Chapter 3

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Impact of the Landfill Site on Respiratory and Enzymatic Activities of Soil

1. Introduction

Soil is one of these biosphere components that are particularly vulnerable to degradation in relation with civilization development. Is should be noted that we do not know currently any better substrate for agricultural economy. Soil is a place of rooting plants, supplying them with water and mineral compounds, thus indirectly it is a source of food for us. Wastes form one of the major threats to the sphere of soil. The development of civilization has destroyed the natural cycle of matter circulation in nature and we are facing increasing amounts of wastes. Wastes can be defined as harmful to the environment, worn and not used living and economic products of our activities. Solid wastes' disposal can be done by storing them in designated places, i.e. landfills. Depending on waste origination, two main kinds are known: communal (municipal) wastes and industrial ones (Karaczun, Indeta 1999). In terms of the type of stored wastes, there are three types of landfills: for hazardous, neutral, or other wastes. Hazardous wastes form a special group. They are toxic and therefore their storage may take place at the landfill, the location of which provides protection for the surrounding waters and grounds. Storage of certain types of hazardous wastes is prohibited and allowed is only their storage before disposal (e.g., medical wastes). Much attention is devoted to biodegradable wastes, including communal ones.

In accordance with the policy of the European Union, we aspire to reduce waste origination. One of the solutions, which are at present emphasised, consists in recovery of recyclable materials from the products already used thanks to recycling. Segregation of wastes carried out by the individual waste producers can reduce their volume by up to 30%. Selected organic wastes may be processed into biogas and compost; glass can be reused by the glassworks, scrap – by steel mills and electrical machinery industry, paper – by pulp and paper industry (Libudzisz *et al.* 2008).

But regretfully, the most common, although arousing a lot of reservations, solution of the waste problem remains storage. The landfill is defined as a building facility, located and arranged in accordance with applicable laws, meant for deposit of wastes of known properties. The composition of this concept is as follows: communal waste landfill, liquid waste dump and heaps of earth and rock masses. There are following types of waste disposal sites: hazardous waste landfills, neutral ones and those non-hazardous and non-neutral (communal) (Rosik-Dulewska 2002). In Poland, communal wastes are stored in disorganized, half-organized, and organized structures. Disorganized landfills are located in natural cavities and require no special preparation. As a consequence, in such a landfill, take place i.a. following phenomena: uncontrolled emissions of gases into the atmosphere, surface waters' contamination and pollution of the surrounding areas with dusts and light fraction waste by dispelling. Half-organized landfills have geomembranes that isolate deposited waste from the grounds. In case of this type of landfills, also emissions of liquid and gaseous substances take place. Organized landfills feature special location, which takes into account the hydrogeological and geotechnical criteria and meets the applicable technical requirements (Rosik-Dulewska 2002).

Kemp and Żuk (1973) divide the municipal landfill site at:

- unauthorized or uncontrolled – which according to sanitary regulations are unacceptable;
- controlled – the storage of waste is carried out in places designated by the authorities of local administration and is agreed with the urban and sanitation authorities;
- improved – storage is carried out as in case of controlled dumps, but in addition to the storage area is specially prepared.

Communal landfill environment is heterogeneous – in different areas of landfill decomposition of organic matter occurs at different speeds. Microorganisms that carry out decomposition of the waste come mainly from the wastes themselves. To waste degrading microorganisms are primarily aerobic and anaerobic bacteria and microscopic fungi. In the first stage (about a week) aerobic microorganisms use oxygen and give rise to anaerobic environment. The next stage is the hydrolysis of organic matter (sugars, proteins, fats) involving, among others following types: *Enterobacter*, *Alcaligenes*, *Escherichia*, *Streptococcus*, *and Clostridium*. The resulting simple compounds are then easily fermented into volatile fatty acids, acetic acid, alcohols and carbon dioxide. The environment becomes acidic, but then again becomes alkaline, by the action of microorganisms using acetic acid as a source of carbon. After stabilization of pH (neutral reaction), methanogenic archaea are activated, which are absolute anaerobes. Their operation is used to produce biogas, a valuable source of thermal energy. Biogas is mainly composed of methane and carbon dioxide ((Libudzisz *et al.* 2008).

Biogas can be disposed from a landfill in a passive mode (migration under own pressure to neutralizing devices) or active mode (using the suction pump and perforated tubes). Practically, the usable gas must you dehydrated and purified. Methane contained in the biogas can be converted to methanol in order to use it in fuels. Uncontrolled release of biogas from landfill sites can have very adverse effects (the main cause of fires, poisonings, increasing the greenhouse effect) (Libudzisz *et al.* 2008).

Landfills form a twofold threat to soils. Firstly, landfills constantly seize new areas. Some of these areas can be restored to agriculture or forestry through reclamation of exhausted landfills. But others, especially those in which there were unauthorized dumps, may be degraded irreversibly. A second threat is the introduction of chemical pollutants into soils and groundwaters. They result from migration of pollutants originating from a landfill along with the rain waters and leachates (Karaczun, Indeta 1999).

