Original Scientific paper
10.7251/AGRENG2303088D
UDC 502/504:622.3

MERCURY POLLUTION IN TWO FORMER MINING AREAS IN SLOVAKIA

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ABSTRACT

The rich mining history in Slovakia has significantly influenced the extent and nature of the current environmental pollution. Owing to insufficient remediation, numerous mine works remain a threat to human health and the surrounding environment. Technical soil samples from two mining bodies (heaps of waste material and open mining pits) from two mining areas were evaluated for Hg content. Technical soil samples were collected directly from the heap surface and from the inside of the mining pits (entrance, middle, and end). The mercury content was determined using an AMA-254 mercury analyzer. Soil pH was determined for all samples. To evaluate the level of pollution, the contamination factor (C_f) and the index of geoaccumulation (I_{geo}) were determined. The aim of this study was to evaluate the technical soil mercury content and compare the mercury content between mining bodies. The mercury content in the soil samples exceeded the limit values set for Slovak soils. Heaps of waste materials showed significantly higher mercury pollution than open mining pits. Soil pH was significantly negatively correlated with soil mercury content. The values of the contamination factor and index of geoaccumulation showed serious pollution of the mining bodies.

Keywords: *contamination factor, index of geoaccumulation, mercury, soil pollution, heaps of waste material, mining bodies.*

INTRODUCTION

Mining and related industrial activities aimed at processing ore material are among the anthropogenic activities that have the greatest impact on environmental pollution (Ispas et al. 2018). A serious current problem, even in former mining areas, is the presence of numerous mining bodies, which are becoming so-called environmental loads because of the lack of efforts for rehabilitation or reclamation.

The danger of environmental loads lies primarily in the high content of risk elements (heavy metals, polycyclic aromatic hydrocarbons (PAHs), persistent organic substances (POPs), etc.), which often reach extremely high values, several times exceeding the limits established by law. Soil is necessary as a basic component of terrestrial ecosystems, as plant growth and life cycles depend on it (Alloway, 1996). It is an irreplaceable natural resource that is important to produce food and timber; therefore, it is necessary that its productive capacity is not disturbed (Bhattacharyya & Pal. 2015). Most studies agree that the soil environment in former mining areas is highly contaminated and poses risks to both human and ecosystem health (Kumar et al. 2020). At the same time, the results of these studies indicate that the content of risk elements in the rhizomes of plants growing directly on mining works or in their immediate surroundings is correlated with their content in the soil environment (Vaculík et al. 2013, Aihemaiti, et al. 2018). If we consider the fact that old mining bodies are often found near human settlements, arable land or vegetable gardens, the danger of contaminants entering the food chain is high (Stefanowicz et al. 2014).

MATERIAL AND METHODS

Samples of technical soil (hereinafter referred to as soil) were collected from two former mining sites (Gelnica and Zlata bana). In Gelnica, 10 soil samples were collected from open mining pits and three heaps, and in Zlata bana, five samples were collected from open mining pits and four from heaps. Soil samples were taken from a depth of 0-10 cm, placed in plastic bags, and transported to the laboratory, where they were air-dried at room temperature for two weeks. Subsequently, the samples were sieved (mesh size of 2 mm) and stored in plastic bags for analysis. The total mercury content in the soil samples was determined using an AMA-254 analyzer (AlTec spol. s.r.o. (Prague, Czech Republic). The exchange pH was measured using an InoLab pH 720 device. To evaluate the state of pollution in the technical soils, two coefficients were used. Contamination factor (C_f) and index of geoaccumulation (I_{geo}) were used to evaluate the degree of soil pollution. The contamination factor (Hakanson, 1980) was calculated as follows:

$$Cf = \frac{C_{0-1}^{i}}{C_{n}^{i}} \ (1),$$

where: C_{0-1}^{i} is the mercury content measured in the soil and C_{n}^{i} is the background value of mercury in the soil environment, which is set at 0.06 mg/kg for the Slovak soils (Šefčík et al., 2008). The state of pollution expressed by contamination factor is evaluated using categories showed in Table 1. The index of geoaccumulation (I_{geo}) established by Müller (1969) was calculated as follows:

$$I_{geo} = log_2(Cn/1.5xBn) \ (2)$$

where *Cn* is the measured concentration of mercury (or another element) in the soil, and *Bn* is the background value of mercury (0.06 mg/kg) (Šefčík et al. 2008). I_{geo} values are divided into 7 categories (Muller 1969) showed in Table 1. The PAST statistical program (Hammer et al. 2001) was used for statistical data processing. Data were log+1 transformed before analysis. The non-parametric

