

INVESTIGATION INTO HEAVY METAL CONCENTRATION BY THE GRAVEL ROADSIDES

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Abstract. Vehicles release large amounts of heavy metals to the environment. There have been done a lot of investigations analysing the distribution of heavy metals in soils near intensive regional roads. However, there is lack of investigations into the impact of small-intensity gravel roads on roadside soil contamination with heavy metals. The object of this investigation is four gravel roads of local significance connecting small villages. The intensity of these roads is very low. The gravel roads are chosen according to application of dust-minimizing materials, for example, CaCl₂ and oil emulsion. According to our results, none of the soil samples had an excess of heavy metal concentration limit. Besides, heavy metal concentrations were decreasing with a distance from the road increasing. We can make an assumption that road dust-minimizing materials do not have a significant impact on heavy metal distribution in roadside soils. The major factors of heavy metal pollution distribution in roadside soils are traffic intensity, roadside trenches, and topographic conditions.

Keywords: heavy metals, soil, soil contamination, gravel roads, background quantity of heavy metals.

1. Introduction

Soil contamination is an urgent problem worldwide to which no universal solution has been found yet. There are zillions of soils contaminated with heavy metals in the world. Even though some pollutants naturally occur in soil, pollutants accompany all spheres of human activities: mining, metal melting, industry, agriculture, transport, sewage sludge treatment, production of fertilisers, etc. All these activities generate pollutants which one way or another way, as gases, solid particles or solutions, access the environment. Heavy metals are the result of the modern industry (Peters 1999; Hooda 2003; Barazani *et al.* 2004; Morel 2002; Sun *et al.* 2001; Khan 2005; Boularbah *et al.* 2006; Wu *et al.* 2006; Pereira *et al.* 2006; Jankaitė 2009). Nearly all chemical elements are found in soil in the form of different compounds. The most widely spread chemical elements are oxygen, silica, aluminium, iron and a number of others (Baltrėnas and Ščupakas 2007). As geo-accumulation indices show, larger amounts of Cr, Ni, Cu, Pb, Zn and Cd are spread in the natural environments of urbanised territories and closer to roads (Wei and Yang 2010; Christoforidis and Stamatis 2009; Yang *et al.* 2010). The following sequence of heavy metals distribution in soil was identified: Cd>Pb>Zn~Cu>Mn>Ni>Fe~Cr (Maiz *et al.* 1997). Heavy metals are particularly dangerous when they are spread in the top layer (up to 10 cm deep) of soil (Yesilonis *et al.* 2008). According to hazardousness to live organisms heavy metals are distributed as follows: Hg, As, Cu, Cd, Zn, Cr, Mn, Fe, Ti, Pb, while their carcinogenic

and mutagenic effect depends on their concentrations and can manifest itself only after some time but not right away (Četkauskaitė 1999). Lack or excess of micro elements in soil predetermine a chemical composition of water and plants. This is the reason why humans or animals can have specific diseases related to metabolic disorders (Četkauskaitė 1999). Underground water and food chains may be exposed to the danger of soil contamination with heavy metals (Farrell *et al.* 2010). It is determined that high concentrations of the heavy metals Co, Cd, Pb, Zn, Mn, Ni and Cu in soil and plants can cause cancer (Turkdogan *et al.* 2002).

High soil contamination is caused by motor vehicles. Particularly dangerous are heavy metals which get into soil (Gardea-Treesdey *et al.* 2005; Baltrėnas and Vaišis 2006). Recently, motor vehicles have been the source of contamination with As, Cd, Cr, Ni and Pb (Kummer *et al.* 2009). It is determined that intensive motor traffic on main roads can have an influence on soil contamination up to 320 m from the road (Viard *et al.* 2004). Today's transport plans hardly take account of transport improvements and influence on land use. The benefit of transport projects for mobility and the environment is overvalued without paying sufficient attention to the possible benefit of the land use or transport policy (Behbahani and Haghghi 2009).

According to currently prevailing opinion, heavy metals are durable pollutants. Even though the majority of organic pollutants and photo oxides decompose in nature, the aforementioned metals cannot be decomposed or destroyed by the natural environment. They can only

be either diluted or combined in temporary conditionally secure complexes. When such complexes decompose, heavy metals spread in the environment again and become dangerous for live organisms. It is important, therefore, to prevent metals from accessing the environment. Otherwise they will spread and one way or another get into a human organism (Četkauskaitė 1999). The effect of heavy metals on organism depends not only on their concentration in the environment but also on their interrelationships, migration form and how much of them can be easily assimilated (Jankaitė and Vasarevičius 2005).

The aim of this research is to analyse the influence of motor traffic on soil contamination and evaluate the level of contamination with heavy metals of the topsoil of gravel roadsides.

2. Investigation

Investigation localities were selected taking account of gravel road treatment with regard to dustiness minimisation. The two gravel roads concerned are treated with CaCl_2 (the gravel roads Krinčinai – Žvirgždė – Šukionys – Meilūnai, and Jusevičiai – Būdvietis – Derviniai), the other two – with oil emulsion (the gravel roads Bagaslaviškis – Neveronys – Mikalajūnai, and Šeiniūnai – Vindeikiai – Uliškiai). Numbering of sampling sections is started from the beginning of the road in the direction which is indicated by the road name.

Sample taking and preparation for analysis is regulated by the national standard.

The maximum permitted concentrations in soil of contamination with heavy metals of the lithosphere's top part is regulated by Lithuanian Hygiene Norm HN 60:2004 "The maximum permitted concentrations of chemical substances in soil" (Table 1). This Hygiene Norm sets the maximum permitted concentrations of hazardous chemical substances in soil which neither directly nor indirectly (via plants, air or water) affect the health of humans and future generations thereof. The main indicator for assessing soil contamination with chemical substances is the maximum permitted concentration (MPC) of hazardous chemicals in soil.

Soil sampling is done by forming a transversal profile. Sampling points are at a distance of 1; 2; 5; 10 metres from the road (transversal profile) depending on

topographic conditions and spatial layout of planted areas (Fig. 1). Diagram of taking samples from the road's transversal profile is presented in Fig. 1.

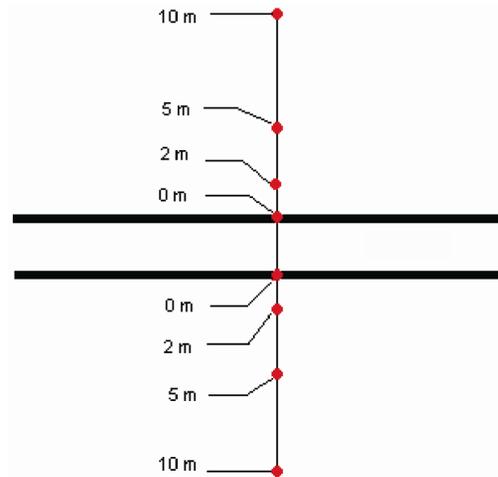


Fig. 1. Diagram of sample arrangement in the roadside transversal profile

Soil sampling is done so as to avoid distortions in analysis results and samples are taken at different distances taking account of the distance from the source of contamination or the direction of the prevailing wind. In order to find out the intensity of the atmospheric load of pollutants to the best possible extent, samples were taken from the top layer of soil, 0–10 cm deep. Each such sample was formed in the manner of "envelope" by covering its entire elementary area, 1×1 m, with at least five sub-samples taken at equal distances from each other. When identifying contents of heavy metals in soil no instruments containing metals can be used and therefore samples are collected with stainless steel scoops and poured into re-closable polyethylene bags.

