Chapter 5

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Impact of the Municipal Landfill Site on Microbiological Contamination of Air

1. Introduction

The quality of the air is one of the major factors that impact the surrounding environment. The atmospheric air beside contaminants of industrial origin (gases, dusts) contains microbiological contaminants in the form of bioaerosols. They are created by small liquid droplets or particles of solid matter that include bacteria, viruses and fungi, as well as independently floating in a gaseous medium microorganisms, pollens, etc. Saprophytic bioaerosols, as well as infectious and mixed ones, have adverse effects, causing a deterioration of the air hygienic conditions and have a number of adverse changes in the environment, such as infections of humans, animals and plants, contaminations of food products, medicinal products, and even bio-corrosion of building materials.

Biological aerosols are systems of 2 or 3 components dispersed in the air. In physical respect, they are colloids, which means they are systems composed of dispersed particles in dispersion medium. Size of the particles included in bioaerosols ranges between 0.3 µm and 100 µm. In natural environment, biological aerosols disseminate firstly as a result of convective flow of air, while the smaller particle sizes, the lower force of the wind suffice to transfer them.

Bioaerosol is an impermanent system, easily changeable. The changeability results from the bioaerosol capability of coagulation, i.e. combining in consequence of a difference in electric charges of individual components. Also, the chemical composition of bacterial capsules that are comprised in the biological aerosol impact durability of colloid particles of this kind. The most durable, in this respect, are bacteria with protein capsules.

Microbiological contaminations gain more and more attention. It is, firs of all, a result of adverse influence of microorganisms on health conditions of humans, animals, or plants; corrosion and decomposition of building materials; contamination of medicinal products or those intended for consumption. It should be emphasized that microbiological contaminations disseminate the fastest exactly in the air.

The objects particularly affecting microbiological quality of the atmospheric air are sewage treatment plants, municipal landfill sites, and composting plants or animal farms. Within such objects, especially those that are inappropriately utilized, considerable bacteriological and mycological contaminations are observed. Ranges of impact of such objects on surroundings and degrees of atmospheric air contamination can differ. They can range from several hundred metres to 1 km.

Landfill sites, even if well protected, beside their basic positive role of contribution to the environment, are likely to negatively impact the public health, since they form a source of diverse air contaminants, such as chemical substances (e.g. biogas contaminations), odours or microorganisms as bioaerosols. Also, landfill sites are bothersome because of birds and insects.

Physical and chemical contaminations of the air arise as the site operates; and additionally as a result of the presence of various technical equipment and lorries that deliver wastes, there are also automotive contaminants, such as: CO, NO, hydrocarbons, heavy metals. Occurrence of odours in the landfill area is related to digestion processes and secretion of biogas that take place in there. Difficulty of their disposal is connected to extensive surface of their emission. In the air zone around landfill sites, beside above-mentioned contaminations, local citizens suffer because of frequent disseminations of oppressive plagues of insects and fowl. Flies and mosquitoes prevail among insects. The most frequent birds are common black-headed gull (*Larus ridibundus* L.) and rook (*Corvus frugilegus* L.). Gulls that feed directly on the landfill are beneficial for they remove scraps of food. Rooks, on the contrary, collect remains of food from the landfill area and transfer them into adjacent areas, thus contributing to clutter the vicinities (Leboda, Oleszczuk 2002).

The air from landfill sites is usually more biologically contaminated than this from areas of urban sewage treatment plants. In the surroundings of municipal landfill sites considerable microbiological contaminations of air is observed within the distance of 100±300 m, depending on the site size and methods of its management (Traczewska, Karpińska-Smulikowska 2000).

The greatest contents of microorganisms include municipal wastes, and in particular – the wet fraction, i.e.: food scraps, remains from raw material for meals composition, empty packages after food products, used cleaning agents and personal hygiene materials, and faeces of domestic animals. Another source of microorganisms that form the bioaerosol above landfill sites are dehydrated sewage sediments. Such sediments are likely to be rich in microorganisms removed from sewage; hence their location in landfill sites results in additional microbiological danger.

