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Composting practice for sustainable waste management: a case study in Istanbul

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ABSTRACT

Increased demand in municipal and industrial facilities has caused growing number of solid wastes generation in the last decades. In this regard, it is necessary to develop sustainable management strategies for maintaining environmental quality. As a developing country, waste management is recognized as a priority issue in Turkey and new policies are in progress to overcome existing obstacles. According to the national strategy, it is planning to reduce the amount of biodegradable wastes to be disposed in landfill facilities by evaluating recycling, composting, or energy/material recovery methods. The aim of this study was to implement a composting system to a housing estate located in Istanbul for reducing organic waste loads to sanitary landfill areas and providing soil amendment for estate's garden. In this scope, two compost tumbler systems with 1 ton/year capacity were set up in the pilot area. Kitchen waste was used in the first system and shredded before composting, whereas second system was only fed with yard wastes and tumblers were turned manually once a day. Final composts' qualities were evaluated according to national regulations. Heavy metal concentrations of two composts were below the regulatory limits (Cd < 1 mg/kg, Co < 20 mg/kg, Cr < 100 mg/kg, Cu < 50 mg/kg, Mo < 10 mg/kg, Ni < 30 mg/kg, Pb < 50 mg/kg, Zn < 150 mg/kg). C/N ratios were calculated as 42.7 and 19.3 for kitchen waste and yard waste composts, respectively. According to the national regulations, C/N ratio of a final compost product must be <35. Therefore, it is suggested to use the mixture of these two types of composts for soil application.

Keywords: Aerobic; Compost; Kitchen waste; Sustainability; Waste management; Yard waste

1. Introduction

Municipal solid waste (MSW) is mostly composed of kitchen and yard wastes, and as landfills have been closed and fewer incinerators have been under construction in recent years, disposal of MWS has become a serious problem in many cities [1,2]. In this regard, composting has been a reliable waste management practice due to its economic and environmental benefits such as reduction in the volume of the wastes, destruction of pathogens that may be present, destroy malodorous compounds, increase in biodiversity and

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activity of the microbial population in soil and also decrease in the germination of weeds, and use of commercial fertilizers in agricultural fields [2–4].

In many countries, strict mandatory regulations are recently made to reduce the amount of biodegradable municipal waste (BMW) entering landfills due to the lack of available space and increasing concerns about climate change. Some countries also advocate that any waste that does enter landfill must first be treated in order to reduce its impact on the environment [5]. The European Union (EU) Landfill Directive sets a 65% reduction target for disposal of BMW at landfills by 2016, compared to the total generation of such waste in 1995 [6,7]. Consequently, biodegradable wastes in Europe will be composted, anaerobically digested or incinerated instead of landfilling. As an EU-candidate country, Turkey has to meet these targets [8].

Composting is the biological decomposition of organic matter under controlled aerobic conditions to form a stable, humus-like final product. A diverse population of microbes is responsible for this process, whose population dynamics vary greatly both temporally and spatially, and usually involves the development of thermophilic temperatures as a result of biologically produced heat [5,9]. During aerobic composting, organic materials are degraded to end products in the presence of oxygen by micro-organisms. The oxygen requirement can be calculated by Eq. (1) [10].

$$\mathrm{C}_a\mathrm{H}_b\mathrm{O}_c\mathrm{N}_d + \left(\frac{4a + b - 2c - 3d}{4}\right)\mathrm{O}_2 \rightarrow a\mathrm{CO}_2 + \left(\frac{b - 3d}{2}\right)\mathrm{H}_2\mathrm{O} + d\mathrm{NH}_3 \quad (1)$$

where $C_aH_bO_cN_d$ is the molar composition of the organic waste.

This equation can be modified according to the type of feedstock used during the composting. The nutrients such as carbon, nitrogen, phosphorous, and potassium are essential for microbial growth in which carbon and nitrogen have a crucial role in the composting process. Micro-organisms require carbon for an energy source and nitrogen for reproduction [11]. The C/N ratio generally represents the nutritional balance and the optimum ratio for composting is in the range of 25–35 [12]. During the early stages of composting, depletion of oxygen is very high and then it decreases gradually. If sufficient amount of oxygen is not supplied to the system, degradation of organic material is decelerated, and anaerobic zones and potential odor can occur [11]. Another important parameter, moisture, provides a medium for chemical reactions of micro-organisms [13]. If the water content is lower than 40% composting process will be decelerated. On the other hand, if the water content is higher than 65% air transport will be prevented [14]. Thus, the sufficient amount of water should be supplied to the system for maintaining the optimum microbial activity and decomposition rate [12].