The samples, placed in special fabric bags (around 500 g), are taken to a laboratory of the Environment Protection Department of Vilnius Gediminas Technical University and analysed by atomic absorption spectroscopy to identify Cr, Cu, Mn, Ni, Pb and Zn. These metals are selected for the analysis due to the fact that they are most commonly found heavy metals in roadsides soils. The collected samples are dried, larger roots, other organic objects and stones removed from them, and they are crushed.

Soil sample preparation for analysis:

- 2 grams of a solid sample are dried at a temperature of 105°C for two hours.
- Dried samples are sieved through a sieve having 1 mm^2 internal diameter meshes. A 0.7 g soil fraction with its diameter below 1 mm is used for analysis.
- The soil in question is poured into mineraliser's vessels and dried at a temperature of 105°C for 30 minutes.
- 90 ml of H_2O_2 , 30% and 10 ml of HNO_3 , 65%, are poured over the sample.

Table 1. MPC of hazardous chemical substances and their background quantities in soil according to Lithuanian Hygiene Norm HN 60:2004

Name of substance	Maximum permitted concentration (MPC), mg/kg	Background quantity of chemical substance, mg/kg	
		in sand and sandy loam soil	in clay loam and clay soil
Chromium (Cr)	100	30	44
Zinc (Zn)	300	26	36
Manganese (Mn)	1 500	427	451
Nickel (Ni)	75	12	18
Lead (Pb)	100	15	15
Copper (Cu)	100	8,1	11

5. Mineraliser's vessels are closed with covers, inserted into holders and covered with cylinder's cover. Mineralisation lasts for 30 minutes.
6. Mineralisation completed, vessels with samples are cooled for an hour.
7. Solution is poured into a 50 ml flask and diluted to the marked point.
8. Sample's solution is analysed with the atomic absorption spectrometer 210 VGP.

3. Investigation results and their analysis

The gravel road Krinčinai – Žvirgždė – Šukionys – Meiliūnai (No 3106) belongs to Panevėžys county. Dustiness on it is being minimised with CaCl_2 . Soil samples from this road were taken for the analysis of heavy metals in the transversal profiles of 13.5 km and 16.0 km. The gravel road is of local significance, connecting four larger settlements with traffic on it being non-intensive. Sampling localities were selected with the aim of determining the spread of heavy metals in roadside soil nearby non-intensive gravel road, in a hilly area.

Nickel. The identified concentrations of Ni exceeded the background quantity but did not exceed the MPC. The highest identified concentration of Ni reached 26.5 mg/kg, which is 2.2 times above the background quantity. This concentration was determined in the samples taken from 13.5 km right next to the carriageway. Ni concentration determined in 16 km next to the carriageway reached 20.0 mg/kg. It is determined that Ni concentration is decreasing in both sampling profiles with a distance from the carriage way increasing. Ni concentrations at 2 m distance from the roadside in 16.0 km and 13.5 km were equal to 16.6 mg/kg and 15.6 mg/kg, respectively. Ni concentration identified in the samples collected at a distance of 5 m from the roadside was 1.3 times above the background value in 16.0 km and 1.1 times above it in 13.5 km. The lowest concentrations of Ni were determined at 10 m distance from the carriageway. Ni concentration in 13.5 km section, at a distance of 10 m from the road edge, was below the background quantity and the samples collected in 16.0 km section insignificantly exceeded the background quantity.

Lead. In all the collected samples Pb concentration exceeds the background quantity but does not exceed the MPC. Higher concentrations of Pb were recorded at distances of 2 m and 5 m from the carriageway. This can be explained by a hilly relief of the locality and the presence of a roadside trench which results in Pb settling somewhat further from the carriageway. Pb concentration identified in 16.0 km profile at a distance of 2 m from the carriageway reached 35.3 mg/kg. The concentration exceeds the background quantity by nearly 2.4 times. Pb concentration identified in another section (13.5 m) at a distance of 2 m was a bit lower reaching 28.1 mg/kg. Pb concentration in the samples taken right next to the carriageway reached 15.2 mg/kg (at 16.0 km) and 19.0 mg/kg (at 13.5 km). Pb concentration in the samples collected at 5 m and 10 m distances from the roadside decreases compared to Pb concentration determined at a distance of 2 m from the

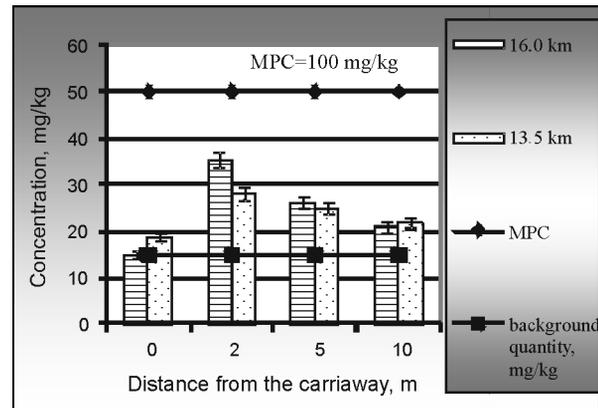


Fig. 2. Lead concentration in the roadside soil of the gravel road Krinčinai – Žvirgždė – Šukionys – Meiliūnai

roadside. Pb concentration in the samples taken furthest from the carriageway reached 21.1 mg/kg (at 16.0 km) and 21.7 mg/kg (at 13.5 km). Pb concentrations at a distance of 10 m differ insignificantly (Fig. 2).

Copper. The identified concentrations of Cu did not exceed the MPC in any of the collected samples, while the background quantity was exceeded in the samples taken closer to the road. Higher concentrations of Cu were identified right next to the carriageway and in the samples collected at a distance of 2 m from it. Cu concentration determined at 13.5 km exceeded the background quantity by nearly 1.5 times (in the samples collected immediately next to the road) and Cu concentration in the samples taken at a distance of 2 m from the roadside reached 11.6 mg/kg. Cu concentration established in 16.5 km profile at a distance of 5 m from the carriageway reached 7.2 mg/kg and was below the background quantity. Cu concentration identified in the sample taken at 13.5 km at the same distance from the roadside was also lower than the background quantity, 6.7 mg/kg. Pb concentration in the samples taken furthest from the roadside reached 7.1 mg/kg (at 16.0 km) and 5.1 mg/kg (at 13.5 km). Consequently, with a distance from the road increasing, Cu concentration is gradually decreasing.

Chromium. The identified concentration of Cr exceeded neither the background quantity nor the MPC in any of the samples. Somewhat higher concentrations of Cr were determined in the samples taken next to the carriageway while Cr concentrations were decreasing with a distance from the road increasing. The highest identified concentration of Cr was in 3.5 km section immediately next to the carriageway. Here Cr concentration was equal to 20.1 mg/kg. Cr concentration determined at 2 m distance from the carriageway decreases to 7.6 mg/kg, at 5 m distance is 6.6 mg/kg and furthest from the road (10 m) – 5.7 mg/kg. A similar situation was in another sampling section (16.0 km) – the highest concentration of Cr was determined right next to the carriageway and the lowest – in the samples collected furthest from the road. The lowest concentration of Cr determined on this road was at a distance of 10 m from the carriageway at 16.0 km – 2.8 mg/kg. It is a tenfold lower concentration than the background quantity (Fig. 3).

