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Investigation and Modeling of Manganese Concentration in the Gravel Roadside

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Abstract. Road transport is one of the biggest soil polluter. There are a lot of investigations of soil pollution near highways, but soil pollution near gravel roadsides needs more experimental research. In this experimental study we selected gravel road Jusevičiai – Būdvietis – Derviniai and analyzed soil pollution near this road. Soil samples were collected on both sides of the road by making the transversal profile, the sampling points move away of the road at a distance 1; 2; 5; 10 meters, the samples were collected in 600 meters long strip. All samples were collected by using the envelope principle, samples were taken from the top of the soil layer 0–10 cm depth. It was established that Mn concentration in the soil sample, which was taken from the middle of gravel road carriageway, reached 238,5 mg/kg – it means 1,79 times less than background value. This value is more than 6 times less than maximum allowed concentration and quit close to the values, which were established on both sides in the soil close to gravel road. The modelling of Mn concentration where made in appropriate scale of mathematical model – 15 meter to both sides of gravel road, the width of the road – 4 meters. The simulated soil volume is 34 x 14 meters, the soil type – medium-coarse sandy loam. It was modeled that after one year Mn concentration in the soil, close to gravel road remains 1,3 times less than background value (at a constant Mn emission in the environment). Moving away from driveway till 10–15 meters the concentration of Mn decrease to 200 mg/kg in the soil depth of 0,5 m. After 10 years this concentration will reach 1 meter depth. Bet there would be no changes of Mn concentration in the groundwater level.

Keywords: heavy metals, gravel roadsides, manganese, soil pollution.

Conference topic: Environmental protection.

Introduction

Anthropologic activities have transformed global biogeochemical cycling of heavy metals by emitting considerable quantities of these metals into the atmosphere from diverse sources (Shahid *et al.* 2017). Soil contamination is one of the greatest concerns among the threats to soil resources in Europe and globally (Tóth *et al.* 2016). Large numbers of contaminants such as polycyclic aromatic hydrocarbons, petroleum and related products, pesticides, chlorophenols and heavy metals enter the soil, posing a huge threat to human health and natural ecosystem (Chen *et al.* 2015). Heavy metals are dangerous pollutants that in spite of occurring naturally are released in major amounts to the environment due to anthropogenic activities. After being released in the environment, the heavy metals end up in the soils where they accumulate as they do not degrade, adversely affecting the biota (Vareda *et al.* 2016). Anthropogenic activities may lead to increased levels of heavy metals in soil environment and to reduced environmental quality (Ćujić *et al.* 2017). Mining operations, industrial production and domestic and agricultural use of metal and metal containing compound have resulted in the release of toxic metals into the environment. Metal pollution has serious implications for the human health and the environment. Few heavy metals are toxic and lethal in trace concentrations and can be teratogenic, mutagenic, endocrine disruptors while others can cause behavioral and neurological disorders among infants and children (Mahar *et al.* 2016; Li *et al.* 2015). Soils contaminated with heavy metals pose a major environmental and human health problem (Jankaitė, Vasarevičius 2005). Human body may be directly exposed to heavy metals in urban soils through oral ingestion, dermal contact, and inhalation of soil particles (Wu *et al.* 2015). Polluted soil may pose danger to groundwater. Groundwater quality deterioration has attracted world-wide concerns due to its importance for human water supply (Chen *et al.* 2016). Toxic chemical pollutants such as heavy metals are commonly present in urban stormwater. These pollutants can pose a significant risk to human health and hence a significant barrier for urban stormwater reuse (Ma *et al.* 2016). Heavy metal contamination is a major environmental concern that restricts plant growth (Mustafa, Komatsu 2016). Toxic heavy metals (such as As, Cd, Pb, Cr, Mn, Ni, Cu, Zn) are found in fruits and vegetables (Shaheen *et al.* 2016). 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.

Metodology

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. 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 0; 2; 5; 10 metres from the road (transversal profile) depending on topographic conditions and spatial layout of planted areas. In the article results are presented from one side of the road due to similar results.

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. The collected samples are dried, larger roots, other organic objects and stones removed from them, and they are crushed (Mikalajūnė, Jakučionytė 2011).

Investigation

There are used a lot of tools and techniques to reduce gravel roads dust and improve road conditions, traffic safety and the quality of life to the people living near the gravel roads. At the same time gravel roads become more sustainable. Gravel dust reduction devices stabilized the gravel particles – it does not fall into the environment and remain profiled coating layer. Gravel dust reduction targets commonly used calcium chloride. Due to the good hygroscopic properties it gravel moisture longer.