The organic matter content in MSW feedstocks to be composted can range from yard and food waste to mixed household wastes, in which the biodegradable proportion vary from 50 to 90% depending upon country [15]. The need to treat and dispose organic wastes has made compost production and its agricultural application an economic and attractive solution. The composting application of materials with high organic matter content and nutrients, such as food and yard wastes, has become a common environmental practice for soil amendment [4]. For instance, composting can be an ideal disposal method for food waste since it has high moisture content, a high organics-to-ash ratio, and a loose physical structure [1]; whereas the application of yard residues as a compost to soil is considered as a good management practice since it stimulates soil microbial growth and activity [16–18].

In this study, a composting system to a housing estate located in Istanbul, Turkey, was implemented for reducing organic waste loads to sanitary landfills and providing soil amendment for estate's garden. For this purpose, two pilot-scale compost tumblers were set up and fed with food and yard wastes separately. Final composts' characteristics were analyzed and compared to the recent national legislations in order to evaluate its possibility to be further used in soil applications.

2. Materials and methods

2.1. Composting system setup

The housing estate, located in Istanbul, Turkey, was selected as the pilot area. Two compost tumbler systems with 1 ton/year capacity were set up in October at ambient temperature around 20 ± 3˚C. Dimensions of the tumblers were 200 cm L × 90 cm W × 150 cm H. Fig. 1 shows the diagram of the composting system used in this study. Shredder includes a pair of counter-rotating knives were used for size reduction of composting materials. Kitchen waste was used as raw material in the first system, whereas second system was only fed with yard wastes. Kitchen wastes were collected separately, and yard wastes including grass trimmings and leaves were originated from the maintenance of the housing

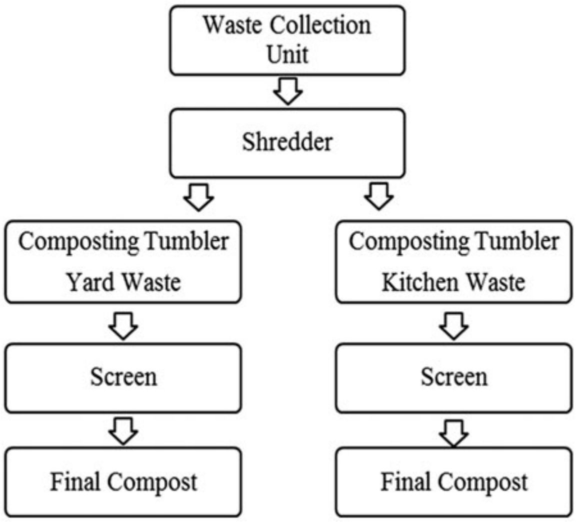

Fig. 1. Diagram of composting system.

estate's landscape areas. The composting systems were operated as a batch system in which feedstocks were added once, and then the systems were allowed to start composting process. Tumblers were turned manually once a day throughout the composting period and the composting process lasted for 30 d.

2.2. Analytical methods

Representative samples were collected at the beginning and at the end of the composting period (30 d). pH values were determined by HANNA HI 221 Microprocessor pH meter according to EPA Method 9045C [19]. Samples were dried at 105˚C for 24 h to determine the moisture content. Dried and grounded samples were used for total carbon and total nitrogen measurement by elemental analyzer (Elemental Combustion System 4010 CHNS-O Analyzer, Costech Analytical Technologies, USA). As a carrier gas, Helium was used at a range of 100 mL/min. The GC oven temperature was 70˚C during the measurements. Heavy metal concentrations were measured by a Perkin Elmer ICP-OES after the digestion of samples according to the procedures outlined in standard methods [19].

3. Results and discussion

Temperature in both compost piles rose immediately after the onset of composting. The temperature increased to 40˚C within the first day of composting, and then it reached about 55˚C. After the thermophilic phase, temperature started to decrease and become stabilized to the ambient at the end of the maturation period.

Characteristics of final compost products are given in Table 1. pH values of kitchen waste compost (KC) and yard waste compost (YC) were measured as 7.63 and 7.25, respectively. The pH of a final compost product has a crucial role on soil applications since it can reduce or increase the soil pH and effects bioavailability of nutrients to vegetation [20]. Soil pH tends to be higher in compost-amended soils after addition of organic amendments compared with unamended soils [21]. If lightly alkaline or neutral compost is applied to soil in appropriate quantities, it will raise the soil pH. Thus, it can minimize the acidification process in soil and enhance the nitrogen fertility [22]. In this study, pH levels are found favorable for soil applications.

The moisture content is an essential factor for micro-organisms to uptake necessary nutrients during composting period [23]. In Turkey, compost applications are managed by the Regulation on the Control of Soil Pollution and compost quality requirements are specified in this regulation [25]. According to this standard, moisture content of compost should not exceed 50%. In this study, moisture contents of compost products lies within the acceptable limits which were measured as 34.4 and 41.2% for YC and KC, respectively.