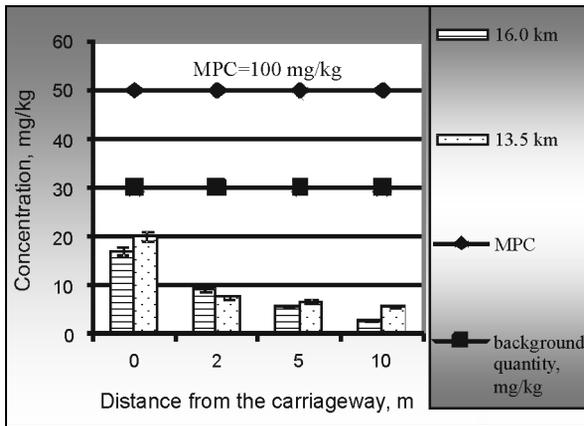


Fig. 3. Chromium concentration in the roadside soil of the gravel road Krinčinai – Žvirgždė – Šukionys – Meiliūnai

Zinc. The identified concentrations of Zn exceeded the MPC in none of the samples. Higher concentrations of Zn were determined in the samples taken at 16.0 km section right next to the carriageway. The concentration of Zn determined here reached 38.4 mg/kg, which is nearly 1.5 times above the background quantity. Zn concentration identified in the same road section at a distance of 2 m reached 34.8 mg/kg, at a distance of 5 m – 21.3 mg/kg. The lowest concentration on zinc determined in this profile was in the samples collected furthest from the road. The concentration of zinc determined here was 14.2 mg/kg, which is 1.8 times below the background quantity. Zn concentration established in the second sampling profile was also decreasing with a distance from the road increasing. Zn concentration in the samples collected right next to the road reached 25.3 mg/kg, showing a slight difference from the background quantity. Zn concentration determined in the samples taken at a distance of 2 m from the roadside was 1.2 times below the background quantity. Zn concentration identified in the samples collected at 5 m distance from the carriageway was 19.6 mg/kg. The lowest concentration of zinc identified on the sides of this road was in the samples collected at 13.5 km profile at 10 m distance from the roadside. Here, Zn concentration was by 1.9 times lower than the background quantity of Zn.

Manganese. The identified concentration of Mn did not exceed the MPC, and exceeded the background quantity only in the soil sample collected right next to the carriageway. Slightly higher concentrations of Mn were established in 13.5 km profile. The concentration of Mn determined in the samples collected immediately next to the carriageway exceeded the background quantity and reached 470.8 mg/kg. The concentration of Mn established in the samples collected in this profile at 2 m distance from the roadside was slightly lower than the background quantity and reached 422.5 mg/kg. Mn concentration determined in the samples collected further from the roadside decreased and reached 145.4 mg/kg at a distance of 10 m. The highest concentration of Mn identified in 16.0 km profile was right next to the carriageway – 427.1 mg/kg. This concentration is nearly equal to the background quantity of Mn (427 mg/kg). Samples

collected further from the roadside showed a lower concentration of Mn. The concentration of Mn determined at a distance of 2 m was 367.8 mg/kg, at a distance of 5 m – 184.5 mg/kg, and at the biggest distance from roadside – 129.3 mg/kg. This is the lowest concentration of Mn determined on this roadside (Fig. 4).

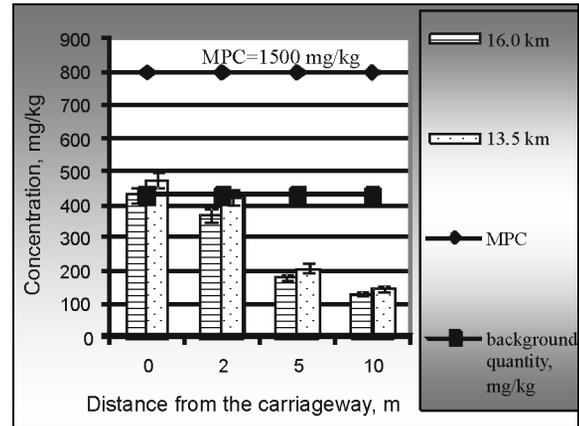


Fig. 4. Manganese concentration in the roadside soil of the gravel road Krinčinai – Žvirgždė – Šukionys – Meiliūnai

As the presented data show, with a distance from the road increasing the concentration of heavy metals is decreasing. Only in the case of Pb the identified concentrations at a distance of 2 m from the roadside are higher than those identified immediately next to the road. This can be related to the presence of a hilly relief in this locality.

The gravel road Jusevičiai – Būdviėtis – Derviniai (No 2608) belongs to Alytus county. Its dustiness is being minimised with the help of CaCl_2 . Soil samples for heavy metals analysis were taken at the transversal profiles of 13.25 km and 13.85 km not far from Būdviėtis settlement. There are cultivated lands on the left side of the gravel road and a hill, meadow, cultivated lands on the right of it without any dwellings on both sides. The locality is hilly with single trees and bushes. The sampling profiles were selected with the aim of determining a spread of heavy metals in a hilly location.

Nickel. The identified concentrations of Ni in the soil of these roadsides did not go above the MPC. Higher concentrations of Ni were determined in the samples taken right next to the carriageway. The concentrations of Ni identified in both sampling sections right next to the roadside are similar – 26.2 mg/kg (13.25 km section) and 26.4 (13.85 km section). This concentration exceeds the background quantity by up to 2.2 times. With a distance from the carriageway increasing Ni concentration in soil was decreasing. The concentration of Ni identified in the samples collected in 13.25 km profile at a distance of 2 m reached 18.3 mg/kg, being by 1.5 times higher concentration than the background quantity. Ni concentration at 5 m distance from the roadside reached 14.5 mg/kg. Ni concentration identified at 10 m distance from the roadside did not exceed the background quantity and was equal to 11.4 mg/kg. A similar situation was in 13.85 km section. The highest concentration of Ni was determined

right next to the carriageway, while at a distance of 2 m Ni concentration reached 17.1 mg/kg, at a distance of 5 m – 13.4 mg/kg. The lowest identified concentration of Ni in the soil of this roadside was 10.2 mg/kg.

Lead. The identified concentrations of Pb exceeded the MPC in none of the soil samples. Higher concentrations of Pb were accumulated immediately next to the carriageway. Pb concentration established in 13.25 km profile right next to the carriageway was 37.7 mg/kg. This concentration is 2.5 times above the background quantity. Pb concentration recorded at a distance of 2 m from the roadside decreased to 17.2 mg/kg. Pb concentration in the samples collected at a distance of 5 m from the roadside reached 15.3 mg/kg. The lowest concentration of Pb identified in this sampling profile was 8.1 mg/kg (at 10 m distance from the roadside). Pb concentration recorded in the second profile right next to the carriageway was somewhat higher than in the first one reaching 39.7 mg/kg, which is by 2.6 times more than the background quantity. Like in the first sampling profile, with a distance from the road increasing, the identified concentrations of Pb were decreasing. Pb concentration at 2 m distance from the carriageway reached 15.4 mg/kg, at 5 m distance was nearly equal to the background quantity – 14.9 mg/kg. In the road Jusevičiai – Būdviėtis – Derviniai the lowest concentration of Pb was identified in 13.85 km section at a distance of 10 m from the roadside – 7.0 mg/kg, being more than by 2 times lower than the background quantity (Fig. 5).

