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Uncontrolled fires of waste landfills (including the illegal ones) as a threat to the environment as well as human and animal health Review for 2017–2022

Niekontrolowane pożary składowisk odpadów (w tym nielegalnych) zagrożeniem dla środowiska oraz zdrowia ludzi i zwierząt, przegląd za lata 2017–2022

The picture of burning warehouses with almost 5,000 tonnes of hazardous waste on 22 July 2023 seems like a tragic finale to the information provided by Regional Environmental Inspector of Lubuskie Province in 2014[1]. It was nine years ago, when it was first established that the company called Avinion sp. z o.o. had begun collecting and storing waste on the site after the decommissioned meat processing factories, on the basis of the relevant permit.

A consequence of the burning landfill sites is the deterioration in recent years of air in Poland, which is considered to be the most polluted in Europe (it is comparable only to air quality in Bulgaria and Romania, countries with a much smaller area and wealth). The concentration values of PM10 and PM2.5 suspended particulate matter and polycyclic aromatic hydrocarbons (PAHs), represented by benzo(a)pyrene, are among the highest in the countries of the European Union.

Air quality and its composition determine living conditions for humans, have an impact on ecosystems, the animal world and plant production. These factors are most responsible for global climate change. The pollutants present in the air cause ailments of the respiratory and

[1] www.zgora.pios.gov.pl (access: 22.11.2022).

circulatory systems in humans and are the cause of many premature deaths. Therefore, the greatest direct impact of air pollution on human health is observed in industrial and urbanised areas.

In Poland, fires of waste have been a scourge for at least 5-6 years, both at legal and illegal landfills. A review of such incidents between 2017 and 2022, involving 780 fires, is presented in this article and data come from the General Headquarters of the State Fire Service (KG PSP – from Polish name Komenda Głównej Państwowej Straży Pożarnej). Illegal landfills are a particular hazard because of the high accumulation of combustible materials, not subject to any control. The article is based particularly on the example of the large fires at the former "Boruta" plant in Zgierz and the landfill site in Trzebinia (Małopolska region of Poland). The authors carried out an analysis of the legal status of waste disposal, storage and the causes of these fires. They also studied the effects of the release of large quantities of harmful substances into the atmosphere, soil and water resulting from the incineration of hazardous waste. A review of the literature, documentation and existing legislation was carried out to establish the characteristics of the risks associated with waste incineration and the ways to prevent them.

Key words: illegal waste landfills, environmental protection, waste disposal, air pollution, landfill fires.

Obraz płonących magazynów z prawie 5 tysiącami ton odpadów niebezpiecznych w dniu 22 lipca 2023 r. wydaje się jako tragiczny finał informacji podanej przez Lubuskiego Wojewódzkiego Inspektora Ochrony Środowiska w roku 2014[2]. To właśnie 9 lat temu po raz pierwszy ustalono, że na tym terenie po zlikwidowanych zakładach mięsnych rozpoczęła działalność na podstawie stosownego zezwolenia firma Avinion sp. z o.o. w zakresie zbierania i składowania odpadów.

Konsekwencją płonących składowisk odpadów jest pogorszenie się w ostatnich latach powietrza w Polsce, które uznaje się za najbardziej zanieczyszczone w Europie (jest porównywalne tylko do tego w Bułgarii i Rumunii, państwach o dużo mniejszej powierzchni i zamożności). Wartości stężenia pyłu zawieszonego PM10 i PM2,5 oraz wielopierścieniowych

[2] Ibidem.

węglowodorów aromatycznych (WWA), reprezentowane przez benzo(a) piren, należą do najwyższych w krajach Unii Europejskiej.

Jakość powietrza i jego skład determinują warunki życia ludzi, wpływają na ekosystemy, świat zwierząt i produkcję roślinną. Czynniki te w największym stopniu są odpowiedzialne za globalne zmiany klimatu. Zawarte w powietrzu zanieczyszczenia powodują u ludzi dolegliwości układów oddechowego i krwionośnego oraz są przyczyną wielu przedwczesnych zgonów. Dlatego największy bezpośredni wpływ zanieczyszczeń powietrza na zdrowie ludzi obserwowany jest w rejonach przemysłowych i zurbanizowanych.

W Polsce od co najmniej 5-6 lat plagą są pożary odpadów, zarówno na legalnych, jak i nielegalnych wysypiskach. W artykule dokonano przeglądu tego typu przypadków w latach 2017-2022, w których wystąpiły 780 pożary, dane Komendy Głównej Państwowej Straży Pożarnej (KG PSP). Nielegalne składowiska są szczególnym zagrożeniem ze względu na dużą kumulację materiałów palnych, nieobjętych jakąkolwiek kontrolą. Artykuł oparto szczególnie na przykładzie wielkich pożarów w byłym zakładzie „Boruta" w Zgierzu i składowisku odpadów w Trzebini (Małopolska). Autorzy przeprowadzili analizę stanu prawnego składowania odpadów i przyczyn tych pożarów. Badali także skutki uwolnienia do atmosfery, gleby i wody dużych ilości szkodliwych substancji powstających w wyniku spalania odpadów niebezpiecznych. Dokonano przeglądu literatury, piśmiennictwa oraz obowiązujących aktów prawnych dla ustalenia charakterystyki zagrożeń związanych ze spalaniem odpadów oraz sposobów ich zapobiegania.

Słowa kluczowe: nielegalne składowiska odpadów, ochrona środowiska, utylizacja odpadów, zanieczyszczenie powietrza, pożary składowisk.

Introduction

The level of air quality and its structure imply conditions for human life, affecting vegetation, ecosystems and the animal world. These determinants are most responsible for global climate change and climate warming. Airborne pollutants resulting mainly from fires at waste disposal sites cause respiratory and circulatory ailments in humans and are the

cause of many premature deaths. Air pollution occurs when gases, dust particles and smoke are released into the atmosphere, with the result that they become harmful to people, infrastructure and the environment. The World Health Organisation (WHO) considers air pollution (including smog) to be the greatest environmental threat to human health in Europe (WHO). The smoke emitted during this type of fire often contains many hazardous chemicals. The following are released into the atmosphere: carbon monoxide, carbon dioxide, nitrous oxide, ammonia, nitrogen oxide, oxides of sulphur, arsenic and its compounds, cadmium and its compounds, dioxins or particulate matter, among others[3].

Table No. 1. Total number of fires at waste collection sites in period 2017-2022

Province	Number of fires	Province	Number of fires
Zachodniopomorskie	38	Łódzkie	105
Pomorskie	42	Dolnośląskie	88
Warmińsko-Mazurskie	33	Opolskie	17
Lubuskie	53	Świętokrzyskie	41
Wielkopolskie	52	Lubelskie	27
Kujawsko-Pomorskie	58	Śląskie	100
Mazowieckie	65	Małopolskie	38
Podlaskie	32	Podkarpackie	20
TOTAL 780			

Source: data from the National Headquarters of the State Fire Service

According to the data of the Central Statistical Office[4] at the end of 2020, 2008 illegal waste disposal sites, so-called uncontrolled waste dumps, with a total area of almost 2 km2, were inventoried in Poland, of which 1111 (55%) were located in rural areas and 897 in urban areas. As part of their activities, the Environmental Inspectorates led to the elimination of almost 10,000 illegal dumps and landfills, from which a total of

[3] K. Cygańczuk, P. Janik, *Bezpieczeństwo środowiskowe a uregulowania prawne w gospodarce odpadami. Environmental safety in the light of waste management regulations,* Przemysł Chemiczny, rocznik 2020, zeszyt nr 7, pp. 971-973.

