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Ecological peculiarities of landfill soils and their environment

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The paper contains summarized data on the Vilnius landfills of domestic wastes. The study is focused on the formation processes of recultivated landfill soils and the influence of landfills on the soils of their environment. It has been determined that in the first seven years, landfill soils are in the first stages of formation. The structure of microarthropod complexes is monodominant, species composition is poor, and herbaceous plants intensively accumulate heavy metals. Fifteen years after the beginning of recultivation, stable polydominant complexes of pedobionts appear. Even after fifteen years, the places of alkaline hydrolysate effusions in the hollows and approaches to the landfills remain polluted with higher concentrations of cadmium, nickel, lead, and zinc.

Isolated sewage sludge storages negligibly increase the adverse effect of landfills on the environment.

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

INTRODUCTION

The areas of damaged and devastated soils are rapidly expanding across the world. Urbanization, exploitation of mineral resources and the increasing number of landfills and dumps are the main causes. The landfills of Lithuania occupy rather great areas. The Environmental Agency of Denmark inventoried 272 Lithuanian landfills. At present, Lithuania has more than 800 landfills (Pinskuvienë et al., 2004). Most of the landfills have been or are being recultivated. A new anthropogenic soil is forming in them. Yet the formation patterns and the ecological status of soils and the impact of landfills on the environment lack comprehensive studies. The Institute of Ecology has implemented a series of field investigations aimed at analysis of the decomposition processes of domestic wastes (organic matter, textiles, paper, solid wastes). The microorganisms and zoocoenoses participating in the processes were analysed (Казицкас, 1987, 1988; Заксайте, 1984, 1989, 1989a, 1993; Kazickas ir kt., 1994; Страздене, 1994, 1996; Budavièienë, 1997; Eitminavièiûtë, 1998). Studies about the vegetation of landfills are rather exhaustive (Мотекайтите, 1994, 1994a; Motiekaitytë, 1998, 2002). A complex ecological investigation of Vilnius landfills was carried out in 1996–1997 (Report, 1997). It embraced agrochemical analysis of soils, concentrations of heavy metals in soils and plants, pathogenic and saprophytic microflora, and soil zoocoeno-

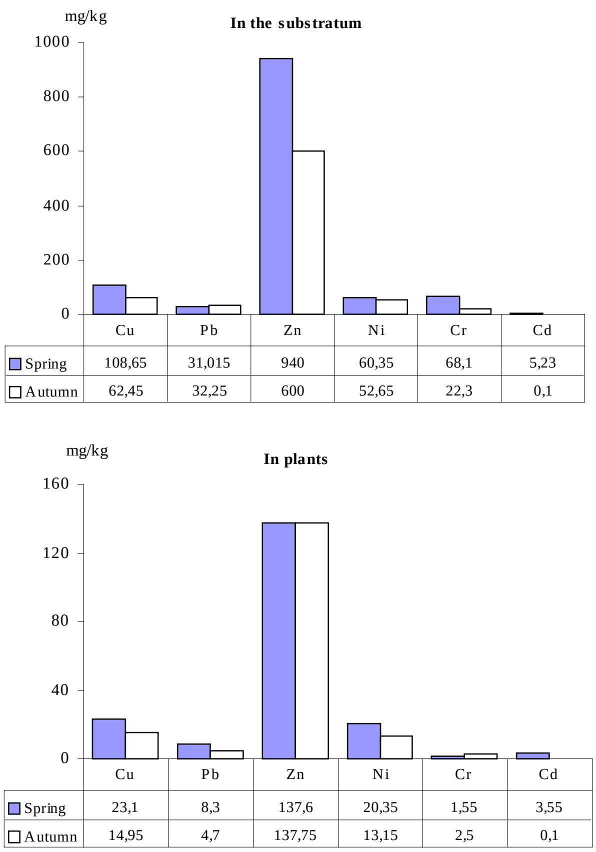
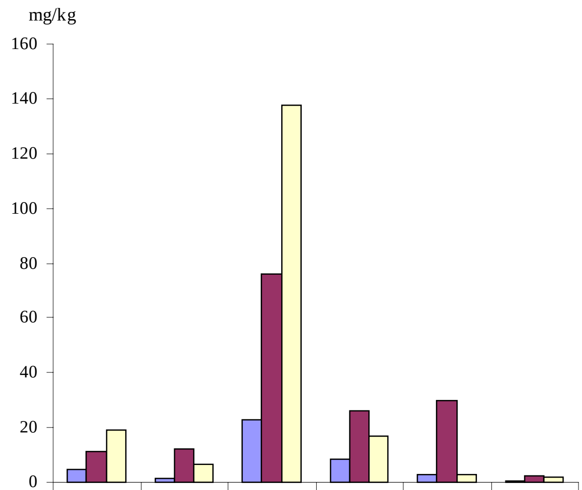


Fig. 1. Concentrations of heavy metals (mg/kg) in the substratum and vegetation of sewage sludge storage periphery (Kariotiðkës, 2003–2004)

Table 1. **Characteristics of the landfills studied**

Landfill	Recultivation time (years)	Soil thickness (cm)	Soil type	Planting (%)
Kariotiðkës	0–1	0–5	sand loam	–
Fabijoniðkës, Mickûnai, Lentvaris	6–7	10–50	sand, loam	100 (meadow)
Polotsk	15	60–70	sand, gravel, clay	100 (meadow, bushes)



	Cu	Pb	Zn	Ni	Cr	Cd
in clean environment	4,7	1,3	23	8,3	2,7	0,4
in landfill	11,2	12	76	26	30	2,1
in storage periphery	19	6,5	137,6	16,7	3	1,9