Copper. The identified concentrations of Cu in these roadsides did not exceed the MPC and only slightly exceeded the background quantity. The highest concentrations of Cu established on these roadsides were at 13.25 km section. Cu concentration identified right next to the carriageway reached 11.9 mg/kg, which is nearly 1.5 times more than the background quantity. Cu concentration at a distance of 2 m from the roadside is slightly above the background quantity and at a distance of 5 m is 1.1 times below the background quantity. Cu concentration recorded in the samples which were collected furthest from the road in this section reached 6.8 mg/kg. Cu concentrations recorded in the second sampling section are similar to those identified in the first one. Cu concentration determined in the samples collected right next to the carriage reached 11.5 mg/kg, which is 1.4 times above the background quantity. The concentration of Cu at 2 m distance decreased to 9.0 mg/kg. Cu concentration at 5 m distance from the roadside reached 7.4 mg/kg. Cu concentration recorded in the samples which were collected furthest from the road in this section reached 6.9 mg/kg. This concentration is 1.1 times below the background quantity.

Chromium. The identified concentrations of Cr exceeded neither the MPC nor the background quantity. A higher concentration of Cr was determined next to the carriageway. In 13.25 km section, the identified concentration of Cr right next to the carriageway reached 27.1 mg/kg, which is 1.1 times less than the background quantity. Cr concentration determined in the samples which were collected at a distance of 2 m from the roadside

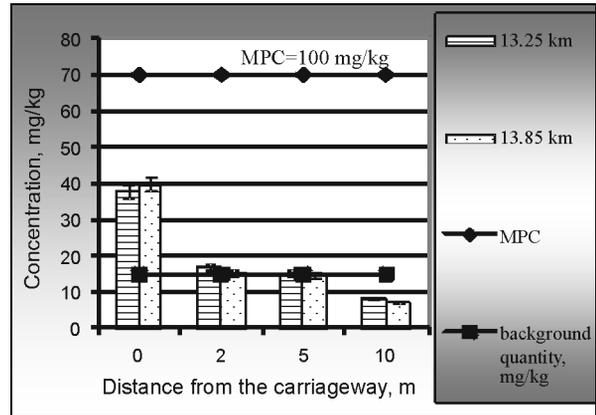


Fig. 5. Lead concentration in the roadside soil of the gravel road Jusevičiai – Būdviėtis – Derviniai

decreased to 14.9 mg/kg, which is 2 times below the background quantity. Cr concentration recorded at a distance of 5 m from the roadside reached 13.6 mg/kg. The lowest concentration of Cr determined on this road was at a distance of 10 m from the carriageway in 13.25 km section – 10.8 mg/kg. This concentration is nearly 3 times lower than the background quantity. Cr concentrations recorded in the second sampling section, 13.85 km, are similar to those identified in the first section. Cr concentration determined in the samples collected right next to the carriage reached 22.3 mg/kg, which is 1.3 times more than the background quantity. Cr concentration identified in the samples which were collected further from the road (2 m) decreased to 19.3 mg/kg. Cr concentration identified in the samples collected at 5 m distance from the carriageway was 16.7 mg/kg. Cr concentration established in the samples which were collected furthest from the road was 15.7 mg/kg, which is nearly 2 times less than the background quantity (Fig. 6).

Zinc. The identified concentrations of Zn were not above the MPC. The background quantity was exceeded only right next to the carriageway. Zn concentration identified in the first section right next to the roadside reached 30.4 mg/kg, which 1.2 times more than the background quantity. Zn concentration determined in the samples taken at a distance of 2 m from the roadside was already

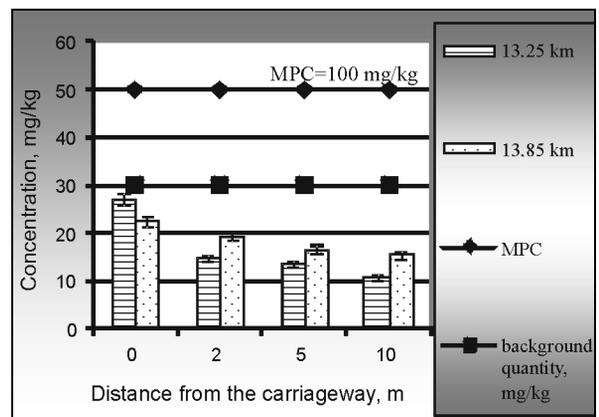


Fig. 6. Chromium concentration in the roadside soil of the gravel road Jusevičiai – Būdviėtis – Derviniai

1.2 times lower than the background quantity. Zn concentration in the samples collected at 5 m distance reached 24.2 mg/kg. Zn concentration identified in the samples collected furthest from the road decreased to 18.2 mg/kg. Zn concentration identified in the second section right next to the carriageway was 33.7 mg/kg. This concentration is nearly 1.3 times above the background quantity. Zn concentration determined in the samples taken at a distance of 2 m from the carriageway was 1.1 times lower than the background quantity. Zn concentration identified in the samples collected at 5 m distance from the roadside was 19.8 mg/kg. The lowest concentration determined in the roadside soil of this gravel road was in 13.85 km section at a 10 m distance from the carriageway. At this point it reached 14.7 mg/kg. This is 1.7 times more than the background quantity.

Manganese. The identified concentrations of Mn in these gravel roadsides exceeded neither the MPC nor the background quantity. The identified concentrations of Mn in these roadsides were similar in both sampling profiles. Mn concentration determined in the first section (13.25 km) right next to the carriageway reached 222.8 mg/kg, and that recorded in the second section right next to the carriageway was 227.7 mg/kg. At a distance of 2 m from the roadside Mn concentration reached 185.2 mg/kg in the first profile, and 196.3 mg/kg in the second profile. Mn concentration determined in the samples taken at a distance of 5 m from the carriageway in 13.25 km section was 2.2 times lower than the background quantity. Mn concentration identified in the samples collected from 13.85 km section at the same distance from the carriageway was 2.26 times below the background quantity (Fig. 7).

Mn concentrations identified in the samples collected furthest from the carriageway were nearly 2.5 times lower than the background quantity. Mn concentration determined in 13.25 km section at a distance of 10 m from the carriageway reached 174.0 mg/kg, while that identified in 13.85 km section at the same distance from the carriageway reached 171.3 mg/kg.

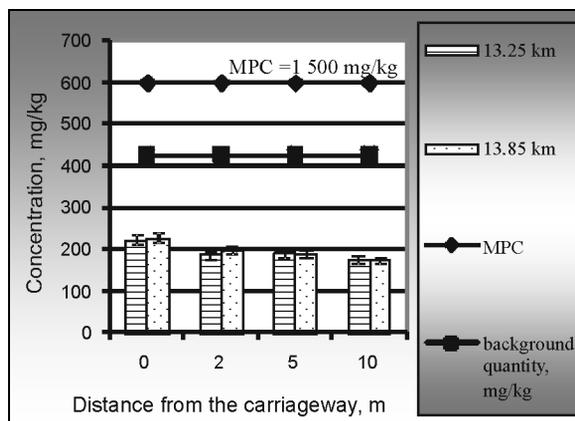


Fig. 7. Manganese concentration in the roadside soil of the gravel road Jusevičiai – Būdviėtis – Derviniai

As the presented data show, the roadside soil of the gravel road Jusevičiai – Būdviėtis – Derviniai is not contaminated with heavy metals. It is determined that with a distance from the carriageway increasing the concentrations of the heavy metals under review are decreasing.

