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Contamination of soil and grass by heavy metals along the main roads in Lithuania

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High concentrations of heavy metals have negative influence on live organisms. So, concentrations of some heavy metals (lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), zinc (Zn)) were measured in roadside soils and grass along the main roads in Lithuania: Kaunas–Klaipėda, Kaunas–Vilnius, Kaunas–Druskininkai, Kaunas–Zarasai, Kaunas–Marijampolė, Kėdainiai–Panevėžys, Panevėžys–Biržai and Prienai–Alytus. Soil samples were taken from 0 cm to 20 cm of depth at distances of less than 50, 50–200, 200–500 and more than 1000 meters from the road; from grass, at distances of 5, 15, 25, 50, 100 and 250 meters from the road. All the concentrations of heavy metals in roadside soils and grass were lower than maximum allowed concentrations in soil (in accordance with HN 60:2004). They were different depending on the distance from the road and direction where the samples were taken. Decrease of concentrations of heavy metals in roadside soils depending on the distance from the road was observed for Pb, Cd, Cu and Zn. The highest concentrations of Cr, Cu and Zn in grass along the highway Kaunas–Klaipėda was detected in the highway separating band grass. Quite big concentrations of Cd, Pb, Cu and Zn were found in grass 5 m from the highway. Contamination of soils and grass varies every year, so it is advisable to monitor concentrations of heavy metals every year.

Key words: heavy metals, soil, roads, grass

INTRODUCTION

Recently, the problem of environment contamination has become especially important, as it is being transformed from the local level into regional and is gradually becoming a global issue (Juknys, 1994; Kuiters, 1996; Medvedev, 1999; Lopez Alonso et al., 2000). Rapid urbanization, unregulated industrialization, growing transport intensity and agricultural activities have created a problem of heavy metal (HM) contamination worldwide. According to the Korte index which expresses hazard to environmental quality, HMs are among such major problems as contamination with pesticides, acid rain, oil spills, chemical fertilizers and noise (Stravinskienė, 2005). HMs are long-term contaminants with the ability to accumulate in soil and plants, and there is no natural way to remove them (White et al., 2002). Most hazardous substances are toxic HMs: lead (Pb), manganese (Mn), chromium (Cr), copper (Cu), nickel (Ni), zinc (Zn), and their soluble compounds (Mažvila, 2001; Navas et al., 2005).

The number of cars in Lithuania has been increasing day-after-day, so the concentration of HMs in roadside soil has been growing as well. Large amounts of HMs are dangerous to plants and animals. Wild animals can be affected by enormous concentration of HMs, and carcinogenic, mutagenic, gonadotrophic and embryotoxic effect can be observed (Балтренас et al., 2003). However, these effects can be recognized after a certain period of time. Acute course can be observed following high concentrations. Central and peripheral nervous system disturbances, destruction of work of blood forming organs and endocrine system can follow. HMs also have negative influence on the reproductive function of both animals and people.

Recently, enough data proving the negative influence of contaminated soil on plants, animals and human beings have been collected. Concentration of HMs in soil could be from 100 to 1000 times higher than natural background in some regions of the Earth. As chloride ions, for example, can form complexes with many cations such as Cd, Hg, Pb, Zn and Cu, salting of roads for de-icing purposes is an important source of chloride ions and such complexes in roadside environment (Doner, 1978). Concentrations of lead and zinc are higher in grass of such soils also. According to Polish scientists, concentration of lead in grass close to the main roads can be up to 250 mg per 1 kg of grass (Maciejewska, 2004).

There is an opinion that even low amounts of traffic emission pollutants can negatively affect the fish organism, causing various disturbances in its health and well-being (Vosylienė et al., 2006). So, monitoring of HMs in soil along the main roads in Lithuania is an essential task to detect hazardous places for plants and animals.

The aim of this research was to measure HMs concentrations along the main roads in Lithuania: in soil and in grass.