[4] Act of 14 December 2012 on waste, Journal of Laws of 2013, item 21, Article 3 section 2.

more than 72,000 tonnes of wastes of various assortments were disposed of; the vast majority (79%) of them were located on the outskirts of cities. Based on data obtained from the Provincial Inspectorates for Environmental Protection (WIOŚ – from Polish name Wojewódzki Inspektorat Ochrony Środowiska), landfill fires in the period under review included, in particular, plastic and textile waste, as well as alternative fuels and other medical and hazardous waste. In the review for the years 2017 to 2022, the authors focused particularly on fires that had a significant negative impact on the environment and occurred, among others, on 27 May 2018 in Trzebinia, the location of a massive tyre depot (Małopolskie region) and twice on 25 May and 6 June in Zgierz (Łódzkie), where plastics were stored; detailed analysis is presented below based on reports from accredited certification bodies. Further highlighted were fires on 10 January 2020 near Karczew (Mazowieckie region), where containers with sulphuric acid waste got unsealed and leaked into the soil, and twice on 11 February and 19 April 2020 in Nowiny (Świętokrzyskie region); there was a fire involving chemical waste stored in 1000 litre Mauser-type IBC containers and 200 litre steel drums.

As a result of these fires, volatile organic compounds, polycyclic aromatic compounds, ammonia, styrene, acetone and other harmful substances were released into the atmosphere. In connection with the irregularities found, the controlling body notified the Public Prosecutor's Office on suspicion of committing an offence under Article 183 § 1 and under Article 164 § 1 of the Act of 6 June 1997 of the Penal Code18 (hereinafter: the Penal Code), and applied to the competent authorities to take immediate measures consisting in the removal of waste and its proper disposition. In addition, sewage samples were taken for testing during the inspection. Water from the Bobrza River as well as soil from contaminated ditches were also submitted for analysis.

Municipal waste management vs. environmental protection

The legislator[5] has described municipal waste management as the picking up, transporting, collecting, processing (recovery or disposal) of municipal waste, together with the supervision of such activities, as well

[5] Ibidem.

as subsequent activities in form of waste disposal, neutralisation and activities performed as a waste seller or agent in waste turnover.

Waste management, on the other hand, is a broader concept and includes the generation and management of waste. In addition, waste management should be carried out in such a way as to protect human life and health as well as the environment and should not cause danger to water, air, soil, plants or animals, cause nuisance through noise or odour, or cause adverse effects to the countryside or places of special interest, including cultural and natural sites[6].

The objective of environmental protection, or rather practical conservation measures based on appropriate legal regulation, is to maintain the desired state of natural balance (Environmental Protection Law). This objective undoubtedly coincides with the idea of environmental protection, which is understood as the undertaking or abandonment of measures that make it possible to maintain or restore the natural balance, whereby the protection of one or several natural elements should always be implemented taking into account the other elements (Environmental Protection Law). The handling of municipal waste (municipal waste management) is an important part of environmental protection, which consists in particular in: rational shaping of the environment and management of environmental resources in accordance with the principle of sustainable development[7] counteracting pollution, restoring natural elements to their proper state[8].

The management of municipal waste undoubtedly requires that rational choices are constantly being made regarding how to achieve the intended environmental effect with the least expenditure. This is tantamount to the economic efficiency of a given pro-ecological project. Importantly, just as economic instruments play a decisive role in achieving environmental protection objectives, the use of economic instruments in legal solutions for municipal waste management contributes to increasing environmental benefits. The system of fees and penalties for the use of the environment plays an important role here[9].

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[6] Cz. Rosik-Dulewska, *Podstawy gospodarki odpadami*, Wydawnictwo Naukowe PWN, Warszawa 2023.

[7] M. Rudnicki, *Prawne i ekonomiczne dylematy zrównoważonego rozwoju w dobie ogólnoświatowego kryzysu*, „Przegląd Prawa Ochrony Środowiska" 2009, nr 2, [*Legal and economic dilemmas of sustainable development in a global crisis*, „Environmental Law Review" 2009, no. 2].

[8] J. Boć, E. Samborska-Boć, *Ochrona środowiska. Zagadnienia prawne i ekonomiczne* [*Environmental protection. Legal and economic issues*], Wrocław 1989.

[9] K. Górka, *Ekonomiczne aspekty ochrony środowiska* [*Economic aspects of environmental protection*]. 1988.

The guiding principle is, first and foremost, the prevention of waste production. If the generation of waste cannot be prevented, all measures should be taken to recover the waste. This should primarily consist of: preparing waste for reuse, recycling, using other recovery methods (e.g. by incineration with energy recovery). The least desirable waste treatment should be just a disposal (e.g., by landfilling, storage). The absolute priority of prevention, i.e., waste generation avoidance, remains unchanged. It also remains the rule that waste that has not been put to any use or reuse must be disposed of. There is a greater focus on the use of waste and a preference for preparation for re-use over recycling and possible other type of recovery. In light of the above, the hierarchy of municipal waste management is as follows: waste generation prevention, preparation for reuse, i.e. recovery consisting of checking, cleaning and repairing, whereby products or parts of products that have previously become waste are prepared so that they can be reused without any other pre-processing activity, recycling, other recovery processes (methods), e.g. energy and disposal[10].

This classification serves to indicate priorities in policy and legal regulations for waste generation prevention and management.

Storage of waste

Storage of waste or landfilling is the handling of waste that has not been put to economic use or otherwise disposed of. The process involves depositing them safely in places designated for this purpose[11] (Waste Act).

Storage of waste is considered to be the least effective method of waste disposal and, at the same time, highly burdensome for the environment and human beings[12]. Major problems with this method are the so-called 'wild dumps', i.e., dumping of wastes in places not intended for this purpose and in a manner that does not ensure protection of the environment

[10] K. Cygańczuk, M. Zielecka, A. Rabajczyk, *Zasady bezpiecznej gospodarki odpadami jako czynnik bezpieczeństwa środowiskowego* [*Principles of safe waste management as a factor of environmental safety*], Przemysł Chemiczny, rocznik 2020, zeszyt nr 7, pp. 994-999.

[11] Act of 14 December 2012 on waste Journal of Laws 2019.701.

[12] R.K. Rowe, *Long-term performance of contaminant barrier system*, Géotechnique, 55, 631-678 (2005).

from their harmful effects, resulting in uncontrolled emission of gases into the atmosphere as well as pollution of ground and surface water[13].

Waste landfills can be divided into 3 types of dumps: hazardous waste, inert waste and waste other than hazardous and inert ones. As mentioned, prior to being deposited in a landfill, waste should be subjected to physical, chemical, thermal or biological treatment, including segregation, in order to reduce the risk to human life and health or to the environment and to reduce the quantity or volume of landfilled waste, as well as to facilitate their handling or recover. These provisions do not apply to inert waste and waste, for which the physical, chemical, thermal or biological transformation process, including segregation, will not lead to the achievement of these objectives[14]. Rules for the storage of particular types of wastes in specific types of landfills must be strictly adhered to[15].

