



The impact of mining activities on the sediment quality in water reservoir Ruzin I. (Slovakia)

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Abstract

The contamination of aquatic and terrestrial ecosystems with heavy metals and other mining chemicals have been major environmental problems in many mining areas of the world. The peak period of metal mining was from the middle to late nineteenth century, although from many sites the pollution continues also at present. In such catchments, almost 90 per cent of the metals are associated rather with sediment than in aqueous forms, and the metal pollutants are primarily mobilised and transported downstream, and deposited in lakes or dams.

Water reservoir Ruzin I. is situated in territory, which is well-known by its mining and metallurgical history for several centuries, such as ore deposit Smolník. Surface water from this area is contaminated by acid mine drainage (AMD) outflowed from abandoned sulphide mine Smolník. AMD with low value of the pH (about 3–4) is a result of chemical oxidation of sulphides and other chemical processes in mine. The pH increasing due to the mixture AMD with surface water is followed by metal precipitation and its sedimentation in water environment. Contaminated sediment is transported by erosion processes into the river Hnilec and then into water reservoir Ruzin.

The aim of this work was to evaluate the chemical quality of the sediment influenced by the mining activities and to assess the present and future potential risks of acid mine drainage to the water reservoir Ruzin I. (Slovakia) by the enrichment factor and pollution load index.

Keywords: acid mine drainage; heavy metals; enrichment factor; water reservoir Ruzin; Slovakia.

Nomenclature

<i>AMD</i>	acid mine drainage
<i>EF</i>	enrichment factor
<i>M_c</i>	content of contaminants
<i>M_r</i>	content of reference elements
<i>S</i>	sample
<i>b</i>	background concentration

1. Introduction

Potentially harmful metal contamination of sediment, soil and groundwater is one of the most substantial threats to environmental quality and human health. High concentrations of these metals are released into the aquatic environment as a result of leaching from bedrocks, atmospheric deposition, drainage, runoff from riverbanks, and discharge of urban and industrial wastewaters [1]. Mining activities are often associated with environmental impacts including metal contamination of sediments and aquatic systems [2]. Water reservoir Ruzin (Slovakia) (Fig. 1) located in east Slovakia (situated on the Hornád river) is one of the most contaminated sites by heavy metals coming from abandoned metallurgical mines produced acid mine drainage (AMD). These acidic waters, which frequently contain high concentrations of heavy metals, often have adverse effect on the quality and ecology of waters receiving the effluent [3], [4]. Studies of the creeks influenced by AMD have detected high concentrations of contaminant metals (Cu, Fe, Mn, As, Zn and Pb) in the water and sediment [5]. When the metals concentration exceeds standard permissible limits, it would have toxic effects on living organisms and cause negative impact on lower life forms. For example, transition metals such as copper (Cu), zinc (Zn), cobalt (Co), manganese (Mn), nickel (Ni), and iron (Fe) are essential nutrients; however, they may be toxic if in high concentration. These metals

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<http://dx.doi.org/10.3846/enviro.2014.091>

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enter the environment and are distributed between the aqueous phase and the suspended sediments during their transport [6]. Metals tend to be assimilated in sediment with organic matter, Fe/Mn oxides, sulphide, and clay thus forming several reactive components, which are harmful to the environment. Hence, sediment is always regarded as the potential reservoir for metals and plays an important role in adsorption of dissolved heavy metals [7], [8].

Water reservoir Ruzin was constructed in order to ensure water for metallurgical and other industrial purposes, for dilution of waste water, the flattening of flood flows, to generate electricity, and is also used for recreation [9]. Ruzin consist of two water reservoirs. The mainreservoirRuzinI.builtin1967has a capacity of59 million meters cubic and expansion tank Ruzin II., which was completedin 1972. Bottom sediments from this reservoir are contaminated above all by heavy metals, which are alluvial into the reservoir from localities of former activities and thus they represent ecological load mainly at the inputs into reservoir. Enhanced contents of heavy metals hinder in direct application of sediments in agriculture, building and field engineering. For this reason it is needed to search for suitable ways of bottom sediments decontamination [10–12].

