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Original Research

Sanitary Quality of Soil in and near Municipal Waste Landfill Sites

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Abstract

The present study was aimed at determining the relationship between the operation of municipal landfills and the fluctuations of bacterial indicators of the sanitary quality of soil. Soil samples were collected at monthly intervals from May 2010 to April 2011 at ten sampling sites located on the premises and in vicinity of the reclaimed Municipal Landfill Site (MLS) and the new Municipal Solid Waste Management Plant in Toruń (WMP). Bacteriological analyses (the titre of coliforms, the titre of *Clostridium perfringens,* and the presence of *Salmonella*) were conducted according to the *Microbiological and parasitological guidelines for the assessment of the sanitary quality of soil* issued by the Institute of Rural Health in Lublin. The results obtained led to distinguishing three zones of impact of the facilities on soil. Good sanitary quality of soil was determined 100 m east of the edges of the landfill cells.

Keywords: municipal landfill, bacterial indicators of sanitary quality of soil, coliform bacteria, *Clostridium perfringens*, *Salmonella*

Introduction

Municipal waste dumps present a double threat to soil quality: they are rapidly expanding to new areas, and a direct consequence of depositing waste on the earth's surface is that rainwater and melting snow filter through the waste, picking up and carrying dissolved chemical compounds and microorganisms, that contaminate soil and underground water [1-3]. Municipal waste, particularly their wet fraction with food leftovers, food packages, used sanitary materials, and domestic animal faeces contain a wide variety of microorganisms. Ranging between 108 and 109 for a gram of soil, they constitute a source of bioaresol [4, 5]. Microbial soil contamination observed in the vicinity of landfill sites results from several factors, including the spreading of bioaresol [4-9], the migration of wild birds, rodents and insects [7, 11], and leachate leakage [12]. Inspections conducted by the Polish Inspectorate of Environmental Protection revealed that only 30% of the total number of landfills in Poland were adequately secured against the contamination of soil and natural water [13].

Bacteria periodically found in soil pose serious health hazards for people, including enteric pathogens such as *Salmonella* sp., *Vibrio cholerae*, *Shigella* sp., *Campylobacter jejuni*, *Yersinia* sp., *Escherichia coli* O157:H7 [14, 15], and other pathogens such as *Mycobacterium bovis* [16].

The higher the number of pathogenic bacteria in soil, the greater the likelihood of human and animal infections [17]. Although the role of soil as a reservoir of certain bacterial pathogens is not a question, recent findings show that soil may have a larger role in the transmission of enteric diseases than previously thought [14].

Acquiring thorough knowledge of the influence that landfill sites have on the environment and human health is extremely important and requires comprehensive, long-

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term monitoring. However, methods used to investigate microbial contamination of soil in Poland are still in development. Regrettably, environmental monitoring conducted by Provincial Inspectorates of Environmental Protection is aimed primarily at the analysis of chemical contamination. Moreover, district sanitary epidemiological stations do not keep regular monitoring of microbial quality of soil in areas surrounding municipal landfills. Considering the fact that because of the scarcity of land a great number of landfills close after their exploitation and then when re-evaluated are assigned for recreational purposes, regular monitoring of soil in operating and in reclaimed landfills seems to be of utmost importance. However, environmental protection measures of this kind are extremely rare not only in Poland but worldwide.

Due to the fact that the detection of all pathogenic species in a soil sample is extremely difficult or sometimes even impossible, indirect methods of evaluating soil sanitary quality are applied – they rely on identifying indicator bacteria, which suggests faecal contamination of soil and the presence of pathogenic microorganisms.

The aim of our study was to determine the effects of the reclaimed municipal landfill site and the new landfill site in Toruń on fluctuations of bacterial indicators of soil sanitary quality, i.e. the titres of coliforms, the titres of anaerobic spore-forming bacilli of *Clostridium perfringens,* and the presence of *Salmonella* bacteria.

Materials and Methods

Research Objective

The research was carried out on the premises and in the vicinity of the reclaimed Municipal Landfill Site (MLS) and the Municipal Solid Waste Management Plant (WMP) opened in November 2009 in Toruń.

The MLS (presently reclaimed) in Toruń was established in 1964. On 31 December 2009, after 45 years of operation, it was closed due to its inability to meet new requirements imposed on this type of facility.