MATERIALS AND METHODS

Eight main roads of Lithuania were chosen for investigation: Kaunas–Klaipėda, Kaunas–Vilnius, Kaunas–Druskininkai, Kaunas–Zarasai, Kaunas–Marijampolė, Kėdainiai–Panevėžys, Panevėžys–Biržai and Prienai–Alytus. Some soil samples were taken from the depth of 0–20 cm along the roads Kaunas–Zarasai, Kaunas–Druskininkai and Kaunas–Klaipėda with distances of less than 50, 50–200, 200–500 and more than 1000 meters from the road. Other samples were taken from the depth of 5–10 cm with distances of 20 and 100 meters from the road. Soils were sandy loam, sandy clay loam, clay loam or silty clay loam. Taking into account a particular road, they were as follows: Kaunas–Klaipėda – Gleyic Luvisols and Gleyic Albeluvisols, Kaunas–Vilnius – Haplic Luvisols, Kaunas–Druskininkai – Calcaric Luvisols, Kaunas–Zarasai – Eutric Planosols, Kaunas–Marijampolė and Prienai–Alytus – Stagnic Luvisols and Gleyic Luvisols, Kėdainiai–Panevėžys and Panevėžys–Biržai – Gleyic Cambisols.

Detailed investigation of grass was carried out along the highway Kaunas–Klaipėda. Mixture of grass was collected in two directions from the road: south–east and north–west at distances of 5, 15, 25, 50, 100 and 250 meters.

Mineralization of each sample and measurement of element concentrations was performed in 3 replicates. The average values resulted were evaluated by statistical parameters, and unreliable results were rejected. Element concentrations were calculated in dry plant matter dried at 105 °C (dry matter).

The total concentrations of HMs (Cr – chromium, Cd – cadmium, Pb – lead, Ni – nickel, Cu – copper and Zn – zinc) in soil and grass samples were determined by flame atomic absorption spectrometry.

The average values of element concentrations in soils and grass were calculated using statistically evaluated mathematical average values by means of statistical R package, version 2.0.1 (Gentlemen et al., 1997).

RESULTS

HM concentrations in surface soil (5–10 cm depth) of roadside up to 100 m were different. Intervals for appropriate element were as follows: Cr – 15.4–21.4 mg/kg, Cd – 0.5–0.95 mg/kg, Pb – 10.7–21.3 mg/kg, Ni – 8.0–12.0 mg/kg, Cu – 7.9–12.5 mg/kg and Zn – 30.0–38.6 mg/kg (Table 1). The soil along the road Kėdainiai–Panevėžys was contaminated most of all. It contained the highest amounts of Cr, Cd and Ni. Moreover, concentrations of HMs up to 20 m from the road were high for all elements in comparison with concentrations of HMs in soil at a distance of 100 m from the road. In comparison with the other roads, there was no significant relationship between the distance from the road and the decrease of HM concentrations. High concentrations of elements were observed just for the road Kaunas–Vilnius in case of Cr, Cd, Pb and Cu and for the road Panevėžys–Biržai in case of Cr, Cd, Pb and Ni (20 m from the road). The soil of road Panevėžys–Biržai had the lowest concentration of Cr, Cd and Ni (100 m from the road), but the highest concentration of Zn (100 m from the road).

Figure shows average HM concentrations in soils along the main roads in Lithuania. There are no big differences between all roads, however, the soil of the road Kaunas–Vilnius is polluted most of all in case of Cr (19.85 mg/kg), Pb (18.15 mg/kg) and Ni (12.5 mg/kg). The highest concentration of Cd is in the soil along the road Kėdainiai–Panevėžys (0.9 mg/kg), Cu – along the road Prienai–Alytus (12.05 mg/kg) and Zn – along the road Panevėžys–Biržai (35.95 mg/kg). The lowest concentrations of elements in soils (100 m from road) were along the road Panevėžys–Biržai for Cr (15.85 mg/kg), Cd (0.525 mg/kg), Pb (14.15 mg/kg) and Ni (8.35 mg/kg). The lowest concentration of Cu was in the soil along the road Kaunas–Klaipėda (8.2 mg/kg) and Zn – along the road Kaunas–Vilnius (31 mg/kg).

HM concentrations in soil of 0–20 cm depth (Table 2) show that high contamination is at a distance of 50–200 m from the main road. The most polluted soil is along the road Kaunas–Zarasai in case of Cr, Cd, Ni and Cu. Soil along the road Kaunas–Klaipėda contains the highest values of Pb and Zn. The lowest concentrations of elements are in soil along the road Kaunas–Druskininkai for Pb, Ni, Cu and Zn at a distance of 200–500 m. For Cd the lowest concentration was along the same road but at a distance of more than 1000 m. The lowest concentration of Cr in soil was along the road Kaunas–Zarasai at a distance of more than 1000 m.