In a landfill for waste other than hazardous and inert one, the following may be deposited: municipal waste, wastes other than hazardous and inert ones, and solid hazardous waste or wastes resulting from the transformation of hazardous waste, which meet the criteria for acceptance to be deposited in a landfill for waste other than hazardous and inert ones specified in the regulations issued pursuant to Article 118[16]. On the other hand, only inert waste may be stored in a landfill designated for inert waste[17]. It should also be emphasised that, pursuant to Article 104 of the Waste Act, two prohibitions are laid down for landfills: the storage of waste at a landfill site and the collection or processing of waste at a landfill site in a manner other than the storage of waste. In addition, the administrator of the landfill, before accepting given waste for storage at the landfill, is also obliged to determine the weight of the waste accepted; to check the conformity of the waste accepted with the data contained in the waste transfer note or the documents required for international shipments of waste; and, in the case of metallic mercury waste, to check the containers and certificates required for the storage of this type of waste[18].

[13] M. Wysocka, *Wpływy lokalizacji składowisk odpadów na jakość wód podziemnych* [*Annual Set The Environment Protection*], Year 2015, ISSN 1506-218X.
[14] Act of 14 December 2012 on Waste Journal of Laws 2019.701, op. cit., art. 105.
[15] Ibidem, art. 106.
[16] Ibidem, art. 107.
[17] Ibidem, art. 108.
[18] Ibidem, art. 119.

At the same time, he is obliged to dispose the waste at the landfill site in a selective manner, taking into account the avoidance of environmentally harmful reactions between the components of these wastes, the possibility of their further use, the regeneration and redevelopment of the landfill site.

The location, construction and operation of a landfill site must meet requirements ensuring that the storage of waste is safe for human life and health as well as for the environment, in particular with regard to the requirements preventing the pollution of surface and groundwater[19] soil, ground and air. The running of a landfill site includes all activities undertaken in the operational and post-operational phases concerning the performance of a landfill site, including the monitoring of a landfill site in the pre-operational, operational and post-operational phases, and the results of monitoring should be communicated to the provincial environmental protection inspector by the end of the first quarter of the calendar year following the end of the year to which the results relate. A landfill site shall be operated by the manager of the landfill site[20].

Very important issue with regard to securing a landfill against negative impacts on human health and against impacts on the deterioration of the natural environment is its location. The selection of a site for a landfill requires the collection of data including: local geological and geotechnical conditions, topographic conditions, the layout of existing watercourses and water bodies, the manner in which water bodies are used (taking into account groundwater and surface water intakes as well as specific requirements for the protection of water intakes), climatic conditions, landscape conditions taking into account the location of the landfill in relation to built-up areas, transport links to public roads and the possibilities of connecting to existing infrastructure (water, sewerage, electricity and telephone networks).

In the relevant literature, factors limiting the location of a landfill site include the presence of nearby areas with intensive housing, leisure and recreation areas, specially protected nature areas, airports, flood-prone areas, wetlands (swamps), unstable areas (landslides, with tectonic faults) and seismic zones. The specific requirements concerning the location, construction and operation of a landfill are set out in an ordinance

[19] M. Wysocka, *Wpływy lokalizacji składowisk…* op. cit.
[20] Act of 14 December 2012 on Waste Journal of Laws 2019.701, op. cit., art. 124.

(Ordinance of the Minister of the Environment), which specifies where hazardous waste landfills and landfills for wastes other than hazardous and inert ones may not be located.

Fires on legal and so-called wild landfill sites

Faulty regulations, inadequate control and an insufficient number of waste disposal facilities have led to a series of fires at waste storage sites across Poland. More than 80 such fires were recorded in the first six months of 2018, in which plastics, tyres and electro-waste were often burnt.

The fire at the waste storage site in Trzebinia, which contained tyres, occurred on 27 May 2018, while the landfill site in Zgierz, which contained plastics, among other things, was on fire twice: on 25 May and 6 June 2018. Table No. 2 shows the number of landfill fires in the record-breaking year 2018, which was 243, with the national average for the years 2017 to 2022 being 108 fires.

Table 2. Total number of waste site fires in record-breaking 2018

Province	Number of fires	Province	Number of fires
Zachodniopomorskie	16	Łódzkie	45
Pomorskie	11	Dolnośląskie	29
Warmińsko-Mazurskie	5	Opolskie	7
Lubuskie	17	Świętokrzyskie	8
Wielkopolskie	15	Lubelskie	7
Kujawsko-Pomorskie	14	Śląskie	28
Mazowieckie	20	Małopolskie	5
Podlaskie	8	Podkarpackie	2
TOTAL 243			

Source: data from the National Headquarters of the State Fire Service

The intensification of waste collection site fires occurred in 2018, according to data from the Central Inspectorate for Environmental Protection (GIOŚ – from Polish name Główny Inspektoratu Ochrony Środowiska) leaves no doubt – more and more waste is being brought into Poland from abroad year after year.

In 2015, 154 thousand tonnes of wastes were brought into Poland, a year later it was already 256 thousand tonnes. In 2017, the increasing rate of waste imports did not slow down, and 378 thousand tonnes of waste entered our country. However, an undoubted record was set in 2018, when as much as 434 thousand tonnes of wastes were brought into our country from abroad. The vast majority of municipal waste and often hazardous materials (e.g., medical) came from Germany, the United Kingdom, Italy and Sweden.

Figure 1. Imports of waste in thousand of tonnes, acc. to Central Statistical Office within years 2015-2018

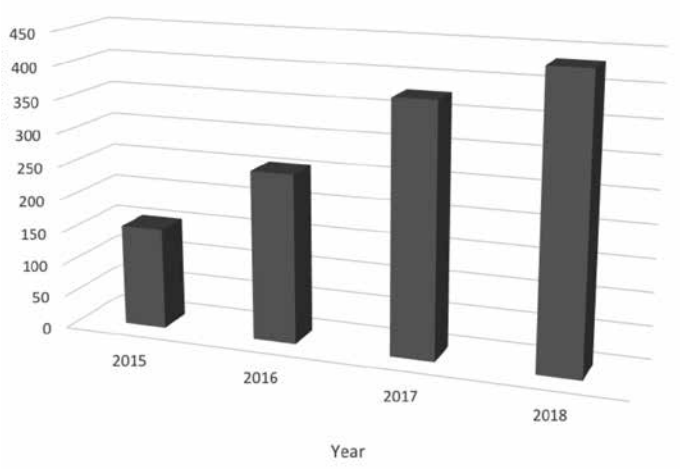
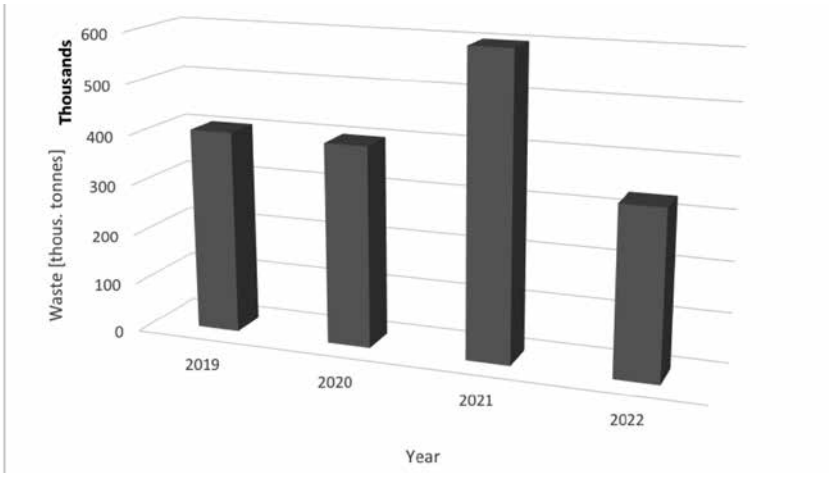


Figure 2. Imports of waste in thousand of tonnes, acc. to Central Statistical Office within years 2019-2022



Why is this happening? The answer is clear, the richer countries of the so-called 'old Europe' are pursuing their 'environmental policy' by exporting municipal and hazardous waste to the countries of the so-called 'new European Union', where the rules of admission to landfill sites were less restrictive and much cheaper. In conclusion, a sustainable waste management policy in Europe does not really exist and unfortunately this has little to do with solidarity-based ecology and environmental protection on our continent.