The landfill site is located in the northern part of Toruń, approximately 12km from the town center. It is surrounded by flat sandy wasteland, stretching a considerable distance from the dense urban development. The MLS facility covers an area of 15.3 ha in total, has the capacity of 3,747,000 Mg, and rises to 35 m above ground level. The landfill borders the EC Toruń ash dump in the north-east, the Elana waste treatment plant in the south-east, industrial areas and a railway line in the south, and the forest in the west.

The landfill received non-hazardous solid waste and contained four landfill cells including a hazardous waste landfill cell, closed in 2002 and reclaimed in the same year, together with reclaimed liquid waste cells. Only one cell out of four, with an area of 1.8ha, put in operation in 1995, was insulated with HDPE geomembrane and had a leachate collection system with drainage pipes; landfill leachate and runoff were directed to a stabilizing tank and then to the municipal sewage system. In July 2010 the MLS was taken over by the Biogas Inwestor Company, which prepared and executed a landfill gas reclamation scheme for 2010-11 that involved the construction of 20 gas wells together with a system of collecting biogas. For 2011-12 the company has planned to launch a soil rehabilitation program that includes placing a cover of soil over the waste (2.7 ha) and the establishment of grass and vegetation on the surface.

The new landfill cell, with an area of 6.6 ha and a capacity of 1,080,000 m^3, constitutes a part of the WMP opened on 25 November 2009 and located northwest of the reclaimed MLS. The WMP comprises, in addition to a landfill cell, two leachate tanks, a leachate treatment plant, composting facilities (for green and organic waste), technological grounds for composting, and a sorting station of raw materials.

The landfill cell is secured by the following elements: a loam liner, a drainage layer of sand for leachate leakage detection, geotextile, a 2.5 mm thick HDPE geomembrane sheet, and a drainage layer of sand for leachate collection. The landfill leachate is directed to the reverse osmosis installation, which ensures its effective treatment.

Sampling Sites

Soil samples were collected at ten sampling sites located on the premises and in the vicinity of the Municipal Landfill Site (MLS) and the Municipal Solid Waste Management Plant (WMP) in Toruń (Fig. 1).

Sampling Site I – located beyond the impact of the MLS and the WMP, along the line of most frequent winds, approximately 800 m to the southeast
Sampling Site II – located near the leachate tank in MLS
Sampling Site III – located at the entrance to the reclaimed MLS near the wheel cleaning facility (filled with disinfectant) for waste collection vehicles
Sampling Site IV – located at the landfill cell MLS
Sampling Site V – located near the leachate tank in WMP
Sampling Site VI – located near the raw material sorting station WMP
Sampling Site VII – located at the landfill cell in the WMP
Sampling Site VIII – located in the forest 100 m east of the edge of the landfill cell in the WMP
Sampling Site IX – located in the forest, 100 m north of the edge of the landfill cell in WMP
Sampling Site X – located in the forest 100m west of the edge of the landfill cell in WMP and approx. 700 m northwest of the edge of the landfill cell in the MLS

Sampling

Soil samples were collected at monthly intervals from May 2010 to April 2011. The surface layer of soil (to a depth of 20 cm) was collected with a soil sampler from plots with an area of 25 m^2 [18]. The soil samples were then placed in sterile glass jars and transported to the laboratory in a portable ice bag, where the temperature was below 4ºC. In the laboratory, after the soil samples from a particular sampling site were mixed thoroughly and then sieved through a 2-3-mm mesh size sieve, material for microbial

tests was collected. Additionally, gravimetric soil moisture was determined with the method of mass loss in drying [19].

The delay between collecting the samples and conducting the analyses did not exceed 4 hours. In situ temperature measurements (with HANNA soil thermometer) as well as soil pH measurements (with Hellige soil pH tester) were taken during the sampling.

The microbiological tests were aimed at determining the following:

- the titre of coliform bacteria inoculated on Kessler-Swenarton medium for 48 hours at 37ºC and inoculated on Endo medium for 48 hours at 37ºC [19]
- the titre of anaerobic sulphite-reducing *Clostridium perfringens* bacteria, inoculated on Kessler-Swenarton medium for 18 hours at 37ºC, on thioglycol medium, and on litmus milk medium at 37ºC for 24 hours and 48 hours, respectively. The inoculations were preceded by pasteurizing the samples for 20 minutes at 80ºC [19]
- the presence of *Salmonella* bacteria inoculated on peptone medium for 24 hours at 37ºC, as well as on several selective media including Rappaport-Vassiliadis medium (24 hours at 41.5ºC), Sodium Selenite Broth (24 hours at 37ºC), and XLT4 (24 hours at 37ºC); colonies typical of the genus *Salmonella* were subjected to diagnostic tests for *Salmonella* (API, BioMerieux)

For bacteriological tests, ten-fold dilutions of the studied soil samples were prepared using Ringer's solution [19]. The results obtained during testing were shown as a titre and converted to 1 gram of dry soil mass.