The data received by measuring HM concentrations in grass along the highway Kaunas–Klaipėda (Table 3) are very mixed. The highest concentration of Cr, Cu and Zn was detected in the

Table 1. **Concentration of heavy metals in surface soil (5–10 cm depth) of roadside up to 100 m**

Road	Distance from road, m	Heavy metals, mg/kg					
		Cr	Cd	Pb	Ni	Cu	Zn
Kaunas–Vilnius	20	20.1	0.80	21.3	12.5	11.0	30.8
	100	19.6	0.75	15.0	12.5	10.7	31.2
Kaunas– Klaipėda	20	18.3	0.75	20.4	11.5	7.9	36.2
	100	17.9	0.75	13.4	10.0	8.5	30.4
Kaunas– Marijampolė	20	19.2	0.5	18.3	10.5	8.7	34.2
	100	17.6	0.76	11.2	12.0	9.3	30.5
Kėdainiai– Panevėžys	20	21.4	0.95	18.4	12.0	12.2	32.4
	100	17.3	0.85	10.7	10.5	11.0	30.1
Panevėžys– Biržai	20	16.3	0.55	17.5	8.7	10.5	33.3
	100	15.4	0.5	10.8	8.0	11.4	38.6
Prienai– Alytus	20	18.3	0.85	18.0	10.0	12.5	32.3
	100	18.6	0.8	10.8	10.5	11.6	30.0
Permissible concentration*		100	3	100	75	100	300

* in accordance with the HN 60 : 2004.

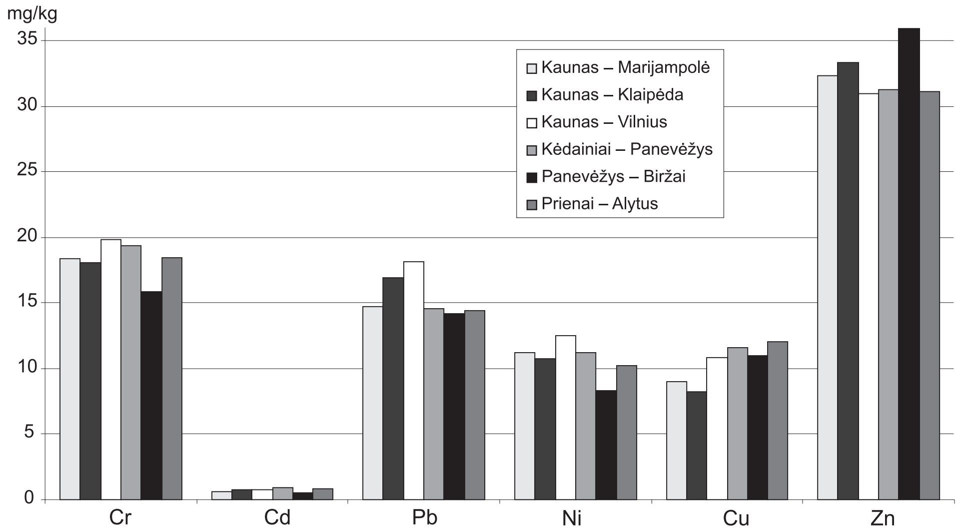

Fig. Average concentrations of HMs in soils along some main roads in Lithuania

Table 2. **Concentration of heavy metals in soil (0–20 cm depth) of territories along the main roads**

Main road, locality	Distance from road, m	Average concentration, mg/kg of soil					
		Cr	Cd	Pb	Ni	Cu	Zn
Kaunas–Zarasai							
Staškūniškis	up to 50	13.2	0.5	9.9	11	9.6	29.3
Daugailiai	50–200	15.2	0.7	10.6	12.7	13.3	36.6
Anykščių and Utenos distr.	200–500	7.3	0.5	8.6	7.1	9.4	34
	>1000	7.2	0.5	8.6	6.8	7.6	29.6
Kaunas–Druskininkai							
Domantonys	up to 50	12.1	0.4	9	7.9	12.8	33.4
Raižiai	50–200	13.7	0.5	10	10.2	10.5	39.7
Punia, Alytaus distr.	200–500	8.4	0.4	7	4	3	17
	>1000	8.9	0.3	7.1	6.1	4.5	19.1
Kaunas–Klaipėda							
Žemaičių road	up to 50	8.7	0.5	14.8	8.3	9.3	42.5
Labardžiai	50–200	11.7	0.6	15.3	10.3	10.3	43.2
Rietavas, Plungės distr.	200–500	7.8	0.4	12.4	7	10.2	40.4
	>1000	9.4	0.5	13	7.7	7.3	25.5