The choice of location depends on many factors. Consideration should be given the opinions of the local community. In order to prevent the pollution of surface and groundwaters, soils and air, the type of geological substrate should be considered (poorly permeable lands are preferred) (Leboda, Oleszczuk 2002). Also the slope should be taken into account (less than 10˚) and the stability of lands and dumped waste. Moreover, landfills must not be located in protected areas (national parks, scenic parks) (Libudzisz *et al.* 2008). The advantage of storing waste as a disposal method is the simplicity of the process and high economic efficiency in a short run, with low individual expenditures (Bilitewski *et al.* 2006).

Storage of waste in landfills contributes to formation of substances that are burdensome and dangerous, and pose a threat to natural environment. This threat to the environment can manifest in: air pollution (physical, chemical, odours, contamination with biogas, microbiological contamination), soil pollution, noise pollution, nuisance associated with the presence of fowl, rodents, insects (Leboda, Oleszczuk 2002).

Physical and chemical air pollution is created both, during the operation of the landfill itself, and in the presence of varied technical equipment and cars delivering wastes on the landfill. Therefore, additionally automotive pollutions are created, typical for roadside strip, such as: CO, NO, hydrocarbons, heavy metals (Leboda, Oleszczuk 2002).

Odours, due to the specificity, can be rated among the most difficult to define and evaluate. Occurrence of odours in the landfill area is related to digestion processes and secretion of biogas that take place in there. The difficulty of their liquidation is associated with too large area of their emissions and failures of a landfill support teams to perform treatment consisting in backfilling layers of wastes with neutral material (Leboda, Oleszczuk 2002).

Leachates belong to the most troublesome pollutants, since they affect surfacewaters, groundwaters and soils. They are formed by digestion processes and as a result of washing the waste layers with waste waters. Therefore, the leachate capture systems belong to major investments at a landfill (Leboda, Oleszczuk 2002). Soil pollutions are among the most difficult to remove. Contamination occurs by release of harmful and dangerous microorganisms into the soil. As for heavy metals the contamination occurs in about 50-meter roadside strip, i.e. where are the transport routes („Protection of air and waste problems” 1997). Hence, in the contaminated roadside strips, there are contraindications for growing leafy crops such as lettuce, beets or cabbage due to the accumulation of heavy metals in the leaves (Curzydło 1994). At landfills, in addition to the aforementioned contaminants, there is also the spread of plagues of insects, fowl and rodents, which are burdensome for local residents. Among insects, flies and mosquitoes predominate, and among birds, black-headed gull *(Larus ridibundus* L.*)* and the rook *(Corvus frugilegus* L.*).* Gull feeds directly on the landfill, and it nests in the vicinity. They are beneficial due to the removal of food debris. 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).

Impact of landfills on the enzymatic and respiratory activities of soil has been studied on the example of Municipal Landfill Site in Toruń, located about 7 km north-east of the centre of the city built-up area. It is a place for communal waste disposal for the town Toruń as well as Lubicz, Obrowo and Wielka Nieszawka. The landfill serves approximately 284 thousand residents. From the north and west, the site is surrounded by forests, and from the other directions with wastelands. Tests at the landfill site pertain to: the volume of precipitation, substances and parameters indicative of leachate and ground waters and landfill gas, the level of groundwater, leachate water volumes, structure and composition of landfill mass, setting of landfill surface (Operating instructions for the landfill in Toruń, in force since 01.07.2004). Research work carried out near the landfill has shown that the area is part of a high terrace in the old valley of Vistula. Geological structure is of Holocene and Pleistocene:

- Holocene is represented by a thin layer of soil bulk; embankments are composed of sands mixed with humus, debris, slag, garbage
- Pleistocene is represented by sands of river-glacial accumulation under the soil and embankments, under which, in turn, are deposited river-glacial gravels over lacustrine-glacial clays (Wilczynski 1989). The river-glacial sands and gravels comrises single aquiferous horizon (Wilczynski 1989).

The landfill site is divided into two zones: MLS – Municipal Landfill Site (closed since December 2009) and MWTP – Municipal Waste Treatment Plant. Municipal Landfill Site is located in the northern part of the town Toruń at Kociewska street, in industrial-storage district, about 12 km away from the town centre. The landfill is located on the flat land, and the substrate is sandy. The MLS area is adjacent to the north-east with EC TORUN ashes storage, from the south-east with the sewage treatment plant premises of ELANA, while from the south with the industrial area and railway line, whereas from the north-west with a forest. The storage area is located outside urban areas. The Municipal Landfill Site in Toruń has operated since 1964. The landfill was established at Kociewska street by decision of the Municipal National Council in Toruń on 10 October 1964. Location of the complex of facilities for the management of wastes is consistent with provisions of the local area development plan of the city of Torun. According to the Act on Wastes, the Municipal Landfill Site in Toruń is storage of non-hazardous and neutral wastes and it features separate sections for storage of hazardous waste.

