How to Remediate Heavy Metal Contaminated Sites with Amended Composts

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ABSTRACT

Modern planning policies recognise that the provision of greenspace such as parkland and community woodland offer multifunctional environmental and social benefits which can contribute strongly to the sustainability of towns and cities. A challenge to such development is that the soils of many former industrial sites often contain elevated concentrations of contaminants, including heavy metals. The bioavailability of heavy metals should be reduced to break the pollutant-receptor pathway prior to establishment of vegetation to create green space.

Compost is often proposed as a suitable material for the remediation of contaminated brownfield sites, vitalising the soil and also for its reported immobilisation of heavy metals. Through immobilisation, the contaminant receptor linkage pathway will be broken and the toxicity of the soil will be reduced. In addition to composts, some inorganic amendments are known for their immobilising effect on heavy metals and therefore may be suitable for soil remediation. In our research we have examined the usage of composts enriched with inorganic materials to increase the immobilising behaviour of the composts.

Tests with compost only showed contradictory effects on the immobilisation of heavy metals between different kinds of composts. One compost immobilised heavy metals in a contaminated soil while another mobilised them. In addition, our results showed that the best metal immobilising compost was not always the best to improve plant growth. On the basis of these results we have tested a mixed compost made of composted sewage sludge and greenwaste compost enriched with iron oxide or zeolite. Initial results show that growth of rye-grass on contaminated soil amended with compost enriched with zeolite or iron oxide performs slightly better than on soil amended with compost or inorganic amendment separately. These results will be complemented with leachability and toxicity tests to create a picture of the possibilities of enriched composts for remediation purposes.

INTRODUCTION

Most large cities in the UK have to deal with brownfield sites within their boundaries. Redevelopment of these sites would prevent greenfield development and so protect greenfield land. The Environment Agency has estimated that around 20,000 contaminated sites in England and Wales may need treatment (Environment Agency, 2004). The costs of treatment of these sites can be made more bearable if their remediation is combined with redevelopment. Nevertheless developers continue to choose greenfield land rather than brownfield land because of the high costs of the remediation of contaminated land (Environment Agency, 2004). This, and the recent increase in landfill costs for contaminated soils has created a market for low cost alternative remediation techniques. One redevelopment option for a brownfield site is its transformation into green spaces in the urban environment. For example, the Land Restoration Trust is planning to manage 10,000 hectares of previously restored derelict and under-used land for public benefit within 10 years (www.landrestorationtrust.org.uk). Similarly, the Newlands project, developed by the Northwest Development Agency and the Forestry Commission, has a budget of £23 million to transform 435 ha of under-used and derelict land into community parks and woodland (Forestry Commission, 2004).

Many urban brownfield sites have heavy metal concentrations that significantly exceed the levels that are generally stated as environmentally acceptable and therefore form a potential health risk for humans, animals and plants. The threat of heavy metals to the environment can be reduced by fixation in the soil itself, so lowering the bioavailability and risk of further mobility. So far a considerable amount of research has been performed on the addition of compost or certain types of minerals to immobilise heavy metals. Soil remediation by the addition of compost alone however, will have a temporal effect because when the compost degrades, the metals will return to their original availability to plants and animals. At the same time addition of minerals alone will not improve the biological quality of the soil or support plant growth. The combination of the two materials could be optimised to provide a long term immobilisation of the metals and also improve biological quality of the soil. By using waste produced materials (waste compost) and cheap minerals (zeolites, bentonites or iron oxide) the method to be developed may offer a low cost, sustainable solution for the remediation and establishment of greenspace on contaminated brownfields. Likewise, because the technology occurs *in situ* and does not involve any thermal treatment, both fuel and money can be saved on transport of the soil, a fact contributing to the sustainability of the solution.

SUBR:IM work package K has the objective to develop a remediation method that aims at four goals: 1. reduced leaching of heavy metals; 2. reduced uptake of heavy metals by plants; 3. improved soil conditions for plant growth; 4. sustainable for a long period.

RESEARCH TECHNIQUES

The main experimental methods used are leaching tests and nursery trials.

Leaching tests have been adopted into standard procedures to test the environmental impact of a polluted soil. The most common compliance leaching tests are agitated batch extraction tests including the UK National Rivers Authority leaching test (Lewin et al., 1994) which is now superseded by the recent EU test series (BSI, 2002). During batch tests, 100 grams of soil is agitated on a bottle roller with 1 litre of carbonated water, with a pH between 5 and 7, for 24 hours after which equilibrium is assumed to have be established. The leachate concentration is then used as a measure of the bioavailable fraction of the heavy metals and can be compared to the maximum acceptable levels of groundwater concentrations for metals. Batch leaching tests have been used to show a strong binding of metals to compost (Grimes et al., 1999) and also to test the immobilising effect of several cement-based soil additives (Al-Tabbaa and Boes, 2002).