Emission of bioaerosols can take place at various stages of waste management, both during transportation and unloading of wastes and during their storage, sorting and storing in dumps. Technical treatment largely affects origination and dissemination of biological aerosols above landfill sites. Traczewska and Karpińska-Smulikowska (2000) include among them for instance: emptying lorries delivering wastes, sweeping, levelling, compressing, and closing sections. These actions result in microorganisms and fungi spores soaring, particularly when given landfill is situated above the ground level and is not tightly encircled with thick greenery.

Scientific studies concerning microbiological contaminations of air in the surroundings of communal structures have been conducted in Poland from the 70'. It has been observed that the microflora of the air around waste landfills usually contains saprophytic bacteria, haemolytic staphylococci, endospore forms of aerobic and anaerobic bacteria, actinomycetes and various species of fungi. Beside saprophytic microorganisms, the air can contain numerous pathogenic microbes that constitute a threat for human health, particularly for people suffering from allergies and respiratory disorders. Increased numbers of airborne microorganisms does not have to denote proportionally increased threat to for people staying in given area. However, increased number of airborne pathogenic microbes increases the risk of their contact with humans, penetration through airway or skin (eyes) into the organism and bringing particular lesions. Bigger amount of organisms that are conditionally pathogenic or pathogenic mean potentially greater possibilities of infections of humans and animals (Kaźmierczuk *et al.* 2004). Besides, the landfills can affect – via air – also soil environments and surface waters. This suggests necessity of monitoring of communal landfills sites influence on the closest vicinity.

2. Determinants of studies

The studies on effect of a landfill on microbiological cleanliness of air were among others conducted in 2010-2011 within the area of Municipal Landfill Site (MLS) in Toruń (Fig. 1), situated ca. 7 km to south-west from the centre of densely built-up town area. It is a place for communal wastes disposal for the town Toruń and Lubicz, Obrowo and Wielka Nieszawka. The landfill site serves ca. 284,000 of citizens. From the north and west, the site is surrounded by forests, and from the other directions with wastelands.

The landfill site is divided into two zones: The first one covers inactive (from the end of 2009) dump of 15.3 ha of area and 30 m of height, which would comprise 4 million tonnes of wastes. This site from 1964 has operated as waste disposal site for materials other than hazardous and harmless with separate section for hazardous materials.

The area meant for waste storage covers four storage sections and rehabilitated liquid waste dumps. Leachates that originate in the landfill site are disposed by means of drainage system and the slope waters by surrounding ditches. The system of leachate management covers reception, transportation and pre-treatment of leachate along with slope waters in the anti-rolling tank and at the final stage pre-treated leachate drainage into the communal sewerage system.

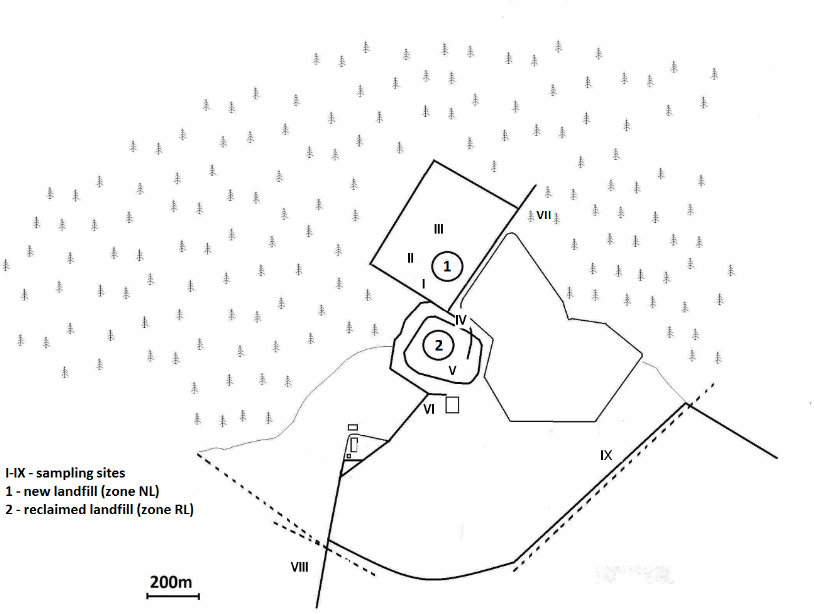

Fig. 1. Location of sampling sites

The anti-rolling tank and related equipments are located in direct vicinity of the landfill site.

