rodent pest control at the landfill sites and disinsection in the landfill facilities.

- Landfill firefighting depends on the landfill regulation and characteristics, combustible material at the landfill, ignition source, type of fire, meteorological conditions, the proximity of the fire brigade, firefighters' protection, water supply, access and mobility of heavy firefighting equipment, logistics, etc.

The following methods are used for fire extinction:

- cooling - lowering the temperature of combustible waste and lowering the temperature of self-ignition and flammability of combustible waste that is not caught by fire;
- separating fuel source from the air or oxygen - eliminating the inflow of oxygen and reducing the concentration of oxygen;
- intensive flame deceleration;
- removing the heat (flame) mechanically - as a result of water jetting or soil backfilling;
- fire partitioning, or
- the combination of the above-mentioned.

According to statistical data, the most common methods of extinguishing fires at the landfill are excavation (40%), soil covering (29%), water addition (17%), foam extinguishing (11%) and inert gas injection (3%).

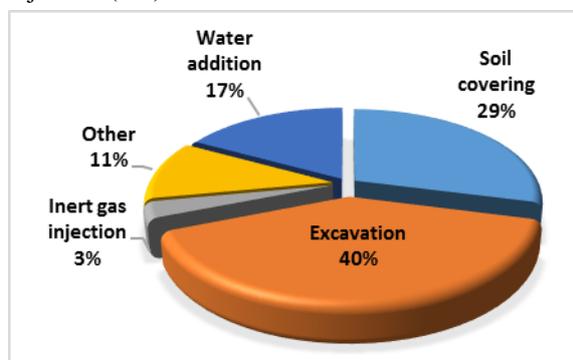


Figure 4. Landfill fire extinguishment methods [9]

- Recovery after a fire - If a fire occurs on the landfill body, it is necessary to properly handle the disposed waste that was affected by the fire and landfill leachate. In order to make a post-fire assessment, it is necessary to assess the damage to buildings caused by a fire within the internal waste reception and dispatch areas at the landfill, to assess the need for rehabilitation of buildings, as well as when and to what extent the damage can be restored and under what conditions a normal work process can be established. It is also necessary to consider how many employees have lost their jobs and whether employees can be engaged in repairing the damage caused by the fire. It is necessary to monitor the post-accident situation and eliminate the possible danger of recurrence of fire or explosion.

CONCLUSION

The Republic of Serbia has the lowest number of sanitary landfills with proper fire protection systems and without negative environmental impacts. Landfill fire outbreaks are initiated by various types of combustible waste, their age and methane as the most common flammable and explosive constituent of landfill gas. The most common cause of landfill fires is the self-ignition of combustible waste. Landfill fires are most prevalent in the summer months (June, July, August). Proper landfill construction, adequate

functioning and development of fire protection plans, waste reception and proper waste management, firefighting interventions and remediation of fire damage are significant steps in preventing the risk of fire and stop fires from spreading.

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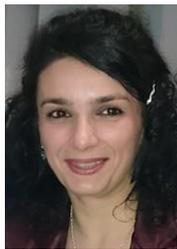
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BIOGRAPHY of the first author

Lidija Milošević was born in Kruševac, Serbia, in 1974. She graduated from the Faculty of Occupational Safety and received a diploma in Fire Protection Engineering and a Master of Technical Sciences degree in the same field from the University of Nis, Faculty of Occupational Safety in Niš. Her main areas of research include fire protection, fire risk, environmental protection, etc. She is currently working as an Assistant Professor at the Faculty of Occupational Safety in Nis, University of Nis.



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Lidija Milošević, Emina Mihajlović, Jelena Malenović Nikolić

Rezime: *Velike količine čvrstog komunalnog otpada koje se odlažu na sanitarnim, nesanitarnim, a ne retko i na divljim deponijama, u čiji sastav ulazi veliki broj zapaljivih materija, predstavljaju visok rizik nastanka požara. Nivo rizika se povećava prisustvom metana koji se oslobađa razlaganjem komunalnog otpada. Broj deponijskih požara varira u zavisnosti od morfološkog sastava otpada, izvora paljenja, meteoroloških uslova, doba godine, kao i mera zaštite od požara. U radu je prikazan uticaj zapaljivih vrsti otpada na deponijske požare, uzroci, učestalost i postupci u sprečavanju i gašenju deponijskih požara.*

Ključne reči: deponijski požari, zapaljivi otpad, metan.