Statistical Analysis

Statistical analysis of data was performed using IBM SPSS Statistics 19 software. Significant differences in the effect of the location of the research site and the season of the year on bacterial concentration in soil were tested using two-way analysis of variance (ANOVA). Tukey's HSD test was used to determine which sites are statistically more different. Differences were considered statistically significant when $p<0.05$. Pearson correlation analysis was applied to find a correlation between the physicochemical factors (soil pH, temperature, moisture) and the number of bacterial indicators in soil.

Table 1. Physicochemical properties of soil of the municipal waste dumping sites in Toruń.

	Site	$pH_{(H_2O)}$	Moisture [%]	T [ºC]
Background	I	6.6±0.2	6.2±2.7	3.4-25.2±0.1
MLS	II	6.8±0.4	6.0±3.9	3.4-25.2±0.1
	III	6.8±0.3	10.0±5.2	
	IV	7.4±0.2	9.6±3.9	
WMP	V	5.8±0.3	4.2±2.4	3.5-26.0±0.2
	VI	6.8±0.5	5.2±2.1	
	VII	6.8±0.3	11.6±4.6	
Forest	VIII	5.4±0.7	6.0±2.4	4.1-24.5±0.4
	IX	5.0±0.3	11.2±6.8	
	X	5.3±0.2	4.1±2.6	

Results

Physicochemical characteristics of soil on the premises and in the vicinity of municipal landfills in Toruń are presented in Table 1. Results demonstrate that pH of the soil ranged between 5.0 and 7.4, its moisture varied from 4.1% and 11.6%, and the temperature was between 3.4ºC and 26.0ºC.

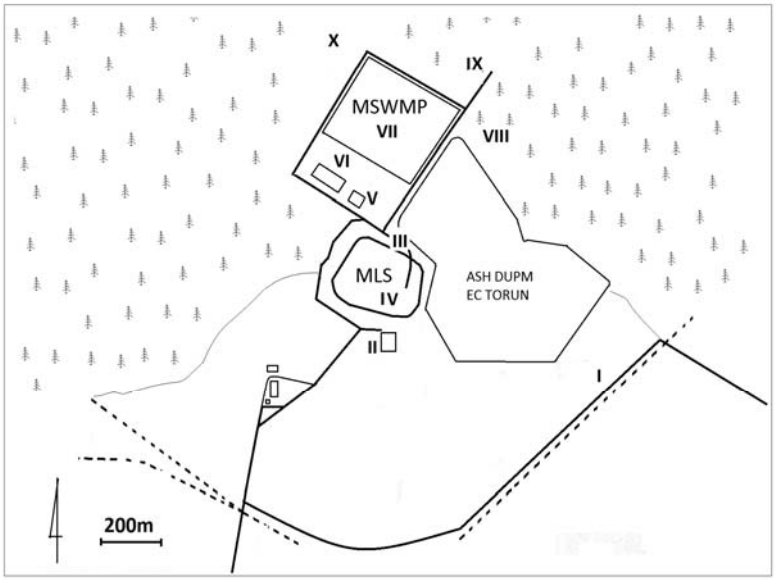

Fig. 1. Outlook of the research sites.
Explanations: MLS – Municipal Landfill Site, MSWMP – Municipal Solid Waste Management Plant; I-X research sites

Table 2. The range of coliform bacteria (titre) in soil of the municipal waste dumping sites in Toruń.

