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Assessment of the Impact of a Municipal Landfill on Microbiological Quality of Air in the Revitalized Area of "Brzeszcze Wschód" Hard Coal Mine

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ABSTRACT

Each improperly located and/or operated landfill affects the environment, polluting soil, surface, groundwater, atmospheric air and, as a consequence of pollution transport, also remote agricultural, urban and recreational areas. In addition, factors affecting the environmental impact of landfills include storage technology, preparation of areas for landfill, sealing of the landfill and technical infrastructure. Over time, landfills can become active sources of emissions of these microorganisms, spreading them over many kilometers. The aim of the conducted research was to estimate, based on results of microbiological tests, the impact of the municipal landfill on the revitalized area of the inactive "Brzeszcze Wschód" Hard Coal Mine. The results of research by domestic and foreign authors indicate that the atmospheric environment in the vicinity of municipal landfills is characterized by the occurrence of different concentrations of bacterial aerosol. This is related to the size of the landfill area, its nature and the topography of the site.

Keywords: bioaerosol, municipal landfill, revitalization.

INTRODUCTION

The increase in the standard of living of modern society and the overproduction of material goods are conducive to the generation of increasing amounts of municipal waste. The dominant method of waste management in Poland is its disposal to landfills, which may entail environmental consequences. Each improperly located and/or operated landfill affects the environment, polluting soil, surface, groundwater, atmospheric air and, as a consequence of pollution transport, also remote agricultural, urban and recreational areas [Barabasz et al., 2007, Błachno, 2009; Binkiewicz, 2007]. The degree of nuisance of these facilities depends on many factors including terrain, ground and hydrological conditions and local microclimate. In addition, factors affecting the environmental impact of landfills include storage technology, preparation of areas for landfill, sealing of the landfill and technical infrastructure [Berleć et al., 2009; Hawrot-Paw and Domżał, 2016; Traczewska and Karpińska-Smulikowska, 2000]. Organic matter contained in deposited materials is decomposed by a complex and highly dynamic microflora containing gram-positive and gram-negative bacteria and fungi [Wery, 2014]. Over time, landfills can become active sources of emissions of these microorganisms, spreading them over many kilometers [Cyprowski et al., 2019; Frączek et al., 2014; Kaźmierczuk and Bojanowicz-Bablok, 2014; Breza-Boruta, 2016]. Airborne biological agents occur in the form of bioaerosols – colloidal systems consisting of air as the dispersing phase and organic matter as the dispersed phase (both vegetative and persistent forms of bacteria, viruses, fungi and their spores, protozoa, fragments of plant and animal cells and fragments of mycelium). Bioaerosols are suspensions that contain not only microorganisms but also products of their metabolism in the form of mycotoxins, enterotoxins, endotoxins and enzymes. Biological aerosols are diverse in droplet size, composition and biological properties and they represent an important route for the transmission of infectious and sensitizing agents [Whitby et al., 2022; Ebisz et al., 2016]. Some of these airborne organisms include pathogens that can have a negative effect on human life, causing acute adverse reactions, various diseases and carcinogenic disorders, among others [Walser et al., 2015; Madhwal et al., 2020; Fröhlich-Nowoisky et al., 2016; Ki-Hyun Kim et al., 2018; Nair A.T., 2021; van Leuken et al., 2016; Breza-Boruta, 2012]. Landfills can also promote antibiotic resistance in bacterial bioaerosol (A.R.B) due to inadequate disposal of pharmaceutical waste. This problem may necessitate the use of last-generation antibiotics and entail additional deaths and costs in the healthcare system [Zhishu Liang et al., 2023; Gamero et al., 2021; Anand et al., 2021]. Small particles of bioaerosol have a long residence time in the atmosphere and can be carried over very long distances by wind. During this time, some pathogens can be inactivated in the air (for example by temperature, humidity or UV radiation) but, despite such environmental stress, many microorganisms remain metabolically active, develop and maintain the ability to reproduce, because they have specific protective mechanisms [van Leuken et al., 2016; Michałkiewicz, 2018]. According to WHO, landfills of municipal solid waste are the third largest anthropogenic source of bioaerosols and are suspected of being one of the main factors contributing to the deterioration of health [Zhang et al., 2023]. The amount of microorganisms in the air is significantly influenced by the height of the landfill above the ground surface, topography of the terrain, type of undergrowth, frequency of precipitation, infrastructure and urbanization, as well as the intensity and angle of incidence of sunlight [Hawrot-Paw and Domżał, 2016]. Technical treatments carried out at landfills also have a significant impact on the amount and spread of bioaerosol. All works related to emptying waste delivery cars, scraping, leveling, tamping or closing quarters cause the rise of microorganisms and fungal spores, especially if the landfill is elevated above ground level and is not tightly girded with dense greenery [Traczewska and Karpińska-Smulikowska, 2000]. Therefore, taking into account public safety, there is an unquestionable need to monitor the level of air pollution with both bacterial cells and their components [Chmiel et al., 2015]. The aim of the research was to estimate, based on results of microbiological tests, the impact of the municipal landfill on the revitalized area of the inactive Hard Coal Mine in Brzeszcze.