Fig. 2. Average concentrations of heavy metals (mg/kg) accumulated by the vegetation of clean environment and of sewage sludge storage periphery (Kariotiðkës, 2003–2004)

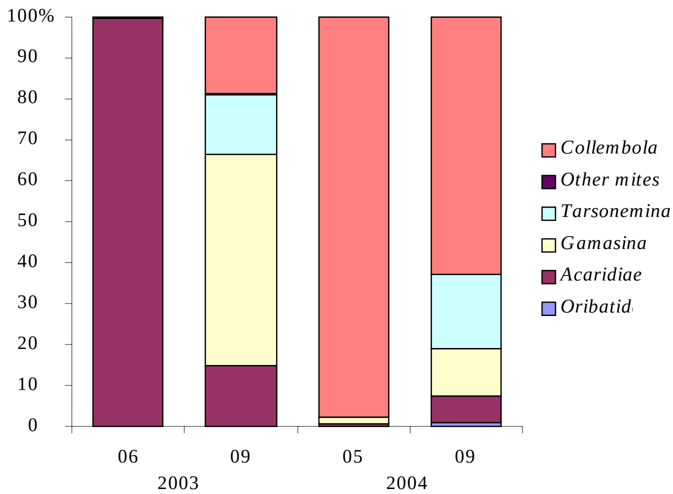


Fig. 3. Dynamics of microarthropod groups (%) in the substratum of sewage sludge storage periphery (Kariotiðkës)

ses. Much factual material about the solid components of landfills and the concentrations of chemical components in liquid wastes is given in the works about the Lapës landfill in Kaunas (Diliûnas ir kt., 2001). These works are in progress.

The aim of the present work is to describe the ecological peculiarities of soil in recultivated landfills and their surroundings and to analyse the environmental impacts of sewage sludge storages (within landfills) on landfills and their approaches.

MATERIALS AND METHODS

Landfills with different recultivation time were selected for the study: the Kariotiðkës landfill where recultivation was started some time ago, landfills recultivated 6–7 years ago (Fabijoniðkës, Lentvaris and Mickûnai) and landfills recultivated 15 years ago (Polotsk). The mentioned landfills were studied in 1996–1997. The investigation of the Kariotiðkës landfill was continued in 2003–2004 (Fig. 1). Depending on the situation and size of landfills, stationary investigation areas were established in them: on the top, in hollows and at the bottom (mostly in the areas of hydrolysate effusions). The investigation continued in the Kariotiðkës landfill in 2003–2004 focused on the environment of Vilnius sewage sludge storage. The samples were taken in the peripheries of and approach to the landfill (in the forest behind the protective dike of the storage). The following indices were evaluated: physical–chemical (soil water; pH; soil, air and topsoil temperature; concentrations of heavy metals in the soil and vegetation; biogenic elements and humus) and biological (microorganisms, microarthropods and insect larvae). Samples were taken in five turns from each investigation area in spring (May–June) and autumn (September). The devices used for laboratory analyses were: atomic absorption spectrometer, Egner–Rimm–Domingus colorimeter (KOHE-SD), Kjeldal's, Turin's light and Tulgren's extractors.

The studied landfills were recultivated with sandy loam and other types of soil piled on the compressed wastes. The piled earth was sowed with perennial grasses. The thickness of the soil layer was uneven (Table 1).

The sewage waste sludge storage of the Kariotiðkës landfill was started in 1997. A clay dike was made in order to isolate the storage from the natural environment. The samples were taken from the peripheries of

Table 2. **Concentration of biogenous elements in the soil of Vilnius city landfills (Budavièienë, 1996)**

Place	Recultivation time (years)	pH_{KCl}	Mobile form		$N\text{-}NO_3$	$N\text{-}NH_4$	$\Sigma N_{min.}$	Total		C/N	Humus %
			P_2O_5	K_2O				N	C		
					mg/kg			%			
P_1	15	6.6	275	109	8.08	4.04	12.12	0.218	3.12	14.3	5.37
P_2		6.4	294	186	2.72	5.06	7.78	0.329	17.56	5.3	30.30
F_1	6–7	7.2	189	185	4.19	7.99	12.18	0.131	1.96	14.9	3.37
F_2		6.4	209	177	5.05	3.86	8.91	0.154	2.16	14.0	3.72
F_3		6.8	200	148	2.76	7.75	10.51	0.135	2.00	14.8	3.44
F_4		7.4	238	117	2.08	4.13	6.21	0.052	0.4	7.7	0.68
F_5		7.1	655	540	4.18	10.14	14.32	0.282	5.5	19.5	9.48
F_6		7.2	76	97	4.43	5.03	9.48	0.302	13.99	13.2	6.87
F_7		7.4	70	623	20.00	6.76	26.76	0.112	1.46	13	2.52
F_8		7.8	200	768	26.75	6.82	33.57		0.97		167
L_1	6–7	7.1	200	203	3.78	13.00	16.78	0.138	1.39	10.1	2.40
L_2		7.6	220	232	3.79	15.6	19.39	0.092	1.97	21.4	3.40
L_3		7.3	350	989	10.5	18.5	29	0.298	3.26	10.9	5.62
M_1	6–7	6.6	591	91	1.47	3.73	5.2	0.068	1.25	17.2	2.15
M_2		6.8	168	81	1.74	3.92	5.66	0.059	1.15	19.5	1.98
K_1	0–1	8.0	180	312	9.65	4.56	14.21	0.04	0.45	11.2	0.77
K_2		7.4	263	110	7.91	4.62	12.53	0.03	0.97	32.3	1.67
K_3		7.6	247	108	16.15	5.58	21.73	0.176	2.69	15.3	4.63

P – Polotsk, F – Fabijoniðkës, L – Lentvaris, M – Mickûnai, K – Kariotiðkës landfills: P_1, $F_{1–2}$, L_1, M_1, K_1 – top of landfill, P_2, M_2 – landfill hollows, $L_{2–3}$ – landfill bottom, $F_{7–8}$ – hydrolysate effusion places, $F_{3–6}$, $K_{2–3}$ – landfill approaches.

