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research bulletin

CL:AIRE research bulletins describe specific, practical aspects of research which have direct application to the characterisation, monitoring or remediation of contaminated soil or groundwater. This research bulletin summarises the results from CL:AIRE Research Project 5.

Remediation of Heavy Metal Pollution via Bone Meal Amendments to Soil: Field and Laboratory Trials

Metals may be present in soils from a variety of sources and may represent a potential hazard to humans and the environment if they are present in soil solutions or are otherwise available to biological processes. However, if such metals are bound up in relatively inert and insoluble compounds, the danger they represent is reduced substantially. The phosphates of many metals (including lead, zinc, cadmium, copper and nickel) can have exceptionally low solubilities and are stable across a very wide range of environmental (Eh and pH) conditions. There now exists a significant body of research showing such compounds will readily form given a source which releases sufficient phosphate to solution. The amendment of soils with such phosphate sources has the potential to control metals release in soils to very low levels. However, given that phosphate itself can lead to environmental problems such as eutrophication of surface waters due to its role as a nutrient for algal growth, the choice of a phosphate source for soil remediation is an important one.

The calcium phosphate mineral apatite has a relatively low solubility when present in its rock crystal form. It is also the principal mineral constituent of mammalian bone. Bone meal has been identified as a potentially appropriate source of phosphate, as it is slowly released due to its poorly crystalline apatite structure. Laboratory experiments using bone meal amendments to a variety of soils have shown release of metals to pore waters to be significantly reduced, with a corresponding reduction in metals availability to plants and soil organisms.

The main objective of the study was to use bone meal amendments in a carefully monitored field trial to test the method in a real contaminated soil environment and assess factors relating to its effectiveness.

The site chosen was at Nenthead in Cumbria. The field trial consisted of two adjacent 5 m x 5 m plots (control and treatment) in an area of extensive gravel tailings from historical lead mining. Analysis of the soil identified metals content of ~30,000 parts per million (ppm) zinc, ~9,000 ppm lead and ~60 ppm cadmium, and a soil pH of 7.6. Analysis of soil solutions extracted from the plots was performed over a two-year period. Two concurrent laboratory leaching column trials at different scales were also undertaken using the field trial soil. These were to provide a comparative link with earlier work and to better understand the processes occurring.

The field trial showed a significant intermittent metals release by the treated soil. In the larger leaching column trial, this effect was shown to be transitory while bone meal-associated organic compounds persisted in the soil. It is concluded that this release relates to the formation of soluble organo-metallic complexes by weak acids produced by the breakdown of the organic fraction of the amendment. The fact that this effect was not observed to be prominent in earlier laboratory trials with other soils may be explained by the unusually high pH of soil at the Nenthead site.

Metals immobilisation was not observed in either the field trial or large column trial. The reason for this is most likely the relatively high pH of the soil (at the upper limit of soils tested previously) which did not allow sufficient dissolution of the bone apatite and also kept metals release relatively low in the untreated (control) soil.

Effective metals immobilisation was seen to occur in the small leaching column trial (based on methodology used in the earlier work). The appearance of consistent levels of phosphorus in the small column leachates indicates steady state conditions quite different to those in the other two trials where phosphorus was mostly below detectable levels. It is suggested that this was due to the greater relative control over soil solution pH exerted by the irrigant due to higher solution/soil ratio and lower solution residence time within the small columns.

Extractions performed upon the small column soil using diethylenetriaminepentaacetic acid (DTPA) and deionised water indicated that bioavailability of lead and cadmium had decreased as a result of bone meal amendment.

The results of the study indicate that metals immobilisation will occur if there is sufficient phosphate present in solution but that solubility of the source material in the prevailing soil conditions needs to be considered carefully. As such, it is suggested that there is an upper limit, in terms of soil pH which is suitable, for the use of bone meal as a phosphate source. Since most soils based on mining waste (and many other metal-contaminated soils) are acidic, it is expected that bone meal amendments may yet prove effective as a remediation method.

Further work should continue with bone meal amendments to investigate more typically acidic contaminated soils. However, as a lesson learned from this research, future field trials should be preceded by extensive laboratory trials based upon the knowledge gained in this and previous work.

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