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REVIEW PAPER

MUNICIPAL WASTE AND RELATED HEALTH RISKS*

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Abstract

The problem of environmental pollution caused by municipal waste landfills is discussed on the basis of literature data. The research identified chemical agents released to the environment, the source of which being leachate from municipal waste landfills and the incineration of landfills. In accordance with the hazards identified, possible health risks linked to the exposure to such hazards were described. Waste generation is an inevitable process, and the amount of waste continues to increase. Waste is the source of many harmful factors: physical, chemical and biological ones, whose impact on human health may be observed at every stage of waste management, i.e. from its creation and collection until its final disposal. Harmful agents emitted into the environment throughout a waste management process are a hazard to surface waters and groundwaters alike, and to the atmospheric air. It is important to highlight the sanitary-epidemiological problem of waste collection; being a medium for various organisms, waste fosters the growth and development of rodent and insect populations, as well as encouraging the predation by wild animals and microorganisms. Thus, waste poses a threat to human health. Awareness of the issue as well as the supervision of the process and direct site of every stage of municipal waste collection are incredibly important. It appears that modern findings of environmental healthcare and environmental education should stimulate people to change their approach towards the broad area of environmental actions, as well as the prevention and diagnosis of diseases of environmental etiology.

Keywords: municipal waste, waste management, danger, health, environment.

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INTRODUCTION

Although the development of technology creates a vast array of ways to process municipal waste, its collection is still a common method of its disposal. Municipal solid waste landfills (MSW) are the cheapest and therefore the basic method of disposal, adopted in many countries around the world, including those regarded as highly developed (Mukherjee et al. 2015, Jovanov et al. 2017).

Municipal waste management is a significant issue for global environmental policy. It is so because incorrect waste management may lead to the pollution of the environment, and as a result may have a negative impact of human health (Mukherjee et al. 2015, Samadder et al. 2017).

Regardless of the promotion of reusing products and rational shopping habits, people are unable to cease waste production entirely (Kalinovskaya 2016). Therefore, taking into consideration the reduction of the negative impact that it has on the environment and human health, MSW landfills have become the object of concern for societies around the world (Klauck et al. 2013).

Substances found in waste and generated as a result of its collection can have long-lasting consequences of the environmental and health kind, whilst the degree of their impact may be difficult to determine, as it can occur at various stages of waste management. Harmful agents found in waste might spread through various elements of the environment, ultimately causing the contamination of the environment or the human body (Naveen et al. 2017, Chmielewski et al. 2020).

Despite technological advancements being developed and improvement in legislation and means of organizing waste management, social acceptance remains low for localizing new sites of its collection and disposal. Generally, society is concerned about the problems connected with waste management (Mishra et al. 2018).

MUNICIPAL SOLID WASTE

Municipal solid waste is defined as waste produced in households, excluding vehicles removed from operation, and hazardous waste from other sources which due to their nature or composition are similar to waste produced by households (Law 2012).

MSW shows a variety of physical and chemical properties and typically has multiple negative traits to it, for example qualitative and quantitative temporal volatility; instability related to the tendency to rot exhibited by organic waste fractions; the presence of hazardous waste (Bhalla et al. 2013).

According to data for 2017, in the European Union (EU) countries 75% of the generated municipal waste was processed, of which 30% of the waste was recycled, 17% was processed to compost, 28% was burned and 24% was

stored in landfills. In the same year, there was 487 kg of municipal waste per EU citizen. It is 175 kg above the Polish average (Zalewska 2019).

There are various factors that influence the levels at which recycling is carried out, the key ones being the state of the economy and development of a given country. According to studies, in the majority of developing countries with low or moderate income, 65 to 80% of municipal waste ends up on MSW landfills (Agamuthu 2013).

According to statistical data (GUS 2020), 12 753 thousand tonnes of municipal waste were produced in Poland in 2019, which shows a 2.1% growth relative to 2018. This means an increase in the amount of municipal waste per Polish citizen from 325 kg in 2018 to 332 kg in 2019. Amongst the municipal waste gathered and received in 2019, 7.1 million tonnes were allocated for recovery (56% of the generated municipal waste), within which 3.2 million tonnes were allocated for recycling (25%), 2.7 million tonnes for thermal treatment with recovery of energy (22%), 1.2 million tonnes for biological treatment processes: compost or fermentation (9%). 5.7 million tonnes of municipal waste were allocated for disposal, of which 5.5 million tonnes (43% of generated municipal waste) were allocated for landfill storage, and the remaining 0.2 million tonnes (approximately 1% of generated waste) were disposed through thermal treatment without the recovery of energy. Mixed municipal waste is the primary component of generated waste, with its amount totalling to 8.8 million tonnes in 2019, i.e. almost 69% of all generated municipal waste. Mixed waste is the main stream of waste in need of disposal on landfills. The share of waste managed through landfill disposal is still large. In 2019, it amounted to 43.0% (in 2018 – 41.6%). The number of functioning MSW landfills in Poland by the end of 2019 totalled 278 landfills accepting municipal waste for storage (286 by the end of 2018), taking up a total area of 1 670 ha.