In this study of environmental contamination, a common approach to estimate how much the sediments is impacted (naturally or anthropogenically) with heavy metals is to evaluate the Enrichment factor (EF) and Pollution load index (PLI) for metal concentrations above uncontaminated background or reference levels.

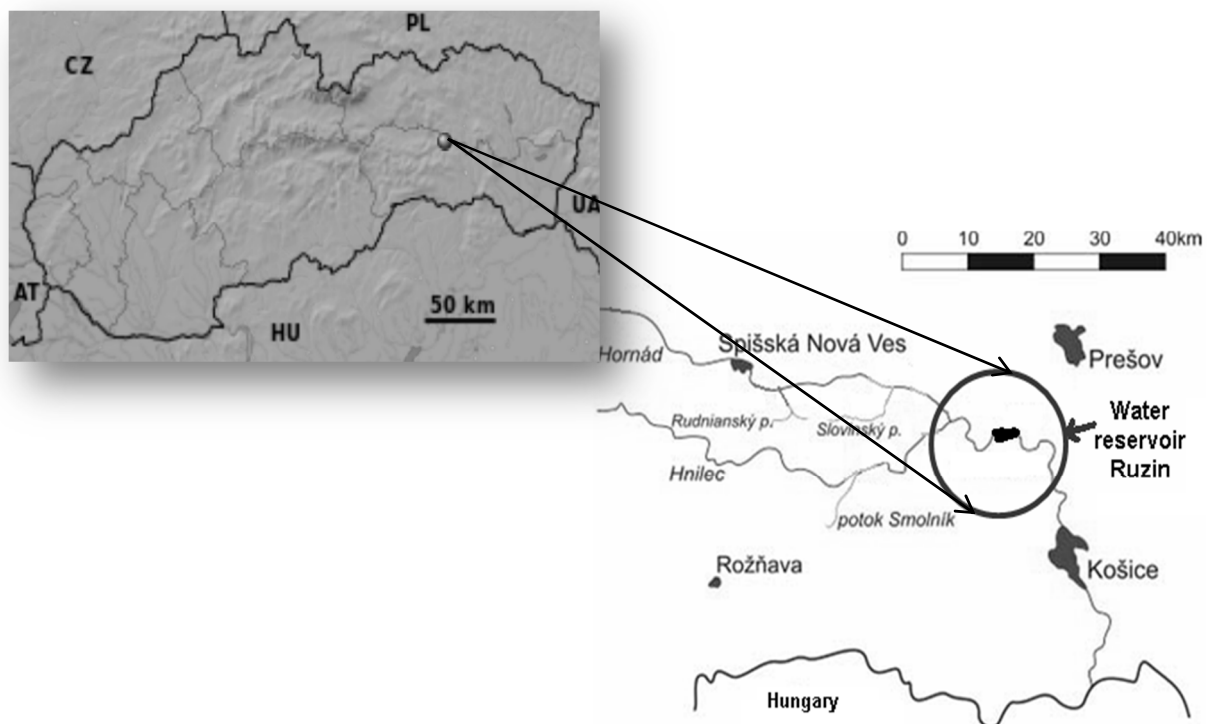


Fig. 1. Location of water reservoir Ruzin

2. Materials and methods

Sediments were sampled in 2012, due to deficiency of the rain the water level has dropped by a few meters. In some places the water is not located at all, on this basis; it can be sampled directly in the reservoirs as shown in Fig. 2. Sediments were sampled from surface (0 cm), from depth 20 cm and 50 cm.