The area of inactive landfill site from December 2009 have been subject to reclamation resulted from mandatory obligation of degassing landfill sites (Regulation of the Ministry of Environment of 24.03.2003 – Journal of Laws No. 61, item 549 as amended). Gas reclamation consisted in construction within the MLS of 20 biogas wells equipped with connections to additional (secondary) pumping-controlling module, installing within the reclaimed area a container module of capacity ca. 375 Nm^3/h and construction of dehydrator of landfill site gas at above-mentioned module.

Ground reclamation will consist in covering the top part of the main section surface with soil reclamation cover (of thickness ca. 0.9 m in total) and sowing with so-called pioneering flora, i.e. mix of graminaceous and papilionaceous plants (element of biological reclamation). The main goal of MLS ground reclamation is to arrange a layer sealing the site bowl surface, which is to limit the migration of the landfill site gas to the atmosphere, implement a layer of gas drainage, which is to improve migration of the gas into the well and enhance its acquisition, and to restore the area usability through correction of the site lump, maintenance of the technological route and sowing the site bowl with graminaceous and papilionaceous plants.

The other part of the landfill site (handed over for operations on 29.11.2009) of surface area of 6.6 ha and capacity of 1 million tonnes is to be, according to the plan, operated for next 13 years.

Fig. 2. The new, operative landfill (zone NL – sites I, II and III) (phot. A. Kalwasińska)

Fig. 3. The waste dump of reclaimed landfill (zone RL – site V) (phot. A. Kalwasińska)

Fig. 4. The tank for leachates from the old landfill (zone RL – site VI)
(phot. A. Kalwasińska)

Fig. 5. View of the reclaimed landfill from the Polna Street (zone S – site IX)
(phot. A. Kalwasińska)

The other part of the landfill site, MWTP – Municipal Waste Treatment Plant (handed over for operations on 29.11.2009) of surface area of 6.6 ha and capacity of 1 million tonnes is to be, according to the plan, operated for next 13 years.

The wastes dumped on the dump are laid in layers in pre-indicated sections and afterwards mashed and covered with insulation layer. In order to protect the adjacent area against blowing of light wastes (paper, films), there was arranged a shield in the form of embankment around the trough with additional fencing of polyamide net from the west. Arousing leachates and rain waters are drained from both, the old and the new landfill sites into separate anti-rolling tanks and then into municipal sewerage system. Both, old (inactive) and operative parts of the landfill site are equipped in the system of biogas acquisition and transformation into electricity. The heat acquired at energy production is used for heating the site back office structures and municipal water.

Within the area of the Municipal Landfill Site in Toruń and its closest vicinity, considering the orientation of predominant winds, there were 9 study sites appointed (Fig. 1):

a) within the new, operative landfill site (zone NL – Fig. 2):
- site I – the tank for leachates from the landfill site,
- site II – the area between sorting department and composting part,
- site III – waste dump;

b) within the area of old, reclaimed landfill site (zone RL):
- site IV – access road of reclaimed landfill,
- site V – waste dump top (Fig. 3),
- site VI – tank for leachates from the old landfill (Fig. 4),

c) in the surroundings of Municipal Landfill Site (zone S):
- site VII – woodland road, 300 m to the east from the new landfill dump,
- site VIII – golf course, Kociewska Str., 1100 m to the south-west from reclaimed landfill,
- site IX – Polna Street., 800 m to the south-east from reclaimed landfill (Fig. 5).

The air sampling took place in accordance with the Polish Norm (PN-89/Z-04008/08), at the altitude of 1.3 m above ground level, in monthly intervals, from May 2010 to April 2011. The samples were placed on surfaces of appropriate culture media using collision method. To this end a Merck Microbiological Air Sampler MAS-100 was applied. The airflow rate of 11 m/s enabled capture of particles larger than 1 µm, which are significant for microorganisms' transfer. In each site, the air analysis was conducted in three courses in order to ensure mitigation of errors related to accidental character of tested samples. Following sampling, the collected material was transported to the lab, where it was incubated at 25 or 37^{o}C for specific period of time. After incubation, the grown cultures were counted up and acquired results were recalculated into 1 m^3 of air.

