

# Air pollution in landfill of wastes other than hazardous or inert

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**Keywords:** landfill, air pollution, microorganisms, gases.

**Abstract:** Microbiological and chemical analysis of air was carried out on the area of landfill of wastes other than inert or hazardous. The landfill covers 20 ha and 40 000 Mg of wastes is deposited annually. Municipal waste is not segregated at the landfill. The research was conducted in April, May and November 2012. Number of the psychrophilic and mesophilic bacteria and fungi was estimated by a culture-based method. Quantitative determination of sulfur compounds and meteorological and olfactometric examinations were also carried out. Chemical analysis was conducted with a Photovac Voyager portable gas chromatograph. Air samples were collected at 5 points. The largest group of microbes were psychrophilic bacteria, especially in summer. The highest concentration of hydrogen sulfide and other odorants was found at leachate tank and landfill body. According to the Polish Standard for the assessment of atmospheric air pollution the air in the area of the landfill is classified as not contaminated and sporadically moderately contaminated. In spring and summer the number of microscopic fungi was increased also in control samples.

## Introduction

Bioaerosols that are emitted at typical urban landfills where a wide range of municipal wastes are deposited affect the microbiological composition of the air. Such landfills are source of fugitive release of chemical pollution, odors, dust and noise (Kalisz et al. 1995, Kośmider et al. 2002, Kulig 2004, Siuta 2005, Pawłowska et al. 2008, Szyłak-Szydłowski and Grabińska-Loniewska 2009, Wójcik 2010).

Cocci of the genus *Micrococcus* sp., *Sarcina* sp., *Staphylococcus* sp., bacilli *Bacillus* sp. (vegetative cells or spores), filamentous fungi of the genera *Alternaria*, *Penicillium*, *Cladosporium*, *Aspergillus*, *Mucor*, and actinomycetes and yeasts of the genera *Rhodotorula* and *Candida* are the most frequently recorded microbes in landfill air. Saprotrophic forms occurring as commensals in human and animal bodies, e.g. in the digestive tract, dominate in landfill air. Good reproduction conditions and the availability of residual organic substances, faeces, mineral substances, water and other components necessary for microbial life makes landfills suitable for these microbes (Barabasz and Albińska 2005). Pathogenic organisms are also found in landfill air. These include bacteria *Clostridium perfringens*, *Clostridium tetani*, *Salmonella typhi* and *Shigella dysenteriae*. Endotoxins that are produced by gram-negative bacteria and are recorded in the air are also hazardous to health as they cause immunotoxic and allergic reactions in humans. When inhaled by humans, they can cause high temperature, breathing difficulties, hypoglycemia, hypotension or an

endotoxic shock and they can affect the number of leucocytes in the blood and adversely influence the course of bronchial asthma (Zaremba and Borowski 2001, Skowron and Gołofit-Szymczak 2004).

Moulds of the genera *Aspergillus*, *Candida* and *Alternaria* which enter the body through the respiratory tract with the spore-infected air, also pose a risk to human health, including allergenic risk. Mycotoxin-producing species are the most dangerous of them. They cause skin infections and toxemias characterized by headaches, diarrhea, changes to immunological mechanisms and damage to the liver, kidneys and the central nervous system, and they can also be carcinogenic (Gołofit-Szymczak and Skowron 2005).

Microbes occurring in the air are mostly attached with dust particles or particles of other solid or liquid pollution. Pollination-enhancing factors such as wind or the lack of the plant cover cause an increase in the number of microorganisms.

Chemical pollution derived from waste can be divided into inorganic gases and vapors of organic substances. The occurrence of inorganic gases results from the biological activity in waste heaps. Gases arising from microbial activity include hydrogen sulfide (H<sub>2</sub>S), ammonia (NH<sub>3</sub>), carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrogen (N<sub>2</sub>) and hydrogen (H<sub>2</sub>), as well as organic acids, aldehydes, ketones, mercaptans, thiols and a variety of other organic compounds (Kulig 2004). The presence of some chemical compounds in the air in municipal landfills can lead to the

damage of the respiratory tract, causing further diseases such as asthma or a variety of aeroallergies. They often cause insomnia, headaches and vertigo, conjunctivitis or diseases of the circulatory system. Hydrogen sulfide works toxically by reducing oxyhemoglobin in the blood and precipitating blood iron as sulfide. Symptoms of exposure to ammonia include inflammation of the mucous membranes of the eyes, nose and throat, headaches, sickness, nausea, tracheitis and breathing difficulties.

