Waste Management 79 (2018) 537–544

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Composting of smuggled cigarettes tobacco and industrial sewage sludge in reactors: Physicochemical, phytotoxic and spectroscopic study

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ARTICLE INFO

Article history:
Received 25 February 2018
Revised 29 June 2018
Accepted 6 August 2018

Keywords:
Smuggled cigarette tobacco
Industrial sewage sludge
Reactor
Maturity

ABSTRACT

The maturity of smuggled cigarette tobacco (SCT) and industrial sewage sludge (ISS) compost during composting in reactors was evaluated through physicochemical, phytotoxic and spectroscopic parameters. The temperatures reached peaks above 52 °C in the three reactors and were enough to achieve the stability of the compounds. The electric conductivity was in the optimal interval for farming uses and the pH alkaline band was favorable to produce inorganic nitrogen. The reduction in the C/N ratio and the increase in cation exchange capacity (CEC) indicated an increase in the compost humification. After 120 days, the seed germination index (SGI) reached 95 % in reactor 3. In the three treatments, the reduction in E_2/E_6 and E_4/E_6 ratios (UV/Vis), the increase in humification indices, obtained through FTIR and the aromatic carbon resonance (^{13}C NMR) indicated a high degree of aromaticity. The composting process in reactors was efficient to degrade different proportions of SCT and ISS, resulting in mature composts.

1. Introduction

In the last few decades, the high portion of organic solid waste (OSW) generated by human and industrial activities has resulted in great concern regarding its deposition in the environment. Among this waste, illegal cigarettes coming from the smuggling activity (Silva et al., 2014; Zittel et al., 2018) and industrial sewage sludge (ISS) which is generated in the sewage treatment stations have become environmental liabilities due to the great volume produced.

Illegally produced cigarettes seized generated a volume of 48.3 billion units worldwide in 2016, which represent approximately 31.2 thousand tons of tobacco. In the European Union, 11 million were seized in 2016 and 31 million units in the first semester of 2017 (KPMG, 2017; OLAF, 2017), while Brazil amassed approximately 15 billion units only in the first semester of 2017 (BFR, 2017).

In addition to smuggled cigarettes, effluent treatment in the food processing industry produces great amount of sludge which is rich in organic matter (Awasthi et al., 2016; Villar et al., 2016). In the European Union, these industries generated around 21 million tons ISS in 2015 (Villar et al., 2016), while in China the annual production reached 3 million tons (Cai et al., 2016; Meng et al., 2017). In Brazil, about 162 thousand tons of sewage sludge was produced in 2016 (NISS, 2018). Both the smuggled cigarette tobacco (SCT) and the ISS require treatment for their reuse, since the incineration process (Silva et al., 2016) and disposal on landfills or their direct application to the soil are sources of contamination to the water, soil and live beings due to the emission of odor, methane gas, carbon dioxide and nitrogen compounds (Awasthi et al., 2016; Gutiérrez et al., 2017; Meng et al., 2017; Zhao et al., 2017).

A simple strategy that presents low cost for the treatment of these residues is the composting in reactors (Campos et al., 2014; Malakahmad et al., 2017; Zittel et al., 2018). This is considered an efficient technology that can reduce the time required to produce mature and toxicity-free compost, when compared to composting in piles, because it allows the control of parameters such as: temperature, moisture and aeration, as well as the emission of odors, leachate and loss of ammonia compounds. Also, it allows the air circulation in the mixture through the holes of the cover (passive aeration) and does not require turning of the mass (Campos et al., 2014; Gutiérrez et al., 2017; Zittel et al., 2018).

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https://doi.org/10.1016/j.wasman.2018.08.009
0956-053X/

The process of composting promotes the formation of humic substances (HS) through mineralization and humification (Amir et al., 2010; Gutiérrez et al., 2017), which when applied to the soil increase the labile carbon fractions that function as catalysts for the microorganisms, improving soil quality (Malamis et al., 2016; Meng et al., 2017). The HS are divided into three fractions according to their solubility: humic acids (HA); fulvic acids (FA) and humin (Hn), which is the insoluble fraction (Tahiri et al., 2016). The characterization of HA extracted from the compost, originated in the composting process, can be carried out using spectroscopic techniques (UV/Vis, FTIR and ^{13}C NMR) and constitutes an essential parameter to evaluate the compost maturity and humification degree (Albrecht et al., 2011; Amir et al., 2010). Also, physicochemical analyses (C/N ratio and cation exchange capacity - CEC) and phytotoxicity test (seed germination index -SGI) are very important parameters to investigate the maturity of the compost (Awasthi et al., 2016; Fels et al., 2014).

The objective of this study was to evaluate the maturity of the compost produced from SCT and ISS waste in reactors using physicochemical analyses, phytotoxicity and humic acid characterization through spectroscopic techniques.