During sampling, also measurement of meteorological parameters took place (temperature, wind rate, air humidity) by means of anemometer Nielsen-Kellerman Kestrel 3500 (Table 1).

Table 1
Basic meteorological parameters during sampling in the area of the Municipal Landfill Site in Toruń and surroundings

Sampling date	Temperature [^{o}C]	Humidity [%]	Wind velocity [m/s]	Wind direction	Atmospheric precipitation
26.05.2010	14,7	53,1	5,2	W	-
24.06.2010	20,1	58,5	4,9	SW	-
26.07.2010	18,7	83,7	1,21	SW	shower
23.08.2010	21,6	81,6	1,3	W	-
27.09.2010	7,6	81,0	4,1	NW	-
21.10.2010	7,3	72,1	26,5	W	shower
25.11.2010	2,1	87,6	4,6	W	snow showers
16.12.2010	- 8,3	76,8	3,6	S	snow showers
19.01.2011	5,3	72,7	1,5	NW	shower
17.02.2011	-7,0	56,5	6,3	SE	snow showers
18.03.2011	0,6	93,3	1,7	E	shower
14.04.2011	5,5	64,3	5,1	NW	-

Microbiological tests of the air covered estimation of number (in 1 m^3 of air) of:

a) mesophilic bacteria – according to Polish Norm (PN86/Z-04111/02) the cultures were managed on PCA medium. In order to hinder growth of moulds an actidione was added in the amount of 0.1 g/l. The cultures were incubated at 37°C for 48 h, whereupon all developed bacterial cultures were counted;
b) mannitol-positive staphylococci – according to Polish Norm (PN86/Z-04111/02) Chapman medium was applied, the cultures were kept at 37°C for 48 h. After incubation, mannitol-positive bacterial cultures were counted assuming positive result when yellow bright spot appeared around a culture;
c) haemolytic bacteria – according to Polish Norm (PN86/Z-04111/02) the cultures were managed on agar with blood at 37°C for 48 h. Afterwards the bacterial cultures surrounded by haemolyse zone were counted. Highlighted were α-haemolytic bacteria surrounded by narrow zone of incomplete haemolyse and β-haemolytic surrounded by wide, distinct zone of complete (full) haemolyse;
d) actinomycetes – on Pochon medium (PN86/Z-04111/02), with cultures' incubation for 5 days at 26°C;

e) moulds – for estimation of moulds number, according to Polish Norm PN-89/Z-04111/03, used were media Czapek Dox and wort agar. Plates with Czapek Dox were incubated for t days whereas wort agar for 2 days at 25°C. Afterwards grown mould cultures were counted and, according to PN-89/Z-04111/03, estimated was arithmetic mean for media Czapek Dox and wort agar, and the final result was recalculated into 1 m^3 of air.

3. Waste management

According to the Act of 27 April 2001 on wastes (Journal of Laws from 2007 No. 39, item 252 as amended), the main principle of waste management id to act in a way that ensures protection of human life and health as well as the environment. This goal should be pursued in the first place by prevention of waste origination or limitation of their amounts. If it is unavoidable the greatest possible amount of wastes should be recycled. The rest of wastes should be neutralized. One of the most widespread methods of waste neutralization both, in Poland and in Kuyavian-Pomeranian Voivodship, is storage of them. Landfills are always nuisances for the environment. And the nuisance severity depends on: physical, chemical and biological properties of wastes, size of waste bulk, ground grade, hydrological conditions and situation of a landfill in relation to terrain, method of management (use) of over-ground and under-ground (mainly under-ground waters) environment within the area adjacent to the landfill, method of a landfill arrangement and operation, and method of reclamation and destination development of a landfill land. Each of these factors plays very substantial role.