Emissions of odors: volatile organic and inorganic substances detected by smell receptors at very low concentrations and perceived as offensive (unpleasant, annoying) by the brain, are another important hazard associated with waste disposal (Kośmider et al. 2002, Kostryko and Wargocki 2012, Zarra et al. 2013). Municipal landfills are reactors of odorous compounds of derivative nitric, sulfuric and oxygen groups. Odorants are generated chiefly during the anaerobic phase of the biodegradation of organic waste mass. Odorous compounds should not be perceptible over 500 m away from the landfill and tolerated at 300–500 m in the prevailing wind direction. They can be defined as periodically offensive at smaller distances, 50–300 m (Kulig 2004). Compounds causing the greatest odor nuisance such as hydrogen sulfide and alkithiols or formic acid, acetic acid and propionic acid, lower alcohols such as methanol or butanol, are recorded in the landfill biogas (Białowiec et al. 2008).

The aim of this study was to estimate microbiological and chemical air pollution at and around landfill of wastes other than hazardous or inert.

## Material and methods

### Site description

Wastes other than inert or hazardous are deposited at the landfill. The landfill opened in 1997 and covers ca. 20 ha. The closest buildings are 500–600 m away from the landfill and the nearest water intake is ca. 850 m away from it. A total of 40 000 Mg of wastes is deposited annually. Municipal waste is not segregated at the landfill. The landfill consists of four plots. Plot 1 is no longer used and the area is undergoing rehabilitation. Plot 2 has been in use since 2006 and rehabilitation works are carried out systematically. Plots 3 and 4 will be used in the future. Plot 4 is forested.

Scope of the studies:

- 1) To sample the air for microbiological and chemical examinations at selected points.
- 2) To estimate the total number of psychrophilic and mesophilic bacteria and fungi in the air samples.

- 3) To conduct chemical analyses of the content of hydrogen sulfide and methyl and ethyl mercaptan in the air samples.

The following receptors were selected for sampling:

- A – point representing the background by the car park (chemical and microbiological examinations)
- B – point by the leachate tank (chemical and microbiological examinations)
- C – point by the landfill body (chemical and microbiological examinations)
- D – point by the plot undergoing rehabilitation (chemical and microbiological examinations)
- E – site 10 m away from the leachate tank, leeward (chemical studies)

### Microbiological examinations

#### Air sampling

A microbial air sampler Sampl'air (AES Laboratoire) was used and the impact method was employed. The flow rate is a constant 100 l/min.

#### Quantitative determination of bacteria and fungi

A 100 l of air was collected in one minute. Two samples were collected for each microbial group at each site. Plates were transported to the laboratory and placed in thermostats at optimum growth temperature.

Incubation conditions for the microorganisms isolated and the substrates used are given in Table 1.

Colonies were counted, compared to the Sampl'air statistical table and converted to the number of colony-forming units in 1 m<sup>3</sup> (cfu/m<sup>3</sup>). The results were compared with numerical values of the permissible level of microbiological air pollution (PN-89/02, PN-89/03).

### Chemical examinations

#### Quantitative determination of sulfur compounds

Air was suctioned into Tedlar bags with a suction and force pump. Two samples were collected at each site. Air was collected first for one minute and then for five minutes.

Sulfur compounds in the air were conducted with a Photovac Voyager portable gas chromatograph. Low detection limits are dependent on compound monitored. Typical low detection limits for that chromatograph are 5 ppb to 50 ppb. Nitrogen was used as the carrier gas.

### Meteorological and olfactometric examinations

Wind speed was measured using a portable electronic anemometer A-1200E. Wind direction was determined with

**Table 1.** Substrates and incubation conditions of microorganisms in air samples.

Micro-organisms	Substrate	Incubation temperature (°C)	Incubation time (day)
Mesophilic bacteria	Plate Count Agar	35–37	2
Psychrophilic bacteria	Plate Count Agar	20–22	3
Fungi	Rose Bengal Chloramphenicol Agar (RBC Agar)	26	6

the dispersion method (Kulig 2004). Temperature and relative humidity were assessed with an Assman psychrometer. Cloud cover was expressed in octants.

The intensity of odors was assessed according to the Just organoleptic scale modified and expanded by A. Kulig (2004) by one degree.