MATERIAL AND METHODS

Air sampling points

The sampling points were located in the area undergoing revitalization, affected by the municipal landfill (Fig. 1). The choice of the location of the measuring points was dictated by the shape and thickness of the tree stand in the area – the area on the west and south-west sides was covered with a dense forest naturally stopping the spread of bioaerosol.

Research methodology

Indicators specific to bioaerosol emitted from municipal solid landfills are not strictly defined, which makes it difficult to link microbial contamination to specific waste management activities carried out on site. However, based on the methodology proposed by Kaźmierczuk, the group of indicator organisms includes bacteria from the *Enterobacteriaceae* family, staphylococci and microscopic fungi. The reason for choosing these microorganisms as indicators was that they were often isolated from air samples taken at and around municipal landfills, and were not observed in atmospheric air samples [Kaźmierczuk and Bojanowicz-Bablok, 2014].

Air samples were taken from July 30 to November 16, 2021, using the impact method and the MAS100NT sampler from MBV AG (supplied by Merck), each time aspirating a strictly defined volume of air onto the agar medium placed in a Petri dish. The principle of this method is to pass air through the holes of the sampler and give this air a speed sufficient to separate impurities when hitting the surface of the microbial medium. The following numbers of microorganisms were determined in the study: the number of psychrophilic bacteria on nutrient agar (Merck Millipore TSA ICR Agar) after 48-72 hours of incubation at 22°C, the total number of mesophilic bacteria on nutrient agar (Merck Millipore TSA ICR Agar) after 48 hours of incubation at 36°C, the number of *Citrobacter freundii* bacteria using MacConkey medium as a pre-differentiating medium (MacConkey Agar – LI Merck Millipore) after 18 to 72 hours of incubation at 36°C, the number of

Fig. 1. Location of the sampling point in the area of the former coal mine undergoing revitalization

actinomycetes on Pochona medium (Grasbiotech) after 3 to 6 days of incubation at 28 °C, *Pseudomonas fluorescens* and *Pseudomonas aeruginosa* on King B medium (Grasbiotech) after 24 to 48 hours of incubation at 30°C and on Agar P agar medium for *Pseudomonas* – LI Merck Millipore after 24 to 48 hours of incubation at 37 °C, the number of *Enterobacter aerogenes* / *cloacae* on Slanetz-Bartley medium (BTL) after 24 to 48 hours of incubation at 37°C, the number of *staphylococci mannitolo* (+) and *mannitolo* (–) in Chapman medium (Agar with mannitol and salt – LI Merck Millipore) after 18 to 72 hours of incubation at 37°C, the number of mould and yeast-like fungi on Sabouraud medium (Saboraud Agar with dextrose – Merck Millipore ICR) after 7 days of incubation at 30 °C. In addition, the number of *Escherichia coli* bacteria on Endo medium was also determined after 48-hour incubation at 37 °C. The concentration of microorganisms detected in the test air was expressed as the number of colony forming units (cfu) per 1 m^3 of aspirated air. The assessment of the degree of air pollution was made on the basis of the PN-89/Z-04111/02 and PN-89-04111/03 standards. The range of values determining the degree of air contamination by individual microorganisms is shown in Tables 1 and 2.

