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Remediation of landfill soils with sewage sludge

1. Pedobiont successions in the first stages of soil remediation

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The present study is devoted to soil formation process in landfills remediated with sewage sludge. Abundance and successions of pediobionts (microorganisms and microarthropods) at the beginning of remediation were investigated in the first and second years of remediation. The results showed that the soil of the remediated landfill was predominated by mites of the *Acarididae* group typical of this stage in the first year after remediation, whereas in the second year the abundance of *Acarididae* reduced and mites of the *Collembola* group gained the dominant position. In the first year of remediation, the number of microorganisms in the landfill soil was 10–100 times higher than in the soil of landfill peripheries. The structural functional ratio of the functional groups of bacteria (M/H) shifted toward the increasing abundance of mineralizers, indicating an intensive mineralization and degradation of organic matter. The processes of mineralization were more intensive than those of humification. The concentrations of heavy metals produced no negative effect on the activity of microorganisms and zoocoenoses. Yet in the first and second years after remediation, all metals accumulated in abundance in the soil of the landfill and its peripheries. In the first year after remediation the grass cover in the landfill and its peripheries accumulated rather high concentrations of heavy metals. These concentrations were respectively 4.6–6.2 and 2.4–6.0 times higher than in the grass cover of a clean environment.

Key words: landfill, heavy metals, microorganisms, microarthropods, sewage sludge

INTRODUCTION

With expanding destroyed soil areas (quarries, landfills) the problem of soil remediation becomes increasingly acute. There are many landfill soil remediation technologies (Rynk, 1992). Yet data on the biological processes and their patterns in remediated soils are scanty.

When poor soils are used for landfill ground remediation, the soil forming process is very slow (Eitminavièiûtë, Matusevièiûtë, 2005). Sewage sludge is an organics rich fertilizer able to intensify soil formation processes. However, this economically cheap fertilizer has some negative features: a large content of nitrogen and phosphorus, heavy metals, various organic (often unidentified) toxic chemical compounds, and pathogenic microorganisms.

Remediation with sewage sludge requires evaluation of the level of pollution of the forming soil. Microarthropod communities are successfully used for soil health evaluation. They reflect pH and the C/N ratio in soils and pollution with heavy metals (Straalen van, 1997). Most soil zoocoenoses are fixed and stable. Their abundance, spread, changes of successions of separate groups and changes of the population in the trophic chain are reliable indices of the ecological state and health of natural and anthropogenic soils (Pankhurst, 1997; Pankhurst et al., 1997; Straalen, 1997; Parisi et al., 2005).

On summarizing investigations of the use of sewage sludge as a fertilizer, V. V. S. R. Gupta and G. W. Yeates (1997) reported that low levels of soil pollution with heavy metals (Cu, Cr and As reach 109–161 mg/kg) stimulate the reproduction of protozoa and do not reduce the abundance and spread of nematodes (Yeates et al., 1994). Yet high levels of pollution with these chemical elements (>700 mg/kg) promote changes in the dominant trophic groups.

The negative impact of heavy metals on soil microorganisms has been reported by many authors. Analysis of roadside soil polluted with Cu, Zn and Pb has revealed that micromycetes, cryptogamous and cellulose decomposing bacteria are most tolerant, whereas actinomycetes, bacteria assimilating mineral nitrogen and oligonitrophilic bacteria are most vulnerable to this impact (Lugauskas ir kt., 2005).

Fertilization of destroyed soils with sewage sludge (250 t/ha of dry material) increased the abundance and species diversity of micromycetes at the beginning of remediation. Rather high concentrations of heavy metals in the remediated soil (Ni 125, Cr 309, Cu 289, Zn 428, Pb 52 mg/kg) in six years produced no adverse effect on the microbiological activity, except ammonifiers (Bagdanavièienë, Ramanauskienë, 1997; Bagdanavièienë, Budavièienë, 1997). Fertilization of poor soils with sewage sludge (8–10 t/ha of dry matter) strengthened the microbiological activity of soils. Yet higher amounts of sludge (20 t/ha) failed to produce this effect.