## Results

The results of microbiological and chemical examinations and meteorological observations are presented in Table 2.

The number of bacteria in the air in the landfill ranged between 50 and  $1.4 \times 10^4$  cfu/m<sup>3</sup>. The highest concentration of bacteria was recorded during unloading and compacting of waste. The number of fungi was lower: 190– $1.8 \times 10^3$  cfu/m<sup>3</sup>. Methyl and ethyl mercaptan, dimethyl disulfide were not detected in the air in chemical analyses. Hydrogen sulfide was detected at the majority of sites. Its concentration ranged between 0.169 mg/m<sup>3</sup> and 0.529 mg/m<sup>3</sup>. Other gases included in the study did not occur in the background.

The strongest odor was detected at the landfill body and was not correlated with the season. Easterly winds dominated slightly and the highest wind speed was recorded for westerly winds (2.25 m/s).

## Discussion

The aim of this study was to establish the influence of landfills of municipal wastes on the air quality. As recorded in each series of the examinations, micro-organisms and hydrogen sulfide were emitted and odor nuisance of the landfill was detected.

The strongest concentration of psychrophilic bacteria was observed in the landfill body where over twice as many

bacteria were recorded as in the control sample ( $5.5 \times 10^2$  cfu/m<sup>3</sup> and  $2.1 \times 10^2$  cfu/m<sup>3</sup>, respectively). This is related to a considerable load of organic matter that is present in the wastes and that is the substrate for saprotrophic micro-organisms such as psychrophilic bacteria. This is also confirmed in studies by Barabasz et al. (2005) conducted at six landfills. The natural saprotrophic microflora derived from, e.g. decomposing municipal wastes, predominated in the qualitative analysis of micro-organisms isolated from the air.

Mesophilic bacteria were the least numerous group ( $50\text{--}2.1 \times 10^2$  cfu/m<sup>3</sup>). However, their number was between 1.4 and 6 times as high as that recorded in the control. The greatest concentration of mesophilic bacteria was noted at the landfill body and next to the escarpment undergoing rehabilitation. Their presence is indicative of the occurrence of pathogenic bacteria in the air posing a health hazard to humans. Mesophilic bacteria can be present in municipal wastes and be emitted into the air. Pathogenic and potentially pathogenic organisms that can occur in municipal wastes include *Citrobacter freundii*, *C. intermedium*, *Escherichia coli*, *Enterobacter cloacae* *Proteus vulgaris*, *Pseudomonas fluorescens*, *P. diminuta*, *P. cepacia*, *P. putida* (Szyłak-Szydłowski and Grabińska-Loniewska 2010).

A high concentration of mould spores in the air ( $3.8 \times 10^2\text{--}1.8 \times 10^3$  cfu/m<sup>3</sup>) was recorded in series I of microbiological examinations. It was especially high in the background samples where twice to ten times as many fungi were recorded as at the landfill ( $3.7 \times 10^3$  cfu/m<sup>3</sup>). This may be caused by the location of the control site on the forest edge. As a qualitative analysis of fungi was not performed and only their abundance was estimated, fungi present in the air may have comprised chiefly saprotrophic organisms developing on, for instance, leaves, needles and other organic

**Table 2.** Results of microbiological and chemical examinations and meteorological observations in three series: I – 26 April, II – 18 May, III – 24 November

		Background			Leachate tank			Landfill body			Plot undergoing rehabilitation			10m away from the leachate tank		
Series		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Mesophilic bacteria	[cfu/m <sup>3</sup> ]	35	$4.1 \times 10^2$	$1.2 \times 10^2$	50	$1.8 \times 10^2$	55	$2.1 \times 10^2$	$2.5 \times 10^3$	60	$2.1 \times 10^2$	$4.7 \times 10^2$	95	Ne*	Ne*	Ne*
Psychrophilic bacteria	[cfu/m <sup>3</sup> ]	$2.1 \times 10^2$	$2.0 \times 10^2$	$2.4 \times 10^2$	$2.3 \times 10^2$	$1.1 \times 10^3$	55	$5.5 \times 10^2$	$6.4 \times 10^3$	$8.2 \times 10^2$	$2.7 \times 10^2$	$1.4 \times 10^4$	$1.6 \times 10^3$	Ne*	Ne*	Ne*
Microscopic fungi	[cfu/m <sup>3</sup> ]	$3.7 \times 10^3$	$1.3 \times 10^3$	$2.5 \times 10^2$	$1.8 \times 10^3$	$6.9 \times 10^2$	$1.6 \times 10^3$	$3.8 \times 10^2$	$1.4 \times 10^3$	$1.9 \times 10^2$	$4.6 \times 10^2$	$6.4 \times 10^2$	$4.4 \times 10^2$	Ne*	Ne*	Ne*
Hydrogen sulphide	[mg/m <sup>3</sup> ]	0	0	0	0.529	0.693	0.417	0	0.172	0.431	0.549	0.431	0.169	0	0.169	0.256
Intensity of odour		0	0	0	3	3	2	4	4	3	1	0	0	1	1	2
Wind speed	[m/s]	0.1	0.7	0.5	0.4	1.2	0.6	1.2	1.4	0.4	1.2	1.7	0.7	0.6	2.2	0.4
Wind direction		E	W	NE	E	W	E	N	W	E	N	W	E	E	W	E

