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Research Article / Araştırma Makalesi

LABORATORY-SCALE INVESTIGATION OF AEROBIC COMPOSTABILITY OF MUNICIPAL SOLID WASTE IN ISTANBUL

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ABSTRACT

In the present study, the aerobic compostability of municipal solid wastes collected from the Composting and Recycling Plant of Istanbul Metropolitan Municipality (IMM) was investigated. A laboratory scale consisting of a cylindrical reactor with air pump and temperature sensor was used in the experimental setup. Parameters affecting the composting process such as pH, temperature, moisture content, total kjeldahl nitrogen (TKN), volatile solids were followed during 56 days in the reactor. Compost self-heating was measured by performing the Dewar test to determine the stability of the compost. At the end of the study, Salmonella test was used for the detection of pathogenic microorganisms. Also, a phytotoxicity test was performed using the cress seeds (Lepidium sativum). The study results showed that Istanbul municipal solid wastes can be used as composting materials, and the compost produced has been attested to be suitable for agricultural activities.
Keywords: Solid waste, composting, pH, temperature.

İSTANBULDAKİ KENTSEL KATI ATIKLARIN AEROBİK KOMPOSTLAŞTIRILABİLİRLİĞİNİN LABORATUVAR ÖLÇEKLİ İNCELENMESİ

ÖZ

Bu çalışmada, İstanbul Büyükşehir Belediyesi (İBB) Kompostlaştırma ve Geri Kazanım Tesisi girişinden alınan karışık kentsel katı atığın aerobik kompostlaştırılabilirliği araştırılmıştır. Çalışmada, laboratuvar ölçekli silindirik reaktör, hava pompası ve sıcaklık sensöründen meydana gelen deney düzeneği kullanılmıştır. Reaktördeki atığın pH, sıcaklık, su muhtevası, toplam kjeldahl azotu (TKN), uçucu katı madde gibi kompostlaştırmaya etki eden parametreleri 56 gün boyunca izlenmiştir. Kompostun, kendi kendine ısınma düzeyini ölçerek stabil hale gelip gelmediğini belirlemek için Dewar testi yapılmıştır. Çalışma sonunda patojen mikroorganizmaların tespiti için *Salmonella* testi yapılmıştır. Ayrıca tere tohumu kullanılarak bitkiye uygunluk testi yapılmıştır. Çalışma sonuçları, kentsel içerikli katı atığın kompost malzemesi olarak kullanılabileceğini ve üretilen kompostun tarımsal faaliyetler için uygun olduğunu göstermiştir.
Anahtar Sözcükler: Katı atık, kompostlaştırma, pH, sıcaklık.

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1. INTRODUCTION

In conjunction with countries development, the amount of solid wastes produced is exponentially increasing with the population growth, industrialization and changes in consumption patterns [1], [2]. To face the impact of increasing waste amount, developing countries such as Turkey as well as developed countries are investigating environmental friendly manner of disposal strategies by means of Integrated Solid Waste Management (ISWM) [3]. Integrated solid waste management (ISWM) is generally defined by the waste management strategies terms such as waste prevention, waste reduction, re-use, recycling, energy recovery and landfill [4]. There are many benefits to gain from the recycled product from a waste management implementation [5] such as a composting system. In fact, in addition to being an effective and environmental friendly method for organic wastes stabilization, pathogens inactivation, and recycle nutrients, composting product is rich in humus and can successfully be used for soil amendment and as organic fertilizer [6]. In addition, composting municipal solid waste (MSW) participates in destroying malodorous compounds, in decreasing germination of weeds in agricultural fields, and more greatly reduces the volume of the waste to be disposed [7].The composting process ensures the biochemical decomposition of organic content solid wastes into compost, under the action of microbe and corresponding enzyme [8], [9], intended to be used for different purposes such as the improvement of agricultural and forest areas [10], [11], [12].

Considering that solid wastes produced in Turkey contain 50% of organic contents, the composting process can be seen to be advantageous in terms of waste reduction and useful product yield [13].

The waste decomposition process can occur in both aerobic and anaerobic conditions [14]. The anaerobic decomposition process that takes place in an airless system is not a process of choice for some reasons such as longer time process, odor problems in the resulting intermediate products and insufficient temperature which doesn't reach desired values [12], [15]. The purpose of an aerobic composting process includes decomposing biodegradable organic matters to a stable end product, reducing the initial waste volume, eliminating pathogenic microorganisms, preventing odors problems and obtaining a fertilizer as a useful end product [9], [16]. However, parameters such as aeration, moisture content, temperature, pH, organic matter content, mixing, and debris size play an important role in the field application of the composting process [6], [8], [9], [16]. The stability (refering to microbial activity) and maturity (refering to the amount of degradation of phytotoxic organic substances) of compost are keys factors determining the compost quality [10], [11]. The quality of the compost depends on the composting facility design, the feedstock source and proportions used, the composting procedure, and the state of maturation. And, the plants response when the compost is applied can vary widely depending on the soil where it is applied and the composting initial waste content [7].