Table 3. **Concentrations of heavy metals (mg/kg) in the soils of Vilnius landfills and their approaches**

Place	Recultivation time (years)	Cu	Pb	Zn	Mn	Co	Ni	Cr	Cd	Fe	Sr
P_1	15	10.6	54	56	150	18	36	20	2.4	5600	12
P_2		760.0	2000	2000	1200	72	176	540	3.4	120000	20
F_1	6–7	9.0	50	44	224	16	38	32	2.4	6400	8
F_2		6.4	20	26	260	14	34	32	2.2	6400	6
F_3		6.4	26	30	400	16	36	32	2.2	7200	4
F_4		11.0	40	46	274	20	38	32	2.4	7600	10
F_5		48.0	64	240	720	38	66	60	2.8	22200	12
F_6		20.0	32	42	384	16	36	30	2.2	7200	2
L_1	6–7	4.8	12	30	340	18	14	10	1.6	56000	2
L_2		9.0	20	38	360	26	28	14	2	8000	18
L_3		4.0	68	300	400	24	26	30	1.6	11200	3
M_1	6–7	4.6	40	30	170	32	80	16	5.6	4000	2
M_2		5.0	28	30	314	16	30	22	2.4	6400	4
K_1	0–1	8.0	28	190	170	16	36	20	2.6	3400	34
K_2		8.0	20	34	150	16	38	22	2.4	5400	20
K_3		6.4	36	30	92	14	36	16	2	4400	2
K_4		85.5	32	733	94	14	57	45	2.6	7600	15
K_5		17.7	19	148	408	13	26	28	2.2	6300	9
K_6		17	10	111			17	12	0.2		
MCL in sandy loam (LAND 20–2001)		100	100	300	1500	30	75	100	3		
Background level (HN 60: 2004)		8	15	26	427	4.3	12	30	0.15		

P – Polotsk, F – Fabijoniðkës, L – Lentvaris, M – Mickûnai, K – Kariotiðkës landfill: P_1, $F_{1–2}$, L_1, M_1, K_1 – top of landfill, P_2, M_2 – landfill hollows, $L_{2–3}$ – landfill bottom, $F_{3–6}$, $K_{2–3}$ – approaches of landfill, K_4 – periphery of the sewage sludge storage, K_5 – landfill periphery (forest sandy loam soil), K_6 – landfill approaches (forest bog soil), DLK – maximal concentration limit.

Table 4. **Concentrations of heavy metals (mg/kg) in the vegetation of Vilnius landfills**

Place	Plant	Cu	Pb	Zn	Mn	Co	Ni	Cr	Cd	Fe	Sr
P_1	wheatgrass	4.6	8	14	10	8	16	1.0	1.2	40	8
P_2	reedgrass	4.0	8	22	50	4	16	3.0	0.6	66	6
F_1	wheatgrass	6.4	10	32	30	10	30	6.0	1.8	84	6
F_3	wheatgrass	5.6	10	22	60	10	26	6.0	2.0	94	6
F_4	wheatgrass	3.8	8	16	24	8	26	4.0	2.0	70	12
F_5	nettles	10.6	16	34	60	16	34	8.0	2.4	270	24
F_6	nettles	9.6	12	60	160	14	30	6.0	2.2	188	26
L_1	wheatgrass	4.6	5	36	76	13	13	1.6	1.6	13	10
L_2	reedgrass	3.0	5	26	66	13	20	1.6	1.6	13	16
L_3	wheatgrass	11.0	5	53	66	13	13	1.6	1.6	12	6
M_1	wheatgrass	3.2	8	16	18	8	24	4.0	2	50	8
M_2	wheatgrass	3.8	8	0.7	46	8	20	3.0	1.6	116	6
K_1	marrows	16.0	12	72	13	10	26	30.0	2.0	116	2
	beets	6.4	12	80	44	10	26	3.0	2.2	276	8
	wheatgrass	13.2	12	36	44	10	34	8.0	1.8	200	8
K_2	wheatgrass	3.6	8	14	46	8	20	4.0	1.6	124	4
K_3	wheatgrass	6.4	10	8	46	10	28	1.0	0.6	104	6
K_4	grasses	19.0	7	138	88	9	17	3.0	1.9	278	15
K_5	grasses	15.4	5	81	306	7	18	0.7	1.9	355	2,7
K_6	grasses	14.1	3	143			15	0.4	0.3		
In grasses of clean soil (Lubytë et al., 1994)		1.9–4.7	0.5–1.3	12–23	30–72		2.7–8.3	0.8–2.7	0.14–0.4	10–109	
In perennial cereal grasses (Lubytë et al., 2001)		2.3	1.2	11.7	38.6		2.72	1.32	0.27	44.4	

P – Polotsk, F – Fabijoniðkës, L – Lentvaris, M – Mickûnai, K – Kariotiðkës landfill: P_1, F_1, L_1, M_1, K_1 – top of landfill, P_2, M_2 – landfill hollows, $L_{2–3}$ – landfill bottom, $F_{3–6}$, $K_{2–3}$ – landfill approaches, K_4 – periphery of the sewage sludge storage, K_5 – landfill periphery (forest sandy loam soil), K_6 – landfill approaches (forest bog soil), DLK – maximal concentration limit.

the storage and from the mixed forest with sandy loam and bog soils behind the dike.