Mann-Whitney U test was used to compare the mercury content between locations (Zlata bana and Gelnica), as well as between types of mining bodies (mining pits, heaps). Spearman's correlation coefficient was used to determine the relationship between mercury content in the soil and soil pH.

Table 1. Categories of contamination factor (C_f) and index of geoaccumulation (I_{geo}).

Contamination factor (C_f) categories (Hakanson, 1980)	
(C_f<1)	low contamination
(1≤C_f<3)	medium contamination
(3≤C_f<6)	significant contamination
(C_f≥6).	high contamination factor
Index of geoaccumulation (I_{geo}) categories (Müller, 1969)	
I_{geo}≤0	background value
0≤ I_{geo} <1	uncontaminated
1≤ I_{geo} <2	uncontaminated or slightly contaminated
2≤ I_{geo} <3	slightly contaminated
3≤ I_{geo} <4	moderately contaminated
4≤ I_{geo} <5	heavily contaminated
I_{geo} ≥5	very heavily contaminated

RESULTS AND DISCUSSION

The mercury content in Zlata bana soils (min-max (average±standard deviation)) ranged between 0.18-0.38(0.28±0.06) mg/kg for mines and 26.6-31.3 (28.4±2.06) mg/kg for heaps. The mercury content in Gelnica soils ranged between 0.14-1.22 (0.74±0.0.31) mg/kg for mines and 27.8-63.7(45.7±17.9) mg/kg for heaps. The limit value of mercury for Slovak soils is set according to the Act. no. 220/2004 Coll. of Laws to 0.5 mg/kg (Aol, 2004). This value was exceeded for all evaluated heaps of waste material, and more than half of the samples from open mining pits (mines). The results of the non-parametric Mann-Whitney U test showed significantly higher values of soil mercury in Gelnica than in Zlata bana ($p<0.05$) (Figure 1a). From the results of the non-parametric Mann-Whitney U test, we can conclude that the mercury content in the soil samples originating from open mining pits reached significantly higher values compared to heaps ($p<0.001$) (Figure 2b). Meyers (2006) stated that it is highly likely that the heaps of waste material will contain risk elements in concentrations that threaten the surrounding environment. Pollution in open mining pits is associated predominantly with acidic water pollution from acid mine drainage (Abdul-Wahab & Marikar 2012; Singovszka et al. 2016).

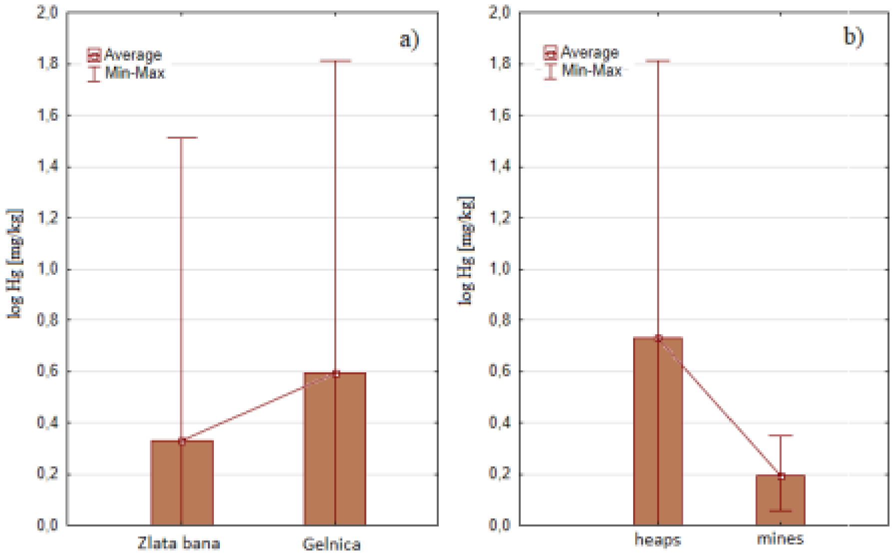

Figure 1. Comparison of mercury content determined in soil from two former mining sites and two mining bodies (a logarithmic scale was used to visualize the data).

