WATER TREATMENT RESIDUALS USED TO TREAT EUTROPHIC SOILS[1]

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ABSTRACT

Soils containing more than approximately 75 mg P/kg necessary for plant growth are considered eutrophic. Excess phosphorus is rinsed from the soil by rainfall and is a major cause of eutrophication of surface water. The soil is so severely laden with phosphorus in some areas that no commercial or large scale land applications of fertilizers or biosolids are allowed. Literature reviews of successful applications of water treatment residuals and aluminum sulfate treated livestock biosolids for the binding of phosphorus in the soil are presented. Uses of aluminum based compounds such as high aluminum clays, aluminum sulfate, and aluminum sulfate treated agricultural biosolids have some prior applications and are currently being investigated in more detail.

Potential heavy metal accumulation from iron based water treatment residuals are compared to potential accumulations from corresponding aluminum based residuals. Heavy metal burdens, although not necessarily "bioavailable" in any given water treatment residue, can dictate lower application rates than needed for adequate phosphorus control.

KEYWORDS : Water Treatment Residuals, Hydrosolids, Soil, Phosphorus, Runoff

INTRODUCTION

Scores of investigators have written hundreds of technical documents on the beneficial reuse of water treatment hydrosolid residuals. Selecting a few samples of the publications directed at land applications for agricultural or recreational use, the major fault of using hydrosolids is that at high application rates they tend to deplete the available soil phosphorus (Bugbee and Frink 1985, Elliott and Dempsey 1991, DeWolfe et al 1989). This, in turn impacts the growth rate of the plants. Elliott et al. (1990) and Elliott and Dempsey (1991) proposed that this ability of alum based hydrosolids to deplete the soil phosphorus (P) could be viewed as a positive feature if the material were applied to soils with high P runoff potential. The rinsing of P from highly fertilized or excessively manured farmland is a major source of phosphorus in surface water and a cause of lake eutrophication.

The poultry industry is a major generator of biosolids and manure, used as a nitrogen source in place of commercial chemical fertilizers. In broiler chicken production the birds are grown in large (16,000 square feet) houses. The floor of these houses are covered with a "litter" to absorb the chicken manure. This litter may be rice hulls, wood shavings, sawdust, shredded newspaper, or any nontoxic absorbent material. This soiled litter is used for fertilizer because of its high nitrogen content. The downside is that it also

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contains considerable phosphorus. Shreve et al (1995) reports a litter P of 24.8 g/kg. Approximately 10% of this is available as dissolved reactive P. As a means to reduce the soluble P in runoff from land that had litter applied to it, Moore and Miller (1994) and Shreve et al. (1995) looked at various aluminum, calcium and iron compounds that could be added to the litter to bind P. Thus bound, it would not be reactive and a source of nutrient for algae in surface waters. The Shreve et al. (1995) work specifically evaluated ferrous sulfate ($FeSO_4$ * $7H_2O$) versus aluminum sulfate ($Al_2(SO_4)_3$ * $14H_2O$). The aluminum sulfate resulted in an 87% reduction in soluble reactive P (SRP) in the first rain event versus a 77% reduction in SRP in the ferrous sulfate tests. The second rain was also in favor of the alum-- 63% reduction in SRP vs. 48% for the ferrous sulfate. Both products were added at the same 1 : 5 ratio. Aluminum sulfate is gaining wide acceptance as a litter management program for ammonia control in broiler houses and phosphorus runoff from land applied litter.

From these efforts Peters and Basta (1996) and Daniel (1997) looked at hydrosolids and various co-products and residuals. Peters and Basta (1996) evaluated cement kiln dust and red mud (by product of aluminum manufacturing) along with water treatment residuals. Daniel (1997) is looking at high clay alumina, water treatment residuals and aluminum sulfate.

RESULTS

Soil phosphorus in excessively fertilized soils can easily reach 500 mg/kg. Plant growth requires an average of 75 mg P/kg. In bench and filed test plots conducted at the University of Arkansas (Daniel 1997) soils were selected that contain approximately 200 mg P/kg. The dosage of hydrosolid was applied at 4 tons dry basis per acre in the field plots and laboratory batch reactors.

