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 *Sorghum* species) were applied to a highly acidic metal ore 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 9.85 µg/l and Zn from 89079 to 29.3 µg/l in drain water and extractable As from 0.404 to 0.086 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 Gyöngyösoroszi, 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 Gyöngyösoroszi is Bányabérc (BB) (Fig. 2 and 3). The stepwise 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 digestion) 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 – $EBQC_{max}$ – in parenthesis): <1.8 (10) µg/l As, 441 (1) µg/l Cd, 1510 (200) µg/l Cu, 17.0 (10) µg/l Pb, 89079 (100) µg/l Zn.

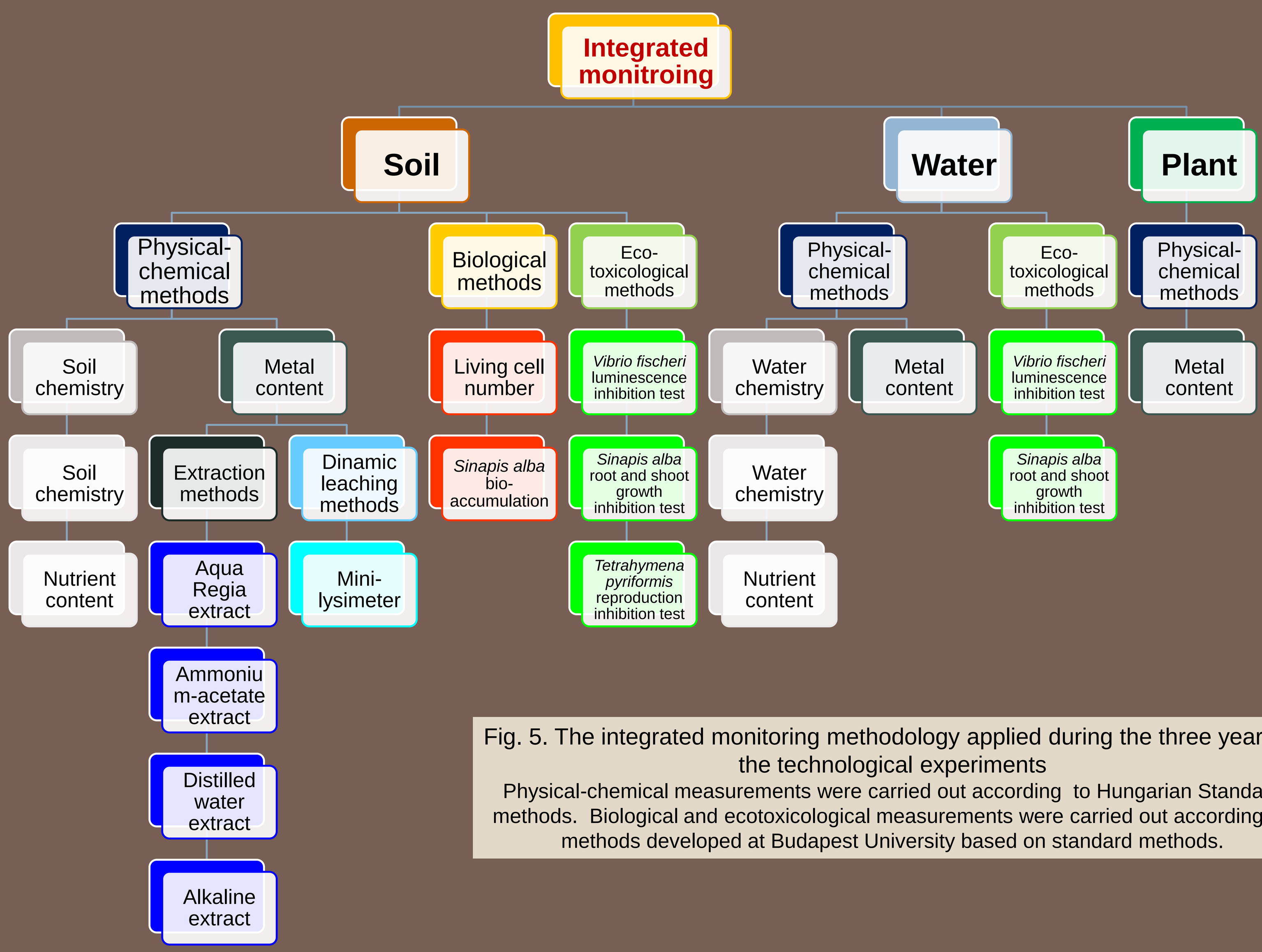

Fig. 5. The integrated monitoring methodology applied during the three years of the technological experiments
Physical-chemical measurements were carried out according to Hungarian Standard methods. Biological and ecotoxicological measurements were carried out according to methods developed at Budapest University based on standard methods.

Location

Fig. 1. Location of the Gyöngyösoroszi lead and zinc sulphide ore mine in the Mátra Mountain, Hungary

Fig. 2. Location of the Bányabérc mine waste heap and the main mine entrance above the village of Gyöngyösoroszi

Fig. 3. and 4. The Bányabérc mine waste heap under excavation near the Bányabérc shaft and the field plots constructed from BB mine waste.

Field experiment

As part of this complex environmental management concept in Gyöngyösoroszi, after the removal of point sources, the diffusely polluted area is planned to be remediated 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 filed 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 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 *Sorghum* species (*Sorghum sudanense* and *Sorghum vulgare*).

The demonstration of the CCP technology was followed for three seasons by integrated monitoring and evaluation method (Fig 5).