IDENTIFICATION OF ORGANIC AND MINERAL COMPOUNDS IN MUNICIPAL SOLID WASTE LANDFILLS

MSW landfills are a kind of bioreactor in which physical, chemical and biological processes take place, with collected waste decomposing as a result. The organic masses stored within them are broken down as a result of the activity of aerobic and anaerobic microorganisms. The changes taking place at landfills may become a source of the emission of leachate, landfill gas and odors (Bani et al. 2011).

The deposition of waste may be a hazard to the environment because of the generation of landfill leachate (Aromolaran 2019). The current European Union (EU) regulations define leachate as any liquid percolating through the deposited waste and emitted from or contained within a landfill (Directive 1999).

The composition of landfill leachate includes dissolved substances eluted from waste by rainwater, as well as organic and mineral compounds which are the byproducts of fermentation processes. Landfill MSW leachate analy-

sis show changes in the physicochemical composition. Characteristic changes are the result of different ways of managing a landfill, period of waste storage, type of waste stores, degree of precipitation density and the stage of degradation (Banu et al. 2013, Molinari et al. 2014, Ogunseiju et al. 2015, Kamaruddin et al. 2017).

Monitoring the state of leachate pollution originating from municipal waste landfills is obligatory in the EU member states and around the world alike.

According to the binding Regulation of the Polish Minister of Environment (Regulation 2013), it is obligatory to monitor the following indicative parameters on waste landfills: acidity (pH); electrolytic conductivity; total organic carbon (TOC); content of particular heavy metals, including Cu, Zn, Pb, Cd, Cr, Cr^{+6} and Hg; polycyclic aromatic hydrocarbons (PAH).

The general composition of leachates from MSW landfills in Poland was determined on the basis of available results of analyses dealing with indicative parameters (Leszczyński 2011, Wdowczyk, Szymańska-Pulikowska 2018).

Research was carried out with the aim of identifying the products of decomposition of organic pollutants present in raw leachate and throughout the anode electro-oxidation in an MSW landfill located within a 1 km distance of the infrastructure of Baniocha and Łubna villages, which are situated in the municipality Góra Kalwaria, in the Mazowieckie voivodship, approximately 40 km from Warsaw. As a result, 54 compounds were identified. Some of the identified compounds are presented in Table 1 (Dmochowski et al. 2015).

Table 1

Selected compounds identified in raw leachates and after time intervals of electrolysis (Dmochowski et al. 2015)

Identified compound / chemical formula	Electrolysis time (min) Compound concentration (μg l^{-1})						
	0	5	10	15	30	45	60
Dibutyl phthalate ($C_{16}H_{22}O_4$)	348	276	272	219	220	215	197
Toluene (C_7H_8)	275	182	113	96	84		51
Naphthalene ($C_{10}H_8$)	65	51	44	35		19	7.3
Ethylbenzene (C_8H_{10})	39	35	22	18		8.2	
Benzene (C_6H_6)	26	13	18		6.5		
Tetradecane ($C_{14}H_{30}$)	24	9.2	7.4	5.8			
Benzoic acid ($C_7H_6O_2$)	22	10	18	20	12		
Butyric acid ($C_4H_8O_2$)	20	63	34	21	6		
Hexanol ($C_6H_{14}O$)		11	37		79	83	65
Trichloromethane ($CHCl_2$)		0.2	5.8	17	22	40	11
Dodecan ($C_{12}H_{26}$)	48	32	26		9	6.2	
Heptan (C_7H_{16})				5.2	14	23	
Chloroacetone (C_3H_5ClO)			7.3	23	19	6.5	
Chlorobenzene (C_6H_5Cl)					9.5	17	12

Studies show that due to the variety of stored waste, MSW landfills are a source of heavy metal contamination of the environment through their translocation to groundwaters, soil and plants. The concentration of heavy metals in MSW leachate is dependent on the period of operating a landfill. The season of the year has a small effect on changes in concentrations of heavy metals in leachate (Olagunju et al. 2018, Aromolaran 2019, Onyekwelu, Aghamelu 2019).

Other than MSW leachates, another source of environmental pollution and health risks is atmospheric contamination resulting from landfill fires. According to official statistics (Enviroment 2020), 177 fires of MSW landfills were recorded throughout entire Poland in 2019 (averaging to 15 fires a month), which shows a 27% decrease relative to the year prior (243 fires).

Studies (North, Halden 2013, Posnack 2014, Witt et al. 2017, Zubero et al. 2017) show that substances threatening human health spread to the environment as a result of MSW landfill fires. They are a source of significant emissions of atmospheric pollution, including CO, NOx, particles of primary organic aerosols (POA) and volatile organic compounds (VOC), PCDD/PCDF. If there is a fire on a landfill storing plastics, air pollution may occur due to the presence of compounds harmful to human health, e.g. PCB or DEHP. Taking into account the fact that the burning of waste usually takes place at high temperatures, it involves the emission of significant amounts of smoke into the atmosphere, containing a large number of fine particles (PM), including toxic radicals, silicon and aluminium. Regarding heavy metals, after a fire they take up the form of solid residuals, while the open burning of PVC causes the emission of PAH, HCl, $COCl_2$ and Cl.

