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Effects of cost-effective amendments on leaching, phytoavailability and fractionation of heavy metals in a contaminated soil

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The combination of revegetation and application of stabilizing soil amendments on large areas with high and multi-elemental contamination is generally considered to be a promising alternative to expensive classical remediation methods. The rationale is that the vegetation cover limits pollutant transfers by runoff, percolation and wind or water erosion, while suitable amendments reduce mobility and toxicity of pollutants. However, the efficacy and the mode of action of several potential amendments have not yet been fully established. Moreover, only a few studies analyzed the effects of amendments on both leaching and phytoavailability of heavy metals.

In order to investigate the influence of amendments on leaching and phytoavailability of heavy metals, a pot experiment in controlled conditions was performed. Each pot was filled in with a mixture of a contaminated soil and different contrasted cost-effective amendments following a 20:1 (w:w) ratio. A control treatment, i.e. without amendment, was also carried out. The soil was sampled at Prayon (Belgium) and originated from a slightly acidic (pH = 5.8) loam surface horizon contaminated by Pb-, Cd- and Zn-bearing atmospheric fallouts. Six amendments were tested: lime (CaCO3), zero-valent iron (iron grit), bone meal, flying ashes, bentonite and cow manure. Leachates and aerial parts of Lupinus albus L. were collected at 6, 10 and 14 weeks after sowing. At the end of the experiment, changes of heavy metals fractionation induced by amendments in soil were assessed by means of sequential extractions (BCR scheme).

Compared to the control, concentrations of Zn and Cd were at least 50% lower in leachates for all amended soils. Moreover, the addition of cow manure, lime, zero-valent iron and bentonite resulted in a Zn and Cd leaching reduction of over 90%. Regarding Pb, the addition of bentonite and lime caused a leaching reduction of over 50% and zero-valent iron of over 90%. Inversely, the addition of bone meal in soil caused a Pb leaching up to 17 times higher than in the control, probably due to a higher dissolved organic carbon release.

The Zn and Cd uptake by L. albus was reduced by more than 80% in soils treated with bone meal and lime. Furthermore, compared to the control, all amendments reduced the Zn uptake by plants, while Cd concentrations in plant tissues were 1.5 and 2.2 times higher when soil is amended with flying ashes or zero-valent iron, respectively. Surprisingly, while iron grit induced the highest Pb leaching reduction, this amendment caused a Pb uptake twice higher than in the control. Conversely, the addition of bone meal, which had dramatic effects on Pb leaching, reduced Pb concentrations in shoots by 60% and turned out to be the best solution to decrease Pb phytoavailability. Addition of lime or manure also decreased Pb uptake by 40 and 50% respectively, whereas other amendments increased slightly Pb phytoavailability.

At the end of the experiment, exchangeable and acid-soluble fraction of Zn, Cd and Pb were reduced in all amended soils by 1 to 50%. Moreover, changes in Zn and Cd fractionation induced by amendments were rather similar (r = 0.70).

Our results demonstrate the efficacy of several amendments while stressing the need to measure simultaneously the leaching and the phytoavailability of metals induced by each amendment. Moreover, since Zn, Cd and Pb have not systematically similar response to the same amendments, this research highlights the difficulty to find amendments effective for all target contaminants in multi-element contaminated soils. In our study, lime appeared as the best amendment to simultaneously reduce leaching and phytoavailaibility for Zn, Cd and Pb.