Approach to assessment of transport risk of inorganic pollutants on the basis of immobilization capability of soil

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1. Abstract

The objective of this paper is an ambition to elaborate the system of judgement of potential transport risk of inorganic risk elements and create a map of soil potential to immobilization of risk elements. The categorization of potential immobilization of inorganic risk elements was realized on the basis of two layers, contamination layer and layer of potential soil sorption. The level of contamination has been evaluated according to Slovak Soil Law. Potential sorption of soil (PSS) is formed by qualitative parameters (soil reaction – pH value, optical quantitative factors (Corg, H -depth of humus horizon) and was evaluated according to equation: [PSS] = F(pH) + F(Q^4_6) + F(Corg)*F (H). Map of soil immobilization potential was created by fusion of contamination layer and layer of potential sorption of soil and shows the distribution of five categories of potential risk elements immobilization. Soils with very low immobilization potential are distributed in Košice and Banská Bystrica region predominantly, where soils are contaminated by geochemical anomalies and anthropogenic sources. In the case of one element – cadmium small differenced between soil immobilization potential of all contaminants and only to cadmium can be seen.
Key words: inorganic contaminants, contamination, immobilization, soil properties

2. Introduction

Inorganic contaminants mainly potential risk elements are serious problem in all environmental compartments. Potential risk elements represent essential important elements (in optimal concentration range): Cu, Fe, Mn, Zn, Co, Se and some non-essential elements – potentially toxic elements: Hg, Pb and Cd. Toxicity of potential risk elements is different and declines in order: Hg>Cd>Ni>Pb>Cr (Yong et al., 1992). The understanding of the potential risk elements behaviour in the soil system is one of the most important tasks in evaluation of their immobilization and transport. In evaluation of the environmental soil function very important role represent immobilization of the soil contaminants and inverse process – their transport. Immobilization of the soil contaminants means ability of the soil to keep substances and prevent them from leaching and contamination of groundwater or from entrance to the food chain. It allows leaching (a chemical may be transported through the soil by solvents (water) or with soil movement) and runoff (a movement to contaminate air, water, soil, plants and animals, chemical moving across a surface with a solvent or with the soil). It is well known that the variation in soil properties such as pH, organic matter content and quality, texture, the quantity and quality of adsorbing sites, can significantly influence the distribution as well as availability of contaminants to plants and water. Soil reaction, content and quality of soil organic matter, content and quality of clay fraction, iron and manganese oxides belong to the main factors which influence mobility of the potential risk elements in soil (Mestek, Volka, 1993; Zeien, Brummer, 1989, Makovníková, 2000; Barančíková, Makovníková, 2003). (Barančíková, Makovníková, 2003) .

Slovak Soil Law (2004) classifies total amount of particular group of inorganic contaminants: Hg, Cd, Pb, Ni, Cr, As, Cu, Zn, Co. The subject of our interest was this group of risk contaminants in total and one of them cadmium individuallyCadmium has no essential biological function, and is highly toxic to plants and animals. Within soil profiles, Cd tends to be present at higher concentrations in the topsoil, which is partly a reflection of the input from atmospheric deposition, fertilisers and cycling through the plants. Cd activity is strongly affected by pH in acid soils. The organic matter and sesquioxides may largely control Cd solubility, and that in alkaline soil, precipitation of Cd compounds is likely to account for Cd equilibrium.

In presented paper we try to work up system of judgement of potential transport risk of this group of inorganic contaminants on the basis capability of soil compartment to immobilization of inorganic contaminants and create a map of the soil potential to immobilization of risk elements as a whole. We realize necessity of simplification at solving of such complex problem, however there were needed for acquire of our aim - estimation of filtering function with respect to inorganic contaminants. Map of soil potential of cadmium immobilization were prepared with the same methodology.