2. Material and methods

2.1. Assembling reactors

The preparation of three reactors (R1, R2 and R3) was performed according to a previous study (Zittel et al., 2018). The reactors were made of bronze metallic alloy (Cu/Zn) with cylindrical vertical shape (anti-corrosive inner coating). All reactors presented the following dimensions: 570 mm diameter, 870 mm height, volume around 240 L and 120 mm from the lid height. In the cap of the reactors were made 120 holes of 1.0 mm diameter that were distributed symmetrically and the reactors were aerated passively. In the reactors bottom was made an outlet for leachate drainage. The mixtures were prepared using four different wastes: SCT, ISS, Sawdust (Sa) and Garden Pruning (GP), according to the proportions presented in Table 1.

2.2. Materials preparation and sampling

The sewage sludge was purchased from a sewage treatment plant of a food processing industry. The cigarettes were removed from the boxes and crushed in an organic waste disposer. Filters and paper were separated from the tobacco in sieves (6.0 mm × 6.0 mm holes) and the particle size of tobacco waste it was around 2.0 mm. The garden pruning was shredded in two steps until it reached particles size 2.0–3.0 mm. The substrates were mixed in different proportions to obtain different C/N ratios (C/N: 18.6, C/N: 15.5, C/N: 20.1), since these ratios are favorable for microbial activity. Also, low ratios enable the treatment of larger amounts of ISS and SCT waste in the reactors R2 and R3. Due to the high nitrogen content in the wastes ISS (6.55%) and SCT (2.69%), bulking agents (sawdust and garden pruning) were mixed as carbon source and to ensure the supply of oxygen and moisture control (Table 1).

In all reactors, the samples were collected by sampling at three different sites from the top and bottom regions using a sampler to minimize the stirring of the mixture. Approximately 600 g sample was collected in triplicate at each sampling period. The representative sample of 200 g was determined by the sampling method (US. EPA, 2014). 50 g fresh samples were used for determination of pH, EC and SGI and 150 g of fresh sample which, after drying at 40 °C and crushed, was used for determination of CEC and for elemental analysis and spectroscopic characterization.

2.3. Temperature, pH, electric conductivity (EC), carbon/nitrogen (C/N) ratio and cation exchange capacity (CEC)

The temperature was monitored daily at three different sites of the top region and bottom region of the reactors over the 180-day process using a digital thermometer. The pH was determined by using 5.0 g compost with the addition of 50 ml 0.01 mol L^{-1} calcium chloride (the pH in calcium chloride determines the concentration of the hydrogen ions in solution and those adhered to the surface of the colloids), and for the EC analysis distilled water was added to the compost in a 1:10 (w/v) ratio. The mixtures were stirred for 30 min and filtered to obtain the extract (MALFS, 2014). The determination of C and N elements percentage was carried out in periods of 1, 60, 120 and 180 days as of the beginning of the composting. Samples containing 100 mg dried and ground compost were analyzed, and the dry combustion method was used for the analysis in a C and N elemental analyzer (TruSpec CN LECO® 2006, St. Joseph, EUA).

The CEC was determined on days 1, 60, 120 and 180 of composting, following the Agriculture Ministry official analytical methods for mineral and organic fertilizers and corrective agents (MALFS, 2014).

2.4. Seed germination index (SGI)

The SGI test was determined as described by Fels et al. (2014). The phytotoxicity was evaluated in 20 g dry weight compost, which was extracted with 200 ml of distilled water, stirred for 2 h and then centrifuged at 9000 rpm. Twenty seeds (*Lepidium sativum L.*) were evenly distributed on filter paper on Petri dishes (10 cm diameter) and moistened with 5 ml compost extract and as a control; 5 ml distilled water was replaced with the extract. Three replicate dishes for each sample were incubated at 25 °C for three days. The number of germinating seeds and the lengths of the roots were measured for each treatment and the SGI was calculated using the following formula:

Table 1
Physicochemical characteristics of feedstocks used in the composting and characteristics of initial mixtures of the reactors R1, R2 and R3.

	Feedstocks (kg)				Parameters					
	SCT	ISS	GP	Sa	pH	MC (%)	EC (mS cm^{-1})	C (%)	N (%)	C/N
SCT	–	–	–	–	7.15	17.8	14.23	38.8	2.69	14.42
ISS	–	–	–	–	7.35	93.4	5.64	44.4	6.55	6.77
GP	–	–	–	–	7.6	5.6	2.71	30.9	1.62	19.07
Sa	–	–	–	–	6.23	13.7	0.23	42.3	0.23	183.91
Reactors										
R1	1.3	1.3	8.5	0	8.01	61.2	2.18	39.1	2.1	18.6
R2	8.3	10	10	0	7.28	72.4	2.31	38.5	2.48	15.5
R3	8	10	0	24	6.64	64.1	1.71	39.7	1.97	20.1

SCT: Smuggled cigarette tobacco; ISS: Industrial sewage sludge; GP: Garden Pruning; Sa: Sawdust; MC: Moisture Content; EC: Electrical Conductivity; C: Carbon; N: Nitrogen.