According to the "Report on condition of Kuyavian-Pomeranian Voivodship natural environment in 2009" issued in 2010 by Voivodship Environmental Protection Inspectorate in Bydgoszcz, in 2009 in the area of Kuyavian-Pomeranian Voivodship operative were 85 communal landfills, which hosted 519,294 Mg, i.e. 251 per one citizen of our region. From the operational launch to the end of 2009 these objects collected more than 7.4 million Mg of wastes. In 2009 it was the Municipal Landfill Site in Toruń that received the bigger amount of communal wastes – 17.5% of annual volume of communal wastes in Kuyavian-Pomeranian Voivodship. The Municipal Landfill Site in Toruń was also the place where the biggest amount of wastes were collected until the end of 2009 – 2952,000 Mg, which constituted around 40% of all gathered communal wastes in the region.

4. Microbiological contamination of air

The analysis of numbers of all microorganism groups occurring in the air of the Municipal Landfill Site in Toruń proves that the highest values of those were always observed within presently operated landfill (Table 2, Fig. 6). Such high numbers of microorganisms in the NL zone air were caused by specificity of the sites it comprised – sampling sites were situated in the area of waste delivery and technical actions. Unloading the lorries that deliver wastes, levelling and compacting the dump largely affect dissemination of bioaerosol.

Table 2

Monthly average values of microorganism numbers (CFU/m^3) in the air of individual zones of the Municipal Landfill Site in Toruń and surroundings

Month	Mesophilic bacteria			Staphylococci m^+			Haemolytic bacteria						Actinomycetes			Moulds		
							α			β								
	NL	**RL**	**S**	**NL**	**RL**	**S**	**NL**	**RL**	**S**	**NL**	**RL**	**S**	**NL**	**RL**	**S**	**NL**	**RL**	**S**
May	2357	320	92	263	57	9	168	58	13	32	62	5	129	213	98	1753	650	648
June	2000	1347	170	146	32	9	40	22	2	65	48	15	43	13	8	2300	980	680
July	101	23	110	8	2	2	40	7	7	5	22	12	27	7	14	6313	3737	2256
August	110	107	100	32	3	8	22	12	9	53	5	19	30	13	12	1847	743	984
September	2560	350	212	150	26	50	15	8	8	32	19	20	57	33	30	1230	697	834
October	157	177	146	13	17	15	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	7	0	12	1177	527	574
November	100	150	86	5	0	0	2	5	1	0	3	1	33	0	4	1473	190	182
December	30	75	98	0	0	0	27	0	10	7	0	3	0	0	10	177	25	63
January	120	50	45	2	2	0	3	3	3	0	3	0	7	3	0	517	200	253
February	130	63	180	0	15	11	20	7	17	63	15	37	80	110	46	193	97	160
March	37	37	36	3	2	4	2	0	3	12	3	16	3	7	2	47	40	5
April	4520	339	646	763	712	143	172	37	8	85	58	31	47	70	42	787	1180	760

Explanation: NL – new landfill, RL – reclaimed landfill, S – surroundings of landfill, n.t. – not tested

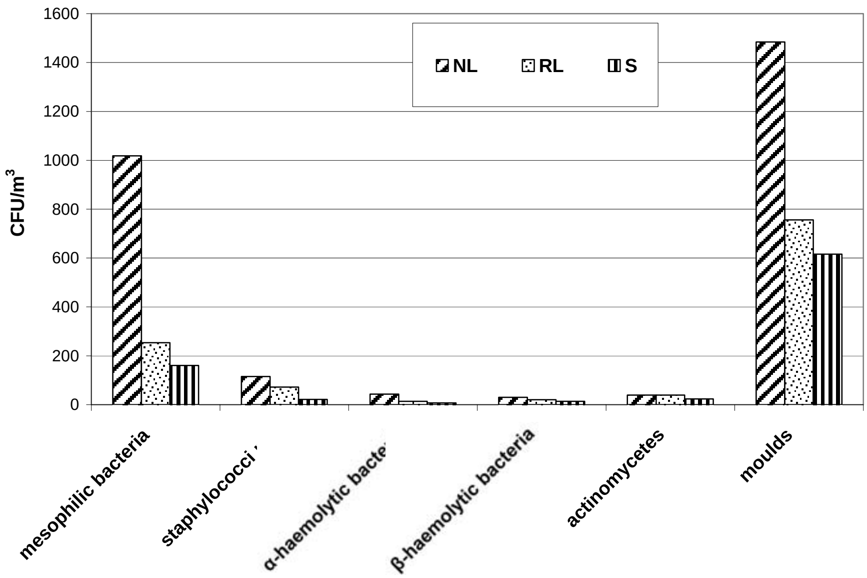

Fig. 6. Yearly average numbers of studied microbes in the air within and in the surroundings of the Municipal Landfill Site in Toruń