The area designed for waste storage covers four storage sections and reclaimed liquid waste dumps:

- Sections for disposal of wastes other than hazardous and neutral A and B of the area 10.5 ha unsealed, where the section B is excluded from the operation since 2002,
- Section for storage of non-hazardous and neutral wastes N of the area 1.8 ha – operated since 1995, sealed with HDPE geomembrane with a built-up leachate drainage system,
- Reclaimed in 1994 sections for liquid waste dumps of the area 1.4 ha,
- Section for storage of hazardous wastes (post-galvanic and post-varnish ones) of total area 0.8 ha – out of service since 2002.

Total area of the landfill is 15.3 ha. The landfill is fenced and monitored and supervised 24 hours a day. Section for storage of hazardous wastes (post-galvanic and post-varnish ones) of the Municipal Landfill Site in Toruń is a separate fenced facility, located in the southern part of MLS, between the access road to the headsections of MLS and the leachate anti-rolling tank. The total area of hazardous waste landfill is 8117 m^2, while the area of hazardous waste section amounts to 2700 m^2, and the total capacity 6100 $m^{3.}$

The landfill section is a ground single chamber tank formed through building embankments. The bottom ordinate is 70.10 m above sea level; ordinate of the surrounding ground bank 73.60-73.70 m above sea level. The section is sealed with a clay layer of thickness 50 cm, and then with an additional 1.5 mm HDPE geomembrane. Under the clay layer, there is a rotational drainage for disposal of gases accumulated beneath the section bottom. On the southern slope of the section, there is an emergency surrounding ditch. The inner western bank has four concrete water catchment troughs. On the western bank crown, there is constructed a road of a width of 3 m for the delivery of wastes. The landfill area is marked.

Leachates and rain waters are discharged from the section periodically, by pumping into an adjacent anti-rolling leachate tank from MLS, and then to the municipal sewerage system (Guidelines 2008). The anti-rolling tank and associated equipment are located in the immediate vicinity of the landfill, near the section, between the existing waste heap, the section for hazardous wastes and local sewage treatment plant of the company "ELANA". 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.

The Municipal Landfill Site has been out of service since December 2009 and undergone a reclamation process. The most essential task is a reclamation of the top part of the main section A+N (surface 2.7 ha) of the Municipal Landfill Site (MLS) in Toruń at Kociewska street, resulting from the mandatory degassing landfills (Regulation of the Minister of Environment of 24.03.2003 r. – Journal of Laws No. 61, item 549 as amended).

The reclamation consists in: gas reclamation (2011) earth reclamation (2012). The gas reclamation consisted in:

- construction in the MLS of 20 biogas wells with connections to the additional (second) pumping-adjustment module (MPR-2),
- installing in the MLS area a container module MPR-2 with a capacity of approximately 375 Nm ^{3}/h,
- construction of landfill gas dehydrator at MPR-2 module.

The earth reclamation will consist in covering the top part of the main section surface A+N (of area 2.7 ha) of the MLS with earth reclamation coat (total thickness of about 0.9 m) and the sowing with so-called pioneer vegetation, i.e. a mixture of graminaceous and papilionaceous plants (element of biological reclamation).

The main objective of the MLS earth reclamation process is:

- Execution of the sealing layer for the landfill bowl surface, thereby reducing the migration of landfill gas into the atmosphere;
- Execution of gas drainage layer, improving migration of gas into the well and increasing its collection;
- Restoration of usability of the land by adjusting the storage body, maintenance of a technological road and sowing the storage bowl surface with grass and papilionaceous plants.

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 heap 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.

The surface soil was collected from the new (MWTP) and reclaimed landfill (MLS) from four zones: I – dump, II – zone 50 m away from landfill dump, III – zone 100 m away from landfill dump, IV – zone 800 m away from landfill dump. Distribution of zones on the new and reclaimed landfill shown in Fig. 1.