3. Materials and methods

The categorization of potential transport risk of risk elements was realized only for agricultural soil on two layers, a contamination layer and a layer of the potential soil sorption (Makovníková, Barančíková, Pálka, 2007). Available data sources for the categorization and mapping are represented by primary (spatial information on the soil bodies- Digital database of soil profiles of Geochemical atlas of Slovakia (Čurlík et Šefčík, 1999) and Digital Soil Map of Slovakia (Kobza, 1999)) and secondary (data of relevant soil properties) geo-referenced data (Digital database of Soil monitoring of Slovakia (CMSP)). Relevant soil properties data were used from last sampling (2002). Data from Geochemical atlas of soils of Slovaki and data from Digital soil map of Slovakia were used to generate layer of contamination. Data from CMSP was utilized to generate layer of potential soil sorption. Territorial unit is soil types/subtypes of PM 400 Database Slovakia. ArcGIS® was applied for work with input geo-referenced digital data and implementation of final digital data layer. This layer represents categorization of potential transport risk of the potential risk elements on the basis capability of the soil compartment to immobilization of inorganic contaminants.

4. Results and discussion

Potential of soil to immobilization and transport of risk elements is dependent on total amount of the potential risk elements in the soil and potential of soil sorbents, which are sensitive to the risk elements sorption. Higher amount of the potential risk elements in soil takes the potential sorbent places and consequently decreases overall potential of soil to risk elements sorption. However, present soil databases do not incorporate data of mobile fraction of risk elements, for that reason we can use only data of total content of risk elements.
Contamination layer: Soil contamination has been estimated as a surface contamination. Data of contamination were obtained from relational soil profile database of GchA. Contamination layer of group of all inorganic contaminants shows figure 1.

