

# Remediation of Heavily-Metal-contaminated Soils by Bone Meal (Phosphate) Additions

Mark Hodson<sup>1</sup>, Eva Valsami-Jones (evj@nhm.ac.uk)<sup>2</sup> & Janet Cotter-Howells (bot156@abdn.ac.uk)<sup>3</sup>

<sup>1</sup> Postgraduate Research Institute for Sedimentology, Univeristy of Reading, Whiteknights, PO Box 227, RG6 6AB, England, UK

<sup>2</sup> Department of Mineralogy, Natural History Museum, London, England, UK

<sup>3</sup> Department of Plant and Soil Science, Univeristy of Aberdeen, Scotland, UK

Remediation of metal contaminated soil is an important environmental issue because of health considerations and pressure for reuse of brown-field sites. The majority of remediation strategies such as soil washing or excavation, disposal and encapsulation attempt to place a physical barrier between the metal contaminated material and the biosphere. These techniques are unsustainable and there is a growing need for alternative remediation treatments. One chemical/mineralogical remediation method that has been suggested is the *in situ* conversion of metals into metal phosphates (e.g. Cotter-Howells and Caporn, 1996).

Many metal phosphates (e.g. Pb, Zn, Cd) are highly insoluble, having solubility coefficients of  $10^{-60}$  to  $10^{-80}$ , and are stable over almost the entire range of Eh and pH conditions found in the natural environment (Nriagu, 1984). If pollutant metals in contaminated soils could be converted into metal phosphates then, it is argued, the metals would be immobilised *in situ* and, due to the low solubility of metal phosphates, metal availability would be reduced. In theory, because it is based on immutable chemical relationships, such a remediation treatment is fully sustainable.

Many experiments carried out in the 1990s indicated that phosphate formation could be a useful remediation strategy for metal contaminated soils (Hodson et al., in press; Lambert et al., 1997). The challenge now lies in finding a suitable phosphate source.

Regarding phosphate sources typically used in experiments, there is concern that 1) the low solubility of phosphate (or P) sources such as rock apatite would result in limited phosphate release so that remediation would only occur on unacceptably long timescales and 2) the high solubility of phosphate sources such as  $K_2HPO_4$  and phosphate fertilisers might result in eutrophication of streams draining metal contaminated soil (Hodson et al., in press).

Poorly crystallised calcium hydroxyl-apatites have a solubility intermediate between highly insoluble rock apatite and highly soluble phosphate phases. Use of synthetic phosphate in laboratory experiments has resulted in metal immobilisation (Hodson et al., in press). However, the cost of synthetic apatite may make the use of such material uneconomic. Valsami-Jones et al. (1998) noted structural similarities between some

synthetic apatites and bone meal. They suggested that poorly crystalline apatites such as those found in crushed bone (bone meal) could therefore provide a cost-effective, natural-phosphate source for remediation of soils contaminated with certain metals. Preliminary experiments were encouraging (Hodson et al., 2000)

The experiments described here were carried out to determine whether bonemeal additions could be a suitable remediation treatment for heavily-metal-contaminated, acid to neutral, soils.

Three soils contaminated with Pb, Zn, Cu and Cd from former UK mining districts, with pH varying between 2.7 and 7.1, were sieved to remove the > 2 mm fraction, mixed with 90 - 500 micron sized bone meal in proportions of 1:50 bone meal:soil and placed in leaching columns. Columns were regularly watered with synthetic rain at a rate similar to rainfall rate in the UK. Leachates were collected over a period of three months.

Bone meal additions resulted in metal immobilisation in the soils and an increase in the pH of column leachate, soil pore water and the soils themselves. Subsequent experiments indicated that metal immobilisation due to bone meal additions was greater than would be expected from the pH rises alone. Analytical scanning electron microscopy of bonemeal treated soil at the end of the experiment revealed that Pb and Zn were associated with phosphorus. X-ray diffraction identified several newly formed phases in the bonemeal treated soil at the end of the experiments with similar peak intensities and positions as reference Pb and Ca-Zn phosphates. Batch experiments and subsequent extraction of metals from controls and bonemeal amended soils using 0.01M  $CaCl_2$  and DTPA indicated that bonemeal additions reduced availability of some metals in the soils. Reduced bio-availability of metals was also indicated by reduction in metal concentration in the soil solution of bone meal treated columns.

