Calculation of mercury accumulation in the Idrijca River overbank sediments

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Abstract: From the historic literature on the Idrija mercury mine it is evident, that part of the smelting and mining waste was dumped into the Idrijca River. This waste was transported downstream during floods. The amount of mercury, which is accumulated in the overbank sediments of the Idrijca River today, was studied. For estimating the volume of overbank sediment we performed the mapping of Holocene river terraces of the Idrijca River. For assessment of mercury concentration we sampled the overbank sediments on the different levels to perform the analysis of variability. The greatest variability is between the different terases inside the same floodplain, regardless with the distance from the source of pollution, with the position inside one terrace or with the depth of a taken sample. Considering this fact, which determined the methodology for calculation, we estimated that about 1500 tons of mercury is stored in the Idrijca River overbank sediments.

Key words: overbank sediments, Idrijca River, mercury accumulation, mercury contamination.

INTRODUCTION

In many areas worldwide present and historical mining and smelting activities are causing a variety of environmental problems. Physical remobilization of abandoned tailings or waste piles and of channel beds and heavy metal-contaminated floodplains alluvium (formed during historic mining activity) provide large amounts of metal contaminants to rivers (HUDSON-EDWARDS, 2003). Because mining necessarily involves disturbing previously stable formations, and may involve exposing large quantities of material to weathering processes, the environmental effects of mining activities can continue long after operations have ceased.

Exploitation of the Idrija Mercury Mine (Slovenia) started in 1490. More than 107.000 tons of Hg was produced in its five-century long history. The production stopped in 1995. The average recovery rate has been estimated to 73 %. Much of the remaining 27 %, which is approximately 40,000 tons of Hg, was dissipated into the environment.

The majority of ore and smelting waste was swept into the Idrijca River, transported by the river downstream during high water events, and deposited as wide areas of contaminated floodplains along the Idrijca and Soča Rivers (GOSAR ET AL., 1997; BIESTER ET AL., 2000). Hg enriched marine sediments have also been found in the Gulf of Trieste (BIESTER ET AL., 2000; COVELLI ET AL., 2001; HORVAT ET AL., 2003).

MATERIALS AND METHODS

Calculation of accumulated mercury was performed by multiplying the quantity of the material accumulated in the overbanks with the concentration of mercury in this media. For this purpose we have geologically mapped the river terraces. The emphasis was put on two parameters: the area of a terrace and its height from the active river sediment. The measurements were performed by means of geodetic measurements and visual estimation. The data were drawn on a scale 1:5.000 topographic map.

The next step was to determine the concentration of mercury. We randomly took samples of sediments with a hand drilling set, regarding the following parameters: distance from the source of pollution (Idrija), height of a terrace, depth and position inside a terrace. The laboratory preparation of samples included drying milling and sieving. A fraction smaller than 0.125 mm was analyzed after aqua-regia digestion (1 hour, 95 °C) by means of ICP.

The analysis of variability shows which parameter carries the majority of information. That was important for determination of the concentration of mercury in terraces that were not sampled. The levels of the performed analysis of variance are:

- distance from the source (each floodplain as one unit);
- different terraces inside one floodplain;
- different sampling points inside one terrace;
- variability inside one sampling point in relation to the depth of a taken sample.

We have repeated the calculation of accumulated mercury over the level, which carries the majority of information and taken the parameters inside other levels as a constant. For example, if the level "distance from the source" carries the most of variability, then we should take the concentrations of Hg inside one floodplain as a constant, but for different floodplains we would assume different concentrations. For calculation of volume of accumulated sediment we have assumed that Idrijca is a gravel-bed wandering river (MIALL, 1996). For this type of river the one or two active channels, sinuous outline, gravel bars and bed forms and floodplain deposits are characteristically with main difference from the theory that in the Idrijca River case the flow channel, espe-

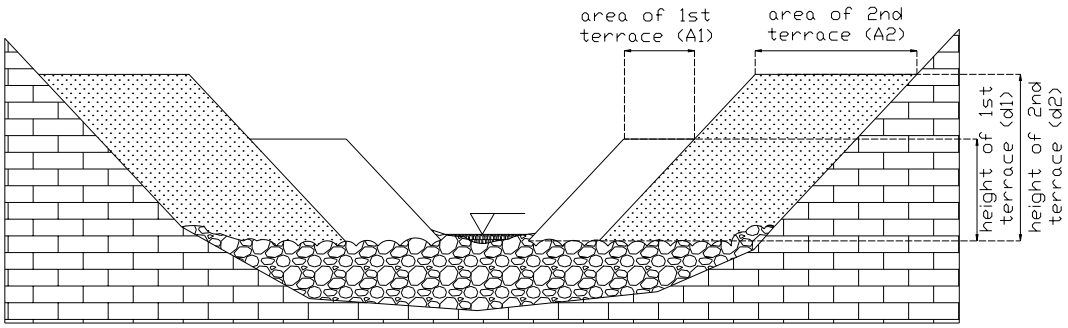

Figure 1. Assumed simplified cross section over the Idrijca river valley.