In the laboratory batch reactors six samples from two different soil types were treated with water treatment residuals (WTR). The average reduction in SRP for the Noark soil was approximately 83% versus approximately 88% for the Enders type soil. The actual filtered SRP ranged from 0.05 mg P/L to 0.3 mg P/L for the treated samples and 0.3 mg P/L to 3.5 mg P/L for the soil control.

The encouraging performance of the unreplicated laboratory studies prompted a look at field plots. The removal efficiency was somewhat less, 68% in the Noark plots and 79% in the Enders soil. From this work in progress a protocol of WTR application rates based on WTR aluminum content and soil test phosphorus content (STP) will be generated.

In Basta and Peters (1996) highly manured soils were treated with 100 g WTR/kg soil. The researchers did not obtain soil P < 200 ppm. Higher dosages were proposed. WTR with lime (from the water treatment process) did show a higher rate of P removal and fixation. The WTR with lime also did not increase the soil salinity like kiln dust or lime residues. Red mud, being a high pH product, was not efficient unless treated with acid to reduce the pH and make the aluminum more efficient at P precipitation.

DISCUSSION

The use of WTR to treat eutrophic soils could be a viable beneficial reuse. The ability of a hydrosolid to precipitate P from the soil making it unreactive solves a reuse problem for the water treatment facility and allow the farmer using the biosolid or litter access to economic nitrogen sources. Investigations into alum based WTR as potting media suggest improved air and water holding capacity (Bugbee and Frink 1985).

Concern over the effects of WTR on the environment has been addressed. The aluminum hydroxide formed in the water treatment process is able to neutralize acid addition such as acid rain. In Connecticut the use of alum WTR at 25 lb./acre was equivalent to 50 lb. limestone/acre with negligible mobilization of aluminum (Bugbee and Frink 1985). The use of iron WTR was cautioned against in low pH soils since it decreased the soil pH more dramatically, favoring the solubilization and uptake of Cu, Zn, Mn and Cd. (Obreza et al. 1993) The aluminum hydroxide was effective at PO_4 uptake as well since as it dissolves it makes aluminum available for precipitation reactions.

EPA leachate tests (TCLP) tests on five alum WTR and one ferric WTR demonstrated the WTR had buffering effects on pH 4.5 rainwater for 24 weeks of the study. Most of the elutriates had pH 6.5 - 7.0. The heavy metals tests on the elutriate did not show any leaching of any significance (Cornwell et al.1992). Aluminum or iron did not leach from the WTR. This should be emphasized since the gross heavy metal content of iron based WTR and alum WTR can be interpreted as criteria for land application (Lind, 1994). Further, metal toxicity to plants, specifically in these cases, aluminum, does not appear to be a problem. Little leachable or extractable aluminum (in monomeric or ionic form) was evident (Bugbee and Frink 1985, Cornwell et al.1992, Peters and Basta 1996).

Iron solubility in relation to plant nutrition can also be misinterpreted as adding value to a WTR. A non-chelated iron is not effective as a plant nutrient because of its propensity to precipitate. Bicarbonate in soil reportedly interferes with the uptake of iron. (Obreza et al. 1993). Direct application of biosolids laden with iron used in treatment produced excellent forage growth, but cattle feeding on the forage did show liver, spleen and gastrointestinal tract toxicity if the iron level in the biosolids was > 4% by weight (Decker et al. 1980). Also copper deficiencies were seen in cattle feeding on freshly applied biosolids, but composted material or biosolids < 4% Fe applied well in advance of feeding showed minimal effect.

CONCLUSIONS

Initial investigation into the application of WTR to eutrophic soils suggests this may be a viable method for binding soluble reactive phosphorus as an insoluble precipitate. In acid soils, iron WTR may further depress the soil pH and mobilize metals toxic to plants -- copper, zinc, cadmium, manganese. Aluminum has not been shown to be released or leached from aluminum based hydrosolids, or hydrosolids based on iron coagulants that coincidentally contain high quantities of aluminum, thus plant toxicity or environmental toxicity in runoff is not anticipated. Hydrosolids also have additional use in buffering acid input to the soil as in acid rain or chemical fertilizers. Work in progress should provide insight into application rates and anticipated longevity of a treatment.

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