	Site	Date of sampling							
		5/4/2010	6/8/2010	7/6/2010	8/3/2010	9/6/2010	10/5/2010	3/3/2011	4/5/2011
Background	I	nd	nd	nd	0.01	nd	nd	nd	nd
MLS	II	0.09	0.02	nd	0.002	0.7	0.05	0.04	nd
	III	0.0004	0.008	0.001	0.002	0.007	0.05	0.1	0.3
	IV	0.01	0.008	0.03	0.0005	0.01	0.04	0.1	0.07
WMP	V	nd	0.04	0.02	0.004	0.07	nd	nd	nd
	VI	0.01	0.04	nd	0.007	0.04	0.04	nd	nd
	VII	0.008	0.005	0.003	0.005	0.008	0.02	0.02	0.04
Forest	VIII	0.04	0.04	0.05	0.01	0.1	0.07	nd	nd
	IX	0.2	0.04	nd	0.05	0.04	0.2	0.1	0.3
	X	nd	nd	nd	0.1	nd	nd	nd	nd

nd – not detected

Table 3. The range of *Clostridium perfringens* (titre) in soil of the municipal waste dumping sites in Toruń.

	Site	Date of sampling							
		5/4/2010	6/8/2010	7/6/2010	8/3/2010	9/6/2010	10/5/2010	3/3/2011	4/5/2011
Background	I	0.05	0.0006	nd	0.2	nd	nd	0.03	nd
MLS	II	0.04	0.004	0.2	nd	nd	nd	nd	nd
	III	0.0005	0.0002	0.0004	0.03	nd	0.01	ns	0.1
	IV	0.005	0.0004	0.007	0.2	nd	0.1	nd	0.04
WMP	V	0.005	0.0003	0.009	0.003	nd	nd	0.002	nd
	VI	0.009	0.001	0.1	0.2	0.05	nd	nd	nd
	VII	0.0006	0.0002	0.001	0.06	nd	nd	0.004	0.008
Forest	VIII	0.006	0.002	0.1	0.004	nd	nd	0.003	nd
	IX	0.07	0.0004	0.004	0.08	nd	nd	0.02	0.06
	X	0.01	0.0008	nd	nd	nd	nd	nd	nd

nd – not detected

The results concerning the number of coliform bacteria in the investigated soil are presented in Table 2. According to the results, coliforms titre ranged widely from 0.0004 to 0.3. Sampling Site III, located at the entrance to the reclaimed MLS near the wheel-cleaning facility filled with disinfectant, was evaluated as the most heavily contaminated. Soil samples collected at this sampling site exceeded the limit values of coliform bacteria in soil as specified by the Institute of Rural Medicine, Lublin [19], from May 2010 to September 2010. As stated in the guidelines [19], the titre of coliforms in contaminated soil is smaller than 0.01. Sampling Site VII, located at the landfill cell in WMP, is considered second in terms of soil contamination with coliform bacteria. Higher than average titres of coliform bacteria in soil were noted here from May 2010 to September 2010. Moreover, considerable soil contamination with coliforms was noted twice, in June 2010 and September 2010, at the landfill cell in MLS. In August 2010 high concentrations of coliforms in soil were observed near the leachate tanks in the MLS and the WMP. However, in both cases the soil contamination may be described as incidental as it occurred only once during the entire research period. At sampling sites located 100 m from the edge of the landfill cell to the east, along the line of most frequent winds, to the north and to the west the titre of coliforms did not exceed permissible standards. Also, at the sampling site located farthest from both landfills and thus beyond the impact these facilities have on the environment, the concentration of coliforms did not exceed acceptable values.

Table 4. Analysis of variance (ANOVA) of the number of coliform bacteria and *Clostridium perfringens* in soil according to the location of the research sites (1) and season of the year (2).

Factor / Indicator	Site		Season	
	F	p	F	p
coliforms	7.09	0.000	4.85	0.010
Clostridium perfringens	1.59	0.135	16.69	0.000

F – among-groups variance/within-groups variance, p – significance level

The results concerning the number of *Clostridium perfringens* in the soil on the premises and in vicinity of the municipal landfills in Toruń are presented in Table 3. According to this data the titre ranged widely from 0.0008 to 0.2. Sampling sites III, located at the entrance to the reclaimed MLS, and VII, located on the WMP landfill cell, were assessed as the most contaminated with *Clostridium perfringens*; the soil samples collected at both sites exceeded the limit values specified by the Institute of Rural Medicine, Lublin [19], contained above-average titres of these bacteria from May 2010 to July 2011. According to the guidelines [19], the titre of *Clostridium perfringens* in contaminated soil is smaller than 0.001. Isolated cases of exceeding norms established for *Clostridium perfringens* were noted only in June 2010 at sampling sites I, II, V, IX, and X.