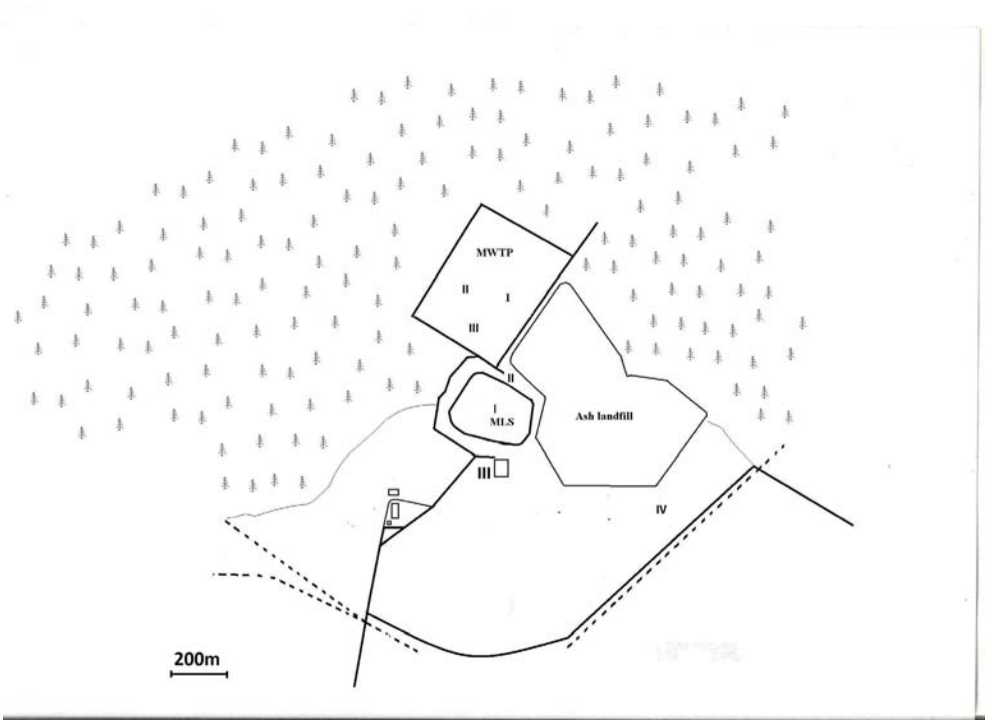

Fig. 1. Distribution of zones on the new and reclaimed landfill in Torun

MWTP – Municipal Waste Treatment Plant, the new landfill area, MLS – reclaimed landfill, area reclaimed, I – dump, II – zone 50 m away from landfill dump, III – zone 100 m away from landfill dump, IV – zone 800 m away from landfill dump

Use of microbiological indicators in the analysis of the soil environment helps to assess the condition of soil, its biological activity, fertility and productivity. Impact of landfills on the soil environment was studied based on the estimation of numbers of soil microorganisms and their enzymatic and respiration activities. The number of soil microorganisms was estimated using a plate method with application surface culture on the substrate surface suitable for the studied group of microorganisms. The number of heterotrophic bacteria culture was estimated on Plate Count Agar medium (Merck). Nystatin was added to the medium (0.1 g dm^{-3}) in order to inhibit the growth of moulds. Incubation was carried out 7 days at 22^oC. The number of actinomycetes was determined on medium Difco Actinomycetes Isolation Agar. Incubation was carried out for 14 days at 28^oC. Moulds were estimated on medium Rose Bengal (Merck). Incubation was carried out for 14 days at 25^oC. All sowing cycles were performed in three instances.

To determine the soil respiratory activity measurement system OxiTop Control 12 (WTW) was applied. The respirometric rule of oxygen estimation is based on the consumption of oxygen by the organisms with simultaneous secretion of carbon dioxide. The second gas is bound by the absorbing agent and therefore it does not appear in the form of free gas. Consequently, the change in pressure is attributed only to oxygen consumption. Samples of soil (100 g) were placed in the measurement vessel, where a quiver with the absorbent CO_2 (0.4 g NaOH) was placed. OxiTop measuring heads were screwed to the measuring vessels, and then they were inserted into the thermostatic cabinet. Recording of measured values was made using the OC 110 controller in „Pressure" mode. Samples were incubated 5 days at a temperature *in situ*. Estimations were carried out in three instances. As a unit of respiratory activity, there was adopted mg O_2 kg^{-1} s.m. of soil within 5 days.

The overall activity of hydrolytic enzymes was estimated using fluorescein diacetate (non-specific substrate for hydrolases) according to Adam and Duncan (2001). Flurescein concentration released under the influence of hydrolases within an hour, at a temperature *in situ* was measured using spectrofluorometer HITACHI F-2500, with an excitation wavelength of 480 nm and an emission wavelength of 505 nm. Estimations were carried out in three instances. As a unit of hydrolase activity adopted was μ fluorescein g^{-1} s.m. of soil h^{-1}.

The results were analysed statistically using an application STATISTICA 6.0. The main statistical method used for calculations was the two-factor analysis of variance ANOVA, which enabled a comparison of independent factors: the zone and the storage area.

2. The number of microorganisms in the soil environment

In recent years, there is observed an increase in municipal and industrial waste. Storing of those in landfills is one of the most common methods. It is worth noting that each landfill, even properly designed and operated, is a potential source of pollution in given environments (Kempa 1994). In order to reduce its adverse impact, it is important to know the scale of nuisance, especially the dynamics and scope of the spread of pollutions around landfills (Żygadło 1999). Landfills pollute the atmosphere, soil, water and plants. Soil contamination occurs primarily through the deposition of bioaerosols, and by wild fowl, rodents and insects. The biggest impact of the landfill is observed in the immediate vicinity, especially within the scope of zones of sanitary protection. Most studies on the effects of dumping sites were based on the evaluation of chemical changes in soil and surface and ground waters. In case of microbiological contamination, available data are scarce because there are no commonly accepted and standardized methods for assessing the impact of landfills on the microbiological parameters of the environment, especially air and soil (Nowak *et al.* 1998).

Our studies show that the soil microorganism numbers in the new landfill and reclaimed one decreased with increasing of distance from the landfill (Fig. 2).