Such a large volume of waste brought in from other countries, as well as the three-year time limit allowed for storage from the issuing of relevant permit, forces the facility storing the waste to get rid of it, i.e. to dispose of it. Regrettably, there is a shortage of disposal sites in Poland, or the cost of disposal is so high that it is no longer profitable for the waste utilisation plants. Unfortunately, the most cost-effective way of disposing of rubbish and wastes, as it results from the data of the State Fire Service (PSP – from Polish name Państwowa Straż Pożarna), is their self-combustion or setting them on fire. From the PSP data it results that there is an increasing trend of fires with their increased imports into Poland.

Table 3 shows the increasing number of fires each year until 2018, the year of the amendment to the Waste Act of 20 July 2018, effective from 5 September 2018. Additionally, after discussions with experts in this field and in order to strengthen the legal arguments against further abuse, an amendment to the aforementioned law was made and it was signed on 4 July 2019 and entered into force on 6 September 2019. Table 3 shows the increasing number of fires from 2015 to 2018, while a definite yearly decrease in fires (from 2019 to 2022) at landfills is visible after the new Waste Act came into force.

Table 3. Number of waste landfill fires

Year	2015	2016	2017	2018	2019	2020	2021	2022
Number of fires	126	117	132	243	177	111	62	55

Source: data from the National Headquarters of the State Fire Service

Furthermore, as of 6 September 2019, an obligation has been introduced to make information available to the area competent Provincial Inspectorate of Environmental Protection (WIOŚ – from Polish name

Wojewódzki Inspektorat Ochrony Środowiska) to allow access to the video monitoring system from places, where such waste is stored or deposited, as: paper and cardboard, textiles, bulky waste (excluding metal waste), plastics, films, tyres, rubber waste, wood and wood-based waste, multi-material waste, waste from the processing of municipal waste, alternative fuel and waste used for its production.

The responsibility for generated hazardous waste has been extended[21] – this means that it is only when the wastes are transferred to a final recovery or disposal process that the responsibility is passed on to the entity, to which they are transferred.

Very important and seemingly effective way to tackle abuses in this sphere of the economy is to introduce an administrative fine of between PLN 5 000 and PLN 1 000 000 for failing to operate a video waste storage control system or operating it in a manner that does not comply with relevant regulations. Additionally, the inspection by the Chief of the State Fire Service (PSP) and the preparation of a fire operative report for plants, which pose a risk of an industrial accident, have been exempted.

Further changes and amendments to the latest Waste Act of 4 July 2019[22] arose from the need to establish specific requirements for waste storage, in view of the recently increasing phenomenon of illegal waste management, in particular the management of waste in the manner violating waste collection or processing permits. Some of these illegal waste management activities have been associated with the occurrence of fires at waste storage sites.

Fire at the landfill in Zgierz

Faulty regulations, inadequate control and an insufficient number of waste disposal facilities have led to a series of fires at waste storage sites across Poland. In 2018, which was a record-breaking year, 243 such fires were recorded, in which plastics, tyres and electro-waste were most often on fire.

The fire at the waste storage site in Trzebinia, which contained tyres, occurred on 27 May 2018, while the landfill site in Zgierz, which contained

[21] Z. Frankowski, P. Pietrzykowski, *Geological and environmental conditions for low and intermediate level radioactive waste repository in Poland*, Biuletyn Państwowego Instytutu Geologicznego, 2011, 446, pp. 41-48.
[22] Journal of Laws 2019 item 1403 Act of 4 July 2019 on amending the Act on waste and certain other acts.

plastics, among other things, was on fire twice: on 25 May and 6 June 2018.

During the fire in Zgierz, air tests were carried out.

Continuous air monitoring was carried out during the firefighting operation on 26 May 2018 by the chemical rescue team of the Provincial Headquarters of the State Fire Service in Łódź (KW PSP – from Polish name: Komenda Wojewódzka Państwowej Straży Pożarnej). Application of the measuring device was intended to establish the possible danger posed by toxic substances generated during the combustion process. As a result of these measurements, no concentrations of hazardous substances were found in the air (information obtained from KW PSP in Łódź).

In the area of influence of the fire, measurements were also carried out by the Central Centre for Contamination Analysis (an organisational unit of the Polish Armed Forces). Qualitative studies showed the presence of compounds such as toluene, benzene, ethylbenzene, styrene, methyl-styrene, sulphur dioxide and o-xylene, i.e., characteristic substances that are released during the combustion processes of plastics. The study did not include quantitative measurements. In addition, the condition of the air was continuously monitored by means of a measuring station located in Zgierz at 1 Mielczarskiego Street (western part of the city of Zgierz). During the fire in Zgierz, a surface water survey was carried out.

Provincial Inspectorate for Environmental Protection (WIOŚ – from Polish name: Wojewódzki Inspektorat Ochrony Środowiska) conducted surface water surveys during and immediately after the firefighting operation. The above surveys were conducted from 28 May to 04 June 2018 and on 27 June 2018.

Due to the fact that the leachate of contaminated water from the burning areas was flowing by gravity into the Wrząca River located on the territory of Zgierz, which is a tributary of the Sokołówka River, which in turn reaches the Bzura River, the laboratory of the Provincial Inspectorate for Environmental Protection in Łódź (which has an AB 590 accreditation system in place) on 28 May 2018 took water samples from the discharge point of water flowing from the fire area through the rainwater sewer system. After performing laboratory analyses, exceedances of the limits for metals were found in the following samples: Copper 0.121 mg/l Cu, Aluminium 1.1 mg/l Al and Antimony 0.215 mg/l Sb, as well as exceedances of the limits for priority substances, including

particularly high values in relation to the maximum permissible level laid down in the ordinance (Ordinance of the Minister of the Environment) mainly for the following substances: Anthracene 1.955 μg/l, Fluoranthene 1.032 μg/l, Benzo(b)fluoranthene – 0.241 μg/l, Benzo[k]fluoranthene 0.126 μg/l, Benzo(g,h,i)fluoranthene 0.341 μg/l, Petroleum hydrocarbons 0.758 μg/l and Volatile phenols 5.4 μg/l.

