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Fractions and biodegradability of dissolved organic matter derived from different composts

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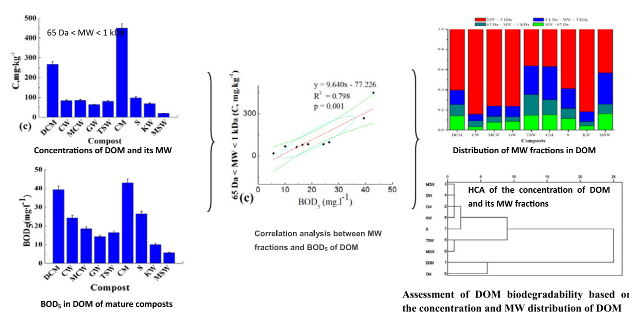
HIGHLIGHTS

- Nine mature composts from different sources in China were investigated.
- Analyze the distribution of MW fractions and BOD_5 of DOM among the samples.
- Identify the correlation of BOD_5 with the concentration of MW fractions.
- Describe the feasibility of BOD_5 as a biodegradable indicator for DOM from compost.

GRAPHICAL ABSTRACT



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ABSTRACT

An experiment was conducted to determine the fractions of molecular weights (MW) and the biodegradability of dissolved organic matter (DOM) in mature composts derived from dairy cattle manure (DCM), kitchen waste (KW), cabbage waste (CW), tomato stem waste (TSW), municipal solid waste (MSW), green waste (GW), chicken manure (CM), sludge (S), and mushroom culture waste (MCW). There were distinct differences in the concentration and MW fractions of DOM, and the two measures were correlated. Fraction MW > 5 kDa was the major component of DOM in all mature composts. Determined 5 day biochemical oxygen demand (BOD_5) of DOM was correlated to the concentration of DOM and all MW fractions except MW > 5 kDa, indicating that the biodegradability of DOM was a function of the content and proportion of fraction MW < 5 kDa. This study suggests that the amount and distribution of low MW fractions affect DOM biodegradability.

1. Introduction

Dissolved organic matters (DOM) are an organic continuum of mixed organisms that can pass through 0.45-μm membranes with a series of different molecular sizes and structures, and is a ubiquitous component in aquatic and terrestrial ecosystem (McDowell et al., 2006; Yue et al., 2006). The structure and composition of DOM, however, are complex and difficult to determine, due to its wide range of chemical compounds and variety of decomposed and synthesized products. The DOM may contain low molecular weight (MW) substances (free amino acids, sugars, etc.) as well as various types of macromolecular components (enzymes, amino sugars, polyphenols, humic acid and other mixtures) (Chefetz et al., 1998). The MW of these substances may range from several hundred to several ten thousand Dalton (Da) (Candler et al., 1988). Usually, DOM contains a large number of organic functional groups with high active sites, such as phenol, hydroxyl, carboxyl, thio and amino subunits. These compounds can bind with heavy

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metals to form coordination complexes that are utilizable for crops (Cano-Aguilera et al., 2005). Analysis of DOM usually includes composition, functionalities, and structural, chemical and spectroscopic characteristics (Chefetz et al., 1998; Provenzano et al., 2001; Santos et al., 2010; Caricasole et al., 2010; He et al., 2011a; Wei et al., 2014). Resin adsorption and ultrafiltration are the main methods for analyzing the composition of DOM derived from various sources (Young et al., 2005; Lou and Xie, 2006; Seo et al., 2007; Lu et al., 2009). Using XAD-8 resin adsorption allows DOM to be fractionated into hydrophobic (acid, base, neutral) and hydrophilic compounds, while ultrafiltration using a tangential flow filtration (TFF) system or a high-pressure size exclusion chromatography separates DOM into different MW fractions. Numerous studies have been conducted to evaluate changes of MW fractions in DOM derived from soil, landfill leachate and aquatic ecosystems (Young et al., 2005; Lu et al., 2009; Jones et al., 2012), but few have focused on the MW fractions of DOM derived from composts.

Composting is a biological process, through which a stabilized material is formed. The material can be used as a source of nutrients and a soil conditioner. Understanding the characteristic of the DOM formed during composting is important, because most of the biologic activities occur in solid–liquid interface, changes in DOM during composting reflect transformation progress and compost stability (Said-Pullicino et al., 2007). Humic acid-like matter is the major component of DOM in mature composts, and can be transformed into humic acid in soils quickly after land application. The movement of DOM from composts through the soil profile enhances the cycling of C and other nutrients and microbial activities (Cronan et al., 1992), thus improving soil quality and its agronomic/biomass productivity. Although numerous studies have been conducted to evaluate changes of these characteristics during composting (Chefetz et al., 1998; Caricasole et al., 2010; He et al., 2011b), few studies have examined the biodegradability of DOM derived from different composts.