The soil pH in Zlata bana soils ranged between 2.79-4.88 (3.79±0.67) for open mining pits and 2.65-2.99 (2.87±0.15) for heaps. The mercury content in Gelnica soils ranged between 5.42-6.82 (6.46±0.26) for mining pits and 6.42-6.49(6.45±0.03) for heaps. Spearman's correlation coefficient was used to determine the relationship between soil mercury content and soil pH. The results showed that soil pH was significantly negatively correlated with soil mercury content. It has been found in earlier studies that soil pollution by heavy metals significantly influences not only soil pH, but also many other physical, biological, and chemical soil properties (Khan et al., 2021). It has also been found in previous studies that an increased content of risk elements in the soil environment leads to a decrease in soil pH (Artiola et al., 2019). The contamination factor (C_f) reflects the anthropogenic input of elemental pollution and is often used to assess soil quality worldwide (Yaylali-Abanuz, 2011). In our study, all samples from the heaps of waste material were found to be highly contaminated with mercury. Soil samples from open mining pits were found to be medium to very highly contaminated with mercury (Figure 1). Based on the results obtained, we conclude that the soil pollution in the evaluated areas is serious. The results of the index of geoaccumulation showed that open mining pit soils were evaluated as uncontaminated to moderately contaminated by mercury. In the case of heaps, very heavy contamination was observed in all samples.

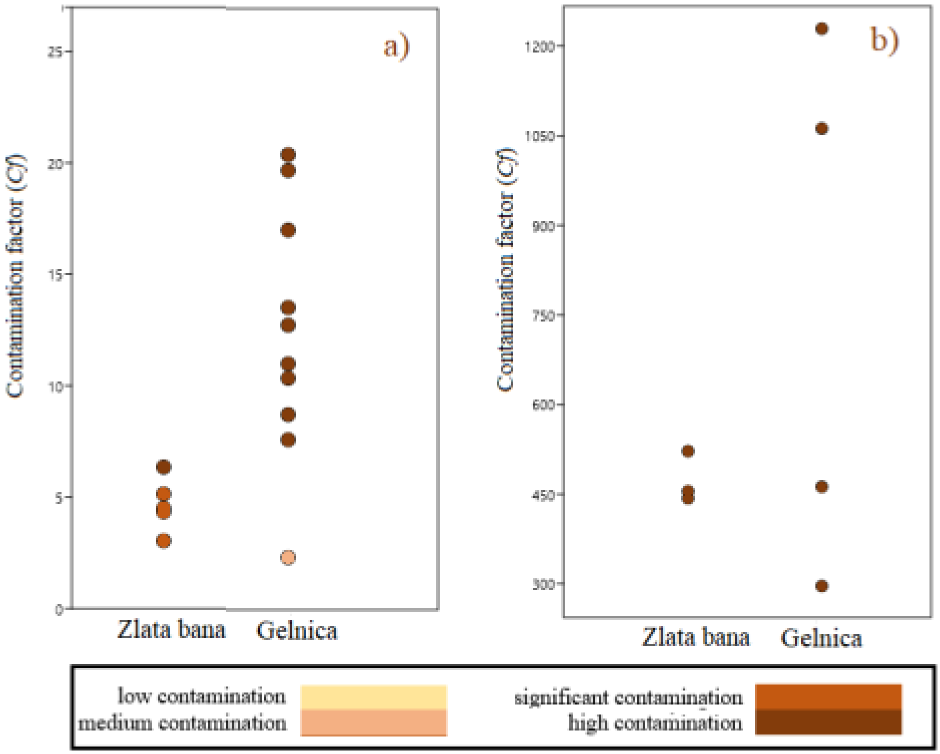

Figure 2 Values of contamination factor (C_f) determined for a) open mining pits and b) heaps of waste material soil samples from two former mining areas.