During the above-mentioned period, samples were also taken from the Bzura River. Water for testing was taken at four locations, i.e., at the outlet of the rain collector to the Bzura River, above the outlet of the rain collector to the river, below the rain collector in front of the foam dam, and below the outlet of the rain collector behind the foam dam.

Test results for the aforementioned sites indicated exceedances of concentrations for the following substances: anthracene 0.0438 μg/l, fluoranthene 0.0686 μg/l, benzo(b)fluoranthene 0.0348 μg/l, benzo(k) fluoranthene 0.241 μg/l, benzo(g,h,i) fluoranthene 0.0916 μg/l, petroleum hydrocarbons 2.1 μg/l and volatile phenols 0.757 μg/l. The values obtained after comparison clearly indicate poor chemical condition of the surface water on the sample taking date, i.e., 30 May 2018.

Based on the analytical results obtained, it can be concluded that the level of contamination of the Bzura River water was caused by leachate run-off from the fire site. Whereas, the values obtained from sampling on the River Bzura are much lower than for the Wrząca River, due to the dispersion of substances during water flow[23].

In connection with the post-fire extinguishing operation that continued until 03 June 2018, in order to further control the quality of the water, on 30 May 2018 water samples were taken for analysis from the Sokołówka River, which is a transporter of contaminated water from the Wrząca River to the Bzura River. Test results obtained indicated single exceedances of relevant indicators, i.e. benzo(g,h,i)perylene, volatile phenols, barium and antimony. The reduction in the amount of pollutants transported was due to a reduction in the amount of water used for firefighting actions, thus reducing the amount of leachate generated.

Analyses of water samples taken on 4 and 27 June 2018, i.e., after the firefighting operation was completed by the PSP, from all 3 rivers at the aforementioned sites did not indicate any exceedances of the specified

[23] Analysis of environmental effects after the fire at the Zgierz landfill site on the basis of studies carried out by the Central Pollution Analysis Facility and the Provincial Inspectorate for Environmental Protection (WIOŚ) in Łódź.

levels, which was related to the cessation of the use of water to extinguish the smouldering waste. Thus, the formation of leachate flowing by gravity, which could reach the Wrząca River, has been reduced.

Tests after the completion of firefighting operation in Zgierz – July 2018

On 2 July 2018, WIOŚ in Łódź started inspection activities in the area, where the fire took place. Samples were taken at the following locations: water from the manhole of the rain sewer from the waste storage area and a puddle in the waste storage area, burnt wastes, from which a water extract was prepared and analysed.

On the basis of the test reports presented, the following was established: elevated values for heavy metals were found in the soil, but not exceeding the parameters defined for the industrial zone (Ordinance of the Minister of the Environment); the conducted tests of the water extract obtained from the collected waste samples indicated the release of the following substances into the environment: heavy metals, polycyclic aromatic hydrocarbons and volatile phenols.

High values of the following indicators were found in the water samples analysed:

Table 4. Test results of samples taken in aqueous sediments

	Place of sample collection	
Indicator	Rainwater sewer (manhole)	Puddle water, post-fire ground
Volatile phenols	1,8 mg/l	0,558 mg/l
Petroleum hydrocarbons	0,31 mg/l	34 mg/l
Total suspended solids	831 mg/l C	2367 mg/l
TOC – Total organic carbon	115 mg/l	614 mg/l C
Conductivity in 25°C	3395μS/cm	7145μS/cm

In the analysed samples, there was also a high content of oil-derived substances and volatile phenols, which are elements that are part of the structure of the plastics or are compounds released during the processes, to which they have previously been subjected. In the case of the fire in

Zgierz, the plastic wastes were subjected, among other things, to oxidation processes at high temperatures.

Table 5. Results of testing of samples taken at the landfill site

	Puddle water	
Indicator	July 2018	December 2018
molybdenum	0,022 mg/l	0,049 mg/l
antimony	0,153 mg/l	0,387 mg/l
anthracene	0,029 mg/l	0,0339 mg/l
fluoranthene	0,021 mg/l	0,2145 mg/l
naphthalene	<0,003 mg/l	0,0069 mg/l
Benzo(a)pyrene	<0,003 mg/l	0,2166 mg/l
Benzo(b)fluoranthene	<0,003 mg/l	0,1983 mg/l
Benzo(k)fluoranthene	<0,003 mg/l	0,0808 mg/l
Benzo(g,h,i)perylene	<0,003 mg/l	0,1786 mg/l
Indenol(1,2,3-cd)pyrene	<0,003 mg/l	0,1292 mg/l
Dibenzo(a,h)anthracene	<0,003 mg/l	0,0128 mg/l

On 6 December 2018, a re-inspection was carried out and 3 samples were taken of the backwaters deposited in the areas leased by the two companies storing the waste. Based on the aforementioned results, it was found that the quantities of polycyclic aromatic hydrocarbons and naphthalene, which is used in the production of plastics, had significantly increased, among others.

Fire of the landfill in Trzebinia

The authors analysed reports from accredited certification bodies investigating the contaminated area; the report included the following scope of works: making a photomap of the fire area together with sizing of the fire residue piles using unmanned aerial vehicles (UAV), area approx. 3 hectares, carrying out UAV raids over the allotment areas, taking soil samples for testing at the sites designated by the client, selecting the piles of fire debris for waste sampling for testing, taking representative samples of fire debris for leachability testing determination of the following metals in the collected soil samples: arsenic, cadmium, chromium, copper, mercury, molybdenum, nickel, lead, antimony, selenium, zinc; furthermore determination of the following substances in the averaged

soil samples: Polycyclic Aromatic Hydrocarbons (PAHs) and Polychlorobiphenyls (PCBs), preparation of leachability tests for post-fire waste samples taken. Determination of the following heavy metals in waste eluates: arsenic, cadmium, chromium, copper, mercury, molybdenum, nickel, lead, antimony, selenium, zinc; also determination of chlorides, sulphates, PAHs and PCBs.

On 27 May 2018, at around 1.30am, a fire broke out at 57 Słowackiego Street, covering approximately 1 ha of land. The firefighting operation involved 69 fire teams, totalling around 240 firefighters. Fire brigade officers, with the help of heavy equipment, made a cut through about 1 hectare of the area where the fire broke out to separate it from the rest of the landfill site and the nearby forest. A firefighting aircraft and water from the Chechlo reservoir as well as water and foam cannons were used to extinguish the fire. Approximately 70% of the fire area was covered with extinguishing foam. Smouldering heaps of waste were being dug through and dislodged by heavy equipment and re-extinguished by firefighters. The fire was extinguished after 70 hours of very difficult action. The WIOŚ began taking measurements on 27 May at 11.30am, in the residential areas, located closest to the site of the fire: on the site of the local prison, next to the prison, at the rescue base located next to the fire site, next to the hospital in Trzebinia and in the residential area.

Measurements were taken using the Rapid mobile spectrophotometer, which is capable of detecting around 100 gaseous substances. Tests did not reveal the presence of harmful substances. On 28 May, the measurements were repeated, and the tests covered the areas, where the wind had carried the fumes emitted into the environment. These included the area of Pila Koscielecka at Chrzanowska Street and the area of the penal institution. Again, the tests did not indicate the presence of harmful substances. Additionally, the results of measurements of PM10, SO2, CO performed at the air quality monitoring station in Trzebinia did not show any deviations from the applicable standards and limits. WIOŚ did not measure air pollution in the fire zone. The cause of the fire, according to the findings of the Regional Police Headquarters in Kraków, was setting the fire.

