Journal of Environment and Waste Management
Vol. 4(1), pp. 156-163, May, 2017. © www.premierpublishers.org. ISSN: 1936-8798

JEWM

Research Article

Selective organic fraction of municipal solid waste degradation under controlled composting conditions

Swapan Das[1*], Bidyut Kr. Bhattacharyya[2]

[1*,2] Department of Mechanical Engineering, Indian Institute of Engineering Science and Technology, Shibpur, Howrah-711103, India.

Municipal solid waste (MSW) analysis in Kolkata indicates a presence of a high percentage of biodegradable organic matter (82%), acceptable moisture content (42%) and C/N ratio (32). These parameters are suitable for windrow composting. Because optimum moisture content for windrow composting is in the range of 40-50%. Windrow composting is a process that reduces the volume of the waste and produces a crumbly earthy smelling soil-like compost material. In the proposed scheme, we improve the quality of the compost material using selected organic material from the collected waste. In the practical implementation phased of proposed scheme, it has found all the quality parameters in compost samples within the acceptable limits set by international standard. The pH ranged between 6.7-8.2, organic matter 48%, moisture 23.02% and have an acceptable amount of plant nutrients C (16.03%), H (0.44%), N (1.26%), O_2 (1.3%), P (0.89%) and K (1.23%). The result would play an extremely important role in substantially reducing the burden of waste disposal, saving soil resources, controlling leachate and achieving malodorous gas reduction. Besides, it could also increase organic fertilizers in place of some chemical fertilizers and protect water resources.

Keywords: Organic matter, segregation, chemical characteristics, process control, quality of compost.

INTRODUCTION

Developing countries are trying to keep organic matter out of landfills, which is still a commonly practiced waste management option (Turan et al., 2009; Guerrero et al., 2013; Mueller, 2013). Landfills have been and will remain the dominant alternative for the ultimate disposal of municipal solid waste (Moy et al., 2008). However, landfilling of municipal solid waste is associated with certain adverse environmental impacts (Korucu and Erdagi, 2012; Greene and Tonjes, 2014). This has created some sort of objection from the public and decision makers' side for setting a new landfill (Zawierucha et al., 2013; Feo and Gisi, 2014). This is because organic matter in landfills generates the greenhouse gases methane and nitrous oxide, which are 23 times and 296 times more potent than carbon dioxide (CO_2), respectively, and are significant contributors to global warming (Mohareb et al., 2008; Ishii and Furuichi, 2013; Zhu-Barker et al., 2016). In addition, landfills are known to cause other undesirable effects such as soil and water contamination, foul odour, and health risks to residents in close proximity (Cossu, 2013; Capanema et al., 2104).
Therefore, it is necessary to divert the organic waste from landfill sites and the most important decisions in planning an organic waste recovery program is the choice of processing technology that will successfully meet the community's diversion needs (Chowdhury, 2009; Edjabou et al., 2015; Corvellec, 2016).

***Corresponding author:** Swapan Das, Department of Mechanical Engineering, Indian Institute of Engineering Science and Technology, Shibpur, Howrah-711103, India. Tel: +91 33 30492949; fax: +91 