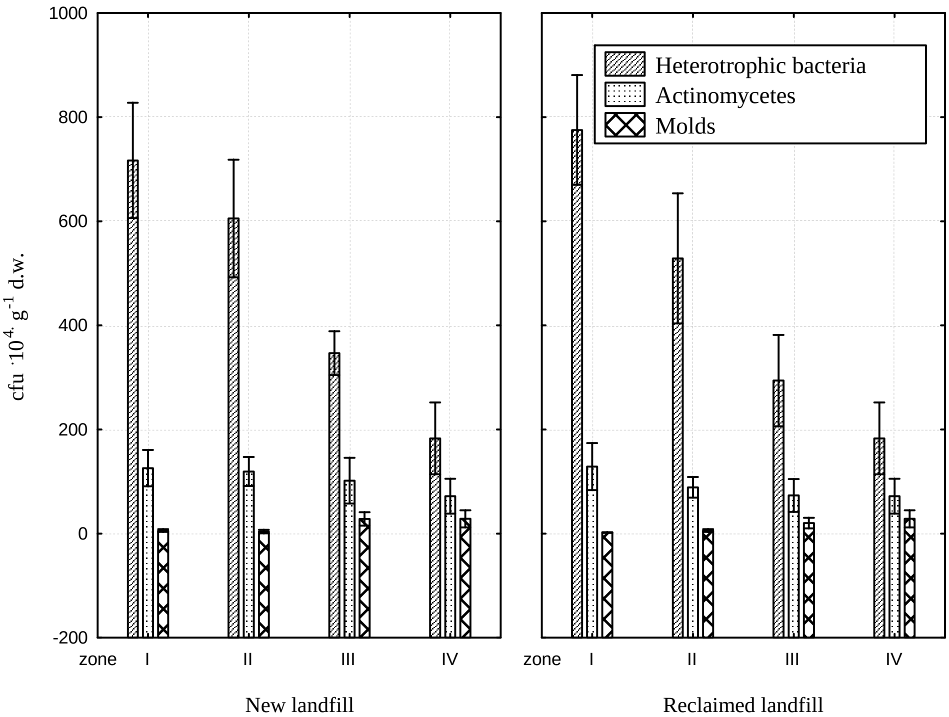

Fig. 2. The number of microorganisms in the soil environment for new and reclaimed landfill in Torun

I – dump, II – zone 50 m away from landfill dump, III – zone 100 m away from landfill dump, IV – zone 800 m away from landfill dump

Only the number of moulds increased with distancing from the dump landfill. Both, in new and reclaimed landfills, dominated heterotrophic bacteria, and the least numerous were molds. The sizes of all groups of microorganisms, both in new and reclaimed landfills were the highest in August and lowest in May and October (Table 1).

Analysis of variance (Table 2) showed statistically significant differences in numbers of soil microorganisms between the points of soil sampling, but there is no significant difference in the number of microorganisms between the new and reclaimed landfills.

Nowak *et al.* (1998), while studying the impact of communal waste landfill operation on soil microflora found that heterotrophic bacteria were most numerous, not much less were the actinomycetes, and moulds were the least. The analysis of variance, acquired by the authors, showed that the number of bacteria and actinomycetes significantly depended on the sampling site. The authors found most of these microorganisms near the landfill. The further away from the landfill, the lower the numbers. In turn, the abundance of microscopic fungi was not affected by the place of soil sampling.

Table 1

The number of microorganisms (cfu · $10^4 \cdot g^{-1}$ d.w.) for new and reclaimed landfill in Torun

Date of sampling	Zone	New landfill			Reclaimed landfill		
		Hetero-trophic bacteria	Actino-mycetes	Molds	Hetero-trophic bacteria	Actino-mycetes	Molds
25.05.2010	I	750	103	5	870	98	3
	II	522	142	1	335	78	5
	III	340	97	13	150	58	19
	IV	115	62	17	115	62	17
07.06.2010	I	780	11	3	987	105	2
	II	610	12	3	481	82	8
	III	360	157	36	279	68	24
	IV	138	78	13	138	78	13
28.07.2010	I	750	119	6	751	110	3
	II	620	125	5	580	110	9
	III	365	135	34	372	109	25
	IV	140	180	16	140	180	16
24.08.2010	I	832	161	7	780	154	2
	II	750	150	10	689	112	7
	III	400	106	43	382	112	34
	IV	276	108	49	276	108	49
06.09.2010	I	650	172	10	733	205	2
	II	680	100	3	576	90	6
	III	334	75	14	300	51	11
	IV	250	45	45	250	45	45
06.10.2010	I	539	89	5	620	100	2
	II	450	79	2	510	65	2
	III	280	40	28	282	42	9
	IV	179	31	31	179	31	31

I – dump, II – zone 50 m away from landfill dump, III – zone 100 m away from landfill dump,
IV – zone 800 m away from landfill dump

Table 2

Two-way analysis of variance of the number and activity of microorganisms in the soil, depending on the zone (1) and landfill area (2) in Torun