Tosun et al. [17] studied the compostability of rose processing wastes in a bench scale study. By using heat insulated reactors, they investigated the effects of porous material made of hornbeam and seed materials on the efficiency of the composting. On the basis of the experimental results, rose waste which is rich in organic content can be considered as a compostable material and produced compost can be used for agricultural purposes. Rihani et al. [18] investigated the aerobic decomposition of wastes containing different constituents; a mixture of household waste and leaves of sugarbeet, and a mixture of household waste, straw, sheep manure and leaves of sugarbeet. During the study, the physicochemical characteristics, the heavy metal content, microbiological parameters have been observed. pH 7.2-7.3, organic matter content 49.7% to 58.3%, NH_4^+/NO_3^- 0.24 to 0.2 have been observed. The compost achieved at the end of the study was relatively rich in nutrient, had low heavy metal content and was attested suitable for agricultural activities.

In this study, samples consisting of municipal mixed solid wastes entering the Composting and Recycling Plant of Istanbul Metropolitan Municipality (IMM) have been collected to investigate their aerobic compostability. During 56 days, Parameter affecting the composting process such as pH, temperature, moisture content, TKN, volatile solids have been observed.

2. MATERIALS AND METHODS

2.1 Material Characteristics

In this study, samples consisting of municipal solid wastes were collected from the Composting and Recycling Plant of Istanbul Metropolitan Municipality (IMM) in the Işıklar village located in Kemerburgaz (Istanbul). The picture of the waste reception unit is shown in Figure 1. The estimated percentage content of the waste is shown in Table 1, [19]. The variation of the waste composition was neglectable in a short period of time due to similar consumption patern in the city.

Table 1. Estimated percentage content of the waste

Wastes	Percentage content
kitchen waste	49.5%
papers and cardboards	16.4%
pouches	8.3%
diapers	5.1%
textiles	4.6%
glasses	3.5%
plastics	2.7%

Figure 1. Waste reception unit of the composting plant of IMM

2.2. Composting Device

The device used in the study was composed with a cylindrical reactor, air pump and a temperature sensor. A cylindrical reactor made of plastic material with a volume about 87 liters capable of receiving 15-20 kg of solid waste was designed. The variation of the reactor temperature was recorded on a daily basis using a temperature probe placed in the reactor. The waste was aerated with an air pump that provided 60 L/h of air debit to the reactor. The C/N ratio was approximately 21/1. This ratio seems good; however addition of nutrients would improve the composting but no addition took place during this study. The schematic representation of the composting device is given in Figure 2.

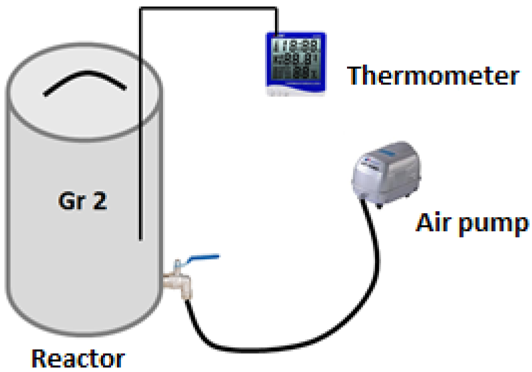

Figure 2. Schematic representation of the composting device

2.3. Methods of Analysis

Parameters which play an important role in the composting process were analyzed weekly. Parameters such as moisture content, volatile solids, total Kjeldahl nitrogen (TKN) and pH have been measured with 2540 B Standard Method, 2540 E Standard Method, 4500-Nr-L C Standard Method and 4500 H Standard Method, respectively. Salmonella test was used for the analysis of pathogenic microorganisms (Salmonella Rapid Test Oxoid) in the produced compost. At the end of the study Dewar test was performed to determine the level of compost self-heating.

3. EXPERIMENTAL STUDY RESULT AND DISCUSSION

In the composting process, organic material in contact with water and oxygen is decomposed by microorganism into compost. Water, heat and carbon dioxide are released during the process as shown in Figure 3. For the process to be efficient, proper organic compound is required in the waste. The C/N rate should be adequate between 25/1 to 40/1, but the consumption of carbon overtime can lead to higher nitrogen content. The present study resulted to compost rich in nutrients and suitable for use, however the moderate amount of biodegradable materials in the MSW collected resulted to reducing the effectiveness of the process. In fact solid waste in Istanbul is mixed with all type of waste from the highly mon-degradable to the highly degradable.