Table 3. **Concentration of heavy metals in grass along the highway Kaunas–Klaipėda, mg/kg of dry matter**

Distance from road	Cr	Cd	Pb	Ni	Cu	Zn
Permissible concentration*		**1**	**30**			
Separating band	**0.80**	**0.025**	**1.45**	**0.67**	**5.75**	**29.00**
Direction South–East						
5 m	0.52	0.025	1.97	0.22	5.25	20.00
15 m	0.52	0.025	1.62	0.75	4.50	23.75
25 m	0.55	0.005	1.35	0.92	2.5	12.5
50 m	0.70	0.005	1.07	2.17	2.75	8.50
100 m	0.60	0.005	1.37	1.22	2.75	10.75
250 m	0.50	0.005	1.32	1.27	1.50	12.00
Correlation	–0.2102	–0.5368	–0.3975	0.3238	–0.7514	–0.4443
Direction North–West						
5 m	0.47	0.025	2.10	0.57	3.75	26.00
15 m	0.62	0.025	2.82	1.05	3.50	20.75
25 m	0.45	0.005	1.70	1.47	1.75	14.50
50 m	0.45	0.005	1.80	0.97	1.25	12.25
100 m	0.60	0.005	2.02	0.85	2.50	13.00
250 m	0.75	0.005	3.02	1.30	2.00	19.50
Correlation	0.8047	–0.5368	0.5683	0.3588	–0.3622	–0.1090

* According to the "Technical Regulation on Obligatory Safety Requirements for Products Intended for Animal Feeding" (2006).

highway separating band grass. Quite large concentrations of Cd, Pb and Cu were found in grass 5 m from the road in the south–east direction. Great concentrations of Cd, Cu and Zn were also observed in grass 5 m from the road in the north–west direction. High concentration of Cr and Ni was at a distance of 50 m in the south–east direction and that of Cr and Pb at a distance of 250 m from the road in the north-west direction.

Correlation between the distance from the road and HM concentrations in grass was calculated. In most cases it was negative. An exception was for Ni, in the south–east direction and for Cr, Pb and Ni, in the north–east direction. The best reverse correlation was for Cu and Cd (south–west direction) and for Cd (north–west direction). High positive correlation was observed for Cr in the north–west direction. Correlation between HM concentrations at different distances depending on directions was calculated also. A very strong correlation was observed for Cd (r = 1), Cu and Zn (0.8403 and 0.7934, respectively). However, a reverse correlation was calculated for Cr (r = –0.5029). Other correlations were not significant.

DISCUSSION

According to the HM concentrations in roadside soils, roads Kaunas–Zarasai, Kėdainiai–Panevėžys and Kaunas–Vilnius could be described as most polluted (Fig. 1). All HM concentrations in roadside soils and grass were lower than maximum allowed concentrations in soil (in accordance with HN 60 : 2004) or raw feeding stuff for Pb and Cd (in accordance with the Technical Regulation on Obligatory Safety Requirements for Products Intended for Animal Feeding). So, contaminated grass can not be very dangerous for wild animals, those that graze close to the main roads in Lithuania. The quality of game meat should also not be affected. Similar results were obtained by other authors (Балтренас et al., 2003), however, some authors detected the levels of HMs in roadside soil above the maximum allowed limits (Motuzas et al., 2001).

HM concentrations in roadside soils were different depending on the distance from the road and direction where the samples were taken (Tables 1 and 2). They could be related to the clay amount in the soil as well as to other soil properties. As HMs are adsorbed by clay minerals, thus, there is a direct relationship between clay amount in soil and HM concentration (Gipiškis et al., 2007). Moreover, HMs can concentrate in pits, where they are brought by rain waters. Direction of winds could also have influence on the distribution of HMs in the investigated territory. Substances emitted are exposed to various aerodynamic and gravitation forces resulting in their separation and, depending on their physical and chemical properties, they settle selectively on the soil surface at different distances from the road surface. The main concentration of heavy metals is settling on the soil surface in the narrow limited zone of the highway itself, its slopes and ditches (Baltrėnas et al., 2003; Kliaugienė et al., 2003).

However, high concentrations of Pb in roadside soils were not far from the main roads – up to 20 m. Grigalavičienė and Rutkovienė (2006) noticed that concentration of Pb in roadside soil is the highest at distance of 5–10 m from the road, and then concentration decreases. Similar observations were done during investigation of Via-Baltica (Балтренас et al., 2003).