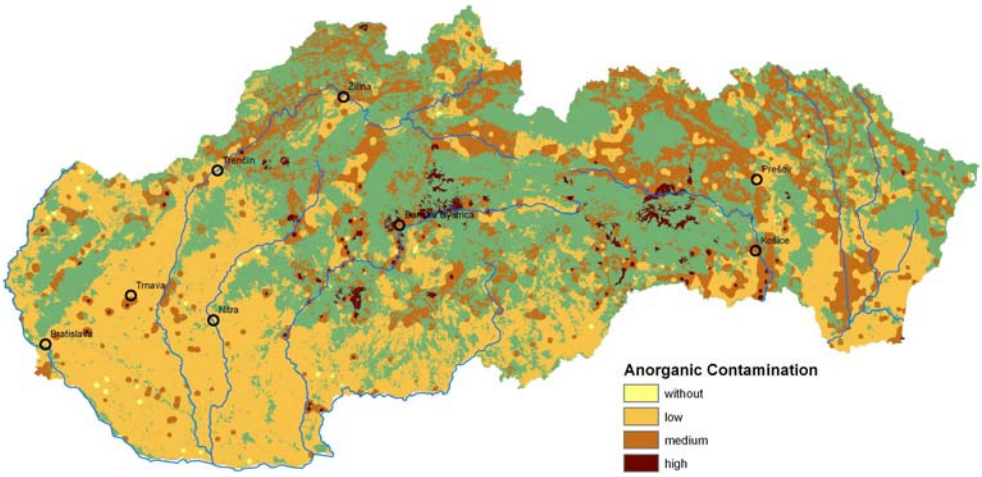

Figure 1 Contamination layer for group of inorganic contaminants

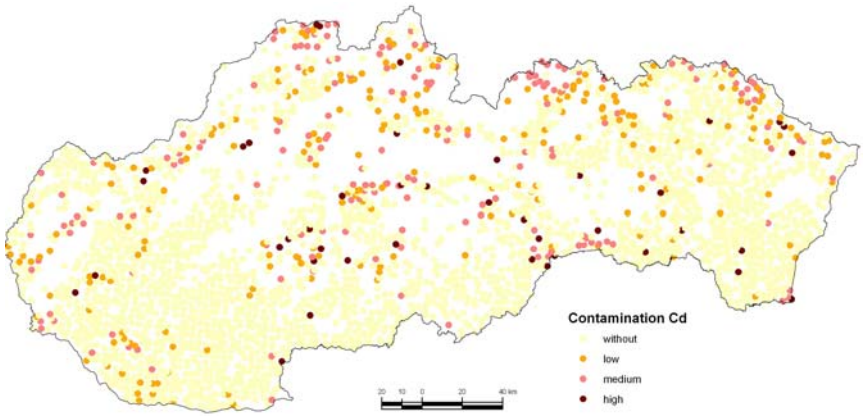

Figure 2 Contamination layer for cadmium

The high level of contamination can be found in the mountain soils on grassland (Podzol, Dystric Cambisols localized south-west and east of Banská Bystrica, east of Spišská Nová Ves and mountain regions of West Carpathians), where is affected predominantly by parent material (geochemical anomalies) (Čurlík and Šefčík, 1999). On some localities of arable soils (Eutric Fluvisols and Fluvi-eutric Gleyosols along the rivers Váh, Hron, Bodrog) high contamination is connected with higher amount of the potential risk elements in sediment deposited on the flood plains as well as with locally anthropogenic sources around factories. The lowest amount of the potential risk elements is characterized mainly for arable soils (Chernozems) on Danube lowland. Cadmium represents one of the the potential risk element with the high toxicity. Contamination layer of one element - cadmium shows the figure 2. Some differences between figure one and two can be seen. In the case of cadmium categories of very high contamination are smaller in Banská Bystrica and Spišská Nová Ves regions, but higher contamination we can see in West Carpathian, Kysuce region and in isolated cases in Záhorie and East-Slovak lowland.

Layer of potential sorption of soil was created by rating method (Makovníková, Barančíková, Pálka, 2007). Point evaluation of potential soil sorption (PSS) for soil polygons was calculated according score function (point evaluation was realised for element with higher toxicity and higher mobility and for that reason is the potential layer for all elements and for cadmium the same): $[PSS] = F(pH) + F(Q^4_6) + F(Cox)*F(H)$

The overall rating is determined as a sum of the soil contamination (contamination score values for soil polygon) and soil potential sorption (PSS value for soil polygon). The high soil contamination was evaluated by the high point value and present high risk. On the other hand high soil sorption potential results by low point value and decreases potential transport risk of hazard elements in soil.

The final map of the soil immobilization potential to the potential risk elements was created by fusion of two layers, the layer of contamination and the layer of potential sorption of soil. Figure 3 shows the distribution of five categories of potential immobilization to all risk elements of agriculture land of Slovakia. Very high potential to immobilization of all risk elements represent 19.74 % of Slovak agricultural soils, high potential 26.06 %, medium potential 27.38 %, low potential 21,64 % and very low potential to immobilization of potential risk elements represent only 5.18 %. Categories with very high and high immobilization potential and in consequence with low risk to transport, cover 45.80 % of all agricultural soils of Slovakia. Most of the arable soils with the high potential production belong to the categories with very high or high potential to immobilization, therefore with low risk of heavy metal transport. There are mainly calcareus soil on loess in Danube lowland and East-Slovak lowland, soils of Záhorie lowland on sandy parent material, Chernozems and Calcaric Fluvisols without anthropogenic deposition. Some Fluvial soils located in alluvial areas (along the rivers Váh, Hron, Bodrog) represent very low or low ability to immobilization of the potential risk elements. It is caused by higher amount of the risk elements in sediment deposited on the flood plains, anthropogenic deposition and simultaneously, the soil sorption potential (low pH of soils on non-calcareus parent material, low content of organic matter) of these soils are low. Soils with very low immobilisation potential are distributed in Košice region and Banská Bystrica region predominantly, where soils are contaminated by geochemical anomalies and anthropogenic sources. This category is created by soils with high content of the risk elements and jointly with soil properties of this regions increase risk mobility and transfer of risk elements .