Poor cultivated sandy loam soils are dominated by an microarthropod complex typical of agrocoenoses. After fertilization of this type of soils with sewage sludge (8–20 t/ha) the dominance of the manure–compost microarthropod group was shortlasting and did not supersede or even reduce the dominant agrocoenose group of microarthropods (Eitminavièiûtë ir kt., 1995). According to the literature data, the abundance, spread and successions of separate groups and populations of microfauna (protozoa, nematodes) and microarthropods after fertilization or remediation of soils with sewage sludge depend on the amount of inserted sludge and the concentration of heavy metals in it. Experiments with collembola have revealed that separate species follow different distribution patterns in soils polluted with copper (Filser, Hölscher, 1997). It has been determined that some collembola species are able of changing diets for survival in an environment polluted with heavy metals. Species tolerant and sensitive to soil pollution have been identified (Gillet, Ponge, 2003). Only a few standard biotests have been developed for soil toxicity evaluation. One of them is based on collembola *Folsomia candida* reproduction (ISO 11267:1999), another on earthworm *Eisenia fetida* survival and reproduction (ISO/FDJS 11268-1, 1994 and ISO/FDJS 11268-2, 1997).

The aim of the present work was to investigate the patterns of biological processes taking place in soil remediated with sewage sludge and to evaluate the health of this soil based on the abundance dynamics of microorganisms and microarthropods and the structure of their complexes. The first article of the series is devoted for pedobiont successions in the first stages of soil formation.

MATERIALS AND METHODS

The Bukiðkës landfill (20 km north of Vilnius) was the object of investigation. The landfill of domestic, building and industrial waste was built in a former gravel quarry. Its area is 1.7 ha. It was remediated with sewage sludge in 2001 using 300 t/ha of dry sludge. Investigations were carried out in 2002–2003 in two areas: 1 – in the middle of the landfill, 2 – in the landfill peripheries, five series of investigations for microorganisms and microarthropods in each. The following indices were investigated: the structure, abundance and species composition of microarthropod complexes, the abundance and species composition of insect larvae, the abundance of microorganisms, physiological groups and the patterns of humification and mineralization processes, concentrations of heavy metals in the soil and the grass cover of the study areas. Soil water content, pH and carbon content were determined during sampling.

Samples were taken in June and September following the standard zoological and microbiological methods for soil (Сэги, 1983; Гиляров, Стриганова, 1987).

Statistical data were processed using Microsoft Excel (Èekanavièius, Murauskas, 2000).

RESULTS

Physicochemical characteristics of soil. A year after insertion of sewage sludge the reaction of remediated soil was close to neutral (6.49 and 6.25); soil water content was 32.0–38.1% and C 34.6–27.2% (Table 1). The temperature of the soil surface and deeper layers was high, especially in spring (29 and 31 °C). The sludge layer was fully covered by plants predominated by wormwoods, cereals, fleabanes and pigweeds.

The poor sandy soil of the control area was characterized by a low water content and alkaline medium (Table 1).

A year after landfill remediation (2002–2003) with sewage sludge (300 t/ha) the sludge layer was uneven (30–50 cm) (Table 1). The concentrations of heavy metals in the landfill were almost the same as in the sewage sludge from Vilnius. Zn and Cd values were considerably higher than the maximum permissible concentrations (MPC) of heavy metals for sandy loam soils (2 and 2.5 times, respectively) (Table 2). The values of heavy metals in the landfill peripheries were considerably lower than MPC for sandy loams. The values of some metals (Cu, Pb, Mn, Co, and Cr) were even close to the background ones. The concentrations of Cu, Zn and partly Ni and Sr in the landfill were considerably higher than in the peripheries. The difference of the concentrations was $p < 0.05$ or close to this value, *i.e.* statistically significant (Table 2).

Table 1. **Physical characteristics of Bukiðkës landfill and its peripheries**

Place	Year	Temperature, °C				pH		Humidity, %				Plant cover, %	Beginning of remediation (2001), amount of used sludge, t/ha	Thickness of sludge layer, cm
		air		surface		5–10 cm								
		months												
		06	09	06	09	06	09	06	09	06	09			
Landfill	2002	25	15	29	18	31	18.5					100		
	2003	15	18	15	18	16	16.8	6.49	6.25	32.0	38.1		300	30–50
Peripheries	2002	25	15	24	14	23	14					20–30		
	2003	15	16	16	16	17	16.7	8.25	8.02	6.2	4.3			

Table 2. **Concentration of heavy metals (mg/kg in the soils and grasses of Bukiðkës landfill and its peripheries**