RESULTS

According to the obtained results, the biological activity of landfill soils directly depends on the course of soil formation, intensity of processes and time since the beginning of recultivation.

The content of biogenic elements in the soils of the landfills varied (Table 2, Fig. 2). The amount of humus in the top of landfills was 0.77% at the beginning of recultivation, ranged from 2.15 to 3.72% after 6–7 years and was 5.37% after 15 years (Budavièienë, 1997; Report, 1997). In the course of time, the soil reaction changed from alkaline to neutral or close to neutral. The wastes dumped in the landfills (organic, industrial, and building) are polluted with heavy metals. The piled earth layer sown with grasses creates a possibility for heavy metals to be included in the soil–plant–soil system. The obtained results show that the concentrations of heavy metals in the surface soil layer (0–10 cm) mostly approach their maximum concentration limits (MCL) for soil, except that of cadmium whose concentration exceeds the limit value by 2.0–2.4 (Table 3) (LAND 20–2001; HN 60:2004). Anomalies of heavy metals occur in the landfill hollows. For example, the concentrations of heavy metals in the hollows of the Polotsk landfill exceeded the limit values 33 times (lead), 9–13 times (chromium, zinc, copper and iron) and 3–4 times (cadmium). High concentrations of heavy metals are also found in the soils of approaches to the landfill (Table 3).

Plants of landfills accumulate great concentrations of heavy metals. The marrows and beets which grew of themselves at the beginning of recultivation accumulated the concentrations of heavy metals exceeding the limit values 73 (Cd), 52 (Ni), 15 (Cr), 12 (Pb), 8 (Zn), 5 (Fe), and 2 (Cu) times (Table 4). Seven years after the beginning of recultivation, the grass growing in the landfills and their approaches accumulated 2 to 9 times as high concentrations of heavy metals as the grass growing in a clean environment (Budavièienë, 1997). After 15 years the concentrations of heavy metals in the landfill grass were considerably lower: 6 (Cu), 2 (Ni) and 3 (Cd) times higher than in a clean environment.

The biological activity, equilibrium between the processes of mineralization and humification, stability of newly forming ecosystems, and self-regulation capacity of soils in the recultivated landfills are directly related to biota and its diversity. The reproduction

Table 5. **Microarthropod species diversity in the soil of sewage sludge storage periphery** in 2003–2004 (Kariotiðkës)

Species	2003				2004			
	June		September		May		September	
	Thou ind./m²	%	Thou ind./m²	%	Thou ind./m²	%	Thou ind./m²	%
Oribatida								
Oppiella nova							1.6	1.2
Scheloribates sp.							0.2	0.1
Tectocepheus velatus							0.2	0.1
Gamasina								
Macrocheles merdarius	5.6	**65.1**	2	12.7			8.8	6.5
Macrocheles sp.	2.9	33.7	0.1	0.6				
Uropoda minima			0.1	0.6			0.1	0.1
Uropoda sp.	0.1	1.2						
Didinychus sp.			2.8	17.7				
Veigaia exiqua					1.5	0.10		
Pergamasus sp.					0.4	0.03		
Dendrolaelaps sp.					0.3	0.02		
Ureobovella sp.					0.1	0.01	0.2	0.1
Geholapsis longispinosus							0.1	0.1
Collembola								
Hypogastrura assimilis			0.7	4.4	274.1	17.4	112.4	**83.2**
Hypogastrura manubrialis							7.8	5.8
Lepidocyrtus sp. juv.			9.5	**60.2**				
Lepidocyrtus sp. 2					5.4	0.3	2.3	1.7
Proisotoma minima			0.5	3.2	1291.4	**82.1**		
Entomobrya muscorum			0.1	0.6	0.1	0.01		
Spheridia pumilis							0.6	0.4
Neanura muscorum							0.7	0.5
Mesophorura gr. krausbaueri							0.1	0.1
Isotoma sp. juv.							0.1	0.1
Insecta *juv.*								
Cercyon sp.			0.1	7.1				
Histeridae					0.1	1.2		
Staphylinidae	0.3	27.3			0.2	2.4		
Coleoptera indet.	0.8	72.7	1.2	**85.8**	0.6	7.3	0.1	25.0
Chironomidae					7.2	**87.8**		
Limoniidae					0.1	1.2		
Itonididae							0.1	25.0
Stratyomiidae			0.1	7.1				
Empididae							0.2	50.0

and spread of pedobionts in the organics-poor soils is a long and slow process. It is important to create active hotbeds in these soils where microorganisms accumulate near mineral particles (Карпачевский, Зубакова, 2005).

Z. Bagdanavièienë (Report, 1997), who investigated the microbiological activity of forming soils in landfills, pointed out that most of these soils are predominated by oligonitrophilic bacteria. This indicates the presence of high concentrations of low- disintegrating organic carbon (hydrocarbons) and low concentrations of mineral nitrogen. The structural composition of the groups of microorganisms in the upper part of landfills is better balanced than in the slopes and at the bottom.