RESULTS

The atmospheric conditions at sampling are shown in Table 3. Slight winds with a minimum impact on the spread of bioaerosols blew at all sampling times. The results of the microbiological analyses are presented in Table 4. The research has shown that the numbers of all the studied groups of microorganisms were affected

Table 1. Assessment of quality of the tested air according to PN-Z-04111/02

Degree of air pollution	Total number of mesophilic bacteria [cfu/m³]	Number of actinomycetes [cfu/m³]	Number of Pseudomonas fluorescens [cfu/m³]	Number of staphylococci [cfu/m³]	
				Mannitolo(+) [cfu/m³]	Mannitolo(-) cfu/m³]
Unpolluted	<1000	<10	lack	lack	lack
Medium polluted	1000-3000	10-100	up to 50	up to 25	up to 50
Highly polluted	>3000	>100	>50	>25	>50

Table 2. Assessment of quality of the tested air according to PN-Z-04111/03

Degree of air pollution	Number of microorganisms [cfu/m³]
On average, clean atmospheric air, especially in late spring and early spring	from 3000 to 5000
Pollution that may have a negative impact on the human environment	from 5000 to 10000
Pollution that threatens the human environment	>10000

Table 3. Atmospheric conditions prevailing on the air sampling day

Air sampling time	Air temperature (°C)	Wind speed [m/s]	Air humidity [%]	Rainfall
July	28	4	45%	0 mm (after 2 days of heavy rain)
September	14	3	64%	0 mm
November	5	1	80%	0 mm

Table 4. The number of microorganisms in the atmospheric air in the revitalized area of the coal mine

Microorganism	Number of microorganisms [cfu/m³]					
	July		September		November	
	P1	P2	P1	P2	P1	P2
Psychrophilic bacteria	712	321	528	194	216	152
Mesophilic bacteria	600	220	252	68	84	14
E. coli	0	0	0	0	0	0
Citrobacter freundii	0	0	0	0	0	0
Enterobacter aerogenes/cloacae	0	0	0	0	0	0
Actinomycetes	6	4	4	2	0	0
Staphylococcus sp. mannitolo (+)	0	0	0	0	0	0
Staphylococcus sp. mannitolo (-)	4	0	0	0	0	0
Pseudomonas aeruginosa	6	0	0	0	0	0
Pseudomonas fluorescens	0	0	0	0	0	0
Microfungi	430	210	400	180	140	150

by both the measurement time and the locations of the measuring points. Most of the indicator bacteria were not found in the air in the studied area, while the number of psychrophilic bacteria indicated presence of natural microflora coming from the surrounding meadows and wastelands. In addition, as can be seen from the data, the total number of mesophilic bacteria in the air ranged from 14 to 600 per 1 m³, which allows the air at both sites to be classified as unpolluted. The number of actinomycetes at individual sites varied depending on season. The number of microorganisms was larger in summer due to high air temperature, while none were found in late autumn.

According to the Polish Standard, the number of actinomycete cells in the air in the range of <10 classifies the air as contaminant-free. Microbiologically clean air should not contain cells of *Pseudomonas fluorescens* or *Staphylococcus sp*. They were not found during the measurements in the autumn, while in the summer a small number of *staphylococci mannitolo* (-) were recorded at the P1 measuring point. The number of fungi showed seasonal variations but it should be noted that abundant precipitation preceding the sampling in summer probably contributed to a decrease in the abundance of fungi and bacteria in the tested air due to wet deposition. According to the standard, all the measurements of mycological purity classified the air as clean.