Place	Year	Months	Cu	Pb	Zn	Mn	Co	Ni	Cr	Cd	Fe	Sr
Vilnius sewage sludge			222.4	21.1	619.6	410.7	13.5	91.8	94.8	5.8	8760.1	18.0
Landfill	2002	06	126	40	300	280	19	46	40	5	6600	20
		09	146	47.5	430	266.6	18,3	55	33.3	5.5	6666	10.6
	2003	06	142	8	1060	336	17	144	4	12,6	8640	11
		09	126	66	660	300	42.8	104	70		11400	13.4
	$\bar{x}$		135.0	40.4	612.5	295.7	24.3	87.3	36.8	7.7	8326.5	13.8
Peripheries	2002	06	7	11	40	300	15	15	18	2.3	6600	13
		09	3.6	9.5	16	106.6	11.6	27	4.3	3	2666	3.3
	2003	06	10.6	19	34	320	10.6	23.8	16.6	6	8000	9
		09	9.6	12.2	40	256	13.4	28.6	7.8		8000	11.6
	$\bar{x}$		7.7	12.9	32.5	245.7	12.7	23.6	11.7	3.8	6316.5	9.2
	$p < 0.05$		0.0002	0.14	0.04	0.29	0.15	0.06	0.20	0.10	0.14	0.06
MPC in sandy loam			**100**	**100**	**300**	**1500**	**30**	**75**	**100**	**3**		
Background concentration (HN 60:2004)			**8**	**15**	**26**	**427**	**4.3**	**12.0**	**30.0**	**0.15**		
Grasses in the landfill	2002	06	15	6	90	250	6	14	2	1.7	176	7
		09	6.1	8.3	33	70	10	18.3	0	2.5	166	3,3
	2003	06	16.6	7.6	78	220	6.8	13.4	2	6.4	200	3
		09	15.8	5	90	180	10.6	18	1		108	1.4
	$\bar{x}$		13.4	6.7	72.8	180.0	8.4	15.9	1.3	3.5	162.5	3.7
Grasses in the peripheries	2002	06	11	6	20	74	6	14	4	1.4	488	6
		09	3.6	5.8	32	70	10	18.3	0	2.2	166	3.3
	2003	06	7	6	23	42	6	13.4	0	5.4	140	4
		09	8.6	7.4	40	100	6.2	20	1		232	3
	$\bar{x}$		7.6	6.3	28.8	71.5	7.1	16.4	1.3	3.0	256.5	4.1
	$p < 0.05$		0.04	0.72	0.06	0.08	0.30	0.39	1.00	0.15	0.34	0.53
MPC in clean grasses (Lubytë ir kt., 1994)			**1.9–4.7**	**0.5–1.3**	**1.3–12**	**30–72**		**2.7–8.3**	**0,8–2.7**	**0.1–0.4**	**10–109**	
Perennial cereals (Lubytë ir kt., 2001)			**2.3**	**1.2**	**11.7**	**38.6**		**2.72**	**1.32**	**0.27**	**44.4**	

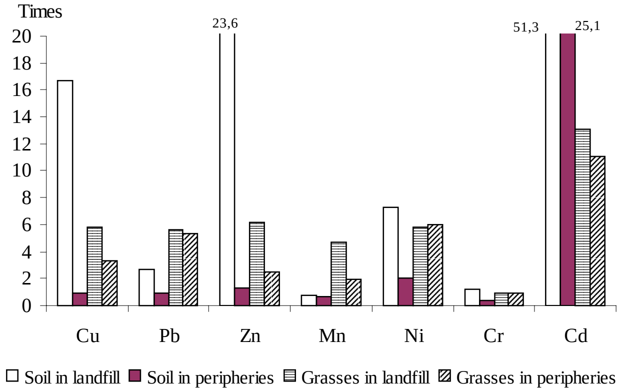
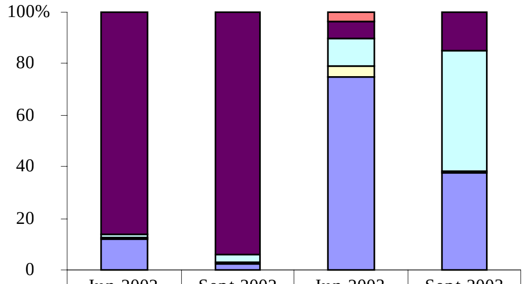
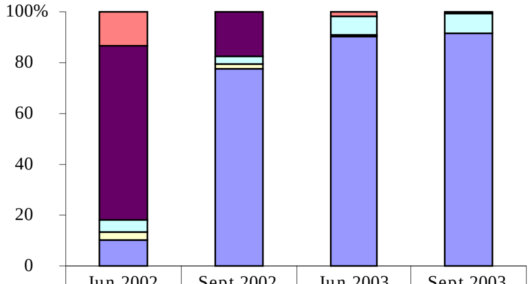


Fig. 1. Relative concentrations of heavy metals in soils and grasses of the landfill and its peripheries (reference value – background value of heavy metals for clean soils and grasses). Times are plotted on the axis