Abundant complexes of zoocoenoses were found to participate in the utilization of wastes (Казицкас, 1988; Заксайте, 1989; Zaksaitė, 1993; Страздене, 1994). The abundance, species composition and structure of microarthropod complexes in the soils of recultivated landfills were in direct dependence on the duration of soil formation and on the content of humus. In the first years of recultivation, the abundance of microarthropods reaches 28.4 thou ind/m². Gamasid mites and Collembola are dominant and account for 61.2% and 23.0% of the total of microarthropods. *Hypogatsrura assimilis* is most abundant among Collembola and *Arctoseius cetratus* and *Macrocheles merdarius* among gamasid mites (Eitminavièiûtë, 1998). Six-seven years after the beginning of

Table 6. **Microarthropod communities in the approaches of sewage sludge storage (Kariotiðkës, 2003–2004)**

Group	Year	Month	Edge of the mixed forest			
			Sandy loam		Bog soil	
			Thou ind./m^2	%	Thou ind./m^2	%
Oribatida	2003	06	14.6	29.0		
		09	6.9	44.2	1.9	8.3
	2004	05	72.6	63.9	67.9	63.5
		09			18.6	74.7
		Σ	94.1		88.4	
Acaridiae	2003	06	2.8	5.6		
		09	1.8	11.5	0.9	3.9
	2004	05	3.8	3.3	7.6	7.1
		09			2.0	8.0
		Σ	8.4		10.5	
Gamasina	2003	06	3.8	7.6		
		09	3.4	21.8	3.9	17.1
	2004	05	18.8	16.5	6.9	6.5
		09			2.0	8.0
		Σ	26		12.8	
Tarsonemina	2003	06	0.9	1.8		
		09	0.4	2.6	15.4	67.5
	2004	05	0.6	0.5	8.7	8.1
		09			0.6	2.4
		Σ	1.9		24.7	
Other mites	2003	06	0			
		09	1	6.4	0.2	0.9
	2004	05	0.5	0.4	0.6	0.6
		09			0.1	0.4
		Σ	1.5		0.9	
Collembola	2003	06	28.2	56.1		
		09	2.1	13.5	0.5	2.2
	2004	05	17.3	15.2	15.2	14.2
		09			1.6	6.4
		Σ	47.6		17.3	
Σ	2003	06	50.3			
		09	15.6		22.8	
	2004	05	113.6		106.9	
		09			24.9	
			179.5		154.6	
Insecta juv.	2003	06	22.1			
		09	0.6		0.8	
	2004	05	0.6		6.8	
		09			1.2	

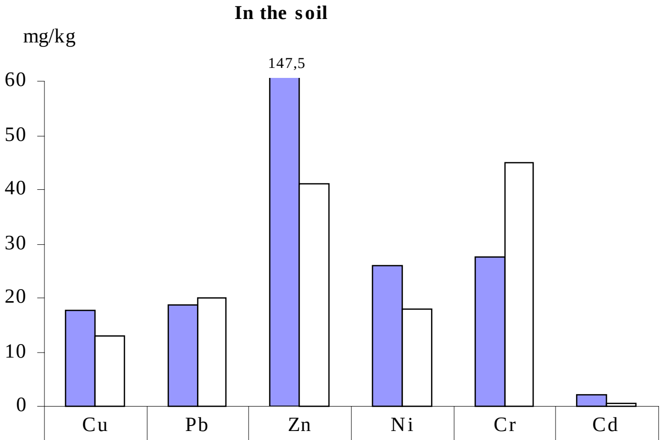
landfill recultivation the total abundance of microarthropods in the soils overgrown with grasses ranged from 33.5 to 88.8 thou ind/m^2. Oribatides dominated. *Tectocepheus velatus* and Collembola *Mesophorura gr. krausbaueri* and *Proisotoma minuta* comprised the nucleus of the coenosis. After 15 years, the number of microarthropods did not increase (80.0 thou ind/m^2), but their species composition became more diverse: 9 species after the first year, 14–20 species after 6–7 years and 45 species after 15 years (Eitminavièiûtë, 1998).

Dry sludge abounds in the peripheries of the sewage sludge storage of the Kariotiðkës landfill. In the spring of 2003, the dry sludge was overgrown by tomatoes and zucchinies and of 2004 by mayweeds, winter-cresses and nettles. The vegetation was very luxuriant. The sludge temperature (at a depth of 5–10 cm) during the spring and autumn sampling was higher than that of soil. In May 2003 it was 33.0 °C and in September 37 °C. In the spring and autumn of 2004 it reached 19 °C. High temperatures were also measured in the sludge surface (31.0, 17.0, 17.6 °C). In autumn, the water content in the substratum of storage peripheries was 34.1% (2003) and 33.2 (2004). The content of carbon in 2003 was 18.6% and it reduced to 9.27% in 2004.

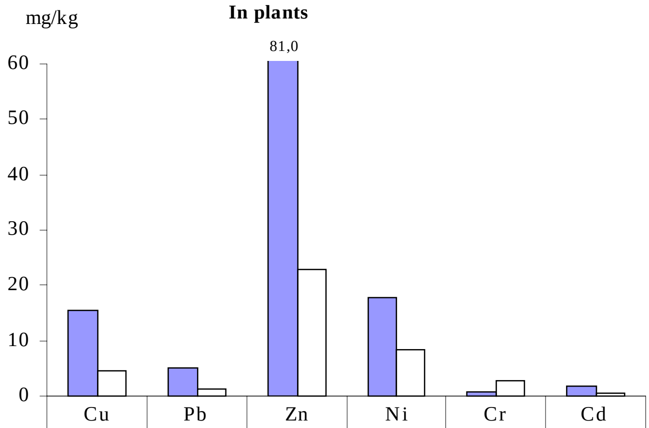
The concentrations of heavy metals in the storage peripheries were subject to seasonal variations. This is accounted for by the reduction of easily decomposed organic matter and increase of the concentrations of some metals (copper, zinc). Often the concentrations of heavy metals were higher in spring than in autumn (Fig. 1). The average two-year concentrations of heavy metals in plants growing in the sludge of storage peripheries were lower than in the substratum but higher than in a clean environment (Fig. 2). In 2004, the plants growing in the sewage sludge storage peripheries accumulated higher concentrations of some metals, zinc and copper in particular.