The results of the investigations conducted for this study show that bacteria from the genus *Salmonella* were not detected in any of the collected soil samples. According to the Polish Norm [18] and the Microbiological and parasitological guidelines for the assessment of the sanitary quality of soil, these bacteria should not be present in soil [13, 19].

Statistical analyses indicate that the number of coliforms in the soil varied depending on the site and the season of the year ($p<0.001$ and $p< 0.010$, respectively, Table 4). No significant differences in the number of *Clostridium perfringens* on different sampling sites ($p< 0.135$) were observed, but their number depended on the season of the year ($p<0.001$, Table 4). A higher number of coliforms in soil was determined in summer (from June to August) than in early spring or autumn, which is directly connected with higher soil temperature (in summer), known to stimulate the growth of these mesophilic bacteria. It was established that site I and site X differed statistically from the remaining sites (except sites V and VI). Site VI differed significantly from site VII, while site VI did not differ significantly from any other sampling site. Physicochemical factors such as soil temperature and moisture had a moderate positive influence on the number of coliforms ($r=0.53$, $r=0.49$) and *Clostridium perfringens* ($r=0.33$, $r=0.29$) in soil.

Discussion

Coliform bacteria, which are defined as aerobic or anaerobic Gram-negative, non-spore forming bacteria, are among the commonly used bacterial indicators of the sanitary quality of soil. They belong to the *Enterobacteriaceae* family and include the following genera: *Escherichia*, *Citrobacter,* and *Enterobacter*. As stated in the *Microbiological and parasitological guidelines for the assessment of the sanitary quality of soil* issued by the Institute of Rural Medicine, Lublin [19], the titre of coliforms in contaminated soil is smaller than 0.01.

The examination of soil quality in landfill sites conducted by Flores-Tena et al. in Mexico [20], Collins and Kennedy in Great Britain [21], and Oviasogie et al. in Nigeria [22] confirm the presence of coliforms in municipal waste dumped in these facilities. Studies carried out by the Polish Institute of Environmental Protection suggest that coliform bacteria spread through leachate, which typically contain substantial amounts of these microorganisms in the initial phase of a landfill operation [13]. The leachate at the San Nicolas landfill in Mexico contained 10^{-4} to 10^{-5} of pathogenic *Escherichia coli* var II, but they were not isolated from the soil [20]. Similarly, Frączek [23] did not determine coliforms in the soil at any of the ten sampling sites located on the premises and in the vicinity of the Barycz landfill site in Kraków.

Research conducted by Marcinowska et al. [24], who investigated the sanitary quality of soil on the premises and in the vicinity of the landfill site in Ujków Stary, indicates that higher than average numbers of coliforms were noted at the entrance to the landfill and near the leachate tank, which corresponds with the results presented in this paper. These deviations from required norms were noted by the author three times in 30 tests. We observed unallowable numbers of coliforms in soil 15 times in 80 tests.

Clostridium perfringens are Gram-positive, anaerobic spore-forming bacteria of the genus *Clostridium* in the *Bacillaceae* family and can be found in the normal intestinal flora of human and animals, in feces, and in soil. They are characterized by long-term survivability in the environment in the form of spores [25].

The data presented in this paper shows that the titre of *Clostridium perfringens* in the soil of municipal landfill sites in Toruń ranged widely from 0.0008 to 0.2. Similar results, ranging between 0.00001 and 0.1, were received by Frączek [23], who investigated the soil sanitary quality in the Barycz landfill in Kraków. The results obtained by Marcinowska [24], who conducted her research in the landfill in Ujków Stary suggest that the titre of *Clostridium perfringens* was higher than 0.001 in all collected soil samples but never exceeded acceptable values.