Landfill soil

	Jun 2002	Sept 2002	Jun 2003	Sept 2003
■ Oribatida	0,02	0,2	3,4	0
■ Acaridiae	86,3	93,6	6,6	15,2
☐ Gamasina	1,3	3,5	10,9	46,4
☐ Tarsonemina	0,5	0,5	4,4	0,5
■ Other mites	0	0	0	0
■ Collembola	11,9	2,2	74,7	37,9



Periphery soil

	Jun 2002	Sept 2002	Jun 2003	Sept 2003
■ Oribatida	13,2	0	1,9	0,3
■ Acaridiae	68,4	17,7	0	0,6
☐ Gamasina	5,3	3,2	7,1	7,6
☐ Tarsonemina	2,6	1,6	0,3	0
■ Other mites	0	0	0,6	0
■ Collembola	10,5	77,5	90,1	91,5

Fig. 2. Successions of microarthropods in landfill soils and its peripheries in the first and second years after remediation

In the first year after soil remediation, plants growing on the landfill accumulated rather great amounts of heavy metals as compared with plants growing in a clean environment. The concentration of heavy metals in the landfill grasses 4.6–6.2 times and in grasses from the landfill peripheries on the average 2.4–6.0 times exceeded the values characteristic of perennial cereals. The concentration of cadmium exceeded the natural values 12.9 and 11.1 times, respectively (Table 2, Fig. 1). The concentrations of metals in the peripheral grass differed but little from the concentrations in the landfill grass, with an exception of Cu. The statistical significance of its concentration differences was $p = 0.04$. The statistical significance of the values of all the other investigated metals was $p > 0.05$ (Table 2).

Characteristics of zoocoenoses. A year after the beginning of remediation, an assemblage of acarid mites (Acaridiae) dominated in the population of landfill soil microfauna (Eitminavièiûtë, 1997). These mites play an important role in the initial stages of soil remediation (Тишлер, 1971). They mechanically crush the matter making it ready for assimilation by microorganisms (Тишлер, 1971). Acarid mites are good indicators of the quantity and quality of organic matter (Чернова, 1982).

Acarid mites accounted for 86.3% of the total of microarthropods in the spring of the first year of remediation with sludge and for 93.6% in the autumn (Fig. 2). At present, *Caloglyphus radionovi* and *Glycyphagus domesticus* are eudominant (Umbrasienë, 1997). The total abundance of microarthropods in the landfill soil reached 916.2 thou/m^2, including 791.2 thou acarid mites. In the soil of landfill peripheries the microarthropod abundance was only 3.8 thou/m^2. *Acaridiae* accounted for 68.4%. The unusual abundance of microarthropods, especially of acarid mites, in the soils fertilized with sewage sludge has been reported by many authors (Lübben, Larink, 1991; Umbrasienë, 1997). Phoresis by insects and small mammals is the cause of this. Besides, part of microarthropods arrive with the sludge, especially when the sludge has been stored in stacks before use. All other species of microarthropods and insect larvae were found only as solitary individuals.

Changes occurred in microarthropod assemblages in the second year after remediation: the abundance of *Acaridiae* reduced whereas the abundance of *Collembola* increased. In the spring of 2003, *Collembola* accounted for 74.7%, *Gamasina* 10.9% and *Acaridiae* only for 6.6% of microarthropods. In the soil of the landfill peripheries *Collembola* accounted for 90.1%, *Gamasina* 7.1% and *Acaridiae* disappeared altogether (Fig. 2). In the autumn of the same year, first marks of microarthropod succession in the soil of the landfill appeared: *Gamasina* (46.4%) and *Collembola* (37.9%) were dominant, whereas in the soil

Table 3. **Species diversity of microarthropods in the soil of landfill remediated with sewage sludge (Bukiðkës, 2002–2003)**