According to the received data Cd and Cu concentrations in roadside soils and plants are the highest at distance from 5 m to 20 m from the road. Grigalavičienė and Rutkovienė (2006) also identified that Cd and Cu concentration in plants at distance of 5–10 m from the road is the highest.

Concentration of Zn in roadside soils usually was higher close to the road, especially along the highway Kaunas–Klaipėda.

Our own investigations as well as the results of other authors show variability of HM concentrations in roadside soils even along the same road. It means that contamination of soils and grass varies every year (Antanaitis, 2006), so it is advisable to monitor HM concentrations annually.

CONCLUSIONS

1. Concentrations of heavy metals in the investigated roadside soils and grass were lower than maximum allowed concentrations in soil (in accordance with HN 60 : 2004) and in grass for Pb and Cd (in accordance with Technical Regulation on Obligatory Safety Requirements for Products Intended for Animal Feeding, 2006).

2. According to the heavy metal concentrations in roadside soils, roads Kaunas–Zarasai, Kėdainiai–Panevėžys and Kaunas–Vilnius could be described as most polluted.

3. Correlation between the distance from the road Kaunas–Klaipėda and Cr, Pb and Ni concentrations in grass is positive (0.8047, 0.5683 and 0.3588, respectively) in case of north–west direction.

4. Concentrations of Cd and Pb in grass along the highway Kaunas–Klaipėda are much lower than permissible concentrations indicated in the Technical Regulation on Obligatory Safety Requirements for Products Intended for Animal Feeding (2006) and can not be hazardous to animals.

5. As heavy metal concentrations in soils and grass vary every year, it is advisable to monitor them annually.

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References

1. Antanaitis Š. 2006. Grūdų užterštumo pesticidais ir sunkiaisiais metalais įvertinimas. *Žemės ūkio mokslo tiriamieji darbai ir jų praktinis pritaikymas*. Vilnius: Lietuvos Respublikos žemės ūkio ministerija. P. 5.
2. Baltrėnas P., Kliaugienė E. 2003. Soil pollution by heavy metals from transport systems in Lithuania. *International conference* "*Integrative approaches towards sustainability*" (Baltic Sea Region taking the lead). http://home.lanet.lv/~asi/Abstracts.htm
3. Doner H. E. 1978. Chloride as a factor in mobility of Ni (II), Cu(II) and Cd(II) in Soil. *Soil Sci. Soc. Am. J.* Vol. 42(6). P. 882–885.
4. Gentlemen R., Ihaka R., Noteson R., 1997. *A programming environment for data analysis and graphics*. Department of statistics university of Auckland.
5. Gipiškis V., Šlepetienė A., Arlauskienė E., Lenkšaitė E., Mališauskas A. 2007. Nemuno žemupio salpos dirvože-