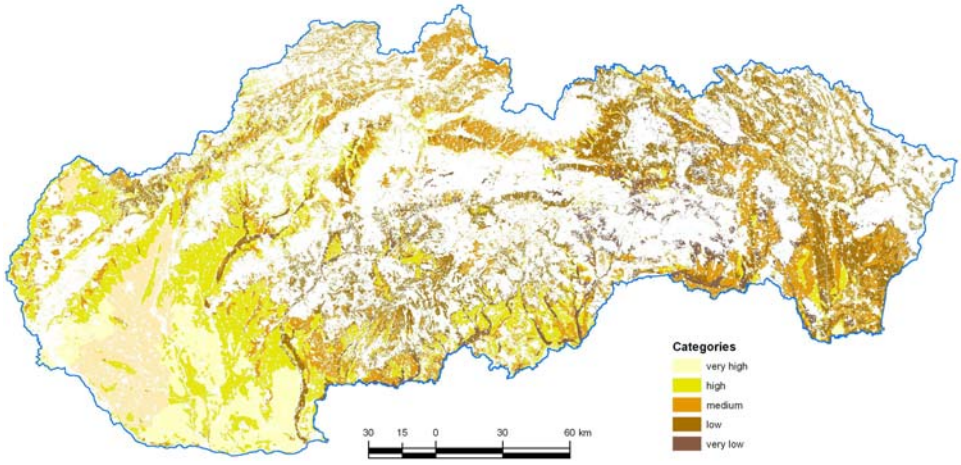

Figure 3 Soil immobilization potential of inorganic contaminants

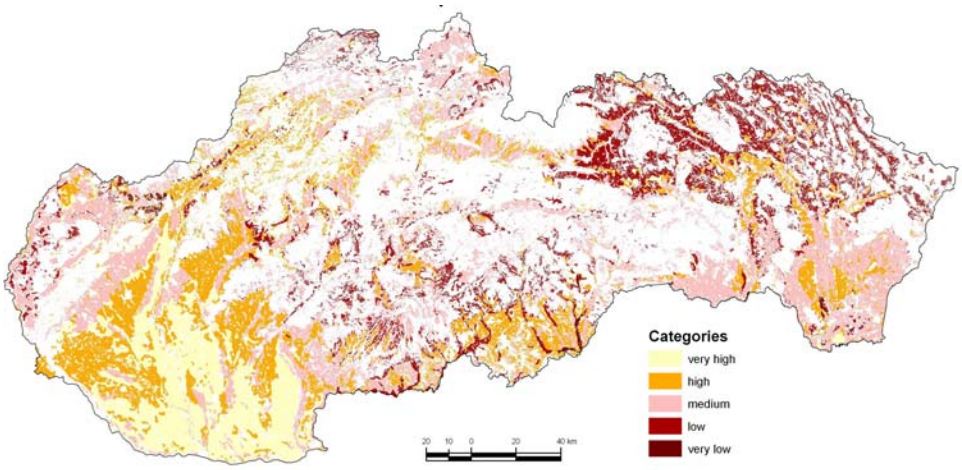

Figure 4 Soil immobilization potential of cadmium

In the case of one element – cadmium small differenced between soil immobilization potential of all contaminants and only to cadmium can be seen. Figure 4 shows the distribution of five categories of potential immobilization to cadmium of agriculture land of Slovakia. Very high potential to immobilization of cadmium represent 22.50 % of Slovak agricultural soils, high potential 27.5 %, medium potential 33.9 %, low potential 15.6 % and very low potential to immobilization of potential risk of cadmium represent only 0.6 %. Categories with very high and high immobilization potential of Cd and in consequence with low risk to transport, cover 50 % of all agricultural soils of Slovakia, more than in case of all risk elements . Most of the arable soils with the high potential production belong to the categories with very high or high potential to immobilization, therefore with low risk of heavy metal transport. Soils in West – Carpathian region, some Fluvial soils located in alluvial areas (along the rivers Slaná, Ipeľ, Hornád) and in isolated cases of Záhorie lowland and Kysuce region represent very low or low ability to cadmium immobilize.

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