Species	Landfill								Peripheries							
	2002				2003				2002				2003			
	months															
	06		09		06		09		06		09		06		09	
	T.ind. /m^2	%	T.ind. /m^2	%	T.ind. /m^2	%	T.ind. /m^2	%	T.ind. /m^2	%	T.ind. /m^2	%	T.ind. /m^2	%	T.ind. /m^2	%
Collembola																
Proisotoma minima	7.5	6.8			5.5	11.2	23.5	83.9								
Proisotoma minuta													0.2	0.3	0.3	1.0
Lepidocyrtus sp. 2	6.7	6.1	0.2	13.3	2.9	5.9										
Lepidocyrtus sp. juv.					3.3	6.7	0.3	1.1	0.1	20.0			0.1	0.2	0.4	1.3
Hypogastrura assimilis	95.0	86.1	0.2	13.3	28.6	58.4	3.6	12.9	0.2	40.0	0.1	2.0	0.5	0.8	25.1	80.7
Pseudochorutes subcrasus	0.1	0.1														
Orchesella csincta	0.1	0.1														
Isotoma notabilis									0.1	20.0						
Isotoma viridis							0.3	1.1								
Isotoma sp. *juv.*					2.6	5.3										
Entomobrya muscorum					0.3	0.6										
Entomobrya sp.			0.7	46.7	1.0	2.0										
Mesophorura gr. krausbaueri			0.1	6.7												
Lepidocyrtus sp. 1			0.1	6.7												
Freisea mirabilis											4.7	96.0				
Protophorura gr. armata					0.2	0.4							0.1	0.2		
Brachystomella parvula													61.1	94.7	4.3	13.9
Folsomia quadriomaculata															0.1	0.3
Gamasina																
Arctoseiuscetratus	0.3	0.3									0.1	2.0				
Alliphis siculus	0.2	0.2			0.3	0.6										
Macrocheles merdarius					2.2	4.5	0.2	0.7					0.3	0.5		
Macrocheles sp.	0.1	0.1			0.2	0.4										
Dinychus sp.			0.1	6.7												
Dendrolaelaps sp.													0.5	0.8		
Hypoaspisaculeifer													0.1	0.2		
Uropoda minima					0.1	0.2										
Neuteria					0.2	0.4										
Amblyseius sp.					0.1	0.2										
Asca bicornis													1.1	1.7	0.8	2.6
Oribatida																
Tectocepheus velatus	0.2	0.2			0.1	0.2	0..1	0.4					0.3	0.5	0.1	0.3
Suctobelba sp.	0.1	0.1							0.1	20.0						
Tectocepheus sp.			0.1	6.7												
Oppiella nova					1.4	2.9							0.2	0.3		

Table 4. **Species composition and abundance dynamics of insect larvae in the soil of Bukðkës landfill and its peripheries (2002–2003)**

Species	Landfill								Peripheries							
	2002			2003			$\bar{x}$		2002			2003			$\bar{x}$	
	months															
	06	09	$\bar{x}$	06	09	$\bar{x}$	Ind./m^2	%	06	09	$\bar{x}$	06	09	$\bar{x}$	Ind./m^2	%
Amara equestris Duft.													100	50	25	16.7
Staphylinidae indet.	400	100	250	100		50	150	7.9								
Ptinidae									100		50				25	16.7
Anobiidae				100		50	25	1.3								
Coccinellidae	100		50				25	1.3								
Chrysomelidae	100		50				25	1.3				100		50	25	16.7
Curculionidae	100		50				25	1.3								
Coleoptera indet.				200		100	50	2.6								
Chironomidae	1100		550	100	800	450	500	26.3					200	100	50	33.3
Itonididae	1200		600	200	1100	650	625	32.9	100		50				25	16.7
Dolichopodidae				300		150	75	3.9								
Empididae	400		200				100	5.3								
Cyclorrhapha	1100		550				275	14.5								
Lepidoptera	100		50				25	1.3								
Σ	4600	100	2350	1000	1900	1450	1900	100	200	0	100	100	300	200	150	100
Number of species	9	1	9	6	2	6	12		2		2	1	2	3	5	

of the landfill peripheries *Collembola* accounted even for 91.5% of microarthropods.

Sixteen species of microarthropods were identified in the landfill soil and 12 in the soil of the landfill peripheries (Table 3).

In the microarthropod succession predominated by *Collembola* and *Gamasina*, collembola *Hypogastrura assimilis* accounted for 58.4% in the spring and collembola *Proisotoma minima* replaced it in the autumn of the second year (83.9%).

In spring and autumn, the dominant species of *Collembola* in the soil of the landfill peripheries were also different, *Brachystomella parvula* reaching 94.7% in spring and *Hypogastrura assimilis* 81.0% (Table 3).

The water content and pH were more favourable in the landfill soil (32.0–38.1% and 6.49–6.25) than in the soil of the landfill peripheries (6.2 and 4.3% and pH alkaline 8.25–8.02). The abundance of *Hypogastrura assimilis* in the landfill soil and in the peripheries in spring was almost the same (28.6 and 25.1 thou/m^2). The abundance of all other species of microarthropods was lower than that of the mentioned species of *Collembola*.

The abundance of insect larvae in 2002–2003 was low (1900 ind/m^2 on the average). Twelve species of larvae were identified (Table 4). Detritomycophagous *Itonididae* (32.9%), algodetritophagous *Chironomidae* (26.3%) and saprophagous *Cyclorhapha* (14.5%) larvae were dominant (Strazdienë, 2003).