DISCUSSION

The results of research by domestic and foreign authors indicate that the atmospheric environment in the vicinity of municipal landfills is characterized by the occurrence of different concentrations of bacterial aerosol. This is related to the size of the landfill area, its nature and the topography of the site. Not without significance are also weather conditions prevailing during the sampling [Cyprowski et al., 2019; Butarewicz et al., 2004; Srivastava et al., 2021]. As a result of the research, it has been shown that the landfill is a source of various microorganisms and their amounts depend on season and topography of the area. The quantitative data provided by the research show that the area undergoing revitalization did not exceed the quantitative standards and the air can be described as unpolluted. Diagnostic studies of microorganisms occurring in the atmospheric air indicate that on the examined municipal facilities we deal mainly with natural microflora coming from decomposing waste and from the surrounding areas. Most of the detected microbes are typical ubiquitous organisms that occur in a variety of environments. However, pathogenic species threatening human health were found among the isolated microorganisms, such as *Pseudomonas aeruginosa* and *Staphylococcus sp.*, which means that the natural barrier in the form of small trees around the landfill is not sufficient to protect the surroundings of the revitalized area. A properly designed green belt around the landfill should be over 10 m wide and consist of trees and shrubs restricting the propagation of dust, odors, bioaerosol and noise and preventing the movement of waste (Journal of Laws 2022, item 1902). The mechanism of limiting the spread of pollutants emitted from the landfill is based on a number of mechanisms, including: dilution, dispersion and dissipation on rusts, deposition of pollutants on the leeward and windward sides of the green belt, absorption of pollutants by trees and shrubs and their accumulation in biomass [Kwiecińska and Szałata, 2014]. Some species of trees and shrubs, from which isolating green belts are formed, secrete phytoncides into the environment, which often have a disinfecting and bactericidal effect [Kopcewicz and Lewak, 2007]. The use of species such as Scots pine (*Pinus sylvestris*), bird cherry (*Padus avium Mill.*) or juniper (*Juniperus communis*) for this purpose may additionally reduce the spread of bioaerosol from the area of the landfill.

CONCLUSIONS

Based on the microbiological analysis of air samples collected in the vicinity of the municipal waste landfill, near the revitalized area of the "Brzeszcze Wschód" coal mine, it was found that lack of most indicator bacteria, while the number of psychrophilic bacteria indicated the natural microflora from the surrounding meadows and wastelands. The total number of mesophilic bacteria in the air ranged from 14 to 600 in 1 m^3, which allows the air at both sites to be classified as unpolluted. In the summer, a small number of mannitol(-) staphylococci was recorded at the P1 measurement point. Among the isolated microorganisms, the presence of pathogenic species threatening human health, such as *Pseudomonas aeruginosa* and *Staphylococcus* sp. The number of all tested groups of microorganisms was influenced by the term and the distribution of measurement points. A natural barrier in the form of a small tree cover around the landfill is not a sufficient protection for the revitalized area (presence of *Pseudomonas aeruginosa* and *Staphylococcus* sp. in the samples).

REFERENCES

1. Anand U., Reddy B., Kumar Singh V., Singh A.K., Kesari K.K., Tripathi P., Kumar P., Tripathi V., Simal-Gandara J. 2021. Potential Environmental and Human Health Risks Caused by Antibiotic-Resistant

Bacteria (ARB), Antibiotic Resistance Genes (ARGs) and Emerging Contaminants (ECs) from Municipal Solid Waste (MSW) Landfill. Antibiotics, 10(4), 374–401.

