Original Research Article

Effects of compost age on the release of nutrients

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ABSTRACT

Composted organic materials are applied to help restore disturbed soils, speed revegetation, and control erosion; these changes are generally beneficial for stormwater quality. Ensuring that nutrient release from compost is adequate for plant needs without degrading stormwater quality is important since composts release nitrogen at variable rates (1–3% of total N/yr) and the leaching process can extend for many years. The aim of this work was to understand the effect of compost age on the extent and rates of nitrogen release by conducting detailed rainfall simulation studies of one compost type at three different ages. Models describing temporal changes in nitrogen release to runoff during a single storm and across multiple storms were developed and applied to the runoff data. Nitrogen content (%) and bulk density of compost increased with the increase in compost age and total nitrogen release decreased with increasing compost age. The three rain simulations (storms) performed on each of the three compost ages show that nitrogen release declined each day of the repeated daily storms. A first-order kinetic model was used to estimate the amount of nitrogen remaining on compost after several storms.

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1. Introduction

Compost can help control erosion problems by mitigating formation of soil crusts because their rough surfaces promote percolation, increase water storage, lower surface flow velocities, dissipate the energy from rain drop impact and reduce the shear forces acting on the soil surface. The compost layer applied to the soil surface reduces evaporation and provides a more suitable environment for root growth and releases nutrients that improve the vegetative cover (Faucette, Risse, Nearing, Gaskin, & West, 2004). Compost addition has been shown to provide significant benefits in the restoration of disturbed soils in urban and highway settings, for example, because reestablishing vegetation and controlling erosion can significantly reduce total suspended solids loads transported to receiving waters by stormwater flows (Cogger, 2005). The Clean Water Act (CWA) amendments of 1987 initiated broad efforts to improve stormwater quality associated with disturbed soils such as those at construction sites (Glanville, Persyn, Richard, Laflen, & Dixon, 2004; Royse, 2010; Zougmoré, Mando, Stroosnijder, & Guillobez, 2004). A parallel stormwater quality concern in some receiving waters relates to nutrient inputs that can promote eutrophication. It is important that compost

addition for soil restoration not lead to unacceptable increases in nutrient leaching from the restored site.

Composted organic materials release nitrogen at rates considered to be slow (1–3% of total N/year), and the leaching process can extend for many years as long as the composted organic materials are decomposing. In contrast, the nitrogen release rates from chemical fertilizers are considered to be high, the release persists for a much shorter time, and the nitrogen content is rapidly depleted (Claassen & Carey, 2007).

Crop and vegetable production is usually coupled with the use of nitrogen-rich fertilizers that result in high nitrogen release to soil (up to 150 kg N ha^{-1}) (Chaves, De Neve, Boeckx, Van Cleemput & Hofman, 2005). When organic matter decomposes, nitrogen usually experiences two different stages of mineralization and immobilization. Mineralization of nitrogen means that nitrogen is decomposed into plant accessible forms such as NH_4^+ (via ammonification) and NO_3^- (via nitrification). Immobilization of nitrogen occurs when the accessible nitrogen species are taken up by microorganisms preventing them from being accessible by plants. The rate and extent of nitrogen immobilization are related to the biochemical composition of the compost. A high C/N ratio in compost will promote nitrogen immobilization. The immobilized nitrogen will be available to plants after the microorganisms die and the nitrogen is released (Chaves, De Neve, Boeckx, Van Cleemput & Hofman, 2007). A model that predicts the nitrogen remaining in compost would assist in decisions related to the need for and timing of nitrogen fertilizer additions (De Neve & Hofman,

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1996), while a model of nitrogen leaching from compost to water will help to assess the potential stormwater quality implications of compost addition.

The forms and availability of nitrogen in compost change as composting proceeds. Agencies that apply compost as part of soil restoration and stormwater quality enhancement programs may be able to control the amount and timing of nutrient release by specifying that composts are subject to additional aging beyond typical minimum values. To support such decisions, the aim of this work is to understand the effect of compost age on the extent and rate of nitrogen release by conducting detailed studies of one compost type at three different ages. The results are used to construct mathematical models of nitrogen released to stormwater and that remaining in the compost following repeated storm events.

2. Materials and methods

2.1. Compost materials

Three different ages of Grover Green Waste (GGW) compost were tested in this study at zero weeks (GGW0), 4 weeks (GGW4) and 9 weeks (GGW9). The composting process included a 15 d thermophilic period with frequent turning, moisture control and temperature monitoring. This was followed by windrowing and weekly turning to produce a finished compost product; Compost material subjected to this minimum curing time is denoted here as GGW0. Following that, an additional curing period of 4 and 9 weeks was provided, and those are denoted here as GGW4 and GGW9 respectively. Moisture content and volatile organic matter were determined gravimetrically for triplicate samples for each compost age. Dry bulk density of the compost was measured by taking a known volume of compost and weighing it; tests were performed in triplicate for each compost age.