Microbiological characeteristics. In the first year after remediation, the abundance of microorganisms in the landfill soil was 10–100 times higher than in the soil of the landfill peripheries. The statistical significance of the difference was $p < 0.01$. In the landfill soil, the abundance of all examined bacteria groups ranged from 1000 to 1500 mln of cells per 1 g of dry soil (Table 5). In the following years the abundance values gradually reduced. The values of abundance in the soil of the landfill peripheries followed an opposite pattern (Fig. 3), but the difference between bacteria abundance in the landfill soil and in the soil of peripheries was statistically significant during the whole period of investigation (Table 5).

The abundance of actinomycetes in the landfill and peripheries differed 27.8 times on the average in the first two years; reaching 579.67 and 20.85 KVF/g of dry soil, respectively. The peak values in the landfill were reached in the spring of the second year (Fig. 4). In the peripheries, the values of abundance were low and stable.

The abundance of cellulose-decomposing microorganisms in the landfill was only 2.4 times as high as in the peripheries (Fig. 4). This difference remained rather stable during the whole investigation

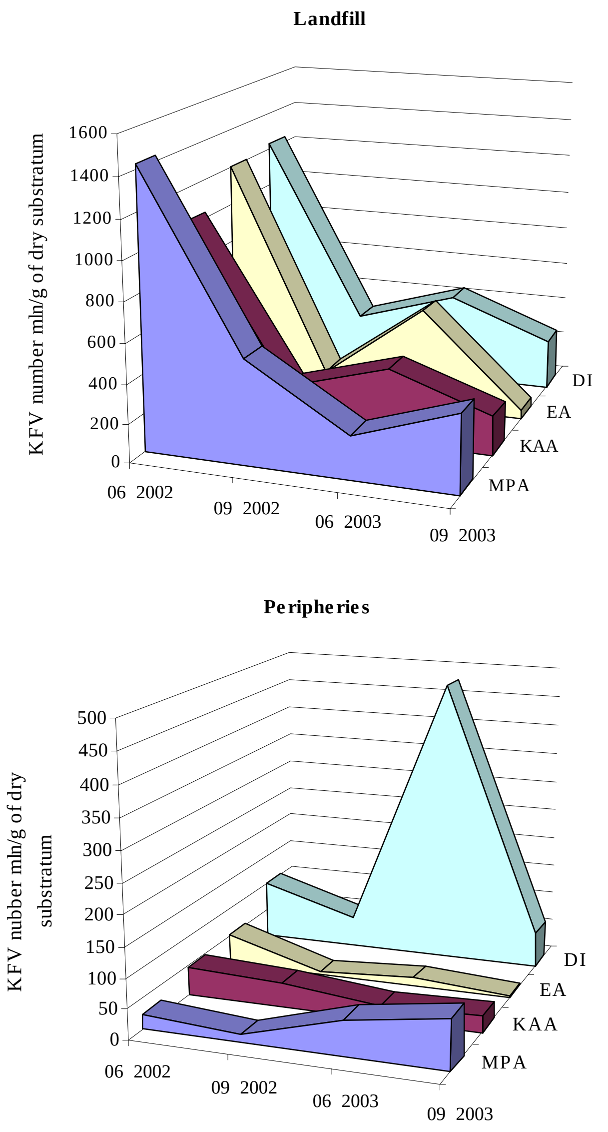


Fig. 3. Abundance dynamics of bacteria groups in the soil of Bukiðkës landfill remediated with sewage sludge and of its peripheries (2002–2003)

(p = 0.05). In the first year after remediation, the functional ratio (M/H) of the functional groups of bacteria was in favour of mineralizers, implying intensive processes of organic material mineralization and disintegration. The processes of mineralization overpowered the processes of humification (Table 5).

DISCUSSION

Rather large amounts of sewage sludge (300 t/ha) were used for landfill soil remediation. The sludge was spread on the landfill surface in a 30 cm thick layer (Table 1). Rather intensive microbiological processes and zoocoenotic activity took place in this layer during the two first years. The obtained experimental data revealed the same intensity pattern as that of the processes in the beginning of remediation of a gravel quarry and peat bog (Bagdanavièienë, Ramanauskienë 1997, 1997a). However, the physicochemical properties of sludge in the landfill differed considerably from those in the quarry and peat bog. This was partly predetermined by the sludge sedimentation technology. The residual sludge used for landfill recultivation was considerably richer in protein-containing organic matter than the mechanically levigated sludge used for quarry and peat bog remediation. This could have been one of the causes of the increasing abundance of mineralizers in the landfill surface in the first year of remediation. Intensive mineralization processes of organic matter presumably released other mineral compounds, including heavy metals.