Salmonella is a genus of rod-shaped Gram-negative bacteria of the *Enterobacteriaceae* family, which indicate a poor sanitary quality of soil. They are considered to be reliable indicators of soil contamination owing to their long-term survivability in the environment. They cause food-borne disease in people and, according to the Polish Norm [18] and the *Microbiological and parasitological guidelines for the assessment of the sanitary quality of soil*, they should not be present in soil [13, 19]. The results of the investigations conducted for this study show that *Salmonella* spp. were not detected in any of the collected soil samples. Similar results were obtained by Collins and

Kennedy [21] in Great Britain as well as by Flores-Tena in Mexico [20]. However, different results were received by Frączek [23], whose findings indicate that *Salmonella* spp. were present in soil samples collected at 9 out of 10 sampling sites in the Barycz landfill site in Kraków. *Salmonella* spp. were not isolated only from soil samples collected at the sampling site located the farthest distance (i.e. 1230 m) from the landfill. *Salmonella* spp. were also found in the soil in the landfill in Ujków Stary by Marcinowska [24], who confirmed their presence at the entrance to the landfill, near the leachate tank, in the operation zone, and at the edge of the landfill cell.

The results obtained during the research account for distinguishing three zones of impact of the reclaimed MLS and the new WMP on soil. The first zone, characterized by the highest contamination, covers an area in close proximity to the entrance to the reclaimed MLS (site III), and the operating landfill cell (site VII) in the MLS as well as in the WMP. Naturally, the contamination on the above sites is caused by the deposited waste and (site III only) by leachate from inefficient (leaky) systems of drainage ditches or damaged sump pumps.

The soil on top of the reclaimed landfill cell was definitely less contaminated, although the current sanitary standards were occasionally violated. The contamination is caused by the waste deposited here in the past and bird droppings (birds are regular residents of landfill sites) [7, 11].

The second zone includes sampling sites where contamination was observed occasionally but at least once (Sampling Sites I, II, IV-VI, IX, and X). The most probable causes of this occasional soil contamination on the premises of the landfill sites and in their vicinity include the following:

1) the spreading of bioaerosol-containing bacterial indicators,
2) animals such as birds, rodents, stray dogs and cats feeding on waste, frequently seen on both landfill sites in Toruń during the sampling.

The third zone, where indicator bacteria were never noted in above-average amounts, covers only sampling site VIII, located 100m east of the WMP and approximately 550 m northeast of the reclaimed MLS.

Conclusions

1. The sanitary quality of soil on the premises and in vicinity of the operating WMP and the reclaimed Municipal Landfill Site in Toruń is similar to the sanitary quality of soil on other municipal premises of this type.
2. The highest soil contamination was noted at the entrance to the reclaimed landfill site (site III) and at the landfill cell in the operating landfill site (site VII). This high contamination is caused by the deposited waste as well as (site III only) leachate from the inefficient (leaky) systems of drainage ditches and/or damaged sump pumps located at the foot of the reclaimed cell.
3. The reclaimed landfill cell continues to be a source of soil contamination.
4. Only at site VIII, located in the forest 100 m east of the landfill site, did soil have good sanitary quality.
5. At the remaining sites excessive soil contamination (above the acceptable standards) was observed occasionally, usually only once in the entire research period. The contamination may be caused by bioaerosol forming on the landfill site, and by animals – mainly birds, rodents, stray dogs, and cats.

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References

1. KARACZUN Z.M., INDEKA L.G. Environmental Protection. Publishing Agency ARIES, Warszawa, **1999** [In Polish].
2. DAVIS M.L., CORNWELL D.A. Introduction to Environmental Engineering. International Edition, 4th ed.; McGraw Hill: New York, **2008**.
3. BASHIR M.J.K., ISA M.H., KUTTY S.R.M., AWANG Z.B., AZIZ H.A., MOHAJERI S., FAROOQI I.H. Landfill leachate treatment by electrochemical oxidation. Waste Manage. **29**, 2534, **2009**.
4. SZPADT R., TRACZEWSKA T.M. Selected sources of microbiological pollution. Environmental Monitoring Library, PIOŚ, Rzeszów **1998** [In Polish].
5. HEALTH PROTECTION AGENCY. Impact on health of emissions from landfill sites. Documents of the Health Protection Agency, Radiation, Chemical and Environmental Hazards, Health Protection Agency, pp. 19-24, **2011**.
6. NOWAK A., PRZYBULEWSKA K., TARNOWSKA A. Microbiological contamination of air in the Szczecin area in different seasons. Microbes in the environment. The occurrence, activity and importance. AR, Kraków 527, **1997**.
7. NOWAK A., PRZYBULEWSKA K., LITWIŃCZUK M. Attempt to assess the impact of the municipal waste landfill in Sieraków near Szczecin in the soil microflora. Ecological aspects of soil microbiology. AR, Poznań 233, 1998 [In Polish].
8. BARABASZ W., CHMIEL M.J., ALBIŃSKA D., MAZUR M.A. Landfills as sources of bioaerosol and microorganisms harmful to health. Pap. Inst. Oil Gas J., **145,** 143, **2007**.
9. HUANG CH.-Y., LEE CH.-CH., LI f.-CH., MA Y.-P., SU H.-J.J. The seasonal distribution of bioaerosols in municipal landfill sites: a 3-yr study. Atmos. Environ. **36**, (27), 4385, **2002**.
10. FRĄCZEK K., ROPEK D. Municipal waste dumps as the microbiological thread to the natural environment. Ecol. Chem. Engin., **18**, (1), 92, **2011**.
11. MRAMBA F., BROCE A.B., ZUREK L. Vector competence of stable flies, *Stomoxys calcitrans* L. (Diptera: *Musciade*), for *Enterobacter sakazakii*. J. Vector Ecol., **32**, (1), 134, **2007**.
12. GRISEY E., BELLE E., DAT J., MUDRY J., LOTFI A. Survival of pathogenic and indicator organisms in groundwater and landfill leachate through coupling bacterial enumeration with tracer tests. Desalination **261**, 162, **2010**.