Gravel road Bagaslaviškis – Neveronys – Mikalajūnai (No 4310) belongs to Vilnius county. Oil emulsion is used for the maintenance of this road. Soil samples for heavy metals analysis were collected in Neveronys settlement, in 5.07 km and 5.85 km sections. The first profile of samples is inside Neveronys settlement, and the second – at the end of it. The gravel road is treated with oil emulsion. Dwellings, meadows and arable land are located right next to the road. Pastures and open localities are stretching along both sides of the road at the end of the settlement. Further are stretching waste lands and forests. Trenches are present on both sides of the road. Localities were selected with the aim of determining the spread of heavy metals in the road environment – in an open locality and within a settlement.

Nickel. The identified concentrations of Ni in the soil of these roadsides were not above the MPC. Concentrations exceeding the background quantity by up to 1.7 times were recorded right next to the carriageway in 5.07 km section. Ni concentration in the samples collected at a distance of 2 m from the roadside decreases to 15.9 mg/kg, which is 1.3 times less than the background quantity. Ni concentration identified in the same road section at 5 m distance from the roadside did not exceed the background quantity and reached 9.0 mg/kg. Ni concentration recorded in the samples collected furthest from the road reached 8.1 mg/kg. This concentration is 1.5 times below the background quantity. A similar situation was in the second sampling section. The highest concentration of Ni was identified right next to the carriageway and reached 17.0 mg/kg. Ni concentration at 2 m distance falls to 11.5 mg/kg being below the background quantity. Ni concentration established at a distance of 5 m is by 1.14 times lower than the background quantity. Ni concentration established furthest from the road in this section reached 9.2 mg/kg (Fig. 8).

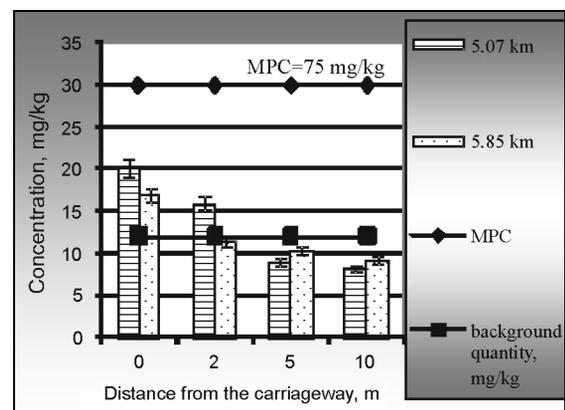


Fig. 8. Nickel concentration in the roadside soil of the gravel road Bagaslaviškis – Neveronys – Mikalajūnai

Lead. The recorded concentrations of Pb exceeded the MPC in none of the points. Somewhat higher concentrations of Pb were accumulated right next to the carriageway. Pb concentration right next to the carriage way in the section (5.07 m) reached 16.5 mg/kg. This concentration was 1.1 times higher than the background quantity. Pb concentration determined at a distance 2 m insignificantly differed from that determined right next to the carriageway reaching 16.2 mg/kg. Pb concentration recorded in the samples collected at a distance of 5 m from the roadside decreased to 12.0 mg/kg. Pb concentration determined in the samples from this section furthest from the roadside reached 11.6 mg/kg. This concentration is nearly 1.3 times lower than the background quantity. Pb concentration in the second section (5.85 km) right next to the carriageway reached 23.6 mg/kg, which is 1.6 times more than the background quantity. Pb concentration identified at a distance of 2 m from the roadside decreased to 14.9 mg/kg and was in fact equal to the background quantity. Pb concentration identified at a distance of 5 m from the carriageway reached 11.2 mg/kg. Pb concentration measured in the samples collected furthest from the road was 10.7 mg/kg being the lowest concentration of Pb determined on this road.

Copper. The identified concentrations of Cu did not exceed the MPC, and the background quantity was exceeded at a distance of 5 m from the carriageway. The highest concentration of Cu identified in the roadside soil of this road was 19.9 mg/kg. This concentration was measured in the samples collected right next to the carriageway of 5.07 km section. Cu concentration at 2 m distance from the roadside in the same section reached 10.1 mg/kg. Pb concentration recorded in the samples collected at a distance of 5 m from the roadside decreased to 9.5 mg/kg. The lowest concentration of Cu on this road was determined at 10 m distance from the carriage way of 5.07 km section. This concentration is 1.6 times lower than the background quantity. Cu concentration identified in the second section right next to the carriageway reached 18.7 mg/kg. This is 2.3 times above the background quantity (Fig. 9).

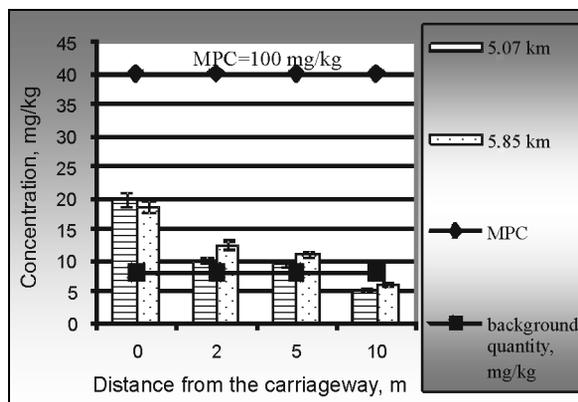


Fig. 9. Copper concentration in the roadside soil of the gravel road Bagaslaviškis – Neveronys – Mikalajūnai

Cu concentration at 2 m distance from the roadside decreased to 12.5 mg/kg, which is 2.5 times above the background quantity. Cu concentration at 5 m distance from the roadside reached 11.2 mg/kg. Cu concentration determined in the samples which were collected furthest from the carriageway was not above the background quantity and reached 6.1 mg/kg.

Chromium. The identified concentrations of Cr exceeded neither the MPC nor the background quantity. The concentrations of this metal in the roadside soil of the gravel road Bagaslaviškis – Neveronys – Mikalajūnai are the lowest. The highest concentration of Cr was identified right next to the carriageway and reached 5.9 mg/kg. This concentration was identified in 5.85 km section, but it is more than 5 times below the background quantity. Cr concentration at 2 m distance from the carriageway in the same section reached 4.4 mg/kg. Cr concentration recorded in the samples collected at a distance of 5 m from the roadside decreased to 4.2 mg/kg. Cr concentration determined in the samples from this section furthest from the roadside was 3.1 mg/kg. This concentration is nearly 10 times lower than the background quantity. Cr concentration determined right next to the road in 5.07 km section reached 5.1 mg/kg. Cr concentration at 2 m distance from the carriageway is in fact the same as right next to the carriageway – 5.2 mg/kg. Cr concentration identified in the samples collected at 5 m distance from the roadside was 3.3 mg/kg. The lowest concentration of Cr on this road was determined at 10 m distance from the carriage way of 5.07 km section. Here Cr concentration was more than 17 times lower than the background quantity.

Zinc. The identified concentrations of Zn did not exceed the MPC, while the background quantity was exceeded only in the samples which were collected right next to the road. Zn concentrations established in both road sections are similar. Zn concentration identified in 5.07 km section right next to the carriageway reached 39.5 mg/kg. This is 1.5 times more than the background quantity. Zn concentration established at a distance of 2 m from the roadside reached 19.4 mg/kg, which is 1.3 times below the background quantity. Zn concentration at 5 m distance is practically equal to that determined at 2 m distance, i.e. 19.2 mg/kg. The lowest concentration of Zn was determined in the samples collected furthest from the road. Here it reached 18.6 mg/kg. This is 1.4 times less than the background quantity. Zn concentration established in the second section (5.85 km) right next to the carriageway reached 40.1 mg/kg, which is 1.5 times above the background quantity. Zn concentration found in the samples collected at 2 m distance reached 20.0 mg/kg and did not exceed the background quantity. Zn concentration determined in the samples taken at a distance of 5 m from the carriageway was 1.27 times lower than the background quantity. Zn concentration identified in the samples collected at 10 m distance from the roadside was 19.7 mg/kg. This Zn concentration is 1.3 times below the background quantity of this metal (Fig. 10).