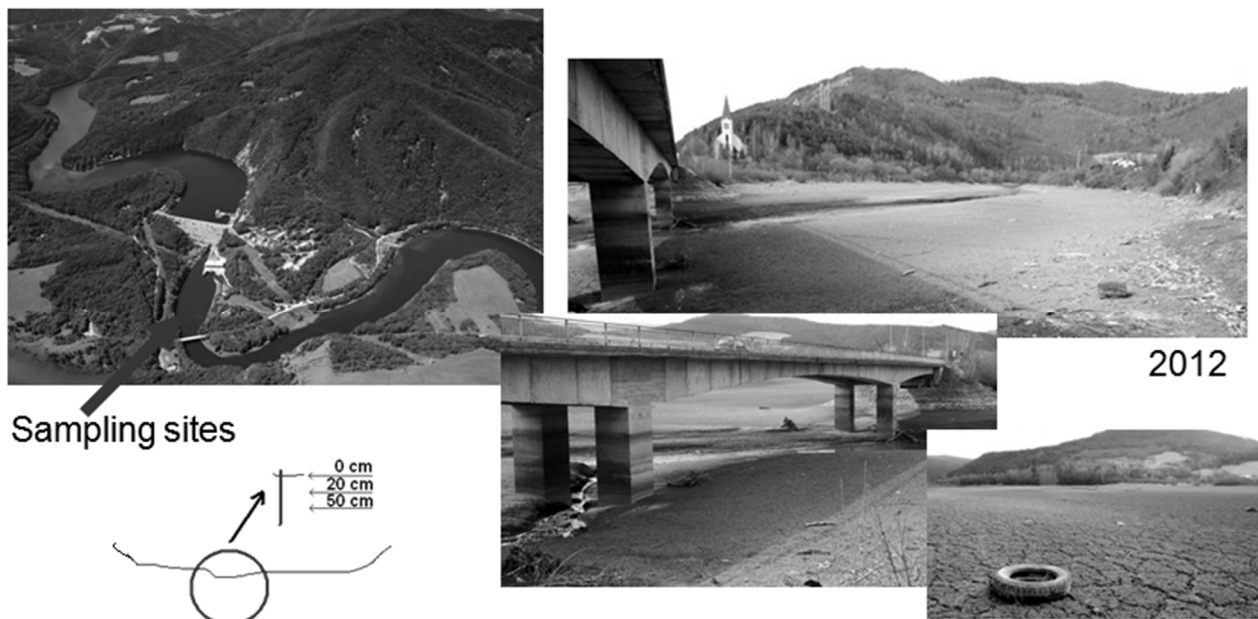


Fig. 2. Sediment sampling site in the Ruzin reservoir

The sediment was dried, homogenized and sieved below 0.063 mm. Chemical analyses were realized by the XRF method using by SPECTRO iQ II (Ametek, Germany). The sediment samples were prepared as pressed tablets with diameter of 32 mm by mixing of 5 g of sample and 1 g of dilution material (M-HWC) and pressed at pressure of 0.1 MPa/m².

3. Results and discussion

The degree of contamination in the sediments is determined with the help of two parameters – Enrichment factor (EF), Pollution load index (PLI). Assessment of contamination has been done on the basis of concentration values described in Table 1. As background concentrations the contents of selected elements in sediment unaffected by mining activities in assessment area were used.

Table 1. The results of chemical analysis of sediment

Sample site	Fe	Mn	Al	Cu	Zn	As	Cd	Pb
	[%]			[mg/kg]				
0cm	4.62	0.14	6.65	245.5	321.1	22.9	5.1	59.4
20cm	5.14	0.12	7.23	650.1	853.6	9.8	5.1	83.9
50cm	5.64	0.12	6.97	959.2	906.5	27.1	2	73.9
Background	4.64	0.10	8.14	190	174	19.8	0.5	60

3.1. Enrichment factor

Enrichment factor calculation is a common approach to estimate anthropogenic impact on sediments. Mathematically expressed is as [13], [14]:

$$EF = \frac{[M_c / M_r]_s}{[M_c / M_r]_b}, \quad (1)$$

where: M_c is the content of contamination; M_r is the content of reference elements; s is the sample, and b is the background. A reference element is often used as a conservative element [13], [14]. In this study, Mn is used as a reference element, it has the least impact on the concentration of metals in sediments. The enrichment factor scale consists of six grades ranging, how show the Table 2.