13. ADAMEK M., DUDEK W., KUDŁACIK J., RAINHARD B., PAWŁOWSKI A., SZYSZKOWSKA B., SZYSZKOWSKI P., ZIELIŃSKI W. Methods of research and recognition the impact of solid waste landfills on groundwater environment. Ministry of Environment, Department of Geology. Warszawa **2000** [In Polish].
14. SANTAMARÍA J., TORANZONS G.A. Enteric pathogens and soil: a short review. Int. Microbiol. **6**, 5, **2003**.
15. EPSTEIN E. Human pathogens: hazards, controls and precautions in compost. In: Compost utilization in horticultural cropping systems.; Lewis Publishers: Boca Roca, USA, pp. 361-380, **2002**.
16. YOUNG J.S., GARMLEY E., WELLINGTON E.M.H. Molecular detection of *Mycobacterium bovis* and *Mycobacterium bovis* BCG (Pasteur) in soil. Appl. Environ. Microbiol. **71**, 1946, **2005**.
17. DRZAŁ E., KOZAK E., KUCHARSKI B., PODGÓRSKI L., STREB M., SUCHY M., SYNOŚ A., Physicochemical and microbiological hazards in the environment by waste. Library of Environmental Monitoring, Warszawa, **1995** [In Polish].
18. POLISH NORM PN -Z- 19000-1:**2001**.
19. STROCZYŃSKA-SIKORSKA M., KŁAPEĆ T., CHOLEWA A., Methodological Guidelines (microbiological-parasitological) to assess the health of the soil. Institute of Rural Medicine. Lublin, **1995** [In Polish].
20. FLORES-TENA F.J., GUERRERO-BARRERA A.L., AVELAR-GONZÁLEZ F.J., RAMÍREZ-LÓPEZ E.M., MARTÍNEZ-SALDAÑA MA.C. Pathogenic and opportunistic Gram-negative bacteria in soil, leachate and air in San Nicolás landfill at Aguascalientes, Mexico. Rev. Latino. Microbiol. **49**, (1-2), 25, **2007**.
21. COLLINS C.H., KENNEDY D.A. The microbiological hazards of municipal and clinical wastes. J. Appl. Bacteriol. **73**, 1, **1992**.
22. OVIASOGIE F.E., AJUZE CH.U., IGHODARO U.G. Bacterial analysis of soil from waste dumpsite. Arch. Appl. Sci. Res. **2**, (5), 161, **2010**.
23. FRĄCZEK K. Seasonal changes in soil sanitary indices in and near the municipal waste dumping site in Kraków agglomeration. Wat. Environ. Rur. Are. **2**, (30), 49, **2010**.
24. MARCINOWSKA K., FRĄCZEK K., GRZYB J. Assessment of soil health in the impact zone of the landfill waste other than hazardous and inert. Probl. Pap. Prog. Agric. Sci. **501**, 283, **2004** [In Polish].
25. QUINN P.J., MARKEY B.K., LEONARD F.C., FITZPATRICK E.S., FANNING S., HARTIGAN P.J. Veterinary microbiology and microbial disease, 2nd ed.; Willey-Blackwell, UK, pp. 243, **2011**.