Fertilizer Value of Lime-Stabilized Biosolids as a Soil Amendment

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ABSTRACT

To promote and guide agricultural uses of lime-stabilized biosolids (LSB), the fertilizer value of this particular organic waste was determined. Lime-stabilized biosolids from a regional wastewater treatment plant were examined for total nutrient content, liming effectiveness, and nutrient release kinetics and supply capacity using chemical characterization, batch incubation, and column leaching techniques. The LSB contained 279 g kg−1 organic carbon, 40.3 g kg−1 N, 13.2 g kg−1 P, 1.8 g kg−1 K, 151 g kg−1 Ca, and 6.6 g kg−1 S, and its lime equivalency was 261 g CaCO3 kg−1. Incubation of the LSB with a sandy loam (pH 5.3; lime buffer capacity 350 g CaCO3 kg−1 per unit pH) at 4 and 12.5 g kg−1 for 90 d raised the soil pH to 6.3 and 7.1, respectively, indicating 56% of the LSB’s CaCO3 equivalency was effective in neutralizing soil acids. Intermittent water leaching of 10 g kg−1 LSB-amended soil columns resulted in sigmoidal release of 15.9 g N, 0.23 g P, 1.1 g K +, 42.0 g Ca 2+, 10.7 g SO4 2−, and nearly 0 g toxic elements in the leachate per kg of the applied LSB in the leachate in 140 d. If applied at 10.4 t ha−1, the LSB would significantly reduce soil acidity and furnish 165 kg N, 2.4 kg P, and 11.4 kg K available to per hectare of seasonal crops.

The annual generation of sewage sludge from U.S. municipal wastewater treatment plants is estimated at 6.5 to 8.0 million dry t (USEPA, 1999; WERF, 2008). Sludge contains plant nutrients such as N (30–60 g kg−1), P (18–36 g kg−1), and K (3–6 g kg−1) (Stechouwer et al., 2000; Grey and Henry, 2002) and is disposed of mainly through land application (USEPA, 1999). Due to its unstable, soupy nature, however, raw sludge normally is treated by anaerobic or aerobic digestion or by alkaline stabilization before land application (Evanylo, 2006). These treatments help sterilize and deodorize sludge and enhance its handleability, resulting in a product termed “biosolids”. In particular, alkaline stabilization involves mixing sufficient lime (CaCO3) or fly ash (combustion residue of pulverized coal, chemically SiO2, Al2O3, Fe2O3, CaO, MgO, K2O, Na2O, and others) with dewatered sludge, producing a high pH (>12.0) and a high temperature (>65°C) to destroy pathogens and mitigate offensive odors. Stabilizing sludge with lime or fly ash (at 20–30% dry sludge weight) reduces leachability and phytovailability of the inherent heavy metals but also causes most NH4 + in sludge to be volatilized and most PO4 3− to be precipitated; the resulting product has a low nutrient value and a high pH and is not qualified as an N and P fertilizer (Su and Wong, 2004; Williford et al., 2007). Orndorff et al. (2008) reported that LSB from wastewater treatment plants in Washington, DC and Maryland had pH 11.9 to 12.5, CaCO3 equivalency 219 to 520 g kg−1, and organic carbon (OC), Kjehldahl N, total P, and K contents 216 to 292, 19.7 to 42.4, 5.9 to 14.3, and 0.5 to 4 g kg−1, respectively. Amendment of acid sulfate soils (pH 3.1) with LSB at lime requirement rates (35–270 dry t ha−1) elevated the soil pH to above 6.5 and led to successful revegetation of a disturbed construction site (Orndorff et al., 2008). In general, utilization of alkaline-stabilized biosolids as a soil conditioner highlights its lime value; the nutrient availability and nutrient release dynamics of the material following land application, however, have not been well documented.

In Delaware, the annual generation of sludge is estimated at 21,000 dry t (National Biosolids Partnership, 2000). Stabilizing sludge with lime is a common practice. The resulting LSB are used dominantly as a lime substitute. Application of LSB to cropland is experimentally conducted at 5 to 10 dry t ha−1 (Kent County, 2010; KCRWTF, 2011). To reduce nonpoint source water pollution and especially to restore the degraded Chesapeake Bay and Delaware Bay, agronomic application of organic waste and chemical fertilizers to cropland is obligatory in Delaware. To determine agronomic application rates of LSB, accurate knowledge of the fertilizer value of the material in terms of its liming capacity and plant-available nutrient contents is necessary. This study was to evaluate the fertilizer value of LSB as a soil amendment by quantifying its nutrient contents and lime equivalency and by examining its nutrient release kinetics and supply capacity using column leaching techniques.

MATERIALS AND METHODS

Lime-Stabilized Biosolids and Soil Materials

Lime-stabilized biosolids were collected from Kent County Regional Wastewater Treatment Plant (Milford, DE), where domestic and a small fraction of industrial wastewater are

Abbreviations: DOC, dissolved organic carbon; EC, electrical conductivity; LSB, lime-stabilized biosolids; OC, organic carbon; TDN, total dissolved nitrogen; TDP, total dissolved phosphorus; TN, total nitrogen; TP, total phosphorus.