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Ecological risk screening of metal (Pb and Zn) contaminated acidic soil using a triad approach

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Abstract

Lead (Pb) and zinc (Zn) are common metal contaminants in terrestrial environments. Decisions on remediation of metal contaminated soil are often based on risk estimates derived from generic guideline values. Guideline values are used at the screening stage of Ecological Risk Assessments (ERA) and have been developed to represent "safe" levels of contaminants applicable over large geographical areas (usually countries). If levels of contaminants exceed these guideline values, the risk is deemed as unacceptable and remediation is often initiated. However, it is now widely known that guideline values often are not effective in estimating true risk to humans or the environment. Using generic guideline values can lead to overly conservative remedial decisions, resulting in costly clean-ups that may not be necessary. Excavation of soil can also increase the risk of exposure to contamination and destroy native ecosystems. A weight of evidence or "triad" approach including information on soil chemistry, soil ecotoxicity and information on the ecological state of the site, taking bioavailability of the contaminants into account, could improve site specific risk screening estimates. These separate lines of evidence complement each other with chemical tests identifying contaminants of concern, bioassays confirming toxicity of the field samples, and ecological tests confirming actual effects in the field. However, current standardized tests usually require extensive handling of the field collected soil, including drying, homogenization and sieving. Handling of soil in this way may change the speciation of metals in the soil and thus the bioavailability. Risk estimates based on these tests may thus be erroneous. To overcome this problem, undisturbed soil cores are proposed. However, if natural conditions of the soil are not within acceptable conditions for the organisms in toxicity tests, they will not survive in controls. This is particularly the case in very acidic soils. The sensitivity of many standardized test organisms to low pH is an important factor to consider, as naturally acidic soils have been estimated to occupy 30% of the world's ice free land area.

The overall objective of this thesis, which is based on papers I-IV, was to recommend tests that can be included in a triad approach at the screening level of ERA at metal (Pb and Zn) contaminated sites with acidic soils. A variety of bioassays and test organisms from three taxonomic groups (papers I, III, IV) as well as chemical speciation methods (papers I-II) and ecological methods (paper III) have been evaluated for use in undisturbed acidic metal contaminated soil cores. A risk characterization method combining the lines of evidence into a risk estimate has also been suggested.

Diffusive gradients in thin films (DGT)-labile metal concentrations and metal concentration in soil leachates from undisturbed soil cores were better predictors of accumulation of Pb and Zn in wheat than total metal concentrations in soil (paper II) and are therefore proposed as possible tools for the chemical assessment line. The wheat (*Triticum aestivum*) bioassay test in soil cores as outlined in papers (I, II) was relatively tolerant of low pH soils but insensitive to the metals of concern (Pb, Zn, Cd and Cu). The *Daphnia magna* test using leachate from the soil cores (paper I) appeared more sensitive to naturally occurring metals in the soil such as Al and Fe as well as low pH. The bioassays with lettuce (*Lactuca sativa)* in paper (I) and (III) appeared sensitive to the metals of concern but also displayed sensitivity to leachate pH below 6. In addition, Microtox, *Hyalella azteca*, and red fescue (*Festuca rubra*) showed similar or higher sensitivity to low pH than to Zn concentrations (III) and are therefore not recommended bioassays for risk screening of acidic soils. The MetSTICK test and growth tests with red clover (*Trifolium pratense*) were confirmed to be suited for risk screening of Zn contaminated acidic soils (paper III). Also, the plant species *Brassica rapa*, , *Allium cepa, Quercus rubra* and *Acer rubrum* were confirmed to be tolerant of low pH soils as well as showed potential to be sensitive to metals. (IV). *Dendrobaena octaedra, Folsomia candida*, *Caenorhabditis elegans*, *Oppia nitens*, were identified as possible invertebrate candidate species (IV) for the ecotoxicity line of evidence. *Colpoda inflata* from the microorganism group may be useful for assessing leachates from the soil cores (IV). For the ecological line of evidence, the screening test Bait Lamina may be suitable for soils with pH above 3.7 (paper III).

In conclusion, bioassay test species, chemical tests and ecological tests have been identified that could be suitable for risk screening of acidic undisturbed soil cores in a triad approach. This approach should result in improved risk estimates based on bioavailable concentrations of metals in soil in comparison with only relying on generic guideline values.

Keywords: Ecological risk assessment (ERA), risk screening, metal contaminated soil, undisturbed soil cores, weight of evidence, triad, bioassays, acid soils, Zn, Pb, diffusive gradients in thin films (DGT)