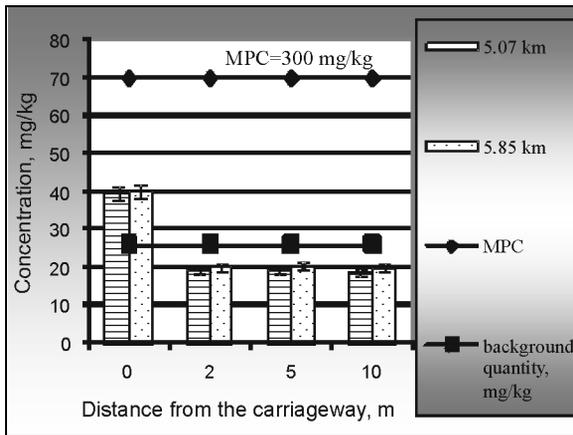


Fig. 10. Zinc concentration in the roadside soil of the gravel road Bagaslaviškis – Neveronys – Mikalajūnai

Manganese. The identified concentrations of Mn in these gravel roadsides exceeded neither the MPC nor the background quantity. Mn concentrations established in both road sections are similar. Mn concentration identified in 5.07 km section right next to the carriageway reached 236.3 mg/kg. This concentration is by 1.8 times lower than the background quantity. Mn concentration recorded at a distance of 2 m from the roadside decreased to 207.1 mg/kg. With a distance from the carriageway increasing Mn concentration was decreasing and reached 121.6 mg/kg at a distance of 5 m from the road. The lowest concentration of Mn determined in this section, and at the same time in the soil of this gravel roadside, was at 10 m distance from the roadside reaching 72.5 mg/kg. This concentration is 5.9 times below the background quantity. Mn concentrations recorded in the second sampling section are similar to those identified in the first one. Mn concentration identified right next to the carriageway reached 248.5 mg/kg. This is 1.7 times less than the background quantity. Mn concentration recorded in the samples collected at a distance of 2 m from the roadside was 216.3 mg/kg. As with a distance from the carriageway increasing Mn concentration was decreasing, at 5 m distance it reached 114.4 mg/kg, at 10 m distance – 83.4 mg/kg. This identified concentration of Mn was more than 5 times below the background quantity.

As the afore-presented data show, the roadside soil of the gravel road Bagaslaviškis – Neveronys – Mikalajūnai is not contaminated with heavy metals. It is determined that with a distance from the carriageway increasing the concentrations of the heavy metals under review are decreasing.

Gravel road Šeiniūnai – Vindeikiai – Uliškiai (No 4315) belongs to Vilnius county and is treated with oil emulsion. Soil samples for heavy metals analysis were collected in Stavarygala settlement, in 3.11 km, 2.63 km and 2.14 km sections. Sampling profiles are allocated at the beginning, in the middle and at the end of the settlement. Dwellings and outhouses, meadows, arable lands and fields are located right next to the road. Roadsides are abundant with fruit-trees and dwarf bushes. There are many open areas, particularly at the end of the settlement, with meadows on both sides of the road. A forest is

stretching in the distance. Localities were selected with the aim of determining the concentrations of heavy metals in soils stretching within the limits of a settlement.

Nickel. The identified concentrations of Ni on the roadsides of this gravel road did not exceed the MPC, while the background quantity was exceeded only in the samples collected right next to the road. The highest concentration of Ni was determined in 3.11 km and 2.63 km sections right next to the carriageway. Here the concentrations of Ni were the same, equal to 16.4 mg/kg. This is 1.36 times more than the background quantity. Ni concentration identified in the samples collected at 2 m distance from the roadside (in 3.11 m section) was 11.7 mg/kg. This concentration is insignificantly below the background quantity. With a distance from the carriageway increasing Ni concentration was decreasing. At a distance of 5 m it reached 8.8 mg/kg, at 10 m – 7.9 mg/kg. Ni concentrations recorded in the second sampling section are similar to those identified in the first section. At a distance of 2 m Ni concentration reached 10.0 mg/kg, 5 m – 9.5 mg/kg. Ni concentration determined at a distance of 10 m from the carriageway was 6.2 mg/kg. This is nearly 2 times more than the background quantity. Ni concentrations recorded in the third section were slightly below those identified in the first two sections. Ni concentration measured right next to the carriageway reached 15.5 mg/kg, at 2 m distance – 10.1 mg/kg, at 5 m distance from the carriageway – 7.1 mg/kg. The lowest identified concentration of Ni in the soil of this roadside reached 5.3 mg/kg. This concentration is 2.3 times lower than the background quantity of Ni.

Lead. The identified concentrations of Pb did not exceed the MPC, while the background quantity was exceeded in the samples collected closer to the carriageway. The highest identified concentration of Pb on this road was 22.4 mg/kg. This concentration was recorded right next to the carriageway of 2.63 km section and by 1.5 times exceeded the background quantity. Pb concentration identified in the same road section at 2 m distance reached 19.3 mg/kg, 5 m – 9.8 mg/kg. Pb concentration determined in the samples from this section collected furthest from the road reached 7.0 mg/kg (Fig. 11).

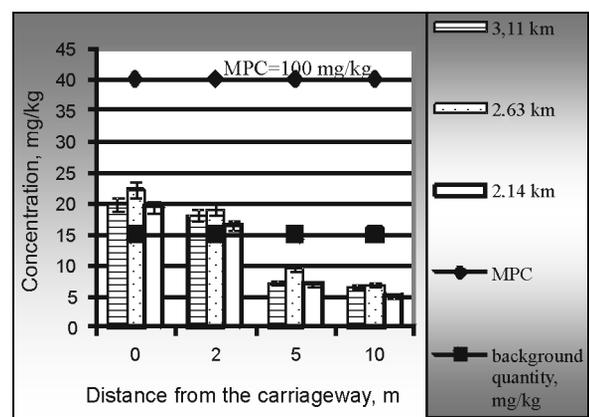


Fig. 11. Lead concentration in the roadside soil of the gravel road Šeiniūnai – Vindeikiai – Uliškiai

Pb concentration determined in the samples collected in 3.11 km section reached 20.0 mg/kg. Pb concentration in the samples collected at a distance of 2 m from the section decreased to 18.2 mg/kg, which is 1.2 times below the background quantity. Pb concentration recorded at 5 m distance from the carriageway reached 7.3 mg/kg while at 10 m distance fell to 6.8 mg/kg. The lowest concentrations of Pb in the soil of this roadside were determined in 2.14 km section. Here, Pb concentration recorded right next to the carriageway was 19.6 mg/kg. Pb concentration determined at a distance of 2 m from the roadside was 16.6 mg/kg. Pb concentration still more decreased at 5 m distance from the roadside where it reached 7.1 mg/kg. The lowest recorded concentration of Pb was in 2.14 km section at a distance of 10 m from the carriageway. Here it reached 5.2 mg/kg. This is 2.9 times below the background quantity.