Moisture content and volatile solids were measured gravimetrically by adding 50 g of compost to a tared metal tray. Weight loss after drying for 24 at 105 °C was assumed to be equal to the moisture content. Mass loss upon heating at 550 °C after another 24 h provided the volatile solids content.

Compost samples were prepared for analysis by adding 5 mL of concentrated nitric acid to 0.5 g of fine compost particles and left overnight. The next day, samples were sonicated for 1 h, diluted to 50 mL, and centrifuged prior to analysis.

2.2. Batch experiments

Batch compost-water equilibration experiments were conducted by adding 5 g of compost passing a 1.7 mm sieve to 50 mL of de-ionized (Milli-Q) water and mixing at 35 rpm for 72 h to allow equilibrium to be attained. After that the aliquot were filtered using a 0.45 μm filter and acidified. The samples were preserved at 4 °C until analysis. The test was done in triplicate for each compost age (GGW0, GGW4 and GGW9).

2.3. Rainfall simulation

Rain simulation was performed on three consecutive days (24 h period between each test) for the three compost samples (GGW0, GGW4 and GGW9) using a drop forming rainfall simulator designed and calibrated as described previously (Battany & Grismer, 2000). The test plot consisted of two 80×80 cm concrete slabs operated as duplicates and having a 2% slope. Test plots were lined with plastic lining and equipped with a 10 cm surrounding wall on three sides to contain the runoff. The last side was equipped with a v-shape channel for runoff collection. The weighed compost was applied in a 4–5 cm loose layer to the test plot surface. Because of the different dry bulk densities between the three compost ages, different compost masses were applied to cover each test plot for each compost age (GGW0, GGW4, and GGW9).

Rainfall intensity was measured by placing a cylindrical pan with a known area under the rainfall simulator for 1 h and measuring the volume of water collected. All simulations were conducted at a rainfall intensity of 55 ± 5 mm/h.

The time interval between starting the rain simulator and the collection of the first 50 mL of runoff was recorded and the first sample was designated as the time 0 sample. Subsequent samples were taken at different time intervals until nitrogen concentration in the runoff was minimal. The compost used had less than 1% of impurities such as plastic bags, paper, cloth tissues and stones. Each day, after the rain simulation ended the test plots were covered with a plastic cover to keep the compost moist. Runoff samples collected were analyzed within two hours of completing the rain simulations for total nitrogen (TN). Runoff samples collected for other analyses were acidified and stored at 4 °C.

2.4. Analytical methods

All nitrogen species were measured by colorimetric methods using appropriate HACH test kits and a HACH DR/890 colorimeter. Samples were analyzed for total nitrogen (TN) using method 10071 following 10-fold dilution. All nitrogen species are converted to nitrate by the alkaline persulfate digestion method. To minimize halogen oxide interferences, sodium metabisulfite was added after digestion. Chromotropic acid then reacts with nitrate to form a yellow complex (absorbance near 420 nm). The method has a detection range of 0 to 25 mg N/L.

Total Inorganic Nitrogen (TIN) concentration in samples was measured using method 10021 following 10-fold dilution. Nitrite and nitrate are reduced by titanium (III) to ammonia in a basic environment. After removing the solids, the ammonia reacts with chlorine and forms monochloramine, which reacts with salicylate to form 5-aminosalicylate. The sodium nitroprusside catalyst oxidizes the 5-aminosalicylate to form a blue compound; this blue color gets mixed with the yellow color from the excess reagent to result in a final green color solution. The method has a detection range of 0 to 25 mg N/L.

Nitrate-Nitrite concentration in samples was measured using method 10020 with no dilution. Chromotropic acid reacts with the nitrate under a strong acidic condition producing a yellow compound. The method has a detection range of 0 to 30 mg N/L.

Ammonia-Ammonium concentration in samples was measured using method 10023 following 10-fold dilution.

2.5. Nitrogen release model

2.5.1. Intra-storm nitrogen release model

The model used here to describe nitrogen release at different times within a single storm (intra-storm model) was originally developed to predict the release of pathogens from manure into the aqueous phase (Bradford & Schijven, 2002). The same model was later applied by Guber, Shelton, Pachepsky, Sadeghi, and Sikora (2006) and compared with two other existing models to predict the release of Phosphorous from manure. In their study, the Bradford and Schijven model performed well, and it was recommended because of the stability of its parameters (Guber et al., 2006).

$$N(t) = \frac{dN_w}{Qdt} = \frac{C_{0j}\alpha N_{0i}}{Q}(1+\alpha\beta t)^{-(1+1/\beta)} \tag{1}$$

Where $N(t)$ is the concentration of nitrogen in runoff at time t