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Environmental impact of the former Pb–Zn mining and smelting in East Belgium

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Abstract

In the mining district of Plombières-La Calamine (East Belgium), extensive Pb–Zn mining activities resulted in an important contamination of overbank sediments along the Geul river. Moreover, a huge amount of heavy metals is stored in a dredged mine pond tailing, which is located along the river. In the dredged mine pond tailing sediments, Pb–Zn minerals control the solubility of Zn, Pb and Cd. Although Pb, Zn and Cd display a lower solubility in overbank sediments compared to the mine tailing pond sediments, elevated concentrations of Pb, Zn and Cd are still found in the porewater of the overbank sediments. The considerable 'actual' and 'potential' mobility of Zn, Pb and Cd indicates that the mine pond tailing sediments and the overbank sediments downstream from the mine pond tailing represent a considerable threat for the environment. Besides the chemical remobilisation of metals from the sediments, the erosion of overbank sediments and the reworking of riverbed sediments act as a secondary source of pollution.

Keywords: Heavy metals; Leaching; Mine tailings; Overbank sediments

1. Introduction

From the Middle Ages until the beginning of the 20th century, extensive Zn–Pb mining and smelting was carried out in Plombières and La Calamine (eastern Belgium). Besides the important amount of waste that is stored in huge mine tailings, overbank sediments along the nearby Geul rive are severely contaminated with Zn, Pb and Cd (Swennen et al., 1994). The distribution pattern, the actual and potential mobilisation and (natural) attenuation of Pb, Zn and Cd in the mine pond tailing sediments of La Calamine and in overbank sediments downstream of La Calamine were investigated.

2. Methodology

Three vertical profiles were sampled in detail within overbank sediments along the Geul river in Plombières (East Belgium), in Sippenaeken and Epen (South Netherlands), respectively, 7, 9 and 12 km downstream from the mine tailing pond of La Calamine. Total metal concentrations (determined after dissolution of the sample with concentrated HF, HNO_3 and HCl), pH and grain size were determined for all the samples. In the overbank sediments, CEC and organic carbon content were also measured. Furthermore, a mineralogical (petrography, XRD, SEM-EDX) investigation of a vertical profile in the dredged mine tailing pond sediments of

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Table 1
pH and concentrations (in mg/kg) of Zn, Pb, Cd and As in the mine pond tailing sediments and in the overbank sediments along the Geul

	Mine tailing (n = 20)					Overbank sediments (n = 100)				
	Zn	Pb	Cd	As	pH	Zn	Pb	Cd	As	pH
Average	37513	19206	146	679	4.92	3858	1302	7	23	6.8
SD	36371	13340	138	444	1.31	3413	1722	8	25	0.6
Min	1439	2434	3	31	3.05	279	38	0.1	4	5.4
Max	108108	39503	307	1491	6.97	13171	6530	37	121	8.0

n = number of samples.

La Calamine was carried out. The DIN 38414-S4 leaching test (extraction with water at a liquid/solid ratio of 10:1), which is used to evaluate leaching with landfill acceptance data (Anonymous, 2003), was carried out on the samples from the mine pond tailing. Single extractions with $CaCl_2$ (0.01 M) and ammonium-EDTA (0.05 M) (Quevauviller, 1998) were performed to estimate the 'actual' (i.e. porewater composition) and 'potential' mobilisation of Cd, Zn and Pb from the overbank sediments. The modified BCR sequential extraction scheme (Rauret et al., 1999) was applied on a selection of samples from the mine pond tailing and overbank sediments. pH_{stat} leaching tests (Van Herreweghe et al., 2002) were performed on overbank sediment samples from Plombières, Sippenaeken and Epen.

3. Results and discussion

3.1. Mine pond tailing sediments

Elevated total concentrations of Pb, Zn, Cd and As were measured in the mine pond tailing (Table 1 and Fig. 1). The main heavy metal bearing minerals in the La Calamine mine pond tailing, determined with XRD, were ZnS (wurtzite), $ZnCO_3$ (Smithsonite), anglesite ($PbSO_4$), pyrite (FeS_2) and marcasite (FeS_2). The oxidation of sulphide minerals within the mine tailing releases H^+, SO_4^{2-}, Fe^{2+}, and trace metals into the porewater. Subsequent pH-buffering in carbonate/sulphate-rich layers results in the precipitation of secondary minerals such as $ZnCO_3$, $FeCO_3$ and $CaSO_4 \cdot 2H_2O$. These precipitation processes result in the formation of cemented layers (for example between 81 and 97 cm depth in Fig. 1), which show an enrichment in Zn.

Although these carbonate/sulphate-rich layers provide some natural attenuation of trace metals, elevated Zn-, Pb- and Cd-concentrations are found in the water extracts (DIN 38414-S4 leaching test) of the surface layers of the tailing (0–2.6 m depth) (Fig. 1), largely exceeding the criteria for landfill acceptance (Anonymous, 2003). Acid pH values (between 3 and 4.9) were encountered in the deeper part of the tailing (between 2.6 and 4 m depth). Nevertheless, a lower mobility of Zn, Pb and Cd was found compared to the upper part of

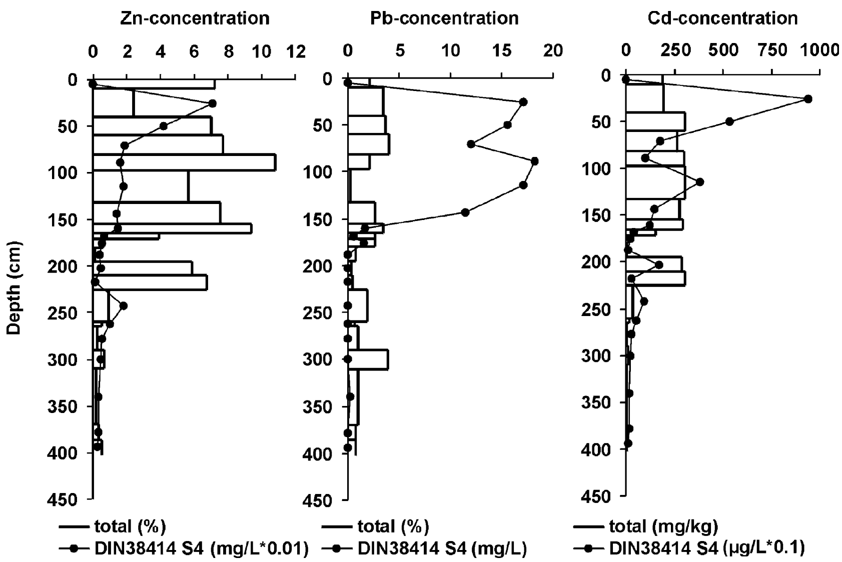

Fig. 1. Vertical distribution of Zn, Pb and Cd in the mine tailing pond of La Calamine and amount of Zn, Pb and Cd released with the DIN38414-S4 test.