The survey in both study areas: i.e., the waste fire area and the allotment gardens, was carried out by photogrammetric method from an unmanned aerial vehicle (UAV). The device used for the survey was a DJI multicopter, model S1000+. A Sony Alfa A7R camera with a Sony

Zeiss Sonnar 35mm lens was mounted on the UAV, whose position was stabilised using a Zenmuse gimbal. The field works included: acquiring photographs for the entire study area using an unmanned aerial vehicle and measuring photo-points using classic surveying methods.

Seven soil samples were taken from the landfill site: W1, W2, W3, W4, W5, W6, W7, in the near-surface layer. Therefore, the samples taken are not pure soil or ground samples. The material taken was a mixture of native soil, topsoil (for surface hardening), waste incineration ash and the waste itself.

The table shows the content of metals in the soil samples taken from the allotment gardens. The red colour, as it results from relevant ordinance[24], indicates exceedances of limit values.

Table 6. Metal content in averaged soil samples from community allotments gardens

Determined metals	Metal content in samples [mg/kg]			Admissible values for group II-1 (allotments)	Admissible values for group I (recreational areas)
	D1 allotments	D2 allotments	D3 Playground		
As	5,48	23,40	6,53	10	25
Pb	258,27	407,97	311,70	100	200
Cu	39,66	105,42	38,70	100	200
Ni	5,45	11,43	5,99	100	150
Cd	6,32	15,62	5,81	2	2
Cr	11,39	13,64	10,71	150	200
Co	< 5	< 5	< 5	20	50
Zn	885,38	1702,99	611,26	300	500
Sn	< 10	< 10	< 10	10	20
Mo	0,79	0,85	0,58	10	50
Hg	0,107	0,213	0,07	2	5

For zinc, lead and cadmium, significant exceedances of the limit values were found in all soil samples taken. For copper, a slight exceedance of the limit value was found only in sample D2.

[24] Ordinance of the Minister of the Environment dated 21 July 2016 on the manner of qualifying the status of surface water bodies and environmental quality standards for priority substances (Journal of Laws of 2016, item 1187).

Table 7. Content of polycyclic aromatic hydrocarbons (PAHs) in averaged soil samples from allotment gardens

Name of substance tested	Substance content in samples [mg/kg]			Admissible values for group II-1	Admissible values for group I
	D1	D2	D3		
Naphthalene	<0,005	<0,005	<0,005	0,1	0,1
Anthracene	0,039	0,031	0,087	0,2	0,2
Chrysene	0,201	0,203	0,448	0,2	0,2
Benzo(a) anthracene	0,144	0,142	0,359	0,1	0,1
Dibenzo(a,h) anthracene	0,037	0,033	0,075	0,1	0,1
Benzo(a)pyrene	0,185	0,169	0,360	0,1	0,1
Benzo(b) fluoranthene	0,212	0,203	0,415	0,1	0,1
Benzo(k) fluoranthene	0,195	0,185	0,399	0,1	0,1
Benzo(g,h,i) perylene	0,142	0,129	0,261	0,2	0,2
Indenol(1,2,3-c,d) pyrene	0,144	0,132	0,251	0,2	0,2
Total PAHs detected	1,3	1,23	2,66		

Exceedances of the limit values for some PAH compounds were found in all soil samples. Whereas significantly higher concentrations of PAHs are found in samples taken from the playground. PAH compounds[25] are subject to degradation under the influence of soil microorganisms (this is one of the methods used to remediate lands contaminated with petroleum compounds). Hence, it can be assumed that in areas used for horticulture, the rate of decomposition of PAH compounds is much faster than in uncultivated areas, due to the richness of microbial life in the cultivated soils.

The source of PAHs in soils in the allotment gardens and playground areas can also not be clearly identified. Indeed, the origin of polycyclic aromatic hydrocarbons in soils can be traced back to the production activities of the Trzebinia Refinery, the recent fire at the landfill site at 57 Słowackiego Street, so-called 'low emissions' coming from the

[25] T. Ciesielczuk, C. Rosik-Dulewska, U. Karwowska, *Migracja WWA z nieuszczelnionego składowiska odpadów do wód podziemnych*, Rocznik Ochrona Środowiska (Annual Set the Environment Protection), 9, 335-342 (2007).

combustion of fossil fuels (mainly coal) for the heating of single-family homes in winter.

Soil samples taken at the landfill were dried to air-dry condition and classified according to the regulation 16) in group IV (industrial sites). The content of metals was determined using a Hitachi Z-2000 atomic absorption spectrometer.

Table 8. Metal content in soil samples from the landfill

Determined metals	Metal content in samples [mg/kg]							Admis-sible values for group IV
	W1	W2	W3	W4	W5	W6	W7	
As	302,8	5,25	280,16	11,20	28,80	15,19	24,53	100
Pb	1736,2	207,38	9086,69	584,00	561,51	235,10	31,17	600
Cu	404,0	311,03	845,20	111,59	186,12	354,94	149,24	600
Ni	26,26	24,39	28,02	42,82	66,14	29,84	58,62	500
Cd	35,69	5,21	29,44	3,66	5,77	5,21	0,70	15
Cr	106,31	122,14	52,94	375,80	326,95	70,58	610,77	1000
Co	10,83	< 5	11,16	< 5	21,08	22,54	8,44	200
Zn	8317,76	759,52	9177,63	1788,51	4379,0	6244,46	216,48	2000
Sn	< 10	< 10	< 10	50,15	< 10	< 10	< 10	350
Mo	2,33	5,76	2,67	8,39	3,47	4,86	2,83	250

Similarly to the soil samples taken from the allotment garden site, the soil samples taken from the landfill site showed exceedances of the limit values for Zn, Pb, Cd and additionally As. Exceedances of values for the listed metals were found only in some samples. Values in individual samples show great variation. It should again be noted that samples were taken from the near-surface layer, i.e., the mixed non-homogeneous material: soil, incineration ash and the waste itself in the form of small particles. As exceedances were found for the same metals as for the allotment gardens, other sources of origin of these metals should be borne in mind, namely previous industrial activity in this area in the form of a foundry on the site of the current landfill as well as a metallurgical plant nearby[26].

Fires always generate air pollution, which poses a health risk to people breathing in what the wind carries for some time after the fire has been extinguished. However, the harmful effects of burning waste do not end

[26] H. Brandl, *Mineral liners for hazardous containment*, Géotechnique 42, 57-65 (1992).

there. The high level of contamination found in samples from the Trzebinia and Zgierz fire sites suggests that the harmful substances, together with smoke and soot, may have leaked into the soil and water, and then found their way into the food produced on nearby agricultural land and been ingested by people.

Waste management in the EU

The EU produces 2.2 billion tonnes of waste each year. More than a quarter (27%) is municipal waste, i.e., everyday waste collected and processed by municipalities; this is the waste mainly generated by households. The amount of waste and how it is managed varies considerably between individual EU countries, but there has been a change towards more recycling and less landfilling. To reduce waste and its impact on the environment, the EU has adopted ambitious recycling and landfill targets and is working on legislation for waste coming from packaging materials. The aim is to support the transition to a more sustainable model, i.e., a closed circle economy.