The gravel road *Jusevičiai – Būdvietis – Derviniai* is a road of low intensity, belongs to Alytus district. Road number is 2608, length – 21.57 km. Its dustiness is being minimized with a help of $CaCl_2$. Soils samples for heavy metals analysis were taken in 2 transversal profiles – 13.25 km and 13.85 km. At the first profile there are cultivated lands on the left side of the gravel road. On the right side there are a small hill, meadow, some trees and shrubberies. At the second profile there are a similar view – cultivated lands on the left side and the hilly locality with single trees on the right side. The sampling profiles were selected with the aim of determining a spread of heavy metals in a hilly location. The dominate soil – sand and sandy loam soil near this gravel road.

With the aim to evaluate natural background with Mn in the soil of this district we take a control sample. This sample were taken 100 m from the road at both profiles. It was established that Mn concentration in control sample at first profile was 157.8 mg/kg and 162.4 mg/kg at the second profile. It is 2.7 times lover than background quantity (background quantity for sand and sandy loam soil is 427 mg/kg). Established control Mn concentrations is 9.5 times lover than maximum permitted concentration MPC (MPC is 1500 mg/kg).

We presume that the highest concentrations of Mn must be in the centre of gravel road. So we take samples in the middle of carriageway. It was established that Mn concentration in first profile carriageway was 238.5 mg/kg and 247.8 mg/kg on the second profile carriageway. Those concentrations is 1,8 times lover than background quantity and 6.3 times lover than MPC (Fig. 1).

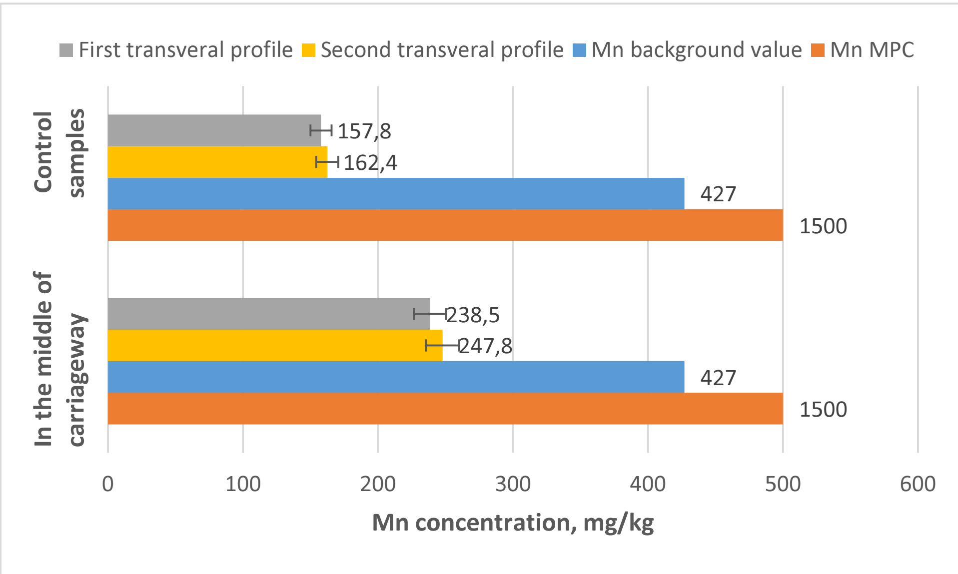

Fig. 1. Mn concentration in control and carriageway samples

Mn concentration near the gravel road (at the end of carriage way) at both profiles were very similar – 222.8 mg/kg at the first and 227.7 mg/kg at tha second profile. Established concentration were 1.9 times lover than background quantity and 6.8 times lover than MPC. 2 meter away from the carriageway (first profile) Mn concentration were 1.2 times lover than Mn concentration, established at the end of carriageway. This concentration was 185.3 mg/kg – it is 2.3 times lover than background quantity and even 8.1 times lover than MPC. At the second profile (13.85 km) established Mn concentration reached 196.3 mg/kg. It is 2.2 times lover than background quantity and 7.6 times lover than MPC. Determined Mn concentrations in the samples taken at a distance of 5 meter from carriageway in the first profile was 2.2 times lower than the background quantity – 190.8 mg/kg.