Acaridic mites were dominant among microarthropods in the spring of 2003 and accounted for 99.7% of the total of microarthropods (Fig. 3). This is characteristic of soils fertilized with sludge. In the first and second years the soils are predominated by acarides (Eitminavièiûtë, 1997; Navickienë, 1997; Umbrasienë, 1997). In the May of 2003 the temperature of this substratum rose to 33 °C (31 °C in the surface) when the air temperature was 22°C. This means that the sludge layer is thick and the processes of composting and intensive mineralization of organic material take place in it. These processes are reflected by the abundance of acarides and microorganisms (Eitminavièiûtë, 1997; Bagdanavièienë, Ramanauskienë, 1997). The total abundance of microarthropods in the spring of 2003 reached 1608 thou ind/m^2. In autumn their abundance reduced even 27.2 times (59 thou ind/m^2) at the expense of acarid mites (Fig. 3).

In the autumn of the same year, pronounced changes took place in the structure of microarthropod complex: the abundance of acarid mites reduced from 99.7% to 14.8%. The number of gamasid mites increased making them the eudominant group (51.6% of the total). The number of tarsonemic mites and collembolan also increased. In 2004, the latter became eudominant accounting for 97.8% of the total of microarthropods in spring and 62.3% in autumn. The



	Cu	Pb	Zn	Ni	Cr	Cd
in sandy loam	17.7	18.7	147.5	26.1	27.6	2.2
MCL for soils	13	20	41	18	45	0.5



	Cu	Pb	Zn	Ni	Cr	Cd
in sandy loam	15.4	5	81	17.8	0.7	1.9
MCL for plants	4.7	1.3	23	8.3	2.7	0.4

Fig. 4. Average concentrations of heavy metals (mg/kg) in the soil and vegetation of the forest outskirt behind the dike

collembola abundance reached huge values: 1571.0 thou ind/m^2 in spring and 124.5 thou ind/m^2 in autumn. They accounted for 97.8% and 62.8% of the total of microanthropods. Four species were detected in spring, predominated by *Proisotoma minuta* and *Hypogastrura assimilis*, and seven species in autumn, predominated by *Hypogastrura assimilis* (Table 5).

The eudominance of gamasid mites in the autumn of 2003 represented an intermediate succession between acarides and collembola. They were mostly nymphs and larvae, which accounted for 83.7% of the total of gamasides. *Macrocheles merdarius* were dominant among the mature ones. Their greatest abundance was identified in the spring of 2003 (65.1%). In 2004 it reduced to 6.5% (Table 5).

The number of insect larvae was small in the peripheries of the storage which abounded in decomposing organic matter, contained sufficient amount of moisture and the temperature of substratum was high. In the spring of 2003 their number amounted to 1.1 thou ind/m^2 and in the autumn 1.4 thou ind/m^2. In the autumn of 2004 their abundance noticeably reduced (to 0.4 thou ind/m^2). The detected larvae belonged to the group of decomposers of organic remains – various saprophages (Table 5). It must be pointed out that in some Vilnius sewage sludge composts the number of insect larvae was by some to even tens of times higher than in the autumn of 2004 in the peripheries of the Kariotiðkës sludge storage (Table 5) (Страздене, 1998).

Evaluation of the succession process of microarthropod groups and of the temperature of substratum as bioindicators makes it possible to assume intensive mineralization processes in the sludge of the storage peripheries. This substratum was in the first stages of disintegration.

The sewage sludge storage borders on the slope were overgrown with forests and shrubs. The slope is separated by a clay dike.

The forest soil was humid, especially in the bogged areas. The soil water content ranged from 60.1 to 85.5%. The soil reaction varied from the close to neutral (pH 7.5) to average (pH 5.8–6.4) values. The soil was rich in organic matter, the content of carbon ranged from 19.6 to 46.8%. The concentrations of heavy metals ranged within a wide interval (Fig. 2). The average two-year values of heavy metals in this soil are comparable with the background values in sandy loams. The concentration of zinc stands out. The grasses in this forest outskirt contain higher concentrations of heavy metals (Fig. 4). The concentration of zinc exceeded its concentration in the plants from a clean environment 3.5 times, nickel 2.1, copper by 3.2, and lead 3.8 times.

The structure of microarthropod complex in the forest soil was characteristic of mixed forest soils: oribatides (52.3%) and collembola (26.5%) were dominant (Table 6). The total abundance of microarthropods ranged from 15.6 to 113.6 thou ind/m^2, 59.8 thou ind/m^2 on the average. Most abundant oribatides were *Oppiella nova* and *Suctobelbidae* and collembola *Hypogastrura assimilis.*

The greatest abundance of insect larvae was identified in 2003 in the forest soil behind the dike. In spring, their abundance reached 22.1 thou ind/m^2. Inhabitants of humid soils rich in organic material, sarcophagous larvae of *Psychodidae* family were eudominant (68.3%). Larvae of the family Chirono-

Table 7. **Concentrations of heavy metals (mg/kg) in the soil and vegetation of Kariotiðkës landfill and its approaches**