From 2017 to 2022, the average amount of municipal waste per capita in the EU has increased, but there are different trends in individual Member Countries. For example, while most EU countries recorded an increase, decreases occurred in Malta, Cyprus, Spain and Romania. In absolute values per capita, most municipal waste is produced in Austria, Luxembourg, Denmark and Belgium, and least in Spain, Latvia, Croatia and Sweden. Richer countries tend to produce more waste per capita. Countries in the EU approach waste management differently.

The EU wants to promote and support the prevention of waste generation and the re-use of products as much as possible. If this is not possible, recycling (including composting) is preferred, followed by use of the waste for energy production. The most damaging option for the environment and human health is waste disposal, for example in landfills, although this is also one of the cheapest options.

Although the amount of waste generated per capita has increased, the way we manage it has improved – recycling and composting have increased and disposal on landfills has decrease. According to the 2021 statistics, 49.6% of all municipal waste in the EU is recycled or composted. This is an increase of 3.6 percentage points compared to 2017.

The EU has set a target of 60% reuse and recycling of municipal waste by the year 2030. Germany, Bulgaria, Austria and Slovenia have already achieved or exceeded this target.

Waste storage is practically non-existent in countries such as Belgium, the Netherlands, Denmark, Sweden, Germany, Austria, Luxembourg, Slovenia and Finland, where incineration plays a major role alongside the recycling. Lithuania, Latvia, Ireland, Italy, France, the Czech Republic, Slovakia and Poland also use incineration and send one-third (or less) of their waste to landfill sites.

Since 2017, there has been an evolution of waste landfilling in EU countries. The share of landfills in the EU has decreased from 24% in 2017 to 18% in 2020. According to the EU Landfill Directive, by the year 2035, EU countries must reduce the amount of municipal waste sent to landfill sites to 10% or less of the total municipal waste generated.

In November 2022, The European Commission presented a draft of new EU legislation regarding the packaging. It includes proposals to improve packaging design, such as clear labelling, to promote reuse and recycling. It also calls for a shift to biobased, biodegradable and compostable plastics[27].

Conclusions

In 2018, 12.5 million tonnes of municipal wastes were collected (an increase by 4.3% compared to 2017). There was an average of 325 kg of municipal waste collected per capita, which is an increase of 13 kg compared to the previous year. 10.4 million tonnes of waste were collected from households, which accounted for 83.7% of all municipal waste generated[28].

Table 9. Municipal waste collected selectively and as mixed waste

Description	2017	**2018**	2017=100
	In thousands of tonnes		
In total	11 968,7	**12 485,4**	104,3
Waste picked up or collected selectively	3 239,4	**3 608**	111,4
Waste picked up or collected as mixed	8 729,3	**8 877,5**	101,7

[27] www.europarl.europa.eu [access: 12.11.2022].
[28] Central Statistical Office – Department of Spatial and Environmental Research.

In 2018, there were 2144 selective municipal waste collection points in operation and 1410 municipal waste collection companies. The municipal waste collected in 2018 was subjected to the following processes:

- recovery – 7 103,1 thousand tonnes (56,9%), including:
- recycling – 3 269,1 thousand tonnes (26,2%),
- biological treatment processes (composting or fermentation) – 1 012 thousand tonnes (8,1%),
- thermal treatment with energy recovery – 2 822,1 thousand tonnes (22,6%),
- neutralization – 5 382,3 thousand tonnes (43,1%), of which:
- by thermal treatment without energy recovery – 191,2 thousand tonnes (1,5%),
- by storage – 5 191,1 thousand tonnes (41,6%).

At the end of 2018, 286 landfills accepting municipal waste were in operation, covering a total area of 1,700 hectares. More than 90% of these were equipped with de-gasification facilities, resulting in the recovery of around 84800 thousand MJ of heat energy and around 105357 thousand kWh of electricity by burning the captured gas. In 2018, 16 landfills with a total area of approximately 46.8 hectares were closed. In 2018, in Poland, 10541 illegal waste dumpsites were liquidated, from which a total of approximately 25 thousand tonnes of municipal wastes were collected. At the end of 2018, the existence of 1607 illegal waste dumpsites were recorded[29].

In 2022, an average Pole generated 355 kg of municipal waste. This is 5 kg less than the year before. 26.7 per cent of waste was sent for recycling, which was the same as in 2020 and 2021. The Central Statistical Office has presented information on environmental protection in Poland. From the reported data it appears that 13.4 million tonnes of municipal waste were collected in 2022 (1.9 per cent less than in 2021).

This means that there was an average of 355 kg of municipal waste collected per capita, which is a decrease of 5 kg compared to the previous year. 11.6 million tonnes of wastes were collected from households, which represented 86.3 per cent of all municipal waste generated.

The data shows that there were 2,301 selective municipal waste collection points in operation last year (in 2021 – 2,279). Municipal waste collection services were provided by 1,325 companies (in 2021 – 1,318).

[29] Ibidem.

The municipal waste collected in 2022 was subjected to the following processes:

- 61.1 per cent (8 199.1 thousand tonnes) of collected municipal waste was sent to recovery processes,
- of which: for recycling 3 585.4 thousand tonnes (26.7 per cent),
- for composting or fermentation – 1 899.5 thousand tonnes (14,2%),
- for thermal processing with energy recovery – 2 714.1 thousand tonnes (20.2 per cent),
- 5 108.2 thousand tonnes (38.1 per cent) of wastes were sent to landfills.

CSO data shows that at the end of 2022, there were 259 landfills accepting municipal waste in operation, covering a total area of 1 624 hectares. 92 per cent of these were equipped with de-gasification facilities, resulting in the recovery of approximately 111,162 thousand MJ of heat energy and approximately 102,487 thousand kWh of electricity by burning the captured gas. In 2022, 11 landfills with a total area of approximately 45.3 hectares were closed. In 2022, 10,714 wild waste dumps were also liquidated, from which a total of approximately 25,000 tonnes of municipal wastes were collected. At the end of 2022, the existence of 2,217 illegal dumpsites was recorded[30].

Municipal waste management is a public task, the implementation of which the legislator assigns primarily to the municipality as the basic unit of local self-government. The municipality's activity in the study area takes the form of both economic and administrative activities. It should be emphasised that the way in which municipal waste is managed depends on the powers and responsibilities of the participants in the municipal waste management system. These are: property owners, entities collecting municipal waste, and also the municipality. The delegation of municipal waste management tasks by the state to the municipality is associated with the granting of "administrative authority" to the municipality.

In the authors' opinion, local governments should put more emphasis on information campaigns, organising conferences, seminars and exchanging experience, acquiring good practices from other cities as well as European countries in the field of waste management. We currently have 9 waste incineration plants in Poland, located in Warsaw, Bialystok, Bydgoszcz, Konin, Krakow, Poznan, Rzeszow, Szczecin and Olsztyn,

[30] Ibidem.

which have the capacity to treat/incinerate 1.6 million tonnes of waste per year. Thinking ahead and taking into account market demand, the authors believe that 4-5 times as many incineration plants need to be built in Poland in order to comply with EU regulations. The provincial waste management plans include the construction of a further 34 such facilities, although the dates for their completion are not specified. However, the EU authorities are not in favour of them and they are currently considering, whether to subject waste incinerators to charges for carbon (CO_2) emissions. They are to prepare a study by 2026 on the basis of which a decision will be taken on the matter[31].