The experiments indicate that bone meal is a suitable phosphate source for remediation of metal contaminated soil. Metal immobilisation is due to both the pH rise associated with bone meal dissolution and, almost certainly, formation of metal phosphates. Field trials to investigate the potential use of bone meal as a remedial treatment are now in development.

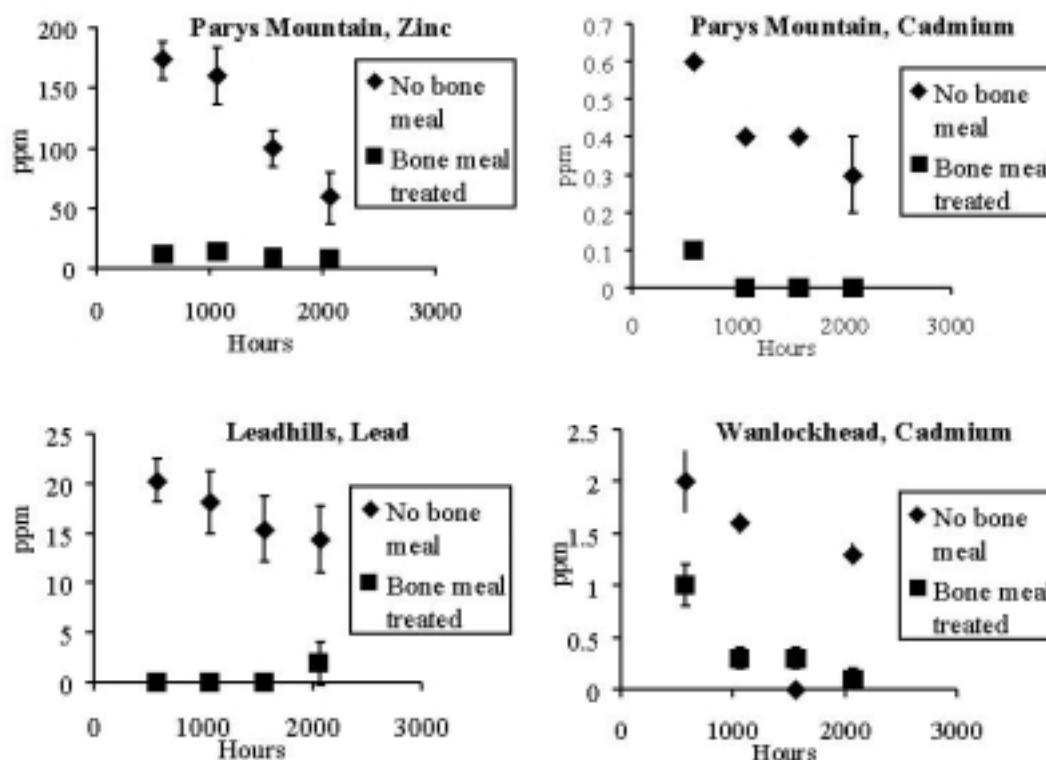


Figure 1: Concentration ( $\text{mg kg}^{-1}$ ) of selected metals in leachates from soil columns containing Parys Mountain, Leadhills and Wanlockhead soils. Error bars = standard deviations about the mean of measurements from triplicate experiments. Where no error bars are visible standard deviations are less than symbol size.

Cotter-Howells JD & Caporn S, *Applied Geochemistry*, **11**, 335-342, (1996).  
Hodson ME, Valsami-Jones E and Cotter-Howells JD, *Environmental Mineralogy*, Mineralogical Society, (In press).  
Hodson ME, Valsami-Jones E, Cotter-Howells JD, Dubbin WE, Kemp AJ, Thornton I & Warren, A, *Environmental Pollution*, **110**, 1-11, (2000).

Lambert M, Pierzynski G, Erickson L & Schnoor, J, . *Issues in Environmental Science and Technology* 7. The Royal Society of Chemistry, 91-102, (1997).  
Nriagu JO, *Phosphate minerals*. Springer - Verlag, London, 318-329, (1984).  
Valsami-Jones E, Ragnarsdottir KV, Mann T, Kemp AJ, Putnis A & Bosbach D, *Chemical Geology*, **151**, 215-233, (1998).