cially in the upper stream part, is limited with the bedrock and can not develop standard architectural model. The supposed cross section of the valley is shoved on the Fig. 1. We assumed the flat gravel bed, inclined slopes of bedrock and the same inclination for the terraces. This model is confirmed also by drilling into the floodplain sediments in the selected terrace systems. The equation for calculation the quantity of mercury inside one terrace, assuming the correctness of cross section in Fig. 1 is: $Hg = Ai \bullet di \bullet ci \bullet \rho$, where Hg means the quantity of accumulated mercury in the terrace in mg, A_i means the area of a terrace in m^2 and d_i means the height from the top of a terrace to the channel bed in m (look also Fig. 1), c_i the mean concentration of mercury in this media in mg/kg and ρ means density of material in kg/m^3, which was estimated to 2082 kg/m^3 (SIMETRIC, 2004).

To calculate the quantity of mercury in sediments we used mathematical (calculation of volume of objects) and statistical methods (analysis of variability, calculation of mean values inside different levels). The final result of research is the quantity of mercury accumulated in the Idrijca River sediments and a map showing the most contaminated areas along the Idrijca River.

RESULTS AND DISCUSSION

The upper part of the Idrijca River valley, between the town of Idrija and Trebuščica River, is narrow. Consequently, there are very few floodplains and a very small quantity of accumulated sediment. In the lover part the Idrijca River valley is widened. There is a lot of deposited sediment with a well-developed system of terraces (Fig. 2).

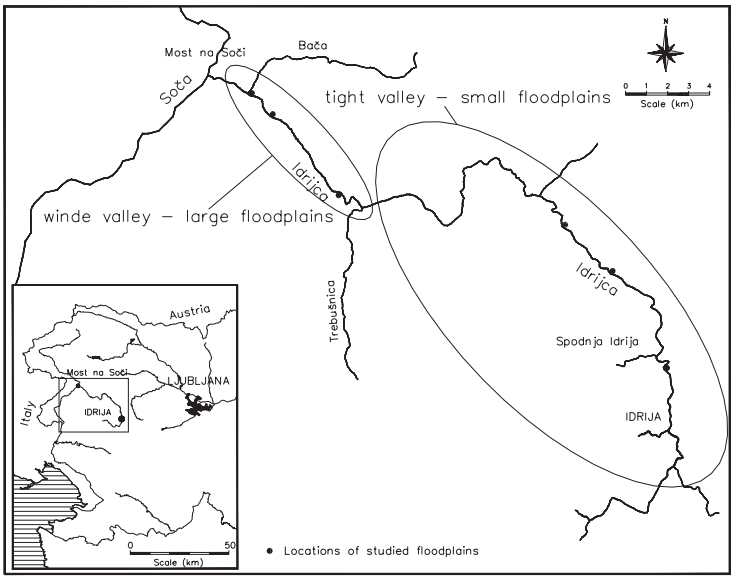

Figure 2. Location of researched area.

The alluvial terraces are used for agriculture, mostly for growing food for people as well as for domestic animals. It has been determined that the lower terraces along the Idrijca River are strongly enriched with mercury. The concentrations on the surface of the first terrace vary between 200 and 500 Hg mg/kg. Hg content gradually decreases with the distance from the river and height above the river stream to approximately 50 mg/kg on the surface of the second terrace and 5 mg/kg on the surface of the third terrace (GOSAR ET AL., 1997; BIESTER ET AL., 2000).

The analysis of variability shows that the first level "distance from the source" carries no information at all. Next level "different terraces inside one floodplain" carries the most of information (71.2 %), the level "different sampling points inside one terrace" carries 11.8 % and the last level "variability inside the one sampling point in the relation with depth of taken sample" carries 17 % of variability. Because of this fact we assumed that concentrations of Hg varies from terrace to terrace inside a floodplain, but does not change in the relation to the source of pollution, neither in the relation with the position inside one terrace nor the depth. The average concentration of Hg in the first terraces is 163.7 mg/kg, in the second terraces 15.1 and in the other upper terraces 3.74 mg/kg.

The estimated volume of accumulated overbank sediment in the lower terraces is 4.05 million m^3, in the upper terraces 2.31 million m^3 and in other terraces 2.31 million m^3. The total amount of accumulated mercury in the overbank sediment of the Idrijca River from the town of Idrija to the town of Bača pri Modreju is 1471 tons. This means that 3.6 % of all dissipated mercury in the environment due to mining in Idrija is accumulated in the overbank sediments of the Idrijca River.

CONCLUSIONS

In the history of the Idrija mercury mine the amount of mercury loss was estimated to 40,000 tons. Some of this quantity finished in the overbank sediments of the Soča and Idrijca Rivers, some in the Tržaški zaliv (Gulf of Trieste), some in the soils nearby Idrija and some in the mine of Idrija as material for backfilling the abandoned galleries. It would be interesting to get the same estimations for the mentioned localities. With those results we would be able to round up the story of lost mercury from the Idrija mercury mine.

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