The main hazards caused by poolfire are temperature rise, thermal radiation and toxic gaseous products emitted in the form of smoke[32]. An important element in preventing fires at waste collection sites and reducing the threat of the occurrence of such events is appropriate cooperation between the relevant public administration units responsible for inspections of entities using the environment (WIOŚ), inspections of compliance with environmental regulations (district and marshal offices) and in recognising fire hazards (PSP units), manifested primarily in the exchange of information on irregularities in the functioning of such sites and on the hazards posed by them (NIK – Polish Supreme Chamber of Control)[33].

Very important element in the supervision of waste collection sites is the control of environmental authorities already at the stage of issuing decisions on the management of particular types of waste. The sluggishness of the authorities and the unreliable implementation of the tasks assigned to them contribute to the emergence of pathologies in the waste market (including the development of the so-called grey market), which can have negative consequences for human life and health, the environment, but also for the economy (media reports www.prawo.pl).

[31] www.portalsamorzadowy.pl [access: 6.01.2023].
[32] R. Cherbański, L. Rudniak, P. Machniewski, E. Molga, J. Tępiński, W. Klapsa, P. Lesiak, *Ethanol pool fire on a one-meter test tray – validation of CFD results, Chemical and Process Engineering*, 2022, 43(1).
[33] J. Tępiński, W. Klapsa, K. Cygańczuk, P. Lesiak, M. Lewak, *Testing of Large Scale Pool Fire of Technical Ethanol*, Safety & Fire Technology, 2022, 59(1).

References

Analysis of environmental effects after the fire at the Zgierz landfill site on the basis of studies carried out by the Central Pollution Analysis Facility and the Provincial Inspectorate for Environmental Protection (WIOŚ) in Łódź.

Boć J., Samborska-Boć E., *Ochrona środowiska. Zagadnienia prawne i ekonomiczne* [*Environmental protection. Legal and economic issues*], Wrocław 1989.

Brandl H.: Mineral liners for hazardous containment. Géotechnique. 42, 57-65 (1992)

Central Statistical Office – Department of Spatial and Environmental Research – Dariusz Bochenek. Tel: 22 608 35 62 e-mail: D.Bochenek@stat.gov.pl.

Cherbański R., Rudniak L., Machniewski P., Molga E., Tępiński J., Klapsa W., Lesiak P., Ethanol pool fire on a one-meter test tray – validation of CFD results, Chemical and Process Engineering, 2022, 43(1), DOI: 10.24425/cpe.2022.140809

Ciesielczuk T., Rosik-Dulewska Cz., Karwowska U., *Migracja WWA z nieuszczelnionego składowiska odpadów do wód podziemnych*, Rocznik Ochrona Środowiska (Annual Set the Environment Protection), 9, 335–342 (2007)

Cygańczuk K., Janik P., *Bezpieczeństwo środowiskowe a uregulowania prawne w gospodarce odpadami* [Environmental safety in the light of waste management regulations], Przemysł Chemiczny, rocznik 2020, zeszyt nr 7, nr katalogowy: 127044. DOI. 10.15199/62.2020.7.1

Cygańczuk. K., Zielecka. M. Rabajczyk. A., *Zasady bezpiecznej gospodarki odpadami jako czynnik bezpieczeństwa środowiskowego* [*Principles of safe waste management as a factor of environmental safety*], Przemysł Chemiczny, rocznik 2020, zeszyt nr 7, Nr katalogowy: 127050. DOI. 10.15199/62.2020.7.5

Frankowski Z., Pietrzykowski P., *Geological and environmental conditions for low and intermediate level radioactive waste repository in Poland*, Biuletyn Państwowego Instytutu Geologicznego, 446: 41-48, 2011 r.

Górka. K., *Ekonomiczne aspekty ochrony środowiska* [*Economic aspects of environmental protection*], 1988.

Janik. P., Cygańczuk. K, *Systemy pomiarowe wykorzystywane w bezzałogowych statkach powietrznych do badania jakości powietrza* [*Measuring systems used in unmanned aerial vehicles for studying air quality*], Przemysł Chemiczny, rocznik 2020, zeszyt nr 7, DOI. 10.15199/62.2020.7.2

NIK, *Zapobieganie pożarom miejsc gromadzenia odpadów* [*Fire prevention for waste collection sites*]. LKI.430.4.2022 Nr ewid. 154/2022/P/22/061/LKI

Rosik-Dulewska. Cz. *Podstawy gospodarki odpadami*. Wydawnictwo naukowe PWN. Warszawa 2023.

Rowe R. K.: Long-term performance of contaminant barrier system. Géotechnique. 55, 631–678 (2005).

Rudnicki. M., *Prawne i ekonomiczne dylematy zrównoważonego rozwoju w dobie ogólnoświatowego kryzysu*, „Przegląd Prawa Ochrony Środowiska" 2009, nr 2, [*Legal and economic dilemmas of sustainable development in a global crisis*], "Environmental Law Review" 2009, no. 2.

Tępiński J., Klapsa W., Cygańczuk K., Lesiak P., Lewak M., *Testing of Large Scale Pool Fire of Technical Ethanol*, Safety & Fire Technology, 2022, 59(1), DOI: 10.12845/sft.59.1.2022.5.

The Headquarters of the State Fire Service.

WHO, „Ambient Air Pollution: A global assessment of exposure and burden of disease", 2016 , p. 15 and EEA „Air quality in Europe – 2017 report" – report from 2017), 2017, p. 12.

Wysocka. M. *Wpływy lokalizacji składowisk odpadów na jakość wód podziemnych*. Annual Set The Environment Protection. Year 2015, ISSN 1506-218X.

Normative acts:

Act of 14 December 2012 on waste, Journal of Laws of 2013, item 21, Article 3 section 2.

Act of 14 December 2012 on waste, Journal of Laws of 2013, item 21, Article 3 section 3.

Act of 27 April 2001. Environmental Protection Law, Journal of Laws of 2001 No. 62 item 627, art. 3 item 13.

Act of 14 December 2012 on waste Journal of Laws 2019.701.

Article 3 section 1 item 19 of the Waste Act.

Journal of Laws 2019 item 1403 Act of 4 July 2019 on amending the Act on waste and certain other acts.

Ordinance of the Minister of Economy dated 16 January 2015 on types of waste.

Ordinance of the Minister of the Environment dated 30 April 2013 on landfills Journal of Laws of 2013, item 523.

Ordinance of the Minister of the Environment dated 21 July 2016 on the manner of qualifying the status of surface water bodies and environmental quality standards for priority substances (Journal of Laws of 2016, item 1187).

Ordinance of the Minister of the Environment dated 1 September 2016 on the manner of conducting an assessment of pollution of the earth's surface (Journal of Laws of 2016, item 1395).

Webography:

http.//www.zgora.pios.gov.pl/niebezpieczne-odpady-w-przylepie/ [access on 22.11.2022].

https://www.europarl.europa.eu/news/pl/headlines/society/20180328STO00751/zarzadzanie-odpadami-w-ue-fakty-i-liczby.

https://www.portalsamorzadowy.pl [access on 6.01.2023].

Based on press release https://www.prawo.pl/samorzad/samorzady-oskarzane-o-wspieranie-patologii-w-gospodarce-odpadami,388.html [access on 12.11.2022].