At the second profile Mn concentration identified in the samples collected at the same distance from carriageway was 2.3 times below than background quantity – 188.9 mg/kg. This concentration is 7.9 times lover than MPC. Mn concentrations identified in the samples collected furthest from the carriageway (10 meters) were nearly 2.5 times lower than background quantity and even 8.6 times lower than MPC. In the first profile Mn concentration was 174.0 mg/kg and in the second – 171.3 mg/kg (Fig. 2).

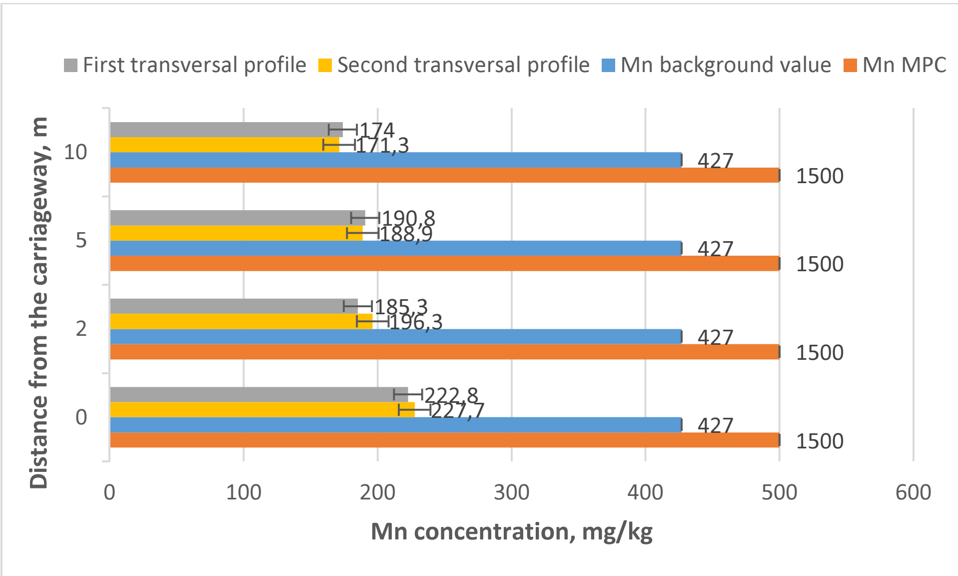

Fig. 2. Mn concentration in the roadside soil

Obvious that with a distance from carriageway increasing the concentration of Mn are decreasing. Mn concentration in samples taken 10 meters from carriageway were 1.3 times lower than is samples taken near carriageway. If we compare concentration in samples in the middle of carriageway and in sampes at the distance of 10 meter, we can see that Mn concentrations decreased 1.5 times in both profiles.

As the present data show and on the basis of other investigation we can presume that Lithuanian gravel roadsides soils are not contaminated with Mn.

Modelling

Mathematic modelling was made by using VS2DTI modelling program. VS2DI is a graphical software package for simulating flow and transport in variably saturated porous media. This software package consists of three components:

- VS2DTI, for simulating fluid flow and solute transport,
- VS2DHI, for simulating fluid flow and energy (heat) transport,
- a standalone postprocessor, for viewing results saved from previous simulation runs.

Both VS2DTI and VS2DHI combine a graphical user interface with a numerical model to create an integrated, window-based modelling environment. Users can easily specify or change the model domain, hydraulic and transport properties, initial and boundary conditions, grid spacing, and other model parameters. Simulation results can be displayed as contours of pressure head, moisture content, saturation, concentration or temperature, and velocity or flux for each time step, thus creating a simple animation. The model can analyze problems in one or two dimensions using either cartesian or radial coordinate systems. Relations between pressure head, moisture content, and relative hydraulic conductivity may be represented by functions. Initial hydraulic condition can be specified as static equilibrium, specified pressure head, or specified moisture content. Boundary conditions include specified pressure or total head, specified flux, infiltration with ponding, evaporation, plant transpiration, and seepage faces. Solute transport processes include advection, dispersion, first- order decay, adsorption, and ion exchange (Hsieh *et al.* 2000).

The aim of this modelling is to model heavy metal Mn dispersion in the soil according to investigation data. We need to describe natural water access to the soil so we need to know rain falling data in our country. It is about 500-700 mm/year in Lithuania (average 625 mm/year). By using this data we can model the influence of the rain to the ground water. In this model we apply that ground water is in the 9 meters depth. The modelling of Mn concentration where made in appropriate scale of mathematical model – 15 meter to both sides of gravel road, the width of the road – 4 meters. The simulated soil volume is 34 × 14 meters, the soil type – medium-coarse sandy loam, there are constant Mn emission in the environmen.