Results

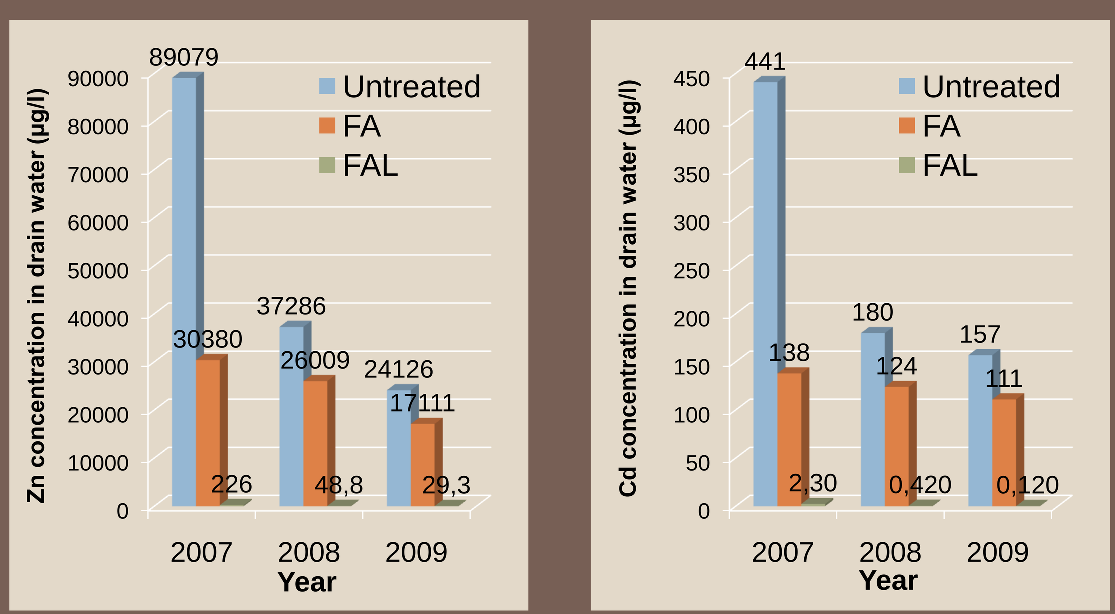

Fig. 6. and 7. Zn and Cd concentration in drain water from plots, $EBQC_{maxZn}$=100 µg/l, $EBQC_{maxCd}$=1 µg/l. FA: fly ash, FAL: fly ash + lime. SS (steel shots) added 2nd year.

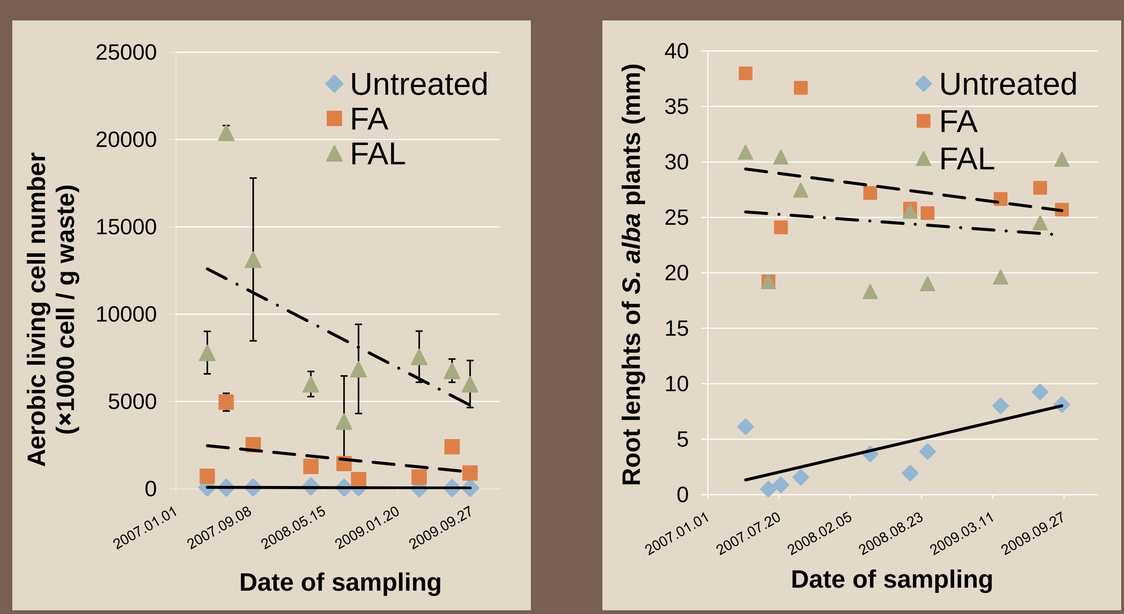

Fig. 8. and 9. Aerobic living cell number (activity) and *S. alba* root growth inhibition (toxicity) on BB mine waste.

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 minilysimeter leaching tests showed that SS thoroughly mixed into the waste can reduce the extractable As and Pb concentrations by 48−78%.

The activity of the waste increased and its toxicity decreased due to the treatments (Fig. 8 and 9).

The metal content of the plants grown on the FAL field plots was under the Hungarian limit value for fodder, which is 2 mg/kg for As, 1 mg/kg for Cd, 100 mg/kg for Cu, 10 mg/kg for Pb and 100 mg/kg for Zn (in dry weight), and there was no significant difference between the metal accumulation of the three plant types used for phytostabilisation.

On the untreated plot the plants were not able to grow at all in field conditions, which proves the importance of the application of chemical stabilisers before the sowing of plants (Fig. 10−12).

Fig. 10. The untreated plot: plants were not able to grow due to high acidity and toxic metal concentrations

Fig. 11. The treated plots with developing vegetation: *Sorghum sudanense*, *Sorghum vulgare* and grass mixture with low metal accumulation

Fig. 12. Healthy and closed grass on the FAL treated plot able to reduce water and wind erosion

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 hinders water and wind erosion.

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