Remediation of Toxic Metal Pollution in Soil Using Bone meal Amendments

Remedial processes for treating heavy metal contaminated materials are primarily based on immobilising metals in-situ or alternatively removing the metal contaminated materials off-site for further treatment (e.g. soil washing) or disposal. Formation of metal phosphates in soils is one approach considered for immobilising heavy metals. Metal phosphates (e.g. lead, zinc, copper, cadmium, etc.) have exceptionally low solubilities, and are stable over a wide range of pH and redox conditions typically encountered within the environment. Metal phosphates in contaminated soils immobilise the metals, and consequently reduce their leaching into groundwater, and their bioavailability to soil flora and fauna.

Rock phosphate (apatite) has a low solubility, and is therefore a less effective source of phosphorus than other more soluble forms. Crystalline synthetic apatite is more soluble than natural apatite and the dissolution of synthetic apatite in a pH range of 2-7 in the presence of lead or cadmium ions is known to result in the formation of lead phosphate and cadmium phosphate. This synthetic apatite is reported to be structurally similar to the apatite present in bone meal in terms of the size of the apatite crysallites. It was therefore proposed that bone meal could provide a suitable phosphate source for immobilising heavy metals in contaminated soils.

This 12 month laboratory study was undertaken to evaluate the potential of commercially available bone meal as a remedial treatment for immobilising heavy metals in contaminated soils. The aims of this study were to;

- Assess the ability of bone meal to immobilise heavy metals in contaminated soils;
- Determine the bioavailability of metals in bone meal treated soils;
- Assess the reduction in toxicity treated soils contaminated with heavy metals;
- Evaluate the environmental impact of treating contaminated soils with bone meal.

Soil leaching columns were constructed using soils sampled from Lambton Coke Works in Sunderland, Parys Mountain, Leadhills and Wanlockhead. Soil pH ranged from 2.7 to 7.7. These soils were contaminated primarily with heavy metals including zinc (94 ppm to >14,000 ppm), copper (83 ppm to >2,000 ppm), cadmium (1 to 63 ppm), nickel (2 to 120 ppm) and lead (200 to >15,000 ppm). The optimum combination of soil to bone meal was found to be 1 part bone meal to 50 parts of soil. Fine–grained bone meal (90-500 μm) was found to be the most effective grain size.

The leaching column experiments indicated that bone meal amendments resulted in a reduction in metal release (though not a complete reduction) from the contaminated soils and a decrease in pH (i.e. increase in alkalinity)of the soil and leachate. This pH change was probably due to a consumption of protons during bone meal dissolution. The reduction of metals released from the bone meal treated soils may have been due to:

- Change in pH from acidic to more neutral and alkaline conditions resulting in precipitation of metal hydroxides and other insoluble metal salts;
- Formation of metal phosphates; and /or
- Adsorption of metal ions onto bone meal and soil particles.

The bioavailability of the metals in the Lambton soils was reduced as a consequence of metal leaching from the soils being reduced. In this study, DTPA (diethylenetriamine penta-acetic acid) and calcium chloride and extractions were used to determine the bioavailability of metals to soil flora and fauna respectively after bone meal treatment. Bone meal amendments were found to reduce the bioavailability of heavy metals to both soil organisms and plants although none of the soils tested showed the bone meal to have immobilised all metals present.

In summary, a reduction in the metals leaching from contaminated soils was observed after soils were treated with bone meal. It is likely that this was due to the formation of insoluble metal compounds as the pH shifted towards more neutral and alkaline conditions although this was not conclusive within this study.

This technical report is aimed at all parties who have an interest in remediating heavy metal contaminated soils including; consultants, industrialists, landowners, developers, regulators, local communities and NGOs.

This R&D Technical Summary relates to information from Project P5-025 contained in the following output:

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