Abstract

Utilization of coal ash and municipal sewage sludge on agricultural soil provides an alternative source for plant essential micro and macronutrients that can have positive impact on crop yield while also offers an alternative to their disposal problems. However, the concentrations of several harmful potential contaminants, heavy metals in particular, can limit their application to land, due to the associated risks to human health through the food chain and the ecosystem.

Both field and pot experiments were conducted to assess the suitability of using a bituminous coal ash, an acidic and a neutral sewage sludge separately and at different rates of application in growing paddy and peanut in an acid lateritic soil with emphasis on heavy metal build up and distribution in soil, plant and the effect produced on the soil microbial health.

Direct and residual effects of amendment application on paddy and peanut were assessed at a maximum of 52Mg/ha in the field study whereas three different application rates of 25, 50 and 75 Mg/ha were used in the pot study. Lime at 2Mg/ha was added to all the treatments in the pot as a separate set of experiment to monitor any possible changes in metal behavior. Evaluation of total and bioavailable concentrations of Cd, Cr, Cu, Ni, Pb and Zn using aqua regia and Mehlich III extractions were carried out in addition to the estimation of various geochemical pools of these metals through a sequential extraction in soil and amendments.

The total concentration of metals in soil and plant were below potential toxic levels for the sludge-ash contributed "metal loading" used in this study. The distribution pattern of heavy metals in amended soil was found to be a function of the soil properties and their original

distribution in the sludge and ash. Neutral sludge contributed heavy metals at all rates distributed them into the resistant and insoluble fractions except for Cd, which showed relatively higher concentrations in the exchangeable fraction. On the other hand, acidic sludge addition caused significant increases in the highly mobile fractions of Cd, Ni and Zn indicating potential bioavailability.

Improved crop performances with increase in pH due to the neutral sludge and ash amendment of soil restricted the metal mobility causing reduction in their concentrations in labile forms which became more pronounced after liming. Acidic sludge amendments to soil, especially at higher doses, caused serious reductions in the crop growth parameters, associated with reduced soil pH and greater metal mobility, which was partially alleviated with the co-application of ash. Lime addition to the acidic sludge amended treatments significantly reduced the metal mobility and enhanced the crop performances.

The vegetative plant parts showed maximum accumulation of metals indicating a physiological barrier in the transfer of metals from the root to the grain or kernel. The plant accumulation of metals was found not only to be controlled by their bioavailable concentrations but also by the total metal present in the amended soil, Pb and Cr showing better correlation with the available concentration. Lime addition to the treatments further reduced the transfer efficiency and principally localized the metals in the root, even though the relationship between the plant and soil total remained linear.

Principal component analysis indicated strong correlations between the total plant metal concentrations of Cd, Ni and Zn and their respective bioavailable forms; the metal mobility being controlled by the resultant soil pH to a large extent.

Soil microbial activity increased remarkably with neutral sludge and ash while on the contrary the acidic sludge addition at higher application rates caused severe reduction. Simple correlation and principal component analysis revealed significant and strong negative correlations of mobile fractions of Cd and Ni with soil microbial properties; pH and organic carbon showing strong positive relations. The microbial activities seem to be sensitive to mobile fractions of some of the heavy metals indicating possibilities of them being useful indicators for the evaluation of toxic effects of sludge borne metals to soil organisms even at low metal application rates.

The crop performance, changes in soil properties, metal distribution, plant accumulation, and microbial activity in the mixture treatments were fundamentally controlled by the quantity and quality of the sludge. Higher rates of acidic sludge addition may lead to increased mobility of heavy metals and hence restricting its use in growing crops. The soil quality was enhanced with addition of neutral sludge, ash or their mixtures with no possible threat of increased bioavailability and mobility of metals and therefore is not an impediment in the use of these materials in agricultural application.