During the composting process, waste temperature, moisture content and pH were followed in the reactor during 8 weeks. Volatile solids and TKN analysis were also carried out. At the end of the process, a test to analyze the suitability of the compost to the plants using cress seed and microbiological salmonella test were performed.

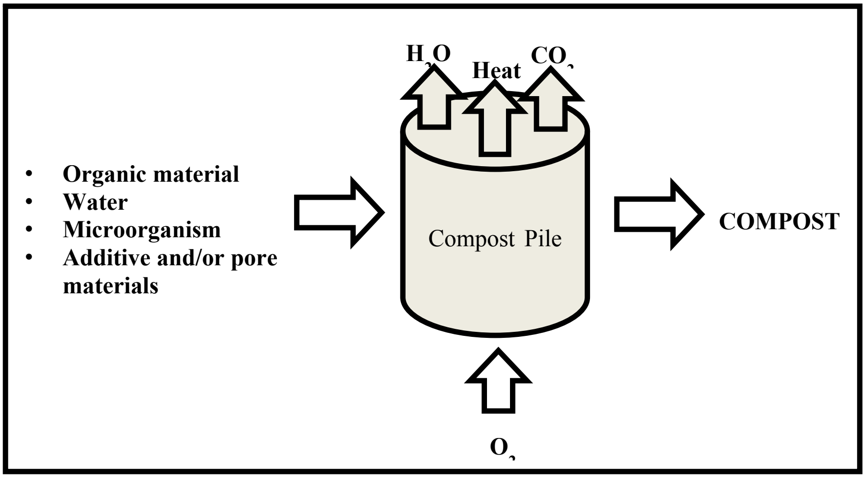

Figure 3. Schematic representation of the composting process

3.1. Temperature and pH

During microbial decomposition the released energy is transformed into heat. Therefore, during the composting process when the ambient temperature increases there is an increase in the biological activity rate. The temperature can reach 60 °C in few days for wastes with high biodegradable contents as reported by Huang et al [10]. The maximum temperature remains around 40 ° C for wastes with low biodegradability properties. In this study, the temperature in the system increased rapidly within few days and reached 40 °C in the third day. As mentioned by Petric et al. [9], the temperature of composting mixtures initially increase due to rapid breakdown of readily available organic matter and nitrogenous compounds by microorganisms. The microbial activity, the organic matter decomposition rate, and the temperature will all decrease once there is very few easily degradable compounds and when organic matter get stabilized. In our study, the temperature remained constant during the first week, and dropped suddenly to 24 ^{o}C at the end of the first week. The temperature remained low during the rest of the days; microbial activity was moderate due to moderate organic materials in the waste. From the graph in Figure 4, we can notice the variation of the temperature between 20-25 ° C for 8 weeks. The temperature decreased overtime and stabilized at day 49 when the compost reached maturity.

The pH is known as an important criterion in waste stabilization and enhancement of microbial activity. The optimum pH for microorganism cultures can vary, but generally it must be between 6 and 9. Initial pH for municipal solid wastes is around 5-7. The graph in Figure 4 shows the change of pH over time. An initial pH of 5.7 reached the value of 6.89 at the end of day 42. The pH rise overtime was the result of microbial activities that caused the production of ammonia during ammonification and mineralization of organic nitrogen. After day 42 a sudden decrease of pH occurs due to the formation of organic and inorganic acids due to the microorganism activity when decomposing organic matters. In addition, the volatilization of ammoniacal nitrogen and the release of H^+ by nitrifying bacteria may cause pH to decrease.