Location	Year	Month	Cu		Pb		Zn		Mn		Co		Ni		Cr		Cd		Fe		Sr	
			soil 1	grass 2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
In the sewage	2003	06	5.8	7	43	15.6	460	160	96	98	11.8	9.4	74	22	28.2	3	9.4	7	7760	400	14.8	24.4
sludge storage		09	9.6	16.8	62.5	7.4	600	70	92	78	16.2	8	86	24	15.6	1			7440	156	18	6
periphery	2004	05	211.5	39.2	19.03	< 1	1420	115.2					46.7	18.7	108	0.1	1.06	< 0.1				
		09	115.3	13.1	< 2	< 2	45.3.4	205.5					19.3	2.3	29	4	< 0.1	< 0.1				
		x̄	85.5	19.0	31.6	6.5	733.3	137.6	94.0	88.0	14.0	8.7	56.5	16.7	45.2	3.0	2.6	1.9	7600	278	16.4	15.0
MCL for sludge (LAND 20–2001)			**600**		**500**		**2000**						**300**		**400**		**6.0**					
Behind the dike	2003	06	3.3	16.6	20	10.6	340	130	456	356	10.6	6.8	22.8	14.4	13.4	2	6.4	5.6	5920	400	4	4
(edge of the mixed		09	10.2	6.6	25	4.2	40	70	360	256	14.6	6.2	27	20	5	–			6720	310	14	1.4
forest)	2004	05	39.7	23.2	11.25	< 1	62.7	43.2					28.5	19	64.5	0.1	0.25	0.3				
		x̄	17.7	15.4	18.7	5	147.5	81	408.0	306.0	12.6	6.5	26.1	17.8	27.6	0.7	2.2	1.9	6320.0	355.0	9.0	2.7
Behind the dike	2003	09	15.2	9	26.6	6	170	170	180	372	12	6.2	27	36.4	9.2	–			5840	206	3	4.8
(near the bogs)	2004	05	40	27.5	10.5	< 1	115.2	114.2					29.2	20	20.7	0.11	0.73	1.01				
		09(1)	8.3	13.9	< 2	< 2	79.7	96					3.6	1.1	5.7	1.47	< 0.1	< 0.1				
		09(2)	4.7	6.1	< 2	< 2	77.7	190.5					9.3	< 1	11.7	0.53	< 0.1	< 0.1				
		x̄	17.0	14.1	10.2	2.7	110.6	142.6					17.2	14.6	11.8	0.4	0.2	0.3				
in marrows	1996			16		12		72		13		10		26		30		2		116		2
in beetroots	1996			6.4		12		80		44		10		26		30		2,2		276		8
MCL for soil (LAND 20–2001)			**13**		**20**		**41**						**18**		**45**		**0.5**					
MCL for grasses in clean soils (Lubytë et al., 1994)			**1.9–4.7**		**0.5–1.3**		**12–23**		**30–72**				**2.7–8.3**		**0.8–2.7**		**0.14–0.41**		**10–109**			

midae were also abundant (20.9%). In the autumn of 2003, the number of larvae reduced to 0.6 thou ind/m². The abundance of larvae in 2004 remained low (Table 8).

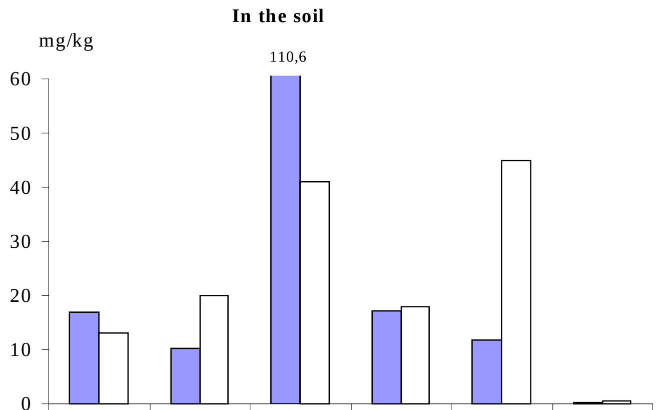
The concentrations of heavy metals in the bog soil behind the dike were liable to reduction (Table 5). They were slightly lower than in the soil of the forest outskirt and close to the concentration in clean soils. The grass cover of bog soil contained smaller concentrations of heavy metals than the grasses in the forest outskirt, but they were higher than in the grasses of a clean environment: copper by 3.0, lead by 6.2 and nickel by 1.7 times (Fig. 5).

The structure of microarthropod complexes in the forest bog soil was typical of fen soils (Эйтминавичюте, 1972). Oribatid (57.1%) and tarsonemic (15.9%) mites were dominant (Table 6). The microarthropod abundance in these soils ranged from 22.8 to 107.2 thou ind/m² (the average of 57.3 thou ind/m²) including 88.4 thou ind/m² of oribatides, 12.8 thou ind/m² of gamasidic mites and 15.9 thou ind/m² of tarsonemic mites. Oribatides *Oppiella nova* (from 19.8 to 53.5%) and *Haplopthiracarus sp.* (from 11.0 to 23.2%) were dominant. *Collembola Protophorura gr. armata* and *Hypogastrura assimilis* (from 17.0 to 17.9%) were also abundant. They were mostly hydrophilic species.

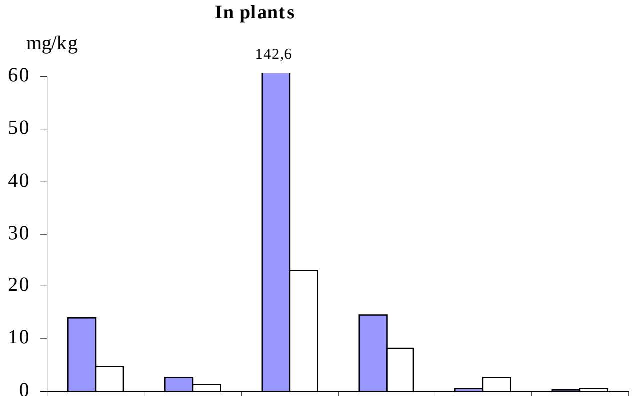
The structure and abundance of the complex of insect larvae in the bog soil behind the dike was typical of the larvae complexes of other forests studied. It included larvae typical of mineral soils (*Malthodes* sp., *Athous subfuscus*) and larvae inhabiting forest litter (Страздене, 1996).