Fig. 3 shows that after one year Mn concentration will be 1.3 times lover than background quantity. Near the carriageway Mn concentration reached 280 mg/kg in the top of the soil and decreased till 200 mg/kg in the depth of 0.5 meter. Further from the carriageway – about 15 meters established Mn concentration in the top of the soil is 330 mg/kg and decrease till 200 mg/kg in the depth of 1 meter. This concentration is 2 times lower than background quantity and 7 times below MPC. As we can see – Mn concentration spread till 1 meter depth and no harm make to ground water which is 9 meters depth (Fig. 3).

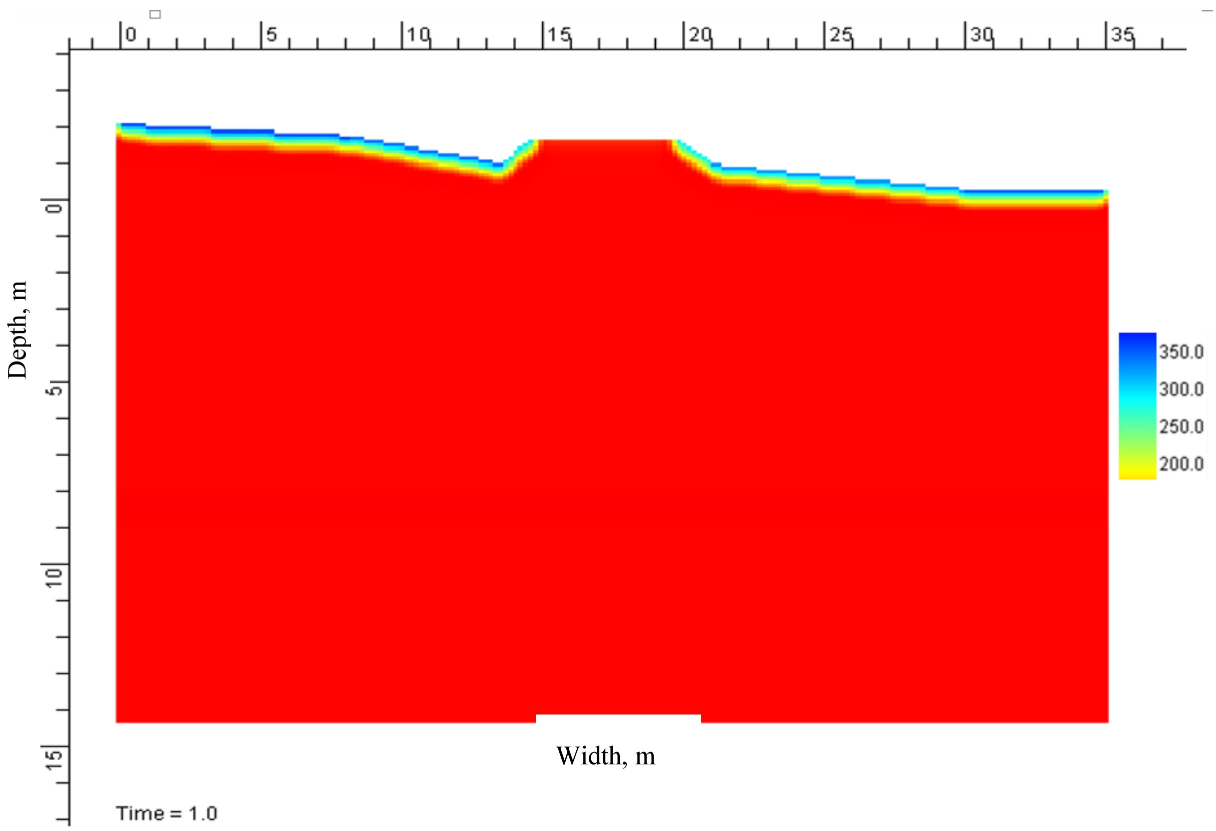

Fig. 3. Mn concentration in the soil after 1 year

Ten years later Mn concentration near the carriageway will reach 300 mg/kg – it is 20 mg/kg more that Mn concentration after 1 year at such distance from the road. The depth of pollution seek 1 meter. In this point Mn concentration decrease till 200 mg/kg – the same as after 1 year. At a distance of 15 meters Mn concentration will reach 350 mg/kg – it is 1,2 times lower than background quantity. The pollution decrease till 200 mg/kg at the depth of 1 meter of a soil. In the depth of 9 meters no Mn pollution – no harm ground water. A little bit higher Mn concentration at a distance of 15 meter can be related a hilly location (Fig. 4).