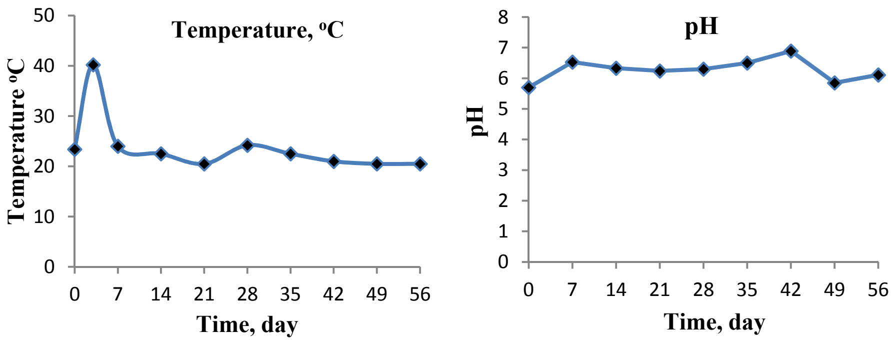

Figure 4. Temperature and pH variation over time

3.2. Moisture Content and Volatile Solids

The moisture content should be in specific proportions to have a good microbial activity in the waste. It is a critical parameter that influences the microbial activity, the process temperature and oxygen transfer [9]. The optimum water content in an aerobic composting process is around 50 to 60 %. Generally, a fall of this value below 30% is undesirable. The variation of moisture content in the mixtures is shown in Figure 5. Initially 60.2% moisture content was recorded and this value decreased over time and fell to 50.2% in the last week. The initial moisture content above 60% was suitable for an adequate composting. Heat generation and vaporization in the mixture due to microbial activity contributed to moisture content decrease overtime.

The initial volatile solids content of the waste in the reactor is computed and estimated to be 65%. The graph in Figure 5 shows the change of volatile solids rate over time. As a result of rapid decomposition of readily biodegradable organic waste, volatile solids rate at the end of day 21 was 60.8%, at the end of day 35 it decreased to 57% and it fell to 39% at the end of the 56th day. Guo et al [11] observed the same phenomenon and they stated that high total organic carbon loss was correlated with high aeration rate. In fact, microbial activity caused CH_4 emission and some volatile compounds such as methyl mercaptan and dimethyl sulfide to vaporize.

3.3. Total Kjeldahl Nitrogen (TKN)

The TKN values variation over time is given in Figure 5. The aeration rate of the composting tank was important during the process; an irregular drop of TKN occurred at day 10 to 15 due to some dysfunctionality in the aeration system. From 1.2 % at the beginning of the decomposition, after 21 days TKN reached around 1.8%. Afterwards, the stabilization of the waste with a decreasing trend of TKN of 1.3% at day 42 and 1.2% at day 56 took place. Then, it shows a decreasing trend with the provision of waste stabilization with TKN values 1.3% at day 42 and 1.2% at day 56. Huang et al [10] and Guo et al [11] observed the same results during their study. During the first days of the composting, ammonification reaction takes place and converted organic nitrogen into ammonia and increased NH_4^+-N contents. After reaching the pick point, NH_4^+-N contents decreased due to volatilization of NH_3 at high pH and high temperature and immobilization by microorganisms of nitrogenous compounds such as amino acids, nucleic acids and proteins. In fact, the decrease of TKN and its low concentration in the compost at day 56 indicated that the compost reached maturity and was stabilized.