\*Ne – not estimated

remains depositing in the forest after winter. Similar results were obtained by Małecka-Adamowicz et al. (2007), who recorded a high concentration of mould spores both within the landfill and in the inblown air.

Only hydrogen sulfide was recorded in chemical analyses. Its highest concentration was noted near the leachate tank ( $0.529 \text{ mg/m}^3$ ). Gases examined in this study did not occur in the background.

A high concentration of mould spores in the air was also recorded in series II but their number was considerably lower than that in series I. Twice as many mould spores were detected in the control than within the landfill. The landfill body was the only exception and the number of fungal spores was higher there than the number recorded in the control ( $1.4 \times 10^3 \text{ cfu/m}^3$  and  $1.3 \times 10^3 \text{ cfu/m}^3$ , respectively). In their studies, Michałkiewicz and Piskorek (2008) also recorded the highest concentration of fungi in spring and summer. It was noted in the proximity of the leachate tank and the landfill plot currently in use and was  $3.8 \times 10^3$  and  $3.5 \times 10^4 \text{ cfu/m}^3$ , respectively.

The strongest concentration of psychrophilic bacteria was recorded at the plot undergoing rehabilitation. Their number was 70-times higher at the plot than that recorded in the control ( $1.4 \times 10^4$  and  $2 \times 10^2 \text{ cfu/m}^3$ , respectively). The concentration of psychrophilic bacteria at the landfill was also 32-times higher than that in the control.

The number mesophilic bacteria in the landfill body exceeded their number recorded in the background six times and was nearly  $2.5 \times 10^3 \text{ cfu/m}^3$ . Values lower or slightly higher than the background were recorded at the other two sites.

A high concentration of microbes from the landfill body was caused by landfill operations during air sampling. Microbes are intensively released from wastes and emitted into the air during unloading and waste compacting. Therefore a higher number of bacteria was recorded at all sampling sites on that day than in the other two series of examinations. The correlation between the concentration of micro-organisms in the air and unloading-related activities was also observed by Buczyńska et al. (2006) and Kaarakainen et al. (2005). They also noticed that this factor was considerably more important than the season.

The concentration of hydrogen sulfide by the leachate tank was also the highest and was  $0.693 \text{ mg/m}^3$ .

A high number of mould spores,  $1.6 \times 10^3 \text{ cfu/m}^3$ , was recorded by the leachate tank in series three. It was over six times higher than the background. Mould spores were also emitted into the air by the escarpment undergoing rehabilitation (1.8 times higher). Such a high abundance of moulds by the leachate tank may have been related to the proximity of the forest as other microbes studied here were not so numerous at this locality.

Psychrophilic bacteria were as abundant as fungi. An increased number of psychrophilic bacteria was observed by the escarpment undergoing rehabilitation ( $1.6 \times 10^3 \text{ cfu/m}^3$ ) and at the landfill body ( $8.1 \times 10^2 \text{ cfu/m}^3$ ). Mesophilic bacteria were the least numerous group. The highest concentration was recorded in the control and its value was even twice as high as that within the landfill.