C/N ratio is considered as one of the most important parameters in composting practices and indicates the maturity of compost [26]. In this study, C/N ratio of YC and KC were measured as 19.3 and 42.7, respectively. In the literature, optimum C/N ratio for composting is recommended as 25–30 [27]. Furthermore, it is stated in the national regulation that C/N ratio of a final compost product should be lower than 35 for soil applications. If this ratio is higher than 35, nitrogen should be supplied to the final compost. The C/N ratios of KC obtained from this study do not comply with the regulation. Therefore, mixture of final KC and YC by ratio of 1:1 (w:w) is recommended in order to meet the regulatory limits and to be able to be used for horticulture.

Heavy metals are not affected during the biodegradation processes and their concentration increase by volume reduction. When their concentrations in the environment exceed acceptable limits, they can cause adverse effects on organisms [28]. In order to assess compost applicability, it is necessary to measure heavy metal content of the final composts. Most EU countries have standards that set limit values for widely distributed heavy metals. However, these limits vary between countries and some of them have limitations for additional parameters [29]. In this study, the concentrations of cadmium, cobalt, chromium, molybdenum, nickel, lead, and zinc were

Table 1
Characteristics of raw yard waste, kitchen waste, and final composts

	Yard waste	Kitchen waste	Yard waste compost	Kitchen waste compost	Regulation limits
pH	6.63	6.56	7.63	7.25	5.5–8.5[a]
Moisture content (%)	78	65	34.4	41.2	≤50[b]
Dry matter content (%)	22	35	65.6	58.8	–
Carbon (%)	42.30	30.20	44.35	46.9	–
Hydrogen (%)	5.70	4.5	5.6	6.1	–
Nitrogen (%)	3.80	1.95	2.3	1.1	–
Carbon:nitrogen ratio	11.1	15.5	19.3	42.7	≤35[b]

[a]Composting bulletin [23].
[b]Regulation on the control of soil pollution [24].

Table 2
Heavy metal concentrations and national regulation limits

	Yardwaste compost (mg/kg)	Kitchen waste compost (mg/kg)	Regulation limits (mg/kg)
Cd	<0.1	<0.1	1
Co	<0.2	<0.2	20
Cr	0.75	0.2	100
Cu	2.45	5.9	50
Mo	0.35	0.9	10
Ni	0.9	1.5	30
Pb	0.3	0.65	50
Zn	25.85	28.15	150

analyzed and given in Table 2. The results showed that final products of both YC and KC consisted of heavy metals less than regulatory limits.

Most countries set targets for reduction of biodegradable wastes disposal in the sanitary landfills regarding the absence of available area and awareness of global warming [5]. The main idea behind this approach is to evaluate organic wastes as a resource and get benefit from possible applications. On the other hand, waste management is one of prior issues in Turkey and laws and regulations are still in progress for better implementations. Thus, Solid Waste Management Action Plan was released by Turkish Ministry of Environment and Forestry to address the waste management practices in national scale [30]. According to this plan, some reduction targets were determined based on the quantity and quality of biodegradable wastes that will be disposed in the sanitary landfill areas. One of the main goals is to reduce biodegradable waste amount to 75% at the end of 2020. In this regard, composting facilities play an important role to manage biodegradable wastes. This approach has benefits on both environmental and economic perspectives, such as reducing the amount of material transfer to landfill area which also decreases the disposal costs, reducing the usage of fertilizers and promoting the waste recycling.

4. Conclusion

A pilot-scale composting application for kitchen wastes and yard trimmings was established in a residential area in Istanbul, Turkey. Final composts' qualities were assessed according to national standards. Heavy metal concentrations of final compost products were measured below the regulatory limits (Cd < 1 mg/kg, Co < 20 mg/kg, Cr < 100 mg/kg, Cu < 50 mg/kg, Mo < 10 mg/kg, Ni < 30 mg/kg, Pb < 50 mg/kg, Zn < 150 mg/kg). However, C/N ratios were 42.7 and 19.3 for kitchen waste and YCs, respectively. In the national regulations, C/N ratio of a final compost is stated to be lower than 35. Therefore, it is suggested to use the mixture of two types of composts for soil application. This study had a great contribution and set an example for local municipal waste management planning in Istanbul in terms of waste minimization that reduces the amount of wastes into sanitary landfills. Besides, sustainable approach was integrated in provincial scale by a strong local support. Since there is a rising trend for construction of residential areas in metropolitan cities, such composting systems should be encouraged by the government and integrated in the local solid waste management program.

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