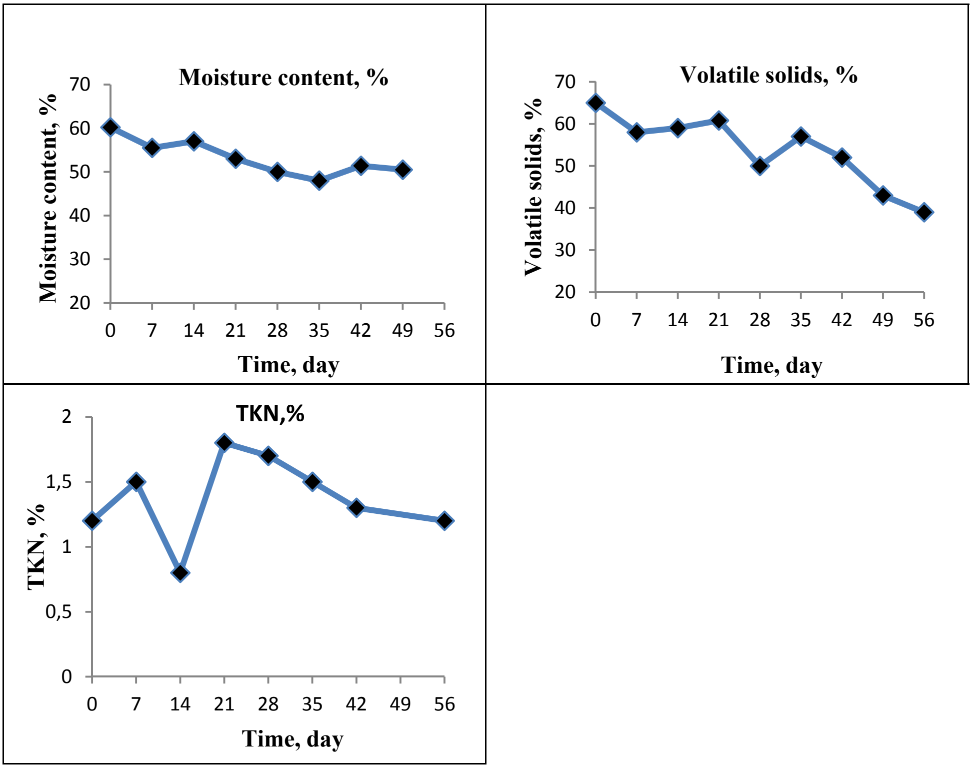

Figure 5. Moisture content, volatile solids and TKN variation over time

3.4. Plants Suitability Test

Three different pots have been used for the plant suitability test; the first pot contained soil without compost and was used as blank, the second contained 25% compost and 75% soil and the third contained 50% of each component. The same weighed amount of Cress seeds (Lepidium sativum) has been sowed in each of these three pots and placed under the sun. After seven days of growth, the plants were harvested and weighed. In Figure 6, the image of Cress seeds' plants at the end of the seventh day of growth is shown. The weighs of the harvested plants show 0.93 g for the pot without compost, 3.48 g for the pot with 25% compost and 3.50 g for the pot with 50% compost. On the other hand, from observation we notice that the plants in the pot without compost were less developed and less flourished compared to the plants which pots contained some compost. This result only may not be enough to explain all the complexity related to the suitability of the compost to the plant, however, it is proof that the compost produced has been beneficial to the cress plant in its development.

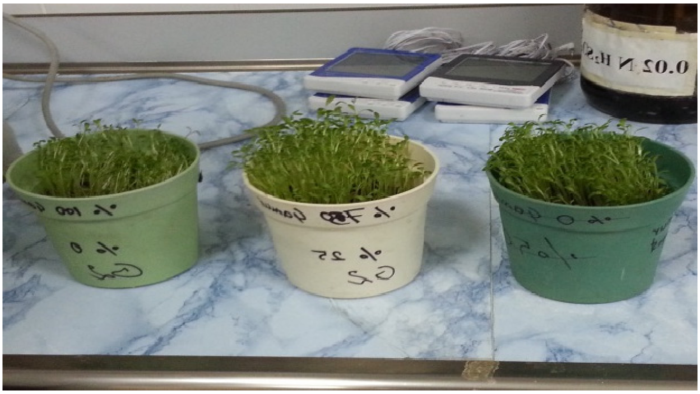

Figure 6. The effect of compost to the development of cress seeds, from left to right: Blank pot-pot with 25% compost+75%sand-pot with 50% compost+50%sand

3.5. Salmonella Test

Temperature and time are two parameters playing an important role in the removal of pathogenic microorganisms. As shown in Figure 4, from the installation of the reactor, the temperature reached about 40 °C within a few days, but it fell to 24 °C at the seventh day and remained stable until the end of the work. These values of temperature are not considered sufficient to eliminate pathogens in the compost. However, another important parameter for the removal of pathogens is time factor, at the end of day 56 of the study, no Salmonella was detected in the microorganism test performed. The compost was assumed safe to be used in agriculture for soil improvement without harm.

4. CONCLUSION

In this study, the stabilization of aerobic composting of municipal solid waste has been investigated. The results obtained are summarized below:

During the composting process, the temperature in the system reached 40 °C within few days, it decreased over time to approximately 20-24 °C and stabilized. Although, the temperature observed was low, indicating a low biodegradable content of the waste, useful compost has been achieved at the end of the process. For an active microbial activity in the waste, moisture content ranged between 50% and 60% was shown to be suitable. When examining volatile solids; as a result of rapid decomposition of readily biodegradable organic waste, volatile solids rate at the end of the day 21 was 60.8%, at the end of day 35 it decreased to 57% and it fell to 39% at the end of the 56th day. A decreasing trend of TKN of 1.3% at day 42 and 1.2% at day 56 has been observed and this ensured the stabilization of the waste.

The plant suitability test proved the advantage of the compost to be used in agriculture. In fact, the plant in which 50% compost is used was almost four times bigger than the plant where compost is not used. In addition, Salmonella test performed at the end of the composting process attested the absence of microorganism in the produced compost.

From this study, it is evident that municipal solid waste in Istanbul is an appropriate waste for composting, and the type of product obtained after composting is suitable to be used in agriculture. However, the mixing garbage and all kind of waste in the same container, organic and inorganic, toxic, and plastics and other materials reduce the composting efficiency. The municipality may address some regulations that separate wastes at the source in order to advantage composting by separating compostable waste to other garbage kind.

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