The nursery trials have been performed with two plant species, namely perennial rye-grass (*Lolium perenne*) and poplar (*Populus trichocarpa* variety Fritzi-Pauley), that are known as metal accumulators (Aten and Gupta, 1996; Hao et al., 2003; Larsen et al., 2004; Laureysens et al., 2004). We have chosen these species so as to thoroughly test the ability of the novel composts at increasing metal fixation in the soil and hence a reduction in bioavailability indicated by a lower metal uptake by the plants. Secondly we will test whether there is a significant reduction in phytotoxicological impact of the polluted soil and a subsequent increase in the health and growth performance of the plants.

Soil amendments and soils

The materials used in the experiments were composted garden green waste (GW-compost), composted sewage sludge (S-compost), a combination of the two composts (GWS-compost), zeolite and iron oxide. Both minerals, zeolite and iron oxide, are known for their metal binding capacity.

The soils on which the soil amendments were tested were sampled at three locations: 1. a former zinc factory near Avonmouth with high levels of zinc, cadmium and lead; 2. arsenic-containing mine spoils from the Tamar valley, Cornwall; 3. soil treated with sewage sludge over a period of 10 years with elevated levels of zinc and copper.

RESULTS/DISCUSSION

The current results from our research show that there is a large variability in effects between different composts. Figure 1 shows the leaching results for soil from Avonmouth treated with different levels of GW-compost or S-compost. From this figure it can be observed that while GW-compost reduces the amount of zinc, S-compost increases the leaching. This means that S-compost added to this soil increases the risk for potential receptors rather than reduce it. Additional leaching tests with a range of composts including GW-compost, S-compost, coir compost, spent mushroom compost, and LimeX70 showed that spent mushroom compost and LimeX70 also have a potential to increase the leaching of some heavy metals from contaminated soils, despite their high pH.

It is, however, not the case that the increased leaching of metals caused by S-compost automatically involved a higher uptake of these metals. Figure 2 shows the uptake of cadmium and zinc into the leaves of poplar and rye-grass growing on Avonmouth soil treated with GW-compost or S-compost. For rye-grass can be seen that S-compost was more efficient than GW-compost in reducing metal uptake into the leaves. For poplar, however, S-compost increased the uptake. It was also observed that GW-compost increased the uptake of cadmium while this compost reduced the leachable fraction of this metal. Tests with other soils have shown that these patterns can differ for different soils. Actual leaching and metal uptake depends on compost type, soil type and the level of contamination.

Improvement of growth by compost amendment also differs between composts and soil. On highly contaminated soils like those from Avonmouth and Tamar valley, which lacked any growth, compost addition significantly improved growth. Plants growing on soils with lower contaminant levels usually did not show improved growth after compost addition and there have even been a few cases of reduced growth performance. Compost addition should be limited on these soil types.

One of the remaining questions is whether there is an advantage of applying compost in combination with zeolite or iron oxide. Experiments to answer this question are still being performed but some initial results indicate a positive answer. It was observed that rye-grass growing on arsenic contaminated soil amended with GWS-compost was much healthier if this compost is used in combination with iron-oxide than on its own (Figure 3). Similarly, rye-grass growing on S-compost amended soil performed better if the compost was amended with zeolite than without. This was probably caused by a better balancing of nutrients (Leggo and Ledesert, 2001) than by immobilisation of metals. Whether the metals are more tightly bound in the soil by combined use of compost with zeolite or iron-oxide cannot be stated yet, and more and different experiments are necessary to determine this.

CONCLUSIONS

The original purpose of this project was to deliver a recipe for a mineral-amended compost that can be used on a variety of metal contaminated sites. However, because of the large differences between composts and soils, each compost to be used for a specific soil should be tested with the soil before applying in the field. This testing should consist of both leaching tests and bioassays to ensure reduced leaching to ground water as well as reduced plant uptake. Results of tests on combined use of compost with minerals like zeolite and iron oxide are promising for improved plants performance. More results on the effect of the minerals on plant uptake and leaching are to come and more tests on the sustainability of the method will be performed.

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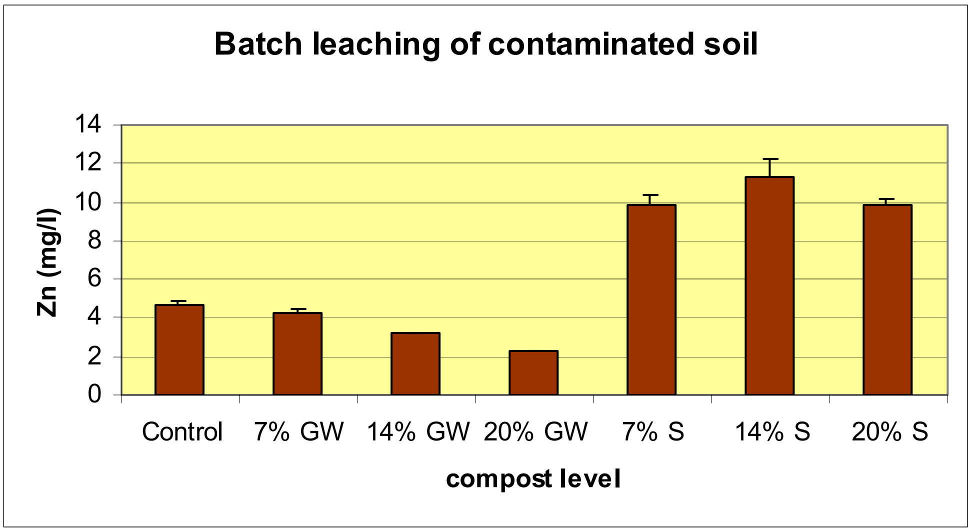

Figure 1. Leaching of zinc from highly contaminated soil treated with composted garden greenwaste (GW) or composted sewage sludge (S). Error bars indicate the standard error., n=2.

