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Uptake of heavy metals and essential trace elements by crops grown on fly ash amended soils

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Abstract

Coal burning fly ash (FA) was tested as soil amendment both directly and via the application to soil of biosolids that was pasteurized by treatment with FA and lime (FALTB). Some 15-30% of the sludge of Greater Tel-Aviv region ('Shafdan', secondary aerated, undigested; 180 g solids/kg) is pasteurized by mixing it with FA and burnt lime at approximately 50:45:5 (v/v) mixing ratio. Inasmuch as windrow composting is by far the leading sludge pasteurization method, the advantages of alkali treatment are the instantaneous pasteurization and vector attraction reduction, and the ability to treat all sludge types. Thus the costly digestion pretreatment, the space and duration needed for windrowing are circumvented, and odors, air-drifting microorganisms and greenhouse gas emissions are avoided. In addition, the ammonia volatilized during composting (at ca. 40 kg N/sludge dry ton) is preserved within the sludge, maintaining its high N mineralization potential virtually intact. The main disadvantage of alkali treatments is the bulkiness of the final product owed to the intake of fillers. In Israel, health, agriculture and environment authorities are also concerned with the phyto-availability of FA-borne trace and heavy elements. The current work was conceived to examine this and other related environmental issues.

Currently, AFATB is applied mainly as fertilizer (N, P, K and micro-nutrients) replacement, however it is also being tested for it ability to improve tilt of clayey-sodic soils and to disinfect sandy soils diseased with plant pathogens. The commercial application rate is 50 tons $ha^{-1}an^{-1}$, however it was tested at 300 tons ha^{-1} in a single application. These three aspects were extensively studied in lab and greenhouse simulations and in full scale field experiments. These revealed AFATB to (i) comprise a fertilizer value (per unit N applied) often as high as that of the original sludge itself, with ample P, K and trace elements phyto-availabilities, (ii) have the potential to reduce soil-borne pathogens in light-texture soils through the toxicity of gaseous NH_3, exploiting both the transient high pH and the ammonification capacity occurring in the soil immediately after application. Finally, (iii) in a field experiment, ASB application at 50 tons ha^{-1} improved seed bed and cotton seed establishment, which significantly increased lint yield. Simulations revealed the ameliorating effect on soil aggregate stability (and resistance to crusting under rain) and hydraulic properties. ASB performance was tested in comparison to other sludge types, including the Shafdan untreated sludge, an anaerobically digested sludge, and sludge composts. ASB was usually equal to or superior to compost in all the above three aspects.

Our greenhouse and full scale field experiments tested elemental composition of wide range of crops (corn seeds and canopy, wheat seeds and canopy, chickpea seeds, potatoes, carrots, clover, *Vicia* and lettuce, some of which were grown on heavy dose application and/or for more then one season. For example, lettuce that is considered a sensitive indicator of metal bio-availability was grown for 3 seasons on three soils that comprise a wide range of textures on repeated two repeated applications. Still, the metal content did not almost differ between unamended control and 2 AFATB applications at up to 1500 tons ha^{-1} each. Molybdenum concentration was the only element that almost consistently increased in parts of plant grown on AFATB treatments (however, often also on other sludge and manure amendments).

Direct FA application was also tested as means to improve physical properties of problematic soils. We will report here results from heavy dose applications (200 and 800 tons ha^{-1}) made to reduce swelling and dispersivity of sodic soils. This exploited the pozzolanic property and its high calcium solubility of the ash. The treated soil ceased to crack upon drying, disking the moist soil left considerably smaller soil clumps, which resulted in an improved seedbed. Corn and chickpeas grown in the first years after these FA additions displayed normal contents of trace and heavy metals even at all application rates.

Hence, our vast experience shows that application of FA and lime pasteurized biosolids in agriculture offers several concurrent benefits including: plant nutrition, improved soil tilth, and reduction of wide-range soil-borne plant diseases, and that this involves no risk to crop quality.