Within the area of reclaimed landfill a decrease of studied microorganisms' numbers is noted, which indicates that appropriately managed reclamation process significantly restricts possible negative impact of environment that is no longer operated. The atmospheric air surrounding the MLS in Toruń featured significantly lower microbiological contamination, compared both to the air sampled from presently functional landfill and the one from the reclaimed landfill (Fig. 6).

Processes that take place in landfills and inside landfills are long-lasting and virtually unpredictable. A diversity of communal wastes stored in normal municipal landfills makes them structures that affect all environmental zones, including microbiological air composition, through bioaerosol emissions. The atmospheric environment of a waste storage features occurrence of high concentrations of bacterial aerosol, however in spite of very high numbers of microorganisms observed in active landfills sections, the further from the landfill, the lower bioaerosol concentration, which is very sudden trend (down to 550-100 CFU/m^3 in referenced studies). In the zones surrounding landfills there are usually noted small amounts of mesophilic bacteria in the air, which enables rating such air as uncontaminated.

5. Evaluation of the air microbiological quality

Polish Norms PN86/Z-04111/02 and PN86/Z-04111/03 provide not only number estimation for individual bacteria and mould groups in atmospheric air, but they also enable quality classification of studied air samples. Using these norms for rating the air of studied MLS surroundings it was observed that only 16.7% of samples taken within the area of NL zone might be classified as strongly contaminated, while as much as 72.2% of air samples can be considered as uncontaminated with mesophilic bacteria. With distancing from the active landfill dump size the number of mesophilic bacteria significantly decreased. Within the area of reclaimed landfill, more than 90% of samples were classified as unpolluted air, and within the areas surrounding the Municipal Landfill Site as much as 98.3% of studied samples corresponded to the values for unpolluted air (Table 3).

Table 3

Evaluation of the air microbiological quality in terms of bacteria occurring within and in the surroundings of the Municipal Landfill Site in Toruń according to PN-89/Z-04111/02

Sampling site	Air pollution levels	Mesophilic bacteria	Haemolytic bacteria		Actinomycetes
			α	**β**	
New landfill (NL)	not polluted	72,2%*	18,2%	27,3%	22,2%
	moderately polluted	11,1%	57,6%	30,3%	66,7%
	highly polluted	16,7%	24,2%	42,4%	11,1%
Reclaimed landfill (RL)	not polluted	91,4%	34,4%	34,4%	42,9%
	moderately polluted	0%	62,5%	43,8%	45,7%
	highly polluted	8,6%	3,1%	21,8%	11,4%
Surroundings of landfill (S)	not polluted	98,3%	35,8%	37,7%	44,6%
	moderately polluted	1,7%	64,2%	47,2%	51,8%
	highly polluted	0%	0%	15,1%	3,6%

* percentage of samples rated within given classes of the air quality

According to PN86/Z-04111/01, the haemolytic bacteria are recognized as indicators of bacteriological contamination of air with a bioaerosol originating from respiratory systems of humans and animals. Hence, it can be assumed that strong contamination of air with those bacterial groups proves potential threat for human health. When analysing numbers of α-haemolytic bacteria, according to PN86/Z-04111/02 it can be concluded that within the area of new landfill, 24.2% were heavily contaminated samples. Within the storage surroundings, none of the samples were found to be strongly contaminated with α-haemolytic bacteria, while at the reclaimed landfill, 3.1% of the total samples were classified as heavily contaminated. Samples classified as moderately polluted prevailed in all examined zones. It seems very important that samples heavily contaminated with β-haemolytic bacteria took large proportions of all studied zones. Portions of these samples in all studied samples amounted to respectively 42.4% (zone NL), 21.8% (zone RL) and 15.1% (zone S) (Table 3).