mių hidrologinės, fizikinės, cheminės ir biologinės savybės bei sąsajos tarp jų. *Žemdirbystė*: *LŽI ir LŽŪU mokslo darbai*. T. 94. Nr. 1. P. 115–149.
6. Grigalavičienė I., Rutkovienė V. 2006. Sunkiųjų metalų koncentracija miško dirvožemiuose bei samanose šalia greitkelio Vilnius–Kaunas. *Miškininkystė*. Nr. 2(60). P. 12–19.
7. HN 60 : 2004 – Lietuvos higienos norma „Pavojingų cheminių medžiagų didžiausios leidžiamos koncentracijos dirvožemyje“. *Valstybės žinios*. 2004. No. 41–1357.
8. Juknys R. 1994. *Lietuvos gamtinė aplinka. Būklė, procesai, tendencijos*. Vilnius: Aplinkos apsaugos ministerija. P. 113.
9. Kliaugienė E., Baltrėnas P. 2003. Research on roadside soil pollution by heavy metals and soil remediation by natural zeolites. *7th International Conference on the Biogeochemistry of Trace Elements (7th ICOBTE)*.
10. Kuiters A. T. 1996. Accumulation of cadmium and lead in red deer and wild boar at the Veluwe, the Netherlands. *The Veterinary Quarterly*. Vol. 18. Suppl. 3. P. 134–135.
11. Lopez Alonso M., Benedito J. L., Miranda M., Castillo C., Hernandez J., Shore R. F. 2000. Arsenic, cadmium, lead, copper and zinc in cattle from Galicia, NW Spain. *Science of the Total Environment*. Vol. 246. P. 237–248.
12. Maciejewska M. 2004. Content of Pb, Cu, Zn and Fe in meadow sward growing in areas affected by local industry and waste dumps in Gryfino district. *Folia Univ. Agric. Stetin. Agricultura*. Vol. 242(98). P. 81–86.
13. Mažvila J. 2001. *Sunkieji metalai Lietuvos dirvožemiuose ir augaluose*. Monografija. Kaunas: LŽI. 343 p.
14. Medvedev N. 1999. Levels of heavy metals in Karelian wildlife, 1989–91. *Environmental Monitoring and Assessment*. Vol. 56. No. 2. P. 177–193.
15. Motuzas A., Vaisvalavičius R., Prosyčevas I., Stučinskienė N., Motuzienė S., Trimirka V. 2001. Metodologiniai sunkiųjų metalų kiekio tyrimai autotransporto taršos paveiktų zonų dirvožemiuose. *Aplinkos tyrimai, inžinerija ir vadyba*. Nr. 1(15). P. 39–46.
16. Navas A., Lindhotfer H. 2005. Chemical Partitioning of Fe, Mn, Zn and Cr in Mountain Soils of the Iberia and Pyrenean Ranges (NE Spain). *Soil and Sediment Contamination*. Vol. 14. No. 3. P. 249–260.
17. Stravinskienė V. 2005. *Bioindikaciniai aplinkos vertinimo metodai*. Kaunas: Vytauto Didžiojo universiteto leidykla. 215 p.
18. Vosylienė M. Z., Jankaitė A. 2006. Effect of heavy metal model mixture on rainbow trout biological parameters. *Ekologija*. 2006. Nr. 4. P. 12–17.
19. White R., LeTard L. A. 2002. Investigating environmental pollution through dendrochemical analysis. *OSCAR Journal*. Vol. 9. www2.selu.edu/
20. Балтренас П., Янкайте А. 2003. Исследование загрязненности тяжёлыми металлами почвы вдоль магистрали Виа-Балтика. *Экология и промышленность России*. С. 41–44.

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DIRVOŽEMIO IR ŽOLIŲ PALEI PAGRINDINIUS LIETUVOS KELIUS UŽTERŠIMAS SUNKIAISIAIS METALAIS

Santrauka

Dėl didelio kiekio sunkeji metalai neigiamai veikia gyvus organizmus. Tyrimo metu buvo nustatyta kai kurių sunkiųjų metalų (švino (Pb), mangano (Mn), chromo (Cr), vario (Cu), nikelio (Ni), cinko (Zn)) koncentracija šalikelių dirvožemyje ir žolėje prie šių pagrindinių Lietuvos kelių: Kaunas–Klaipėda, Kaunas–Vilnius, Kaunas–Druskininkai, Kaunas–Zarasai, Kaunas–Marijampolė, Kėdainiai–Panevėžys, Panevėžys–Biržai ir Prienai–Alytus. Dirvožemio mėginiai buvo paimti iš 0–20 cm gylio, mažiau nei 50, 50–200, 200–500 ir daugiau nei 1 000 m atstumu nuo kelio, o žolių – 5, 15, 25, 50, 100 ir 250 m atstumu nuo kelio. Visos sunkiųjų metalų koncentracijos pakelių dirvožemyje ir žolėje buvo mažesnės nei leidžiama didžiausia koncentracija dirvožemyje (pagal higienos normą HN 60 : 2004). Jos skyrėsi priklausomai nuo atstumo nuo kelio ir krypties, iš kur buvo imami mėginiai. Sunkiųjų metalų koncentracijos sumažėjimas pakelių dirvožemyje atsižvelgiant į atstumą nuo kelio pastebėtas Pb, Cd, Cu ir Zn. Didžiausia Cr, Cu ir Zn koncentracija nustatyta autostrados Kaunas–Klaipėda skiriamosios juostos žolėje. Didelės Cd, Pb, Cu ir Zn koncentracijos buvo nustatytos žolės sausoje masėje 5 m nuo autostrados. Dirvožemio ir žolės užteršimas sunkiaisiais metalais kiekvienais metais skiriasi, todėl rekomenduotina stebėti jų koncentraciją kiekvienais metais.

Raktažodžiai: sunkieji metalai, keliai, dirvožemis, žolės