2. Gollakota A.R.K., Gautam S., Santosh M., Sudan H.A., Gandhi R., Jebadurai V.S., Chi-Min Shu, 2021 Bioaerosols: Characterization, pathways, sampling strategies, and challenges to geo-environment and health. Gondwana Research, 99, 178–203.
3. Barabasz W., Chmiel M.J., Albińska D., Mazur M.A. 2007. Składowiska odpadów jako źródła bioaerozolu i mikroorganizmów szkodliwych dla zdrowia. Prace Instytutu Nafty i Gazu, 145, 143–152.
4. Berleć K., Budzińska K., Szejniuk B, Kułakowska A. 2009. Ocena oddziaływania składowiska odpadów komunalnych na wybrane parametry mikrobiologiczne powietrza. Rocznik Ochrona Środowiska, 11, 1317–1328.
5. Binkiewicz P. 2007. Budowa i eksploatacja składowiska odpadów komunalnych jako elementy wpływające na intensywność oddziaływania na środowisko. Problemy ekologii krajobrazu, 19, 227–232.
6. Błachno B. 2009. Pojemniki na odpady komunalne jako źródło zanieczyszczeń mikrobiologicznych powietrza. Ochrona Środowiska i Zasobów naturalnych, 41, 362–368.
7. Breza-Boruta B. 2012. Emisja drobnoustrojów przez składowisko odpadów komunalnych jako czynnik zagrożenia zdrowotnego. Proceedings of ECOpole, 6(2), 617–623.
8. Breza-Boruta B. 2016 The assessment of airborne bacterial and fungal contamination emitted by a municipal landfill site in Northern Poland. Atmospheric Pollution Research, 7(6), 1043–1052.
9. Butarewicz A., Kowaluk-Krupa, A. 2004. Mikrobiologiczne zanieczyszczenie powietrza atmosferycznego na terenie i wokół składowiska odpadów komunalnych w Augustowie. Ochrona Powietrza i Problemy Odpadów, 38(5), 167–173.
10. Chmiel M.J., Frączek K., Grzyb J. 2015. Problemy monitoringu zanieczyszczeń mikrobiologicznych powietrza. Woda-Środowisko-Obszary Wiejskie, 15(1), 17–27.
11. Cyprowski M., Ławniczek-Wałczyk A., Gołofit-Szymczak M, Frączek K., Kozdrój J., Górny R.L., 2019. Bacterial aerosols in a municipal landfill environment. Science of The Total Environment, 660, 288–296.
12. Ebisz M., Król K., Lar K., Mroczek A., Zbrojkiewicz E., Kopciak M., Złotkowska R. 2016. The health risk due to exposure to bioaerosol occurring in health care institutions Environmental Medicine, 19(2), 55–62.
13. Frączek K., Różycki H., Ropek D. 2014. Statistical Analyses of Bioaerosol Concentration at Municipal Landfill Site. Ecol Chem Eng S., 21(2), 229–243.
14. Fröhlich-Nowoisky J., Kampf C.J., Weber B., Huffman J.A., Pöhlker C., Andreae M.O., Naama Lang-Yona, Burrows S.M., Gunthe S.S., Elbert W., Su H., Hoor P., Thines E., Hoffmann T., Després V.R., Pöschl U. 2016. Bioaerosols in the Earth system: Climate, health, and ecosystem interactions. Atmospheric Research, 182, 346–376.
15. Gamero W.M., Parody Muñoz A.E., Rodriguez-Villamizar L.A., Medina Altahona J.J. 2021. Multi-antibiotic resistant bacteria in landfill bioaerosols: Environmental conditions and biological risk assessment. Environmental Pollution, 290, 118037.
16. Hawrot-Paw M., Domżał A. 2016 The impact of municipal waste landfill on the microbiological air quality, Archiwum Gospodarki Odpadami i Ochrony Środowiska, 18(3), 1–8.
17. Kaźmierczuk M., Bojanowicz-Bablok A. 2014. Bioaerosol concentration in the air surrounding municipal solid waste landfill. Environmental Protection and Natural Resources, 25(2), 17–25.
18. Ki-Hyun Kim, Kabir E., Jahan S.A. 2018. Airborne bioaerosols and their impact on human health. J Environ Sci [China], 67, 23–35.
19. Kopcewicz J., Lewak S. 2007. Fizjologia roślin. PWN, Warszawa.
20. Kwiecińska K., Szałata Ł. 2014. Wegetatywne bufory środowiskowe w strategii redukcji uciążliwości zapachowej instalacji IPPC, na przykładzie projektu pasa zieleni dla składowiska zuo w ścinawce dolnej. Inżynieria Środowiska, 36, 58–65.
21. Liu Y., Zhang Y., Shi Y. 2021. Characterization of fungal aerosol in a landfill and an incineration plants in Guangzhou, Southern China. Science of The Total Environment, 764, 142908.
22. Madhwal S., Vignesh Prabhu V., Sundriyal S., Shridhar V. 2020. Distribution, characterization and health risk assessment of size fractionated bioaerosols at an open landfill site in Dehradun, India. Atmospheric Pollution Research, 11(1), 156–169.
23. Michałkiewicz M. 2018. Powstawanie, przenoszenie i szkodliwość bioaerozoli emitowanych do powietrza atmosferycznego. Ochrona środowiska, 40(4), 21–30.
24. Michałkiewicz M., Piskorek J. 2008. Składowiska odpadów jako źródło skażenia mikrobiologicznego Rynek Instalacyjny, 10, 115–118.
25. Nair A.T. 2021. Bioaerosols in the landfill environment: an overview of microbial diversity and potential health hazards. Aerobiologia, 37(1), 185–203.
26. PN Z-04111-02: 1989. Oznaczenie liczby bakterii w powietrzu atmosferycznym (imisja) przy pobieraniu próbek metodą aspiracyjną i sedymentacyjną.
27. PN Z-04111-03: 1989. Oznaczenie liczby grzybów mikroskopowych w powietrzu atmosferycznym (imisja) przy pobieraniu próbek metodą aspiracyjną i sedymentacyjną.