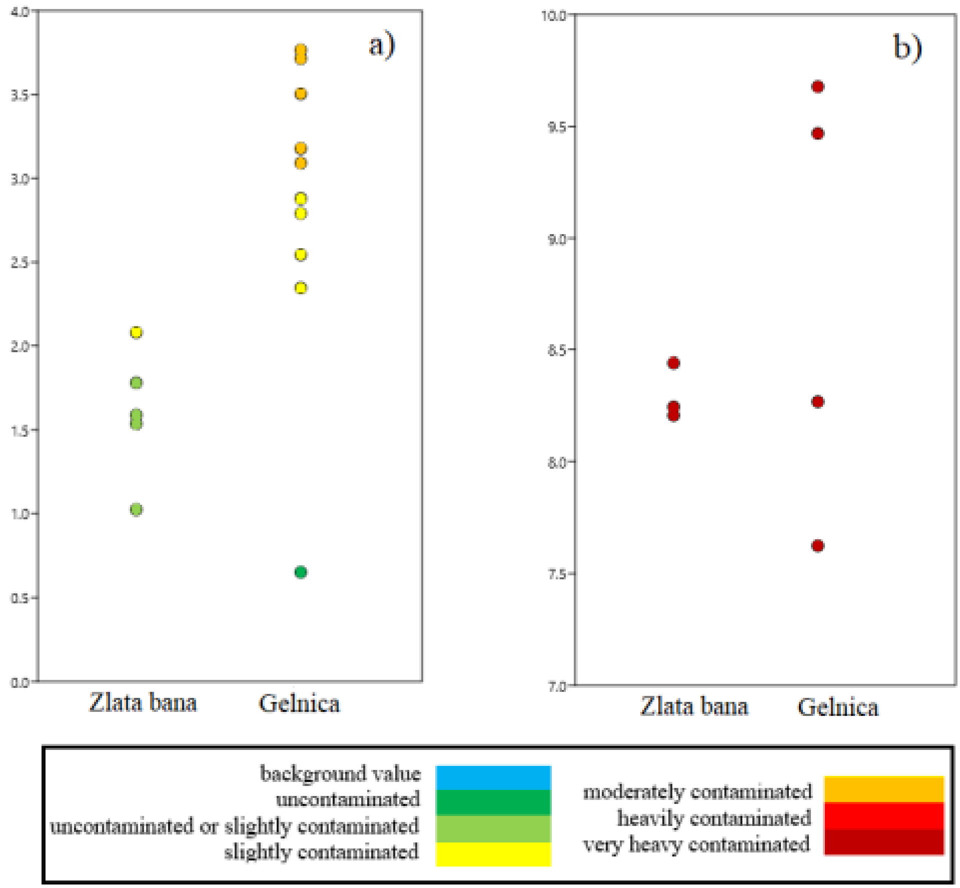

Figure 2 Values of index of geoaccumulation (I_{geo}) determined for a) open mining pits and b) heaps of waste material soil samples from two former mining areas.

CONCLUSIONS

Serious mercury pollution was detected at both evaluated locations, and the main source of this pollution was the heaps of mining waste material. At some sampling points, the Hg values were extremely high and exceeded the permitted limit value by more than a hundred times. The impact of pollution is also manifested in the acidification of the soil environment. Because several mining works are located near areas that are inhabited or used for agriculture, this pollution poses threats to both environmental and human components. Because it was only a pilot study that focused only on mining works, we consider it necessary to expand the research and monitor the nature of pollution in the wider vicinity of mining works.

ACKNOWLEDGEMENTS

This research was founded by the Scientific Grand Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic – VEGA no.1/0213/22.

REFERENCES

Abdul-Wahab, S., Marikar, F. (2012). The environmental impact of gold mines: pollution by heavy metals. Central European Journal of Engineering, vol. 2, pp. 304–313.