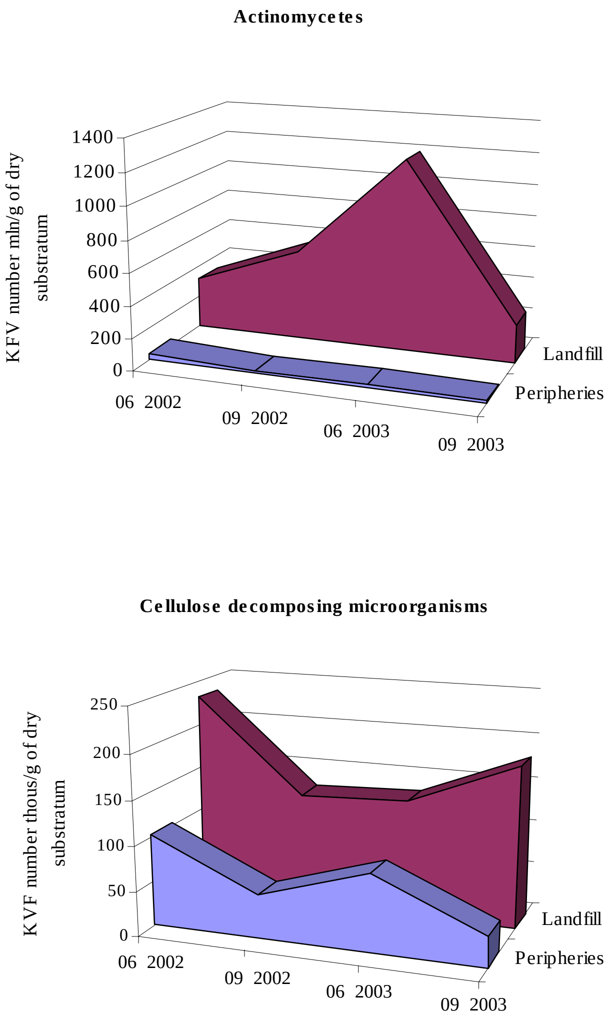


Fig. 4. Abundance dynamics of actinomycetes and cellulose decomposing microorganisms in the soil of Bukiðkës landfill remediated with sewage sludge and of its peripheries (2002–2003)

The concentrations of heavy metals in the sludge had no adverse effect on the activity of microorganisms, but all heavy metals in great amounts accumulated in plants (Fig. 1). The concentrations of heavy metals (except Ni and Cd) in the approaches to the landfill did not exceed the background values for soil, but the plants growing in the landfill peri-

Table 5. **Abundance, structural composition and functional ratio of bacteria (KFV per 1 g of dry substratum) in the soil remediated with sewage sludge**
KFV – compositional unit of colonies, KVF – number mln/g of dry substratum

Place	Year	Month	MPA*10^6	KAA*10^6	EA*10^6	DI*10^6	MPA %	KAA %	EA %	DI %	M/H
Landfill	2002	06	1430.12	1032.53	1201.61	1226.10	29.24	21.11	24.57	25.07	1/0.79
		09	530.95	229.52	135.24	289.52	44.80	19.37	11.41	24.43	1/0.41
	2003	06	221.12	380.48	525.22	448.37	14.04	24.15	33.34	28.46	1/0.49
		09	395.80	204.09	46.31	257.94	43.78	22.57	5.12	28.53	1/2.34
Peripheries	2002	06	24.47	47.57	52.74	98.93	10.94	21.26	23.57	44.22	½.71
		09	13.36	39.38	3.16	50.63	12.54	36.96	2.97	47.52	½.32
	2003	06	58.91	23.28	13.76	479.01	10.25	4.05	2.39	83.31	1/0.34
		09	83.25	28.21	2.44	59.21	48.09	16.30	1.41	34.21	½.78
$p < 0.05$			0.002	0.002	0.006	0.018					

KFV – compositional unit of colonies, MPA (beef agar) – bacteria decomposing organic forms of nitrogen, KAA (starch ammonia agar) – bacteria assimilating mineral nitrogen, EA (Ashby agar) – oligonitrophilic bacteria, DI (soil extract agar) – autochtonic bacteria

pheries accumulated as high concentrations of heavy metals as did the plants growing in the landfill. According to I. Budavièienë's data (Budavièienë, 1997), cereals growing in the remediated quarry accumulated rather high concentrations of heavy metals, but the values of metals in plants growing in the peripheries of the quarry were close to the MPC for plants, except Cr which was accumulated in concentrations as high as by plants growing in the quarry.

