HEAVY METALS AND THE BENEFICIAL REUSE OF BIOWASTES

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Introduction

Biowastes are unwanted material of biological origin. They include the products of human excreta, animal effluents, and residues from forestry, agriculture and fisheries. While many biowastes are incinerated or disposed of in landfills and water bodies, land application can have both economic and environmental appeal. Biowastes affect the fluxes of metals (HMs) in the soil-plant system by changing the concentration and solubility of HMs as well as the physiological and morphological characteristics of plants and soil organisms. Biowastes are often high in organic matter and plant nutrients, thereby promoting root development and the growth of other soil organisms. That same organic matter can increase the number of functional groups in soil thereby reducing HM solubility via cation exchange and specific adsorption (Haering et al., 2000). Biowastes, particularly those derived from industrial or domestic effluents, may also contain elevated concentrations of heavy metals, particularly Cd, Cu and Zn (Haynes et al., 2009). Continued application of such biowastes can result in accumulation of these elements in soil. Potentially, two or more biowaste streams can be combined to improve environmental outcomes (Paramashivam et al., 2016). We aimed to determine the fluxes of HMs following the addition of various biowastes to low fertility and degraded soils with a view to elucidating the best strategies for the beneficial reuse of biowastes.

Methods

We collected degraded soils and low fertility soils, from former pine forests, intensively cultivated market gardens, intensive dairy farms, alpine pastureland, and coastal sand dunes. Production on these soils was limited by either low organic matter contents, low plant nutrient status or elevated heavy metals such as fertilizer-derived Cd. These soils were amended with one or more of the following biowastes: biosolids, *Pinus radiata* sawdust, *Pinus radiata* biochar (pyrolysed at 350 ^{o}C), compost manufactured from municipal green waste, low grade lignite coal that was unsuitable for sale due to its high moisture and sulfur contents.

Pot trials, lysimeter experiments and field trials were used to determine the metal fluxes in these amended soils planted with perennial ryegrass, sorghum, maize, mustard, common vegetables, willows, *Pinus radiata*, and a selection of NZ native vegetation. We measured the growth and morphology of these species as well as the HM concentrations in plants and soils. Details of the species and experimental setups can be found in: (Al Mamun et al., 2016; Esperschuetz et al., 2016; Gartler et al., 2013; Simmler et al., 2013).

Results

A single application of biosolids was sufficient to restore fertility to degraded soil. The application rate required was in the order of 50-100 t/ha. These applications increased plant uptake of Cd, Cu and Zn across a range of species, however, these levels were always below food safety standards. Blending the biosolids with other materials, such as sawdust, biochar and lignite, resulted in significantly reduced nitrate leaching and reduced plant-Cd uptake. Importantly, blending the biowastes had little effect on the uptake of Zn and other essential trace elements. Therefore, the addition biosolids blended with other materials may be an effective and safe means of bio-fortifying plants with Zn, an element that is deficient in a quarter of humanity. Feeding trials using sheep demonstrated that pasture and willows that had been bio-fortified using blended biowastes showed that the plant-borne Zn effectively increased serum Zn levels and that bio-fortified material was a more efficient than inorganic Zn for nutrition.

Applying municipal composts or lignite to intensively cropped soil that was low in organic matter significantly reduced the Cd uptake by crop plants, while not significantly reducing the concentrations of other elements. Unexpectedly, the reduction in plant-Cd uptake caused by compost increased after one year.

Conclusion

A single, high application of blended biowastes can effectively restore fertility to degraded soils without resulting in unacceptably high HM concentrations in either soils or plants. We do not propound the continual application of biosolids, which would result in the accumulation HMs in soil to unacceptable concentrations. Single biowaste additions can restore fertility, bio-fortify food and fodder crops with Zn, and reduce the uptake of Cd.

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