Aihemaiti, A., Jiang, J., Li, D., Liu, N., Yang, M., Meng, Y., Zou, Q. (2018). The interactions of metal concentrations and soil properties on toxic metal accumulation of native plants in vanadium mining area. Journal of Environmental Management, vol. 222, pp. 216-226.

Alloway, J.B. (2010). Heavy Metals in Soils: Trace Metals and Metalloids in Soils and their Bioavailability. Springer Science-Business Media: London, United Kingdom.

AoL - Act of the National Council of the Slovak Republic, No. 220/2004 Coll. Available online:http://www.podnemapy.sk/portal/verejnost/konsolidacia/z_220_2004.pdf〉 (Accessed 7th July 2023).

Artiola, J.F. Walworth, J.L., Musil, S.A. Crimmins, M.A. (2019). Environmental and Pollution Science. In Brusseau, M. L., Pepper, I.L., Gerba, CH. P. (eds.), " Chapter 14 - Soil and Land Pollution" Academic Press, pp. 219-235,

Bhattacharyya, T., Pal, D.K. (2015). The Soil: A Natural Resource. In Rattan, R.K., Katyal, J.C., Dwivedi, B.S., Sarkar, A.K., Bhattacharyya, T., Tarafdar, J.C., Kukal, S.S. (eds.), "Soil Science – an Introduction". ISSS: New Delhi.

Hakanson, L. (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. Water Research, vol. 14, pp. 975–1001.

Hammer, Ø., Harper., D.A.T., Ryan, P.D., 2001. Past: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica, vol. 4, pp.1-9.

Ispas, G., Roba, C., Balc, R., Coada, M., Gligor, D. (2018). The quality of water and soil in Hanes mining area, Alba Country, Romania. Carpathian Journal of Earth and Environmental Sciences, vol. 13, pp. 505-517.

Khan, I., Awan, S.A., Rizwan, M., Ali, S., Hassan, J.M., Brestic, M., Zhang, X., Huang, L. 2021. Effects of silicon on heavy metal uptake at the soil-plant interphase: A review. Ecotoxicology and Environmental Safety, Vol. 222, pp. 112510.

Kimáková, T., Nasser, B., Issa, M., Uher, I. (2019). Mercury cycling in the terrestrial, aquatic and atmospheric environment of the Slovak Republic – an overview. Annals of Agricultural Environment and Medicine, vol. 26, pp. 273–279.

Kumar, A., Tripti, Maleva, M., Kiselva, I., Maiti, K.S., Morozova, M. (2020). Toxic metal(loid)s contamination and potential human health risk assessment in the vicinity of century-old copper smelter, Karabash, Russia. Environmental Geochemistry and Health, vol. 42, pp. 4113–4124.

Meyers, R.A. (2006). Encyclopedia of Analytical Chemistry (Applications, Theory, and Instrumentation). Industrial Wastes and Waste Dumps, Sampling and Analysis. John Willey & Sons, pp. 2188.

Müller, G. (1969). Index of geoaccumulation in sediments of the Rhine River. Geojournal, vol. 2, pp. 108-118.

Šefčík, P., Pramuka, S., Gluch, A. (2008). Assessment of soil contamination in Slovakia according by index of geoaccumulation. Agriculture, vol. 54, pp. 119–130.

Singovszka, E., Bálintová, M., Demčák, Š. (2016). Sediment influenced by acid mine drainage in the Smolnik Creek-Qualitative and Quantitative Characterization. Chemical Engineering Transactions, vol. 52, pp. 937-942.

Stefanowicz, A.M., Woch, M.W., Kapusta, P. (2014). Inconspicuous waste heaps left by historical Zn-Pb mining are hot spots of soil contamination. Geoderma, vol. 235–236, pp. 1–8.

Vaculík, M., Jurkovič, Ľ., Matejkovič, P. (2013). Potential Risk of Arsenic and Antimony Accumulation by Medicinal Plants Naturally Growing on Old Mining Sites. Water Air and Soil Pollution, vol. 224, pp. 1546.