Factor	Heterotrophic bacteria		Actinomy-cetes		Molds		Hydrolytic activity		Respiratory activity	
	F-ratio	*P*	F-ratio	*P*	F-ratio	*P*	F-ratio	*P*	F-ratio	*P*
Zone (1)	92,2	***	6,2	**	20,9	***	194,4	***	53,1	***
Area (2)	0,45	ns	2,1	ns	0,77	ns	12,6	ns	3,9	ns

*** values statistically significant at $P < 0.001$, ** values statistically significant at $P < 0.01$,
ns – value not significant

Frączek *et al.* (2006), studying the chemical and microbiological properties of soil in the vicinity of municipal landfills in Tarnów, confirmed that the numbers of microorganisms in the soil environment depended primarily on the distance from the landfill. Further, Marcinowska *et al.* (1998) investigated the occurrence of actinomycetes in the air and soil within the landfill in Barycz near Kraków. Tests were conducted in the spring and summer in three consecutive years (1996-1998), and soil samples were drawn from nine measurement sites. The greatest abundance of actinomycetes in the soil was found at the measuring site far away from landfill site (1,200 m). The authors believe that this is a natural phenomenon, because at this point there are large amounts of organic matter, a source of nutrients for actinomycetes. At the measurement site located at an active landfill, the numbers of actinomycetes are lower than reported in other sites. The authors argue that it could have been caused by adverse environmental conditions that had been created to these microbes. In turn, Bis *et al.* (1998) investigated the occurrence of fungi, including toxin-forming ones, in the air and soil within the same communal waste landfill. The tests were conducted in the plant vegetation period in three consecutive years (1996-1998), and soil samples were drawn from nine measurement sites. The smallest number of fungi was observed at the site located in closest proximity and at the landfill itself. Similar studies were conducted on the landfill of communal wastes in Tarnów Krzyż by Frączek (2004). He studied the impact of communal waste landfill on the numbers of fungi in the soil environment, with particular emphasis on toxin-forming fungi. He ran the study from April 1999 to March 2000, and drew the samples from eight sites. The author observed the greatest numbers of these microorganisms in the active part ofthe landfill. Outside the zone of operation, in the most distant point, the numberof these microorganisms decreased by half. Many studies show that the number of microorganisms in the soil is conditioned, inter alia, by their presence in the air (Marcinowski *et al.* 1998; Bis *et al.* 1998). The authors report that from among 35 species of actinomycetes isolated from soil and 20 from air, 14 occurred with high frequency in both, the soil and the air. While 21 species of moulds isolated from air, 39 species from soil and 18 species represented both environments. This situation is caused deposition of bioaerosols and transfer of contaminations by wild fowl, rodents and insects (Nowak *et al.* 1998). It is worth noting that the air is a transitional environment for microorganisms, and therefore it is not suitable for proliferation or life. According to Barabasz *et al.* (1997) an infection with microorganisms that are found in the air around landfills is dependent on many factors: the degree of dispersion, air movement, composition of particles, and biomicroclimate and biometeorological parameters (temperature, humidity, atmospheric pressure, radiation, precipitation, electrical phenomena).

3. Hydrolytic activity of soil

Microorganisms inhabiting various environments feature manifold activities and operations. One of the roles they play is the decomposition and transformation of macromolecular organic substances. These processes occur thanks to the existence of heterotrophic microorganisms that are capable of producing enzymes that cause decomposition of polymeric organic compounds. Kobus (1995) believes that microbial activity is determined by various factors. The main factor is the amount of available organic matter, which comes primarily from plant residues, root secretions, and partly from microflora and microfauna biomass. Hydrolytic activity is a good measure of the economy of organic matter in natural habitats, because 90% of the energy flows through microbial destruents (Heal *et al.* 1975). Suitable techniques for measuring the total hydrolytic activity must be simple and sensitive and the incubation period should be as short as possible. Spectrophotometric determination of hydrolysis using fluorescein diacetate (FDA) has proved to be simple, sensitive and rapid method for determination of microbial activity in soil and garbage (Schnürer, Rosswall 1982). FDA is hydrolysed by many different enzymes, such as proteases, lipases, esterases (Rotman, Papermaster 1966), and the product of its decomposition is fluorescein, estimated by spectrofluorometric method (Schnürer, Rosswall 1982).

Our research shows that the highest hydrolytic activity, just like the numbers of soil microorganisms, was found in the soil near the dump of studied landfills, and least in soil distant 800 m from the landfills (Fig. 3).