28. Pop M., Bucur I.M., Zoldan D., Imre K. 2021. Chemical and Microbiological Air Quality in a Municipal Solid Waste Landfill and Its Surroundings, in South-Eastern Romania. Sustainability, 14(1), 156.
29. Samadi M.H., Mahvi A., Leili M., Bahrami A. 2021. Characteristics and health effects of potentially pathogenic bacterial aerosols from a municipal solid waste landfill site in Hamadan, Iran. Journal of Environmental Health Science and Engineering, 19(4), 1057–1067.
30. Srivastava A., Mehta D., Nehru J. 2021. Characterization of bioaerosols in and around a landfill site in Delhi. Aerobiologia, 37, 585–596.
31. Traczewska T., Karpińska-Smulikowska J. 2000. Wpływ składowiska odpadów komunalnych na jakość mikrobiologiczną powietrza. Ochrona Środowiska, 2(77), 36–38.
32. van Leuken J.P.G., Swart A.N., Havelaar A.H., Van Pul A, Van der Hoek W., Heederik D. 2016. Atmospheric dispersion modelling of bioaerosols that are pathogenic to humans and livestock – a review to inform risk assessment studies. Microb. Risk. Anal., 1, 19–39.
33. Walser S.M., Gerstner D.G., Brenner B., Bünger J., Eikmann T., Janssen B., Kolb S., Kolk A., Nowak D.,Raulf M., Sagunski H., Sedlmaier N., Suchenwirth R., Wiesmüller G., Wollin K.-M., Tesseraux I., Herr C.E.W. 2015. Evaluation of exposure–response relationships for health effects of microbial bioaerosols – a systematic review. Int. J. Hyg. Environ. Health, 218(7), 577–589.
34. Wery N. 2014. Bioaerosols from composting facilities – A review. Frontiers in Cellular and Infection Microbiology, 4(42), 1–9.
35. Whitby C., Ferguson R.M.W., Colbeck I., Dumbrell A.J., Nasir A.S., Marczylo E., Kinnersley R., Douglas P., Drew G., Bhui K., Lemon M., Jackson S., Tyrrel S., Coulon F. 2022. Chapter Three - Compendium of analytical methods for sampling, characterization and quantification of bioaerosols. Advances in Ecological Research, 67, 101–229.
36. Zhang T., Chen Y., Cai Y., Yu Y. 2023. Abundance and cultivable bioaerosol transport from a municipal solid waste landfill area and its risks. Environmental Pollution, 320, 121038.
37. Zhishu Liang, Yun Yu, Xiaolong Wang, Wen Liao, Guiying Li, Taicheng An, 2023. The exposure risks associated with pathogens and antibiotic resistance genes in bioaerosol from municipal landfill and surrounding area. Journal of Environmental Sciences, 129, 90–103.