Biodegradability is an important factor that influences the utilization of DOM in soils, but varies, depending on the chemical composition, MW, and size of DOM. While it is known that DOM in an ecosystem is typically composed of a labile pool, consisting of simple organic molecules, and a refractory pool that is composed of higher MW humic acids (Geller, 1986; Young et al., 2005), there is no standard method that has been developed for measuring the biodegradable fraction of DOM in terrestrial or aquatic ecosystems (McDowell et al., 2006). The degradability of DOM has been typically determined based on production of CO_2 or consumption of dissolved organic carbon using batch materials and flow-through or static bioreactors (Trulleyová and Rulík, 2004; McDowell et al., 2006). However, long terms (several months), large amounts of test materials and costly equipment are needed for the process (Yano et al., 1998; Trulleyová and Rulík, 2004). Alternatively, the amount of dissolved oxygen consumed in a 5-day period by bacteria (5-day biochemical oxygen demand, BOD_5) in wastewater is usually used as an indicator of organic loading (Jung et al., 2008). Relatively, measuring BOD_5 is less time-consuming, and demands less materials and other consumables. However, the use of BOD_5 could be as a biodegradable indicator for DOM derived from different composts has not been studied.

The objective of this study was to determine the fractions of DOM derived from different composts based on MW by ultrafiltration and to evaluate the biodegradability of DOM based on the amount and distribution of MW fractions. Furthermore, the feasibility of using BOD_5 as a biodegradable indicator for DOM derived from different composts was also demonstrated.

2. Methods

2.1. Sample collection and storage

Nine trapezoidal piles of dairy cattle manure (DCM), kitchen waste (KW), cabbage waste (CW), tomato stem waste (TSW), municipal solid waste (MSW), green waste (GW), chicken manure (CM), mushroom culture waste (MCW), and sludge (S) were prepared by Shanghai Songjiang Composting Plant. Composting was considered finished when the temperature of the pile became stable and the germination index approached 80%. Approximately 2 kg of each of the mature composts were collected and stored at 4 °C for analysis of DOM. The concentration of microorganism of different mature compost was from 6.8×10^6 to 2.3×10^7 CFU g^{-1}, details of composting and other DOM properties were described in a separate paper (Wei et al., 2014).

2.2. Extraction of DOM

DOM was obtained as described by Said-Pullicino et al. (2007). Briefly, samples of composts were extracted with distilled water (solid to water at 1:10, w/v) for 24 h in a horizontal shaker at room temperature. The suspensions were centrifuged at 10,000 rpm for 10 min and filtered through a 0.45-μm membrane. The MW of DOM was fractionated within 24 h.

2.3. Ultrafiltration

A tangential flow filtration (TFF) system equipped with membrane packages of 65 Da, 1 kDa, and 5 kDa (Pall Corporation) was used to separate fractions of MW < 65 Da, 65 Da < MW < 1 kDa, 1 kDa < MW < 5 kDa, and MW > 5 kDa.

2.4. Measurements

DOM (C, mg kg^{-1}) was analyzed using an aurora combustion total organic carbon analyzer 1030C (OI, America). Total organic matter (TOM) was measured based on potassium dichromate oxidation (Nelson and Sommers, 1982).

The dilution method BOD_5 test was carried out (Fulazzaky, 2013), and the dissolved oxygen (DO) was determined using the Winkler's iodometric method (APHA, 1992). Briefly, 25 ml of DOM were transferred into a dissolved oxygen bottle, and diluted inoculated water was added through a siphon to bring the volume to 250 ml. The DO was measured and the bottle was sealed to prevent oxygen from further dissolving in. A blank (no DOM) was prepared following the same procedure. All bottles were then placed into a constant temperature incubator (20 °C) and kept for 5 d ± 4 h in the dark to prevent photosynthesis. The DO was then measured again. The difference between the final DO and initial DO measured was used as the BOD_5.

2.5. Multivariate statistical analysis

Multivariate analysis was conducted using SPSS, version 17.0, to analyze one-way ANNOVA, correlations, and hierarchical clusters (HCA).

3. Results and discussion

3.1. DOM and its fractions

Fig. 1 illustrates the concentrations of DOM and its fractions in different composts. The concentration ranged from 211.8 to