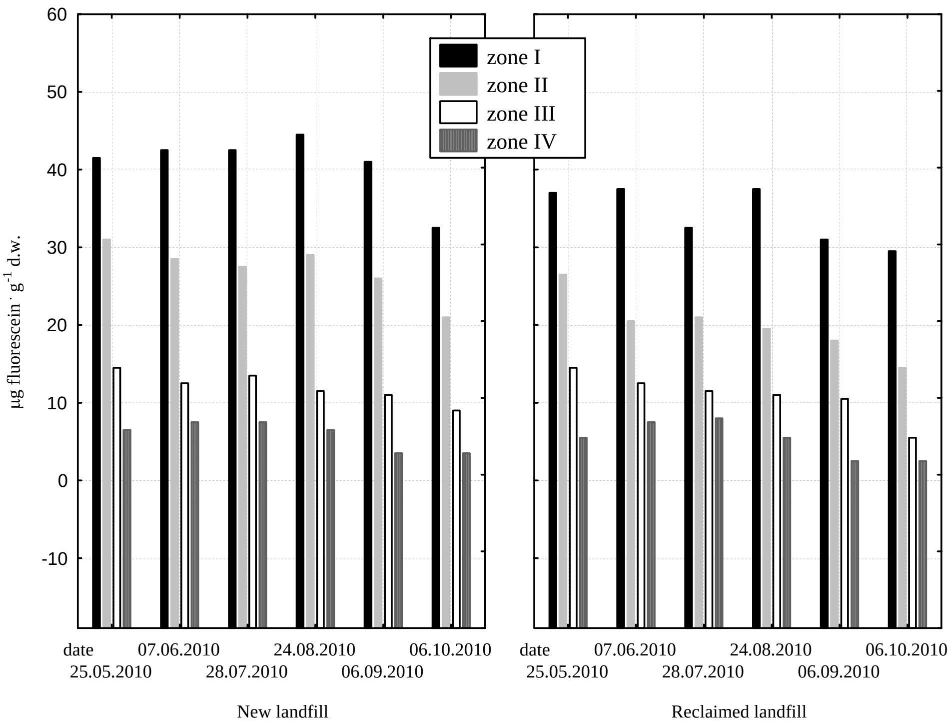

Fig. 3. Hydrolase activity in the soil for new and reclaimed landfill in Torun

I – dump, II – zone 50 m away from landfill dump, III – zone 100 m away from landfill dump, IV – zone 800 m away from landfill dump

When analysing the activity of hydrolases in individual periods of research, it can be stated that from May to September it was similar. In October, it fell slightly. Analysis of variance (Table 2) showed significant differences in the hydrolytic activity at covered sites, but no significant differences between the hydrolytic activity of the new and reclaimed landfills were observed. Most probably, the landfill pollutions significantly affected increase of this activity. Research by Schnürer and Roswall (1982) point to the differences in hydrolytic activities between the layers of soil, which may be a reflection of smaller amount of soil organic matter at greater depths. A similar correlation was observed by Domsh *et al.* (1979) and Witkamp (1973). Garbolińska and Borkowski (2006), by studying the activity of acid phosphatase and assimilable phosphorus content, observed higher enzymatic activity in the surface soil than in deeper layers, both in samples drawn from meadows and beech and fir forest. In case of ecotone, i.e. the transitional zone between different biocoenoses, they noticed no significant differences in enzyme activity between the layers of soil. The authors argue that this is probably due to higher activity of microorganisms in the topsoil and greater amounts of fine roots of plants. It is they that are responsible for the production of enzymes in the soil. George *et al.* (2005) confirm that the enzymatic activity is overalls higher in rhizosphere than in loose soil, which is due to secretion of enzymes by the roots. Lalke-Porczyk *et al.* (2008) noticed a two times higher activity of hydrolytic enzymes in soil samples connected with willow roots than in soil beyond the reach of roots operation. It is assumed that the total enzymatic activity of soils consists of intra- and extra-cellular activities of microorganisms. This depends on many factors, and the greatest impact is the type of added organic matter. Kucharski and Władowska (2004), in soil fertilized with liquid manure, have found the greatest activity of dehydrogenases in the structures fertilized with manure less than the higher dose, which is justified by the decline in fertility of the soil fertilized with too high doses. Hydrolytic enzyme activity is also affected by changes in humidity and oxygenation of the soil (Gliński *et al.* 1983). Chmielewski (1998), studying the microbiological activity in grassland soils in three peat bog habitats of Wizna stated that the peat moisture was the main factor to determine the activity of enzymes studied by the author. The level of respiratory activity of microorganisms, beside enzymatic activity, is an important indicator that determines the intensity of transformations of organic matter in water bodies (Gossens *et al.* 1984).

4. Respiratory activity of soil

Oxygen plays an essential role in aquatic and terrestrial ecosystems, because it has a direct impact on occurring in there chemical and biological processes. It is most actively acquired by heterotrophic bacteria. The level of respiratory activity of microorganisms, beside enzymatic activity, is a good indicator of the intensity of transformation of organic matter in aquatic and terrestrial environments. The rate of oxidation of respiratory substrates by microorganisms depends on their physiological diversity and enzymatic activity. Bacterial respiration is controlled by multifunctional complex endoenzymes determining the flow and rate of diffusion of oxygen through the membrane into cells. Microorganisms oxidize respiratory substrates of varying intensity depending on availability of nutritional substrates. Undoubtedly, respiration activity is correlated with the abundance of microorganisms colonizing the environment. In the aquatic ecosystem, the intensity of microbiological processes is proportional to the degree of lake eutrophication. With increasing trophy increases the amount of availability of organic matter. This results not only in increase of total number of microorganisms but also to increase the percentage of metabolically active cells.