Copper. The identified concentrations of Cu did not exceed the MPC, while the background quantity was exceeded in the samples collected closer to the carriageway. The highest concentrations of Cu in these roadsides were determined in the samples collected in 2.63 km section. The concentration of this metal right next to the carriageway was 15.2 mg/kg, which is 1.9 times above the background quantity. Cu concentration identified in the samples collected at 2 m distance from the roadside was 10.4 mg/kg. Cu concentration recorded at 5 m distance was nearly equal to the background quantity – 8.3 mg/kg. Cu concentration at a distance of 10 m from the carriageway reached 3.2 mg/kg, which is 2.5 times below the background quantity of Cu. The highest concentration of Cu in the samples collected from the first section was right next to the carriageway reaching 14.8 mg/kg. Cu concentration at 2 m distance fell to 9.6 mg/kg, while at 5 m distance Cu concentration was below the background quantity and reached 7.7 mg/kg. Cu concentration determined in the samples collected further from the carriageway reached 3.5 mg/kg, which is 2.3 times below the background quantity. The lowest concentrations of Cu were determined in 2.14 km section. Cu concentration recorded in the samples collected right next to the roadside was 13.5 mg/kg. Further from the road Cu concentration was increasing. Cu concentration identified at 2 m distance reached 9.9 mg/kg, at 5 distance – 7.7 mg/kg. The lowest concentration of Cu determined in this section of the road in question was at a distance of 10 m from the carriageway. Here it reached 2.2 mg/kg. This is 3.7 times less than the background quantity of Cu.

Chromium. The identified concentrations of Cr exceeded neither the MPC nor the background quantity. Somewhat higher concentrations of Cr were accumulated right next to the carriageway. Cr concentration determined right next to the roadside in 3.11 km section reached 8.2 mg/kg. This concentration is 3.6 times lower than the background quantity. Cr concentration at 2 m distance from the carriageway reached 5.8 mg/kg, at 5 m – 5.3 mg/kg. The lowest concentration of Cr in this section was determined at 10 m distance from the carriageway. Here it reached 2.5 mg/kg, being the lowest

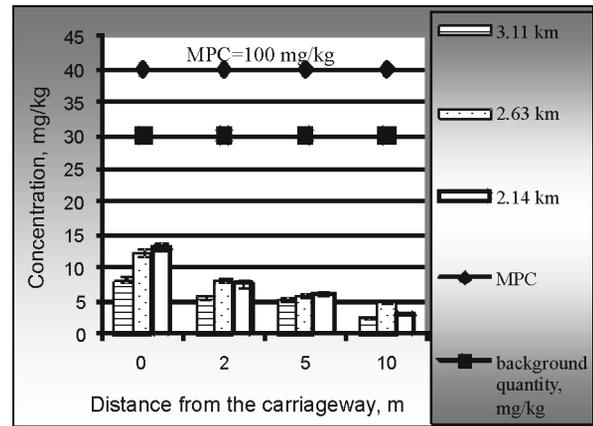


Fig. 12. Chromium concentration in the roadside soil of the gravel road Šeiniūnai – Vindeikiai – Uliškiai

concentration of Cr determined in these roadsides, and 12 times below the background quantity. In the second sampling section Cr concentration right next to road reached 12.3 mg/kg. Somewhat further from the road, at 2 m and 5 m distance, Cr concentrations were equal to 8.1 mg/kg and 6.0 mg/kg, respectively. Cr concentration determined in the samples from this section furthest from the roadside reached 4.9 mg/kg. In the third section Cr concentration right next to the carriageway was equal to 13.2 mg/kg. Cr concentration identified in the samples collected at 2 m distance from the roadside was 7.7 mg/kg. Cr concentration recorded in the samples collected at a distance of 5 m from the roadside decreased to 6.2 mg/kg. Cr concentration determined in the samples from this section furthest from the roadside reached 3.1 mg/kg (Fig. 12).

Zinc. The identified concentrations of Zn did not exceed the MPC. Higher concentrations of Zn in soil were accumulated closer to the carriageway. The highest concentrations of Zn in the roadside soil of this road were determined in 2.63 km section. Zn concentration identified in this section right next to the carriageway reached 43.2 mg/kg. This concentration exceeds the background quantity by nearly 1.7 times. At a distance of 2 m Zn concentration was 1.3 times above the background quantity. At 5 m distance from the roadside Zn concentration decreases to 27.7 mg/kg, and at 10 m distance from the roadside it is equal to 16.2 mg/kg, which is 1.6 times below the background quantity of Zn. Zn concentration identified in 3.11 km section right next to the carriageway reached 42.6 mg/kg. At 2 m distance Zn concentration fell to 30.7 mg/kg, while Zn concentration identified at 5 m distance was 1.13 times below the background quantity. Zn concentration at a 10 m distance from the roadside reached 10.8 mg/kg. The lowest concentration of Zn right next to the carriage way was determined in 2.14 km section. Here it reached 38.0 mg/kg. At 2 m and 5 m distance Zn concentration decreases to 31.5 mg/kg and 26.5 mg/kg, respectively. Zn concentration determined in the samples from this section furthest from the roadside reached 11.9 mg/kg.

Manganese. The identified concentrations of Mn exceeded neither the MPC nor the background quantity. Mn

concentration identified in the first section (3.11 km) right next to the carriageway reached 233.0 mg/kg. This concentration is 1.8 times lower than the background quantity. Mn concentration identified at 2 m distance from the roadside reached 209.6 mg/kg, at 5 m distance – 129.2 mg/kg. The lowest concentration of Mn identified in this section was at 10 m distance from the roadside. Here it reached 106.6 mg/kg, which is 4 times below the background quantity. Mn concentration identified in the second section right next to the carriageway reached 211.6 mg/kg. The concentration of Mn at 2 m distance decreased to 173.5 mg/kg. With a distance from the roadside increasing Mn concentration was decreasing and at 5 m distance from it was 128.9 mg/kg, at 10 m distance – 120.4 mg/kg. Mn concentration identified in the third section right next to the carriageway reached 210.3 mg/kg. The concentration of Mn at 2 m distance was to 152.6 mg/kg. Mn concentration recorded in the samples collected at a distance of 5 m from the roadside decreased to 125.0 mg/kg. The lowest identified concentration of Mn in the roadside soil of this road reached 96.5 mg/kg. This concentration was recorded in 2.14 km section at 10 m distance from the carriageway. This Mn concentration is 4.4 times lower than the background quantity (Fig. 13).

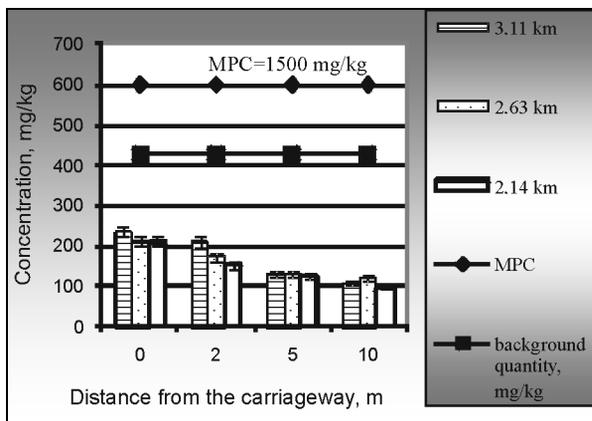


Fig. 13. Manganese concentration in the roadside soil of the gravel road Šeiniūnai – Vindeikiai – Uliškiai

As the presented results show, the soil of the gravel road Šeiniūnai – Vindeikiai – Uliškiai is not contaminated with heavy metals. It is determined that with a distance from the carriageway increasing the concentrations of the heavy metals under review are decreasing.