Table 2. The enrichment factor scale [13]

EF ≤ 1	background concentration
EF 1–2	deficiency to minimal enrichment
EF 2–5	moderate enrichment
EF 5–20	significant enrichment
EF 20–40	very high enrichment
EF > 40	extremely high enrichment

In order to assess the metal content in river sediments, it is important to establish the natural levels of these metals. Apart from natural contribution, heavy metals may be incorporated into the aquatic system from anthropogenic sources such as solid and liquid wastes of industries [15].

The EF values for every sample site are given in the Table 3. The table shows depletion trend for Fe, Cu and Al (< 1) for sample site in 0 cm. The depletion trend is reflected for Pb for each sample sites. The EF for Cu and Zn (20cm) and Fe, Cu, Zn (50 cm) is about minimal enrichment, while in case Cd (20 cm) is shown significant enrichment. Very high enrichment (EF 20- 40) constitutes As in depth 20 cm with value 37,164. Cd and As in depth 50 cm shows very high EF values (> 40).

Table 3. Enrichment factor values of heavy metals in water reservoir Ruzin bed sediments

	Fe	Mn	Al	Cu	Zn	As	Cd	Pb
0 cm	0.701	1	0.910	0.909	1.299	0.814	7.183	0.692
20 cm	0.954	1	1.212	2.949	3.221	37,164	16.897	0.073
50 cm	1.069	1	1.190	4.436	4.844	40,230	47.627	0.029

4. Pollution load index

The pollution load index, proposed by Thomlinson *et al.* [16], was calculated using following equation:

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n}, \quad (2)$$

where n is the number of the metals (eleven in the present study) and CF is the contamination factor. The contamination factor can be calculated from the following relation:

$$CF = \frac{\text{Metal concentration in the sediment}}{\text{Background value of the metal}} \quad (3)$$

The contamination factor scale shows the Table 4.

Table 4. The contamination factor scale [13]

CF < 1	Low contamination
1 ≤ CF ≤ 3	Moderate contamination
3 ≤ CF ≤ 6	Considerable contamination
CF > 6	Very high contamination

Table 5. Contamination factor (CF) values and pollution load index (PLI) of metals in the sediment of water reservoir Ruzin

	Fe	Mn	Al	Cu	Zn	As	Cd	Pb	
	CFI								PLI
0cm	0.99	1.42	1.29	1.29	1.85	1.15	10.2	0.99	6.36
20cm	1.11	1.16	1.41	3.42	4.91	0.49	10.2	1.39	26.74
50cm	1.22	1.14	1.136	5.05	5.21	1.37	4.00	1.23	41.61

The PLI is able to give an estimate of the metal contamination status and the necessary action should be taken a $PLI < 1$ denote perfection; $PLI = 1$ present that only baseline levels of pollutants are present and $PLI > 1$ would indicate deterioration of site quality [16].

The results of contamination factors and pollution index show the Table 5. Contamination factor for Fe (0 cm), and As (20 cm) indicate low contamination. The CF for each element except Cu and Zn (20 cm and 50 cm) shows moderate contamination. Cu and Zn show considerable contamination ($3 \leq CF \leq 6$). The high PLI values 6.36 (0 cm), 26.74 (20 cm) and 41.61 (50 cm) indicated strong signs of pollution deterioration for each sampling sites.

5. Conclusion

Identification and quantification of heavy metal sources, as well as the fate of those heavy metals, are important environmental scientific issues. The presented study gives the useful tools, methods, and indices for the evaluation of sediment contamination. Sediment pollution in this study was assessed using Enrichment factor (EF) which shown significant enrichment of elements such as Cd (50 cm) and mild enrichment for elements As and Cd. The higher Cd value indicated that the sediments were enriched by anthropogenic activity. The very high values of PLI indicate deterioration of site quality.

The data obtained from this study will become part of baseline data and also important to the environmental agency as a policymaker for proper environmental management. This study also provide initial information to the relevant agencies and authorities in preparing preventive plan to control of heavy metals and other pollution from industries against direct discharge into the rivers.

Acknowledgements

This work has been supported by the Slovak Research and Development Agency under the contract No. APVV-0252-10 and by the Slovak Grant Agency for Science (Grant No. 1/0882/11).

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