According to mathematical modelling results we can make a conclusion that soil pollution with Mn will not increase not after 1 or 10 years, the pollution will not exceed the permissible norms and no Mn concentration will reached ground water – it means no harm to human health trought drinking water.

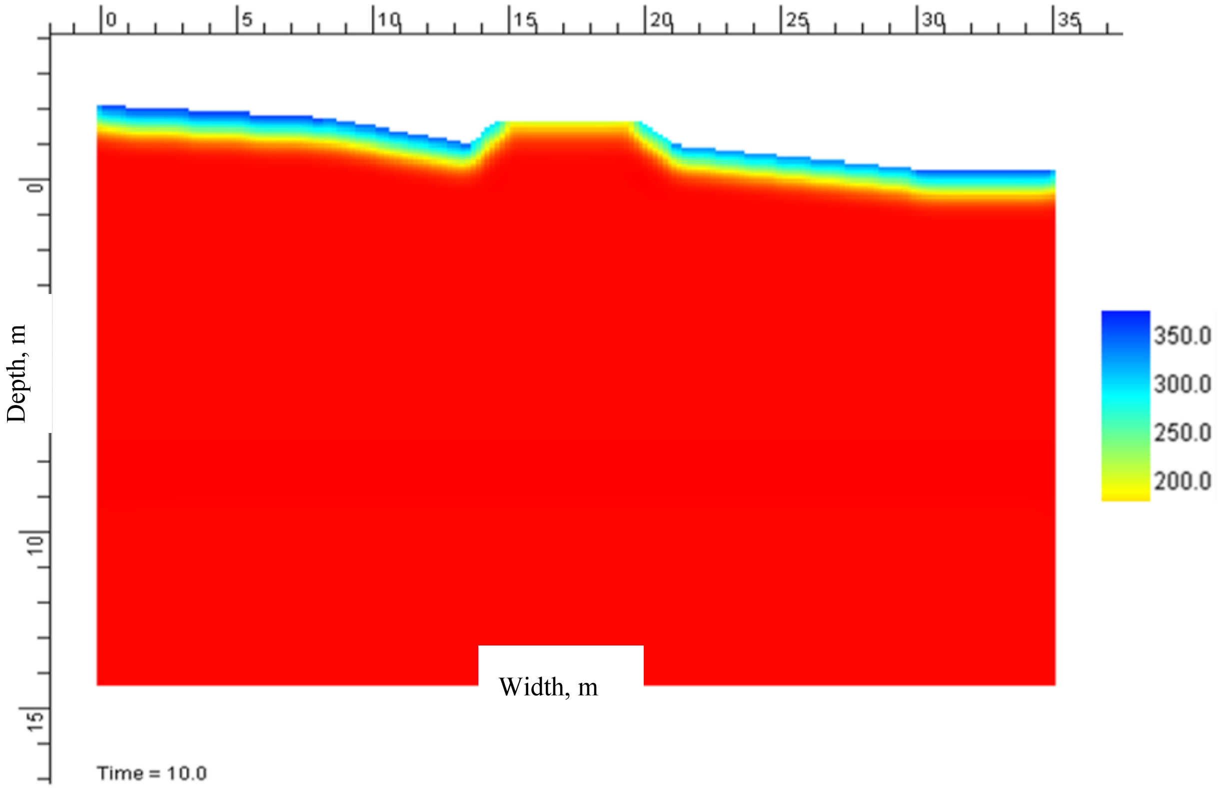

Fig. 4. Mn concentration in the soil after 10 years

Conclusions

For investigation selected gravel road Jusevičiai – Būdvietis – Derviniai is a road of low intensity, its dustiness is being minimized with a help of $CaCl_2$. Soil samples were taken in two profiles. It was established that the highest Mn concentration was in the middle of carriageway, but it didn't exceed background quantity or MPC. Mn concentrations are lower than MPC from 6,3 till 8,76 times. So the soil of the gravel roadsides is not heavy contaminated with Mn. Mathematical modelling shows that Mn concentration at such conditions will not exceed MPC after 10 years and no Mn concentratipn wilol seek ground water level.

It is obvious that the concentrations of Mn in gravel roadsides are not high and do not exceed the regulated parameters. It can be assumed that materials applied on road to minimise dustiness do not have a significant influence on the distribution of Mn in roadside soils, in the meantime the spread of Mn in roadsides is influenced by the intensity of traffic flows, roadside trenches and topographic conditions.

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