Soil contamination in the area of magnesite mining in urban and agrarian land

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Abstract. Contamination of soil with potential risk elements is one of the most pressing environmental problems in the world and causes serious environmental damage, but also threatens human health. This paper presents the results of research that was focused on analyzing soil contamination in the field of magnesite mining in urban and agrarian land nearby the former factory in Košice (Slovakia). Field and laboratory research were performed. Soil sampling was performed in 10 localities of the studied area. The content of risk elements (Cd, Hg, Pb, Cr, Zn, Cu, As, Ni, Mn, Mg) in soils was analyzed under laboratory conditions. The obtained data expressed as average concentrations of metals in sampled soils, as well as background values of the contents of monitored elements for the soils of the Slovak Republic, were used to assess soil pollution and identify the environmental risk. The acquired knowledge about the contamination of the soil with risk elements in the area around the former magnesite factory in Košice could help in the planning of remediation measures and improve the state of the environment in the studied area.

1. Introduction

Soil contamination currently poses a serious environmental threat and is one of the most pressing environmental problems in the world [1–4]. Anthropogenic activities result in environmental and soil damage, ecological imbalances, and expanding areas of contaminated soil, culminating in severe degradation [5]. Among all anthropogenic activities, mining is one of the main sources of environmental pollution [6–8]. Mining operations not only destroy the original soils and vegetation cover, but often also leave a lot of waste materials, which also pollute the air and water [9]. Activities associated with mining, ore concentration, and transport processes cause dust emission and wastewater to form, especially near mines [10]. Sludge, dust emissions, and acid mine wastewater cause the release of large amounts of pollutants, including heavy metals, into the environment [11,12]. This can endanger soil productivity, ecological integrity, and the safety of habitats in mining areas [13–16]. Mining activities contribute to the damage and destruction of the surrounding environment, resulting in the abandonment of many plots [17–19]. Pollution from mining causes environmental and social problems. There is a growing number of research showing that heavy metal pollution in mining areas has caused not only damage to soil health but also the health of local people [20–23]. Heavy metals persist in the environment for millennia, spread to remote areas, and accumulate in ecosystems [24,25]. Therefore, they can adversely affect human health and ecosystems long after release and far from the source [26–28].

Slovak magnesite deposits are among the largest and most important not only in Europe but also in the world. Approximately 1.5 million tons of magnesite are mined annually in Slovakia, which ranks it fourth in the world in the mining of this rock after China, Russia, and Turkey [29]. In the East Slovak city of Košice, it is currently possible to find the remains of a former magnesite factory, which in the past was one of the largest employers in the Košice region. Permission to open a deposit in Bankov was obtained in 1901 and annually produced 17,000 - 18,000 tons of magnesite, which was exported mainly to the USA and Germany. During the Second World War, mining slowed down. In 1947, construction began on a new factory in the village of Ťahanovce. From Bankov to Ťahanovce, magnesite ore was
transported by overhead cable car. In the 1960s, the magnesite factory gained more and more attention in terms of the ecological consequences of its operation. The dust generated during the processing of magnesite significantly polluted the air in Košice, and the city became one of the most polluted cities in Czechoslovakia. Mainly ecological reasons led to the complete shutdown of operations in 1996. At present, the industrial area of the plant and the mine is devastated and dilapidated [30,31]. Magnesite mining results in serious soil pollution and degradation. The direct effects of magnesite mining on the environment come from the deposition of Mg-rich dust generated during calcination of magnesite. Mg-rich dust consists mainly of MgO and / or (MgCO₃), which can seriously damage the surrounding soils and vegetation [32–34]. Mining of magnesite causes a change in the physico-chemical properties of soils in the mine area and soils in the surrounding agricultural areas. The result is the loss of major nutrients and deterioration of soil quality [35]. The aim of the paper is to assess the contamination of soil in the urban and agrarian areas near the former magnesite factory in Košice.

2. Materials and Methods

2.1. Study Area
The research was conducted in the urban and agrarian area near the former magnesite factory Košice (N48°42'50.2" E21°15'29.1"). Košice is located in the Eastern Slovakia in the Kosicka Basin surrounded by Slovak Ore Mountains, Volovske Mountains and Slanske Mountains [36]. The environmental regionalization of the Slovak Republic classifies the territory of Kosice in the Kosice region of the 3rd environmental quality with a strongly disturbed environment. In this area, soils such as Rendzinas and Pseudogleys predominate [37]. The climate in Košice is warm and slightly humid. The average temperature in January is -3 to 2 °C, and in July it ranges from 15 to 26 °C. The annual total precipitation is approximatelly 530 mm [38].

2.2. Soil Samples and Analyses
In the studied area, 10 monitored sampling points, situated near the former magnesite factory, were located and recorded by GPS (DMS) (Figure 1). The sampling points are used as agrarian land and permanent grasslands. Soil samples were taken in September 2020. Sampling was performed from soil horizon A, from a depth of 0.05 to 0.15 m, to quantify the heavy metal content. The soil samples were placed in labelled polyethylene bags, transported to the laboratory, and cleaned of plants and other materials. The individual samples were dried at room temperature, crushed, and sieved through a 2 mm stainless steel sieve. The total content of potential risk elements in the soil was determined in cooperation with the State Geological Institute of Dionsy Štúr Spišská Nová Ves in an accredited geoanalytic laboratory (certificate no. 042/S-004) by X-ray fluorescence spectrometry (Cd, Pb, Cr, Zn, Cu, As, Ni, Mn, Mg), and atomic absorption spectrometry (Hg). The measured values were compared with the limit values set by the Act of the National Council of the Slovak Republic No. 220/2004 Coll. [39,40]. The descriptive statistics was performed with the help of IBM SPSS Statistics 26 and graphical outputs were created using MS Excel.
Figure 1. Location of investigated points nearby the former magnesite factory Košice (Slovakia) (Source: author’s work created in Openstreetmap.org).