Measurement of respiratory activity in aquatic and terrestrial ecosystems, still, faces many unresolved methodological problems. In the ecology of organisms, the measurement of respiratory activity, respiration techniques are used as well as enzyme and radiological ones. In our study we used respirometric measuring system OxiTop that allows recording the results in larger intervals. It is important when using compounds difficult to decompose which may be present in the landfill. A new generation of OxiTop for determining respiratory activity allows saving the measured values of the successive days, by providing an electronic system for measuring pressure and memory (WTW 1998). Vähäoja *et al.* (2005) have searched for the precise method of determining the biodegradability of different oils in groundwater. The method they have applied to determine oxygen consumption using OxiTop have brought more accurate and precise results compared to traditional methods. Similar observations had Hufschmid *et al.* (2003) studying pollution in industrial wastewater.

Our results indicated that oxygen consumption was greatest in soil at the dump of surveyed landfills, and the smallest in the soil 800 m away from the landfill (Fig. 4). The level of respiratory activity of soil in different periods of the research was very diverse.

Analysis of variance (Table 2) showed significant differences in the hydrolytic activity at covered sites, but no significant differences between the hydrolytic activity of the new and reclaimed landfills were observed. Undoubtedly, the landfill pollution contributed to increase of the respiratory activity of soil. Swiontek Brzezinska *et al.* (2010), by examining the level of respiratory activity in the soil in the presence of shrimp waste, found that the respiration activity depended on: temperature and time of incubation, soil reaction, and shrimp waste. The authors noted the highest values of respiratory activity in summer in the presence of head segments of shrimp, which is mainly composed of protein. On the other hand, the soil microorganisms the least used the shells of shrimp that contain significant amounts of difficult to decompose chitin. Quemada and Menacho (2001), studying soil respiration one year after the addition of sewage sludge, found that temperature and water content affect the soil respiration. Further, Nadelhoffer *et al.* (1992) believed that soil respiration increases exponentially or linearly with increase of temperature.

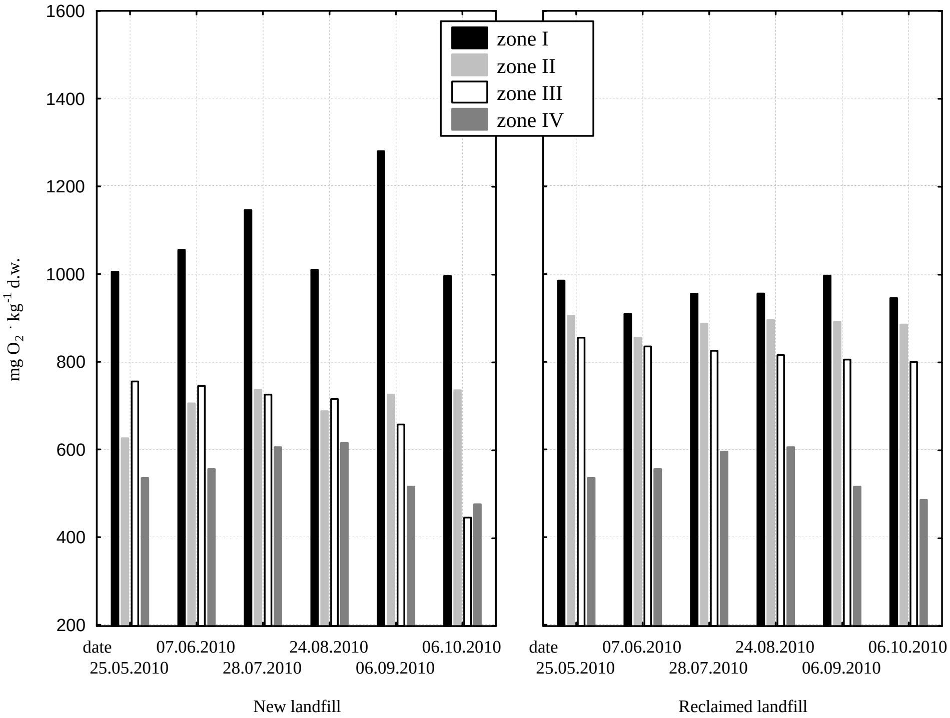

Fig. 4. Soil respiration activity of a new landfill and reclaimed landfill

I – dump, II- zone 50 m away from landfill dump, III – zone 100 m away from landfill dump, IV – zone 800 m away from landfill dump

Hence, the above environmental factors influence the biological activity of soils and the diffusion of carbon dioxide (Kelting *et al.* 1998). The chemical substances present in soil are unstable and can be rapidly oxidized by soil microorganisms. Therefore, they affect the rate of microbiological soil respiration (Silora, McCoy 1990).

Conclusions

The numbers of microorganisms in the soil environment depend primarily on the distance from the dump landfill. In the soil environment, at the landfill, a higher hydrolytic and respiration activity was observed than in the soil beyond the reach of the landfill impact. No significant differences in soil microbial abundance or hydrolytic and respiratory activity between the new and reclaimed landfill.

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