Thus, we may state that the level of soil pollution with heavy metals in the forest behind the dike was low, yet the concentrations of heavy metals accumulated by grasses were higher (zinc in particular) than in the clean environment (Fig. 5).

The obtained results show that soil formation in the recultivated



	Cu	Pb	Zn	Ni	Cr	Cd
in bog soil	17	10,2	110,6	17,2	11,8	0,2
MCL for soils	13	20	41	18	45	0,5



	Cu	Pb	Zn	Ni	Cr	Cd
in bog soil	14,1	2,7	142,6	14,6	0,4	0,3
MCL for plants	4,7	1,3	23	8,3	2,7	0,4

Fig. 5. Average concentrations of heavy metals (mg/kg) in the bog soil and vegetation of the forest near the sewage sludge storage (Kariotiðkës, 2003–2004)

landfills is a long and slow process. Judging from the bioindication indices, the soils after 5–7 years of recultivation are still in the initial stage of formation. The content of humus in them ranges from 2.15–3.37%. After 15 years its content is 5.37%. Stable and rich in species diversity pedobiont communities appear only after 15 years.

For a long time the soils of landfills remain polluted with cadmium, nickel, lead, and zinc. Hollows and approaches of landfills (areas of hydrolysate effusions) are especially highly polluted.

According to J. Diliûnas and other authors (2001), pollutants in the zone surrounding landfills migrate with groundwater and may pollute the area within the radius of 500 m from the landfill bottom. They indicate that organic compounds, nitrogen, phosphorus, potassium, and heavy metals (to a smaller extent) are the main pollutants in the landfill filtrate.

According to our data, plants growing in landfills and their environs accumulate heavy metals. Even 15 years after the beginning of recultivation, grasses in landfills contain higher concentrations of cadmium and nickel than grasses growing in clean soils. For this reason any kind of economic activity in such areas must be forbidden. Only permanent monitoring of landfill soils (analysis of bioindicators) can reveal the soil quality and safety for human health (Pankhurst et al., 1997; Parisi, 2003). The storages of sewage sludge established in landfills require permanent observation. It was determined that the soil behind the protective dike is not strongly polluted with heavy metals, yet their concentrations in the forest grass cover exceed the values determined in clean environment 3.0 (copper), 2.0 (lead), 6.2 (zinc), and 1.7 (nickel) times (Table 7).

Complex analysis of landfill soils allows assuming that soil formation during landfill recultivation by poor sandy loam or loam soils is a slow and long process. Stable self-regulating complexes of pedobionts develop in them only in 15 years, indicating that the self-cleaning processes in these soils are slow and ineffective.

Table 8. **Species composition and abundance of insect larvae in the soil behind the dike (outskirt of mixed forest) in 2003–2004 (Kariotiðkës)**

Species	2003				2004	
	June		September		May	
	Thou ind./m^2	%	Thou ind./m^2	%	Thou ind./m^2	%
Helodidae	0.7	3.0				
Malthodes sp.					0.1	16.7
Adrastus limbatus					0.1	16.7
Coleoptera indet.	0.2	0.9			0.2	33.3
Psychodidae	15.7	68.3				
Chironomidae	4.8	20.9				
Itonididae	0.4	1.7	0.6	100	0.2	33.3
Dolichopus sp.	0.2	0.9				
Cyclorhapha	0.1	4.3				
Σ	22.1	100	0.6	100	0.6	100
Nomber of species	7		1		4	

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BUITINIØ SÀVARTYNØ IR JØ APLINKOS DIRVOÞEMIØ EKOLOGINIAI YPATUMAI

Santrauka

Darbe pateikti Vilniaus sàvartynø kompleksiniø tyrimø apibendrinantys duomenys. Iðaiðkintas rekultivuojamø sàvartynø dirvoþemiø formavimosi procesas ir sàvartynø poveikis jø prieigø dirvoþemiams. Nustatyta, kad per pirmus septynerius metus sàvartynø dirvoþemiø formavimosi stadijos yra pirminës. Mikroartropodø kompleksø struktûra monodominantinë, skurdi rûðinë ávairovë, þolinë augmenija intensyviai kaupia sunkiuosius metalus. Po penkiolikos metø nuo sàvartyno rekultivacijos pradþios susiformuoja stabilûs polidominantiniai pedobiontø kompleksai. Sàvartyne susiformavusiose ádubose bei jo prieigose, ðarminio hidrolizato iðsiverþimo vietose dirvoþemiai net ir po 15-os metø bûna uþterðti kadmiu, nikeliu, ðvinu bei cinku, kuriø kiekiai, padidëjæ. Sàvartyne áruoðtos vandens valymo árenginiø nuotekø dumblo saugyklos pakraðèiuose gausu dumblo, kuriame vyksta organiniø medþiagø degradacijos ir sunkiøjø metalø kaupimosi procesai. Saugyklos pakraðèiuose ant dumblo augantys augalai aktyviai kaupia sunkiuosius metalus, ypaè cinkà ir vará. Izoliavus dumblo saugyklà nuo gamtinës aplinkos specialiu pylimu, miðraus miðko dirvoþemyje ir neuþterðtuose dirvoþemiuose aptinkamø sunkiøjø metalø kiekiai yra panaðûs. Taèiau þolinëje dangoje sunkiøjø metalø kiekiai, palyginti su aptinkamais kiekiais augaluose, auganèiuose ðvarioje aplinkoje, yra didesni: vario aptikta 3, ðvino – 2, cinko – 6,2, nikelio – 1,7 karto daugiau. Dumblo saugykla ðiek tiek padidina bendràjá neigiamà sàvartyno poveiká aplinkai.

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