Combined chemical and phytostabilisation of an acidic mine waste
Long-term field experiment
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Abstract
The combination of chemical stabilisation (using fly ash, lime and steel shots) and phytostabilisation (using grass mixture and two Sorskium species) was applied to a highly acidic mine waste in a field experiment. The change in metal mobility was monitored by chemical, biological and ecotoxicological methods. Chemical stabilisation reduced the amount of Cd from 441 to 0.120 µg/l, Cu from 1510 to 5.85 µg/l and Zn from 89079 to 29.3 µg/l in drain water and extractable As from 0.044 to 0.006 mg/kg in waste within three years. The high toxicity of the mine waste was reduced to non-toxic and healthy vegetation developed on the previously barren surface with metal content fulfilling animal fodder quality criteria. The technology reduced the risk on all possible pathways fulfilling all target criteria.

The site
The area of the former lead and zinc sulphide ore mine in Gypsyőszoroszi, Hungary (Fig. 1) is heavily polluted with toxic metals, such as Zn, Cd, Pb, Cu and As. A complex survey was carried out in the former mining area to assess the impacts of mining activity and a complex risk management strategy was developed, which uses GIS based, catchment scale risk assessment. One of the biggest waste heaps in Gyypsyőszoroszi is Bányabérc (BB, Fig. 2 and 3). The stopes risk assessment of the waste depositions in the area showed that the BB waste dump is highly risky and remediation or other risk reducing intervention is needed. Total metal content (Agua Regia digested) of BB mine waste: 524 mg/kg As, 1.90 mg/kg Cd, 35.1 mg/kg Cu, 3394 mg/kg Pb, 483 mg/kg Zn. Metal content in leachate (Max. Effect Based Quality Criteria – EBOCmax – in parenthesis): -1.8 (10) µg/l As, 441 (1) µg/l Cd, 1510 (200) µg/l Cu, 17.2 (10) µg/l Pb, 89079 (100) µg/l Zn.

Field experiment
As part of this complex environmental management concept in Gyypsyőszoroszi, after the removal of point sources, the diffusely polluted area is planned to be re-natured with an in situ technology, the combination of chemical stabilisation with phytostabilisation (CCP). For the selection of effective stabiliser and plant combinations scaled up experiments were performed in laboratory microcosms, field lysimeters and field plots. The latter is presented here. Three 6 m × 15 m field plots were constructed from BB waste material (Fig. 4). The plots were isolated from the underlying ground by a plastic foil, above that, a 5 cm thick layer of andesite gravel was placed to provide a filter layer. The water filtering through the plots was collected by a drainage system. The first plot was amended with 5% by weight non-alkaline fly-ash (FA) T originating from a power plant in Hungary; the second was treated with two non-alkaline fly-ashes T and V in 5% by weight (2.5% by weight each), together with hydrated lime in 2% by weight (FAL). The FAL plots were amended with steel shots (SS) after the first year in 5 kg/m². The third plot remained untreated and was used as a control. Three plant types were grown on the field plots near each other: a grass mixture and two Sorskium species (Sorskium sudeticum and Sorskium vulgaris). The demonstration of the CCP technology was followed for three seasons by integrated monitoring and evaluation method (Fig. 5).

Results
The results of the three years experiment showed that the FAL treatment is more effective in reducing the extractable metal amount in the BB mine waste, than the FA treatment (Fig. 6 and 7), and it is able to reduce the metal contents in drain water under the effect based quality criteria. However, the FAL treatment resulted in higher As concentrations. UNT (and FA: -1.8 µg/l. FAL: 21.33 µg/l) in the drain water due to elevated pH (Unt.: 2.9, FA: 4.2, FAL: 7.6), and FA treatment caused higher Pb concentrations (Unt.: 13-17 µg/l, FA: 131.192 µg/l, FAL: 1.5 µg/l). Laboratory minisystem leaching tests showed that SS thoroughly mixed into the waste can reduce the extractable As and Pb concentrations by 48-78%.

Conclusions
The three years experiment showed that CCP technology is suitable for the remediation of a highly acidic, toxic metal containing mine waste. The combination of fly ash and lime is highly effective in reducing metal mobility, especially of Zn and Cd, and its efficacy can be further enhanced by SS addition. The closed grass cover further decreases the leaching of metals and renders water and wind erosion.

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