Regretfully, the literature concerning microbiological contamination of air within areas of landfills usually presents haemolytic bacteria as a single group with a slight indication of forms which prevailed (α- or β-haemolytic ones). Kocwa-Haluch *et al.* (2004) noticed numbers of those microorganisms exceeding 500 CFU/m^3 of air in the centre of Municipal Landfill Site in Żębocin near Proszowice. In further sites they observed gradual decrease of haemolytic bacteria numbers in the air (down to 50 CFU/m^3), which according to specific norm proves strong contamination. The authors stated that most frequent were bacteria conducting haemolyse β – just as it was in case of tests within the area of the Municipal Landfill Site in Toruń. Also Kaźmierczuk *et al.* (2004) noted considerable numbers of haemolytic bacteria, both within the area of the active landfill and in the surroundings. It follows that, in spite of the fact that numbers of virtually all groups of microorganisms significantly decreased with distancing from active landfill zones, even at some distance they can however pose a potential threat to human health.

Table 4

Evaluation of the air microbiological quality in terms of fungi occurring within and in the surroundings of the Municipal Landfill Site in Toruń according to PN-89/Z-04111/03

Sampling site	Number of moulds in air (CFU/m^3)	Percentage of samples in category (%)
New landfill (NL)	<3000 3000-5000 5000-10000 >10000	83,4 8,3 8,3 0
Reclaimed landfill (RL)	<3000 3000-5000 5000-10000 >10000	94,3 0 5,7 0
Surroundings of landfill (S)	<3000 3000-5000 5000-10000 >10000	96,6 3,4 0 0

Legend:
< 3000 – contaminated air
3000 – 5000 – moderately clean air
5000 – 10000 – a contamination that can adversely affect human natural environment
> 10000 – a contamination posing a threat to human natural environment

Actinomycetes, according to Polish Norm PN86/Z-04111/01, are indicators of air contamination with soil particles. In the course of present studies, it was proved that also for other bacterial groups the greatest percentages of samples heavily contaminated with actinomycetes were observed in the active landfill (42.4%), while the smallest – in the areas surrounding the Municipal Landfill Site (15.1%). Exactly opposite situation was observed in case of percentages of samples that were, according to PN86/Z-04111/02, classified as uncontaminated with actinomycetes (Table 3).

The actinomycetes' numbers observed in the course of present studies did not exceed 400 CFU/m^3 of air. The actinomycetes number noticed by Breza-Boruta and Paluszak (2009) reached much higher levels of 33-1120 CFU/m^3. In case of studies of these authors, more notable was also an impact of landfills on actinomycetes' numbers in the site surroundings. In turn, Kaźmierczuk *et al.* (2004) during estimation of aerosanitary conditions within communal landfill sites noticed an increase of actinomycetes' numbers in the air with distancing from a dump.

Next, Butarewicz i Kowaluk-Krupa (2004) proved strong contamination of air with actinomycetes in all measurement sites within the communal landfill site in Augustów. The noted the greatest numbers of actinomycetes in the centre of the landfill (382 CFU/m^3), despite adverse atmospheric conditions from the perspective of their growth, i.e. frozen soil and low air temperature (-1.1°C). Traczewska and Karpińska-Smulikowska (2000), when conducting air monitoring at the landfill of municipal wastes in Wrocław, also proved large oscillations in numbers of actinomycetes, depending on the season, and thus a strong dependence of the concentration of actinomycetes on actual weather conditions.