3. Results and Discussion

One of the reasons for pollution and heavy metals contamination of the soil in Košice is the former mining and processing of magnesite in a mine in Bankov and a factory in Ťahanovce. Potential risk elements adversely affect not only environmental systems but also human health [41,42]. They can accumulate in various body organs, for example, when consuming contaminated plants or in direct contact with the skin [43,44]. Figure 2 shows the concentrations of Cd, Hg, Pb, Zn, Cu, Ni, Cr, As, Mn, and Mg. The soils in the studied area are significantly contaminated, especially Cr and Mg. Table 1 shows the results of the descriptive statistics of the measured values of heavy metals.

The content of cadmium in the investigated localities did not exceed the values set by law [39]. Genchi et al. [45] pointed out the toxicity of Hg, and stated that even at low concentrations, it could cause many health problems, such as cardiovascular, reproductive, and developmental toxicity, neurotoxicity, nephrotoxicity, immunotoxicity, and carcinogenicity. The average Hg value was 0.28 mg/kg, and the values set by law were exceeded in the two studied areas. Pb toxicity can cause kidney failure, and cardiovascular disease, also affect the development of children, who may have reduced intelligence, short-term memory loss, coordination problems, and reduced learning ability [46]. Pb values were below the established limit values, except one locality where a value of 239 mg/kg was recorded. Copper, zinc, and nickel are relatively low toxic heavy metals, but excessive concentrations can pose a serious health risk, such as brain and kidney damage, fatigue, dizziness, and lung cancer. [47]. Higher copper concentrations were recorded at three sites with a maximum value of 89 mg/kg. The values of zinc and nickel did not exceed the statutory values, except one studied locality. De Oliveira et al. [46] pointed out that arsenic and chromium cause severe hair loss. Arsenic reached values exceeding the limit values at two localities. Chromium values exceeded the statutory limits at all investigated sites, with a maximum value of 91,550 mg/kg, which is more than 1,300 times exceeded.
Table 1. Descriptive statistics of measured values of heavy metals (mg/kg).

|       | Minimum | Maximum | Mean  | Median | Standard deviation | Limit value* |
|-------|---------|---------|-------|--------|--------------------|--------------|
| Hg    | 0.08    | 0.84    | 0.28  | 0.15   | 0.28               | 0.5          |
| Cd    | 0.50    | 0.50    | 0.50  | 0.50   | 0.00               | 0.7          |
| Pb    | 24.00   | 239.00  | 52.90 | 33.00  | 65.57              | 70           |
| Cr    | 69.00   | 91 550.00 | 9274.60 | 93.00   | 28 908.88          | 70           |
| Zn    | 51.00   | 219.00  | 100.10 | 102.50 | 48.26              | 150          |
| Cu    | 17.00   | 89.00   | 44.40  | 32.50  | 27.31              | 60           |
| As    | 8.00    | 26.00   | 18.20  | 17.50  | 6.75               | 25           |
| Ni    | 19.00   | 573.00  | 83.40  | 31.00  | 172.12             | 50           |
| Mn    | 600.00  | 1 500.00 | 1 050.00 | 1 000.00 | 291.55            | not specified |
| Mg    | 4 500.00 | 90 300.00 | 24 790.00 | 10 700.00 | 32 275.46        | not specified |

Note: *Act No. 220/2004 Coll. of Laws.

The law does not set limit values for manganese and magnesium. The average content of manganese in the soils of the Slovak Republic is in the range of 2.10 - 95.27 mg/kg [48]. The manganese content in the studied area reached the values of 1,000 ± 291.55 mg/kg (median ± standard deviation).

According to Kobza et al. [49], the average values of magnesium for the Slovak Republic are in the range of 200 - 400 mg/kg. The measured values of magnesium in all research areas exceeded the average...
values for the Slovak Republic several times. The magnesium content in the soils in the area of the former magnesite factory in Košice reached values in the range of 24,790 ± 32,275.46 mg/kg (median ± standard deviation). The highest measured value of magnesium exceeded the average value 450 times. Fazekaš et al. [50], Štofejová et al. [51], and Fazekašová et al. [52] pointed out significant soil contamination with magnesium and noted in the areas of magnesite mining Jelšava-Lubenik several times exceeding the average values for magnesium in Slovakia. They pointed to secondary salinization with magnesium, chemical intoxication, and soil devastation. Although the mining of magnesite in the Bankov mine and its processing were stopped in 1996, it is still possible to observe severe contamination with heavy metals in the surrounding soils.

4. Conclusion
The paper presents the results of field and laboratory research of heavy metals in soils in the field of magnesite mining of the former factory in Košice (Slovakia). The obtained data expressed as average concentrations of metals in the examined soil samples, as well as background values of the contents of the monitored elements for the soils of the Slovak Republic, were used to assess soil pollution and identify the environmental risk. Košice and its surroundings were one of the most polluted areas in Czechoslovakia in the past. One of the main sources of pollution is emissions from the mining and transportation of magnesite. Based on the research results, it was found that the soils near the mine and the factory are significantly contaminated with Hg, Pb, Zn, Cu, Ni, Cr, As, Mn, Mg, with the most significant concentrations of Cr and Mg. Soil contamination persists, although mining and processing activities were stopped 25 years ago. In the selected investigated localities, the measured values of heavy metals several times exceeded the statutory limit or average values in soils for the Slovak Republic. The presence of heavy metals in the soil can cause serious damage and degradation of the environment and also endanger the health of the inhabitants of the city and its surroundings. The results of the research could contribute to raising awareness of soil contamination in the study area and to increasing interest in the planning and application of remediation techniques.

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