The obtained results show that accumulation of heavy metals in plants may depend not only on the concentrations of heavy metals in the substratum, but also on other factors, such as air saturation with dust, wastewater flow from the centre of the landfill to the peripheries, the pH of soils, and mobile forms of metals (Brazauskiene et al., 2002; Sabiene, 2004).

We did not investigate the distance from the landfill of plant pollution with heavy metals. According to the literature, pollutants in the peripheries of landfills usually migrate via groundwater to a distance of up to 0.5 km (Diliûnas ir kt., 2001). The changes in soil zoocoenoses entailed by air-born pollution occur up to 5 km from the source of pollution.

The variability of different species of microarthropods caused by disintegration of organic matter was reported by many researchers. It is also known that many species of collembola and oribatids are tolerant to a certain degree of soil pollution and this is related with the soil pH.

Sewage sludge is widely used for fertilization and soil remediation (Gradeckas ir kt., 1994; Gradeckas, Kubertavièienë, 1998; Kapots et al., 2000) and presents no hazard for soil health. In our opinion, pollution in the landfill peripheries is related with the landfill rather than with the sludge (Eitminavièiûtë, Matusevièiûtë, 2005). On the contrary, more intensive processes of soil formation and development complexes of pedobionts activate the self-purification processes in soil and inhibit the spread of toxic substances from the landfill to its peripheries.

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SÀVARTYNØ DIRVOÞEMIØ REKULTIVACIJA NUOTEKØ DUMBLU

1. PEDOBIONTØ SUKCESIJOS PIRMINËSE DIRVOÞEMIO REKULTIVACIJOS STADIJOSE

Santrauka

Rekultivuojant dirvoþemius, taip pat buitinius sàvartynus nuotekø dumblu, labai svarbu iðaiðkinti dirvoþemio formavimosi proceso intensyvumà, organinës medþiagos kieká, sunkiøjø metalø akumuliacijà organinëse medþiagose ir dirvoþemio ekologinæ bûklæ. Ðiame procese aktyviai dalyvauja pedobiontai – mikroorganizmai ir zoocenozës. Darbo tikslas – iðtirti rekultivuojamø nuotekø dumblu sàvartynø besiformuojanèiø dirvoþemiø biologiniø procesø kryptingumà ir, stebint mikroorganizmø ir mikroartropodø gausumo bei jø kompleksø struktûros pokyèius, iðaiðkinti dirvoþemio formavimosi ypatumus ir jo ekologinæ bûklæ.

Tyrimai atlikti Bukiðkiø (Vilniaus r.) sàvartyne 2002–2003 m. Sàvartynas rekultivuotas 2001 m., uþveþus 300 t/ha sausos medþiagos Vilniaus miesto nuotekø dumblo. Tirtas sàvartyno ir jo prieigø (10–20 m nuo sàvartyno) dirvoþemis.

Tyrimo rezultatai parodë, kad pirmaisiais po dumblo uþveþimo metais sàvartyne ir jo prieigose uþaugusios þolës kaupia gana daug sunkiøjø metalø, atitinkamai 4,6–6,2 ir 2,4–6,0 karto daugiau, palyginti su þolëmis, auganèiomis ðvarioje aplinkoje. Kadmio koncentracija sàvartyno þolëse ir jo prieigose atitinkamai 12,9 ir 11,1 karto didesnë nei ðvarioje aplinkoje auganèiose þolëse.

Pirmaisiais po rekultivacijos metais sàvartyno dirvoþemyje vyrauja bûdinga ðiai stadijai akaridiniø erkiø grupuotë, o antraisiais metais prasideda intensyvus sukcesinis procesas: sumaþëja akaridiniø erkiø, pradeda vyrauti kolembolos (iki 74,4% visø mikroartropodø).

Pirmaisiais rekultivacijos metais mikroorganizmø kiekis sàvartyno dirvoþemyje buvo 10–100 kartø didenis nei prieigø dirvoþemyje. Bakterijø funkciniø grupiø struktûrinis funkcinis santykis (M/H) sàvartyno dirvoþemyje rodo bakterijø mineralizatoriø gausëjimà. Tai byloja apie intensyvius organinës medþiagos mineralizacijos ir irimo procesus. Mineralizacijos procesai nustelbia humifikacijos procesus.

Sunkiøjø metalø koncentracijos dumble nedarë neigiamo poveikio mikroorganizmø ir zoocenoziø veiklai. Taèiau visi metalai pirmais ir antrais metais gana gausiai kaupiasi ne tik sàvartyno, bet ir jo prieigø dirvoþemiuose.

Raktaþodþiai: sàvartynas, sunkieji metalai, mikroorganizmai, mikroartropodai, nuotekø dumblas