It is assumed that loads on the gravel roads Krinčinas – Žvirgzdė – Šukionys – Meiliūnai, Jusevičiai – Būdvielis – Derviniai, Bagaslaviškis – Neveronys – Mikalajūnai, and Šeiniūnai – Vindeikiai – Uliškiai are the same. Higher concentrations of Ni were determined in the roadsides of the gravel roads Jusevičiai – Būdvielis – Derviniai, and Krinčinas – Žvirgzdė – Šukionys – Meiliūnai (being nearly the same in these localities). Ni concentration in the roadside soil of these roads is up to 1.3 times higher than in the roadsides of the gravel road Bagaslaviškis – Neveronys – Mikalajūnai, and 1.6 times higher than in Šeiniūnai – Vindeikiai – Uliškiai. Higher

concentrations of Pb were also identified in the roadsides of Jusevičiai – Būdvielis – Derviniai. Pb concentrations determined in the roadside soil of this road are by 1.7 times higher than those in Bagaslaviškis – Neveronys – Mikalajūnai, by 1.8 times higher than in Šeiniūnai – Vindeikiai – Uliškiai roadside soils, and by a mere 1.07 times higher than in Krinčinas – Žvirgzdė – Šukionys – Meiliūnai roadside soil. Analysis of Cu concentrations showed the largest contents of this metal in Bagaslaviškis – Neveronys – Mikalajūnai roadsides. The highest identified concentrations of Cu in the roadsides of this road are up to 1.7 times above those in Jusevičiai – Būdvielis – Derviniai, up to 1.3 times higher than in Šeiniūnai – Vindeikiai – Uliškiai roadsides, and up to 1.6 times higher than those determined Žvirgzdė – Šukionys – Meiliūnai roadside soil. Cr concentrations did not exceed the background quantity in the soils of any of the roadsides, while the highest concentrations of this metal were recorded in the roadsides of the gravel road Jusevičiai – Būdvielis – Derviniai. The identified concentrations of Zn in Šeiniūnai – Vindeikiai – Uliškiai roadsides was up to 1.7 times, in Bagaslaviškis – Neveronys – Mikalajūnai roadsides – up to 1.54 times, and in Krinčinas – Žvirgzdė – Šukionys – Meiliūnai roadside soil – 1.48 times above the background quantity. The background quantity was least exceeded in the roadsides of the gravel road Jusevičiai – Būdvielis – Derviniai – up to 1.3 times. The identified concentrations of Mn did not exceed the MPC in any of the sampling places while the background quantity of Mn was exceeded only in the samples from the roadside soil of the gravel road Krinčinas – Žvirgzdė – Šukionys – Meiliūnai right next to the carriageway. At this point the background quantity was exceeded by 1.1 times.

Both the presented findings and comparison of the roads show that the concentrations of heavy metals in the gravel roadsides are not high and are decreasing with a distance from the carriageway increasing.

4. Conclusions

1. The roadside soil of the gravel road Krinčinas – Žvirgzdė – Šukionys – Meiliūnai is not contaminated with heavy metals. Concentrations of none of the heavy metals concerned exceeded the MPC.

2. The background quantity on the gravel road Jusevičiai – Būdvielis – Derviniai was most exceeded by the concentration of lead – up to 2.6 times. Concentrations of the other heavy metals analysed were conditionally low and with a distance from the carriageway increasing were decreasing.

3. Compared to the background quantity, the highest identified concentrations in the roadside soil of the gravel road Bagaslaviškis – Neveronys – Mikalajūnai were those of copper. It has been determined that the concentrations of this metal were up to 2.5 times above the background quantity. Concentrations of none of the heavy metals concerned exceeded the MPC.

4. Higher concentrations of heavy metals in the roadsides of the gravel road Šeiniūnai – Vindeikiai – Uliškiai were determined right next to the carriageway,

while with a distance from it increasing heavy metal concentrations were decreasing. No exceedances of the MPC were determined.

5. The soil of the gravel roadsides is not heavy contaminated with heavy metals. Concentrations of none of the heavy metals concerned exceeded the MPC. It is obvious that the concentrations of heavy metals in gravel roadsides are not high and do not exceed the regulated parameters.

6. It can be assumed that materials applied on road to minimise dustiness do not have a significant influence on the distribution of heavy metals in roadside soils, in the meantime the spread of heavy metals in roadsides is influenced by the intensity of traffic flows, roadside trenches and topographic conditions.

Acknowledgements

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SUNKIŲJŲ METALŲ KONCENTRACIJŲ ŽVYRKELIŲ PAKELIŲ DIRVOŽEMIUOSE VERTINIMAS

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Santrauka

Eksplatuojant autotransportą, į aplinką patenka daug sunkiųjų metalų. Atlikta nemažai tyrimų sunkiųjų metalų paplitimui dirvožemyje šalia intensyvių magistralinių kelių nustatyti, tačiau mažo intensyvumo keliai šiuo požiūriu tiriami mažai. Tirti pasirinkta 4 žvyrkeliai – vietinės reikšmės keliai, jungiantys nedideles gyvenvietes. Eismo intensyvumas šiuose keliuose mažas. Žvyrkeliai pasirinkti pagal taikomas priemones dulkėtumui mažinti, t. y. du nagrinėjami žvyrkeliai apdoroti CaCl_2 , kiti du – naftos emulsija. Nė viename mėginyje sunkiųjų metalų koncentracijos neviršijo DLK, o tolstant nuo važiuojamosios kelio dalies sunkiųjų metalų koncentracijos buvo mažesnės. Galima daryti prielaidą, kad kelio apdorojimo medžiagos dulkėtumui mažinti žymios įtakos sunkiųjų metalų pasiskirstymui pakelių dirvožemyje nedaro, lemia transporto srauto intensyvumas, kelio grioviai pakelėse bei reljefo sąlygos.

Reikšminiai žodžiai: sunkieji metalai, dirvožemis, dirvožemio tarša, žvyrkeliai, foniniai sunkiųjų metalų kiekiai.

ОЦЕНКА КОНЦЕНТРАЦИЙ ТЯЖЕЛЫХ МЕТАЛЛОВ В ПОЧВЕ ОБОЧИН ГРАВИЙНЫХ ДОРОГ

A. Микалаюне, Л. Якучёните

Резюме

При эксплуатации автомобилей в окружающую среду попадает много тяжелых металлов. Проведено немало исследований, посвященных анализу распространения тяжелых металлов в почве обочин интенсивно эксплуатируемых магистральных дорог, однако исследований, касающихся аналогичных проблем дорог малой интенсивности, в настоящее время имеется немного. В настоящей работе в качестве объекта исследований выбраны четыре дороги местного значения с гравийным покрытием, соединяющие небольшие поселения. Интенсивность дорог небольшая. Гравийные дороги выбраны с учетом их обработки для уменьшения пыльности – две дороги обработаны с применением CaCl_2 , а две другие – с применением нефтяной эмульсии. Ни в одной пробе не было зафиксировано концентраций тяжелых металлов, превышающих допустимые нормы. С удалением от проезжей части концентрации тяжелых металлов уменьшались. На основании исследований можно сделать вывод о том, что материалы, применявшиеся для уменьшения пыльности дорог, большого влияния на распространение тяжелых металлов в почве обочин дорог не оказывают. На распространение тяжелых металлов в почве обочин оказывает влияние интенсивность транспортного потока, кюветы на обочинах и условия рельефа.

Ключевые слова: тяжелые металлы, почва, загрязнение почвы, гравийные дороги, фоновые количества тяжелых металлов.

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