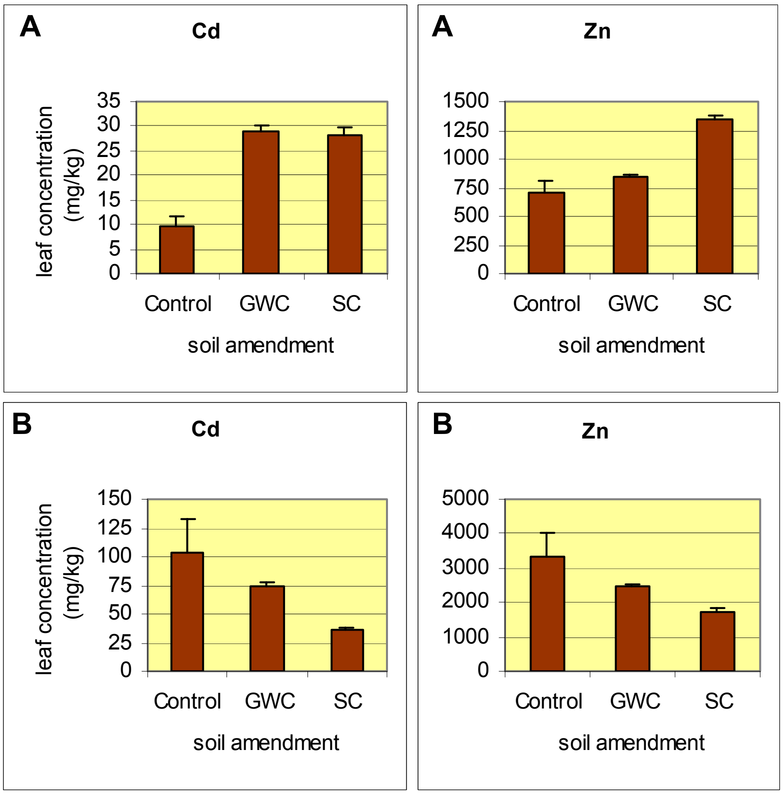

Figure 2. Uptake of cadmium and zinc in the leaves of poplar (A) and rye-grass (B) growing on highly contaminated soil treated with composted green waste or composted sewage sludge. Error bars indicate the standard error, n=3.

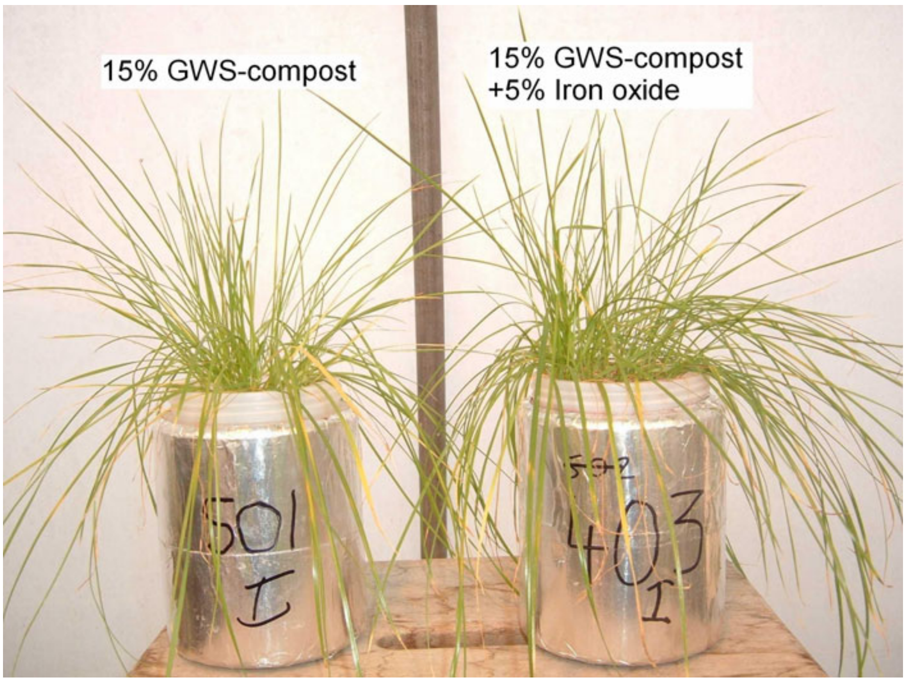

Figure 3. Rye-grass growing on soil highly contaminated with arsenic amended with compost, or compost amended with iron-oxide.