Integrated monitoring of red mud contaminated soil in microcosms

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The worst environmental catastrophe of Hungary occurred on October 4, 2010. The red mud reservoir in Ajka storing 3–4 million cubic meters of highly alkaline (pH 13) red sludge broke and released 800.000 m3 of slurry into the environment. Our research group together with the RISSAC (Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences) assessed the soil of the affected agricultural land. The aim of our experimental work, presented in this study, was the assessment of the short- and long-term environmental risk of those red mud contaminated soils, which in addition to the alkalic infiltrate were polluted also by the red mud mixed into the soil by tilling.

A three-tiered risk assessment procedure showed that the major environmental risk posed by the red mud is due to its high alkalinity and high Na content. The risk of toxic metals and radioactive isotopes are negligible, in spite of the fact, that the high alkalinity has mobilized some of the toxic metals, typically As, Se, Ni and Cr. Alkalinity has had detrimental effects on the soil as a whole, adversely affecting soil texture, function and quality as habitat of microbes, animals and plants while the high Na-concentration increased the risk of sodification. Characterization of the extent of these adverse impacts was one of the aims of our study.

Infiltration of the alkalic solute and incorporation of some red mud into the soil was an unavoidable process in the area. Incorporation of a certain amount of red mud by tilling occurred as an alternative in addition to red mud removal, because the available mechanical tools could not remove the very thin red mud layers from the soil surface. Thus the second reason for testing red mud mixed into soil in soil microcosms was to find the red mud concentration with no adverse effects on the soil as natural habitat and agricultural production medium. We measured toxicity on soil organisms, particularly plants and monitored the short- and long term sodification in red mud containing soil microcosms.

To determine the maximum proportion of red mud which can be mixed into the soil we added 0−100% red mud in the first series and 0−40% in the second series. To study the sodification tendency we tested the microcosms of uncontaminated reference soil, soil contaminated only with alkalic infiltrate and soil including 5% and 10% red mud. We followed all these cases under 3 conditions: deep ground water level, high groundwater level and surface irrigation simulating precipitation (rain). The evaporation was enhanced by ventilation and the summer months were simulated by heating.

The experiments were monitored by an integrated methodology combining physical, chemical, biological and ecotoxicological methods. Environmental toxicity tests measured the aggregated adverse effects on the test organisms from three trophic levels: *Vibrio fischeri* (luminescent bacterium), *Sinapis alba* (plant) and *Folsomia candida* (animal). The aim of the biological and ecotoxicity tests was to assess the amount of red mud that can be mixed into the soil without toxic effect.

The conclusion of our experiment was that red mud can be mixed into the soil without any long-term adverse effect on soil living organisms at up to 10%. The chemical analysis confirmed that red mud mixed into the soil increased the Na^+ and total salt concentration of the soil, but both remained at an acceptable level at up to 5% red mud addition rate. 5% red mud shifted the pH of the soil to the highly alkaline domain. The sodification tendency slightly increased with 5% red mud in soil, while 10% red mud enhanced considerably the risk of sodification.

The work was funded by the National Innovation Office (SOILUTIL project, TECH_09-A4-2009-0129).