Microscopic fungi and their spores constitute important elements of air pollution around the landfill of municipal waste. Within the landfill areas, large amounts of spores and hypha fragments of moulds, like *Penicillium, Cladosporium, Aspergillus, Alternaria, Fusarium, Acremonium, Drechslera,* are observed in the air, as well as yeasts, mainly of genus *Candida*. According to PN86/Z-04111/03, 83.4% of air samples taken in sites situated within the new landfill can be rated among uncontaminated with moulds. In reclaimed site, as much as 94.3% constituted uncontaminated samples, whereas within the areas around the landfill the air samples that were uncontaminated with moulds formed as much as 96.6% (Table 4). The most important circumstance is a fact that none of tested samples proved to contain moulds in numbers exceeding value of 10,000 CFU/m^3, which would be an evidence for pollution posing a threat to natural environment for humans. Bis *et al.* (1998), when analysing the impact of the Communal Landfill Site in Barycza near Cracow on occurrence of fungi, observed relatively small numbers of fungi in (less than 3000 CFU/m^3) in all tested samples from immediate vicinity of the landfill and at the site itself. In turn, Traczewska and Karpińska-Smulikowska (2000), within the landfill in Wrocław, obtained results considerably exceeding the Polish Norm -- both in the summer and autumn seasons in selected sites, the numbers of fungi exceeded 10,000 CFU/m^3, and in case of one site the value reached as much as 20,000 CFU/m^3. Studies by Bis *et al.* (1998) and Breza-Boruta and Paluszak (2009) prove that higher numbers of moulds are often noted in the surroundings of landfills than in the active zones. Similar correlations, particularly in the summer, were also observed in studies carried out in China (Taiwan) (Huang *et al.* 2002) and in Finland (Kaarakainen *et al.* 2008). Nevertheless, it should be noted that although the case of Toruń the data took different values the percentage of fungi in total pool of microorganisms in the areas around the landfill was very high (77%) – the moulds in these areas formed decidedly predominant group of microorganisms.

6. The impact of weather condition on microbiological air pollution

Most studies on microbiological air pollution in landfills confirm that the number of microbes is dependent on weather conditions. Presented in Table 1, basic meteorological parameters measured during the sampling indicate that in the spring and summer months featured generally favourable conditions for growth of microorganisms in the air. It should also be noted that during the autumn-winter season collection of almost all samples were made during the brief rain or snow falls, which had a definite influence on the numbers of microorganisms identified in the air, because precipitations are important atmospheric factors for removing bioaerosols from the air to large extent. Perhaps this is why the results presented in this work have often lower values than quoted literature data. On the other hand, although the values do not exceed norms very much, the presence in the air, among other microbes, numerous mannitol-positive staphylococci and haemolytic bacteria always poses a potential threat to human health.

It should also be noted that in case of this kind of research, each time air sampling for analysis, features current, i.e. momentary state of microbial contamination in the precise time and place. Therefore, undoubtedly it would be useful to systematically monitor the microbiological condition of air within and in the surroundings of the Municipal Landfill Site in Toruń, which would allow accurate assessment of this structure impact on the environment.

With an increase of public awareness of the problem of municipal wastes and their impact on ecosystems, people become more interested in the methods of storage and disposal of sewage, so that each decision on the landfill location must be preceded by a precise analysis of the impact of such structure on all the elements of the environment in such a way as to minimize pressure of the wastes and reduce the risk of santary contamination.

Location of given landfill to a large extent determines a nuisance for the environment and difficulties in operating the landfill. It is generally assumed that landfills should be situated on grounds of low usability: lands degraded in connection with industrial activities, natural hollows and flat lands, however featuring as high as possible thickness of aeration zone. Counteractions toward microbiological contaminations originating from landfill development include appropriate designing, construction and proper operations (Łuniewski, Łuniewski 2010).

7. Summary

To conclude, it should be affirmed that the Municipal Landfill Site in Toruń has a little impact on microbiological contamination of air, since numbers of all tested microbial groups were considerably lower in the landfill surroundings. Only occasionally noted were samples classified as heavily contaminated with β-haemolytic bacteria and actinomycetes in the areas around the landfill. Cases of heavy contamination with other groups of microbes were not observed, which also proves minor influence of the landfill on surroundings. Acquired results prove that appropriately managed reclamation process leads to considerable decrease of air pollution within a closed landfill. Even though some minor cases of outpass of microbiological quality norms were noted, there were observed among others numerous haemolytic bacteria in the air, which always pose a potential threat to human health. This is indicative of a need of constant monitoring of microbiological contaminations emissions, in particular those within the landfill, for a threat to people who work in that area.

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