The total emission of identified heavy metals in Poland for 2016 related to the management of waste (expressed in mg) was as following: As 0.02, Cr 0.14, Zn 10.07, Cd 1.44, Cu 1.44, Ni 0.05, Pb 16.78, Hg 0.53 (Chmielewski et al. 2020*a*).

The emission of pollutants from landfill fires is illustrated in Table 2 (Chmielewski et al. 2020).

HEALTH CONSEQUENCES OF EXPOSURE TO IDENTIFIED POLLUTANTS EMITTED FROM MSW

Research in the field clearly indicates the presence of compounds threatening human health and the atmosphere in MSW landfill leachates. Landfill fires cause contamination with nitrates, heavy metals such as As, Cr, Cr(6) Hg, Zn, Pb, Cd, Cu, PAH or PCDD/PCDF and others. The above is a threat to inhabitants of the area surrounding a landfill as well as to people who work in the area (Lar, Złotkowska 2013, Li et al. 2014, Weichenthal et al. 2015, Han et al. 2016, Mataloni 2016, Kamaruddin et al. 2017, Mishra et al. 2018, Yu et al. 2020, Zeng et al. 2021).

Table 2

Emissions of pollutants from landfill fire, ng m^{-3} (Chmielewski et al. 2020)

Pollutant (compound) Class compound	Controlled MSW landfill fire	Uncontrolled MSW landfill fire
Acenaphthylene	90	60
Acenaphthene	50	30
Fluoranthene	100	50
Phenanthrene	520	30
Anthracene	160	85
Fluorene	120	180
Pyrene	120	170
Benzo[a]anthracene	60	60
Chrysene	80	70
Benzo[a]pyrene	20	15
Indeno[1,2,3-cd]pyrene	10	10
Dibenz[a,h]anthracene	10	10
Benzo[g,h,i]perylene	10	10
Total PAHs (polycyclic aromatic hydrocarbons)	1480	810
Total PCBs polychlorinated biphenyl	15.5	590

On the basis of available data, we are able to demonstrate that being exposed to pollutants emitted to the environment from MSW landfills may have negative consequences to health, depending on their properties as well as the duration and location of the exposure (Mataloni 2016).

The research findings show that the closer a person exposed to pollution lives to a landfill, the greater the risk of adverse health effects and, as a matter of logic, the greater the risk of environmental pollution by compounds generated in the landfill (García-Pérez 2013, Mataloni et al. 2016, Zubero et al. 2017).

The environmental pollution related to MSW landfill operation as well as landfill fires has negative health consequences both in short- and long-run. Examples of short-term effects are congenital anomalies, asthma and other respiratory system diseases, stress, anxiety, headaches, vertigo, nausea and the irritation of respiratory tracts. Long-term effects include chronic illnesses of the respiratory system and the cardiovascular system, kidney diseases, tumors or cancers and illnesses of the lymphatic and hematopoietic system. Studies also show that they have an impact on the reproductive system, as well as fetuses and infants and on the emergence of congenital defects (Gajski et al. 2012, Kah et al. 2012, García-Pérez 2013, Ashworth et al. 2014, Blanes-Vidal et al. 2014, Mukherjee et al. 2015, Kumari et al. 2017, Khalil et al. 2018, Chmielewski et al. 2020*b*,*c*).

The negative health consequences resulting from the duration of exposure to heavy metals, their concentrations and the means of spreading into a human body may lead to their chronic accumulation in the kidneys and the liver, causing the dysfunction of various biochemical processes, which contributes to disorders and diseases of the cardiovascular, skeletal, renal and nervous systems. Proven negative health consequences of heavy metal exposure include: malignancy of the tissues of the lungs, nose, sinuses and respiratory tracts, while the consumption of contaminated water may be linked to mouth cancer, stomach cancer and colorectal cancer; loss of hearing; dysfunction of the liver and kidneys; neurological disorders in the form of peripheral neuropathy, paresthesia, orthostatic hypotension and the disorders of excretion and angioedema; damage of the central nervous system (Zhou et al. 2017, Boroń et al. 2018, Cyran et al. 2019, Ochwanowska et al. 2019, Chmielewski et al. 2020*d*, *e*, *f*).

CONCLUSIONS

Given improper management and lack of appropriate protection, municipal solid waste landfills may pose a threat to the environment and human health. Exposure to identified factors may have negative consequences on health in the short- and long-term perspective. As research has shown, due to potential hazards, it is necessary to monitor MSW landfills in order to increase the safety of local residents and workforce employed in the area.

There is a need for far-reaching customization of the process of diagnosing a person's health condition as far as health consequences of contamination are concerned, accounting for the domestic and occupational conditions of environmental exposure.

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