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Long-term evaluation of acid rock drainage mitigation measures in large lysimeters

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Abstract

In the course of a German–Romanian scientific project, large lysimeters with a volume of up to 65 m^3 were used for up to 3 years long experiments on controlling acid rock drainage formation in three different types of pyritic mine waste: (A) weathered 6 years old waste rock material, (B) sorted, freshly broken, low-grade ore, and (C) unweathered tailings material. An addition of sodiumdodecylsulphate (SDS) partly reduced the activity and number of metal sulphide oxidizing bacteria of the type *Acidithiobacillus ferrooxidans* but did not kill the bacteria. Consequently, the release of metals and sulphate from mine waste was not significantly reduced. The application of the biocide isothiazolinone (Kathon RH 886) reduced the release of Cu, Zn, Fe and sulphate between 5% and 50% for different types of mine waste. A cover of organic material only achieved a moderate reduction of the heavy metal and sulphate release from the weathered 6 years old waste rock material: Cu was reduced by 50%, Zn by 30%, Fe by 90%, and sulphate by 40%.

Keywords: Acid mine drainage; Acid rock drainage; Biocides; Microcalorimetry; Mine waste; Pyrite oxidation

1. Introduction

Abatement of acid rock drainage (ARD) is of increasing scientific and technical interest because of stringent regulations regarding environmental pollution. Acidity and dissolved heavy metals released from different sources of mine waste including underground and open pit mines, mine waste rock deposits, and tailings heaps and ponds result in a deterioration of soil and water quality. For new mine waste deposits high safety standards have been established in several countries to prevent ARD generation. Substantial costs are required for mine waste remediation. Measures for ARD prevention and safe storage of sulphidic mine waste have been thoroughly evaluated. Results of large scale experiments using control of water- and oxygen-flow, under water storage, or application of pH-regulating or inhibitory substances are well known (Dugan and Apel, 1983; Onysko et al., 1984; Erickson et al., 1985; Backes et al., 1988; Watzlaf, 1988; Evangelou, 1995; Rastogi,

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1995; Schüring et al., 1997; Schippers et al., 2000; Mudder and Olson, 2004), but little information is available about the long term effect of mitigation measures on metal sulphide oxidizing, bioleaching bacteria (Ledin and Pedersen, 1996).

In the course of a long-term-project in the framework of a German–Romanian scientific cooperation, large mine waste lysimeters were constructed and used for experiments on ARD abatement (Cosma et al., 1999; Jozsa et al., 1999; Schippers et al., 2001). Geochemical and microbiological data were collected over a period of 3 years. Additionally, a technique based on microcalorimetry was applied to rapidly evaluate the effects of abatement measures. This paper summarizes the most relevant findings of the 6 year project on mitigation of ARD.

2. Materials and methods

The following subsections describe the experimental setup, the material used, and how the experiments were run and samples analyzed.

The experiments were carried out in the Cu-, Pb-, and Zn-mine Ilba near Baia Mare, Maramures, in North-West Romania. The underground mine has been in operation for more than 40 years. The main waste dump consisted of sulphidic sedimentary rock, was about 5 m high and was located on the bottom of a valley surrounded by about 500 m high mountains. The climate in that area is humid. During the summer moderate temperatures (~10 to 30 °C) prevail and in the winter there are freezing temperatures (~−10 to 5 °C) and snow.

2.1. Lysimeters

The lysimeters were installed into the main waste dump to ensure natural climatic conditions. The four-chamber percolator (4CP) was constructed of reinforced concrete and was protected against acid attack and mechanical stress by spray-application of CORODUR 2K® (Lehmann and Voss and Co., Hamburg, Germany). It consisted of four separate lysimeters with a volume of 65 m^3, each. Approximately the same amount of waste material (ca. 120 t) was excavated in the vicinity of the 4CP for two additional chambers each. A HDPE-liner was put in these chambers for isolation and the waste rock was replaced to fill the excavations. The six column percolator (6CP) was made of prefabricated concrete pipe segments and contained 2.3 m^3 waste material in each lysimeter column. The overall height of the waste in all devices was approximately 3 m. Sampling of solids from different depths in the lysimeters through hollow PVC pipes with a diameter of 100 mm, and a separate, quantitative collection of the effluents was possible.

2.2. Mine waste and tailings material

The waste material used for the experiments in the 4CP and the excavations consisted of weathered 6 year old run of mine waste rock material from the main waste dump. The entire material was of brownish colour due to iron precipitates. The rocky material showed a lot of cracks and cleavage surfaces, which were also partly brown, indicating that iron precipitation also occurred at inner surfaces inside the rocks. In the 6CP three materials of different grain size were tested: (A) weathered waste rock from the main waste dump (grain size <100 mm), (B) the 4–30 mm fraction selected by screening from freshly crushed waste rock, and (C) an unweathered, coarse flotation tailings material (grain size less than 1 mm, with 10% addition of fresh flotation pyrite concentrate to increase the amount of leached ions). The composition of the materials in the different lysimeters is given in Table 1.

Table 1
Chemical composition of the mine waste used for lysimeter experiments (mean values of at least three samples; 4CP=four-chamber-percolator; Excav.=excavations; 6CP=six column-percolator, SDS=sodiumdodecylsulphate; *Pyrite content was calculated from Fe and S values; nd=not detected)

Experiment	Grain size [mm]	Total amount [%]												
		Al_2O_3	CaO	MgO	Na_2O	K_2O	SiO_2	Cu	Zn	Mn	Pb	Fe	S	*Pyrite
4CP (control)	<400	15.00	3.75	1.78	1.33	4.38	64.50	0.05	0.14	nd	0.20	4.38	2.03	3.79
4CP (SDS)	<400	12.06	0.85	1.03	0.77	4.57	65.15	0.07	0.05	nd	0.42	4.76	1.87	3.50
Excav. (control)	<400	12.06	0.85	1.03	0.77	4.57	65.15	0.07	0.05	nd	0.42	4.76	1.87	3.50
Excav. (cover)	<400	12.08	0.86	1.13	0.80	4.60	64.58	0.06	0.06	nd	0.46	5.60	1.78	3.34
6CP (weathered)	<100	12.49	2.34	2.43	2.00	3.72	61.33	0.03	0.09	0.07	0.07	6.04	2.22	4.16
6CP (crushed)	4–30	2.44	3.77	2.65	3.86	8.17	61.05	0.05	0.17	0.10	0.09	4.73	2.19	4.09
6CP (tailings)	<1	1.11	6.35	1.69	3.20	4.85	59.41	0.04	0.40	0.21	0.11	7.71	8.74	16.37