## Conclusions

Results of microbiological examinations show that the concentration of mould spores both at the control site and at the study sites was typical of uncontaminated air as defined by Polish standards of microbiological contamination of the air (PN-89/2, PN-89/3). The number of mesophilic bacteria was within the upper limit of the averagely polluted air only in the landfill body in the second (May) series ( $2.5 \times 10^3 \text{ cfu/m}^3$ ). The air should be treated as uncontaminated in other cases. A very high abundance of psychrophilic bacteria at the landfill body and by the plot undergoing rehabilitation which is directly adjacent to the landfill plot currently in use was recorded in series two ( $6.4 \times 10^3 \text{ cfu/m}^3$  and  $1.4 \times 10^4 \text{ cfu/m}^3$ , respectively). However, these microbes are not covered by the above standards.

The highest concentrations of hydrogen sulfide were recorded in the landfill body and by the leachate tank ( $0.431 \text{ mg/m}^3$  and  $0.417 \text{ mg/m}^3$ , respectively). They were lower than in series I and II of our study.

A portable chromatograph could not be used *in situ* as the oxygen peak was also included to determine the concentration of hydrogen sulfide. When this is examined, chromatographic peaks must be corrected manually *ex situ* each time. The strongest olfactory sensations were recorded at the site by the leachate tank as chemical odorous compounds from leachate drained from under the landfill were released.

Concentrations of bacteria, fungi and odorous compounds, including hydrogen sulfide, from the landfill were recorded in microbiological and chemical analyses. The strongest concentrations were noted for psychrophilic and mesophilic bacteria. A high concentration of mould spores was recorded, also in the air blown into the landfill. This may be explained by the close vicinity of the forest. Landfill operations, such as waste compacting or unloading, cause increased emissions of microbes and odors into the air while they do not increase the concentration of hydrogen sulfide. Of gases studied in the chemical analysis, only hydrogen sulfide was recorded at the landfill. The emission of odorants was not influenced by seasonal changes and was the strongest at the landfill body and by the leachate tank. Personal protective equipment should be used to protect the respiratory system and the skin from exposure to the greatest emission of harmful biological and chemical substances.

Depending on the operations performed and the pollution emitted, the composition of the landfill air usually differs from the air commonly accepted as clean and suitable for long-term occupancy by humans. Due to the presence of biological, dust and chemical pollution in the air, the well-being and general health of occupants may worsen. The risk to which landfill operators are exposed differs and depends on the amount and type of pollution and microclimate parameters. The presence of a range of pollutants can contribute to an increased health risk. Even if the concentration of individual pollutants is not high, the combined occurrence of pollutants can have negative health effects (Barabasz et al. 2005). A variety of regulations and resolutions in Poland and in the EU describe the biological factor that, if emitted from municipal sites, can pose a direct risk to the health of employees.

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## Zanieczyszczenia powietrza na składowiskach odpadów innych niż niebezpieczne i obojętne

Przeprowadzono badania nad zanieczyszczeniem powietrza na terenie składowiska odpadów innych niż obojętne i niebezpieczne. Wybrany obiekt został otwarty w 1997; zajmuje 20 ha i rocznie przyjmuje 40 000 Mg odpadów komunalnych, które nie podlegają segregowaniu na składowisku. Zakres badań mikrobiologicznych obejmował analizę ilościową bakterii mezofilnych, psychrofilnych oraz grzybów mikroskopowych. Do poboru próbek powietrza zastosowano metodę zderzeniową. Analizy chemiczne polegały na oszacowaniu stężenia siarkowodoru oraz merkaptanu etylowego i metylowego za pomocą przenośnego chromatografu Photovac Voyager. Określano ponadto takie parametry jak prędkość i kierunek wiatru oraz intensywność zapachu. Pobór próbek przeprowadzono w pięciu punktach. Wykazano emisję mikroorganizmów oraz siarkowodoru i odorów z terenu składowiska. Najliczniejsze

były bakterie psychrofilne, zwłaszcza w porze letniej. Wysoką liczbę bakterii mezofilnych i grzybów mikroskopowych stwierdzono na bryle czynnego składowiska. Najwyższe stężenie siarkowodoru i odorów wykryto w sąsiedztwie zbiornika na odcieki oraz na składowisku. Na podstawie polskiej normy dotyczącej jakości powietrza atmosferycznego należy określić powietrze na terenie składowiska jako nie zanieczyszczone (liczba grzybów) oraz średnio zanieczyszczone i nie zanieczyszczone (liczba bakterii psychrofilnych). Wiosną i latem zaobserwowano podwyższoną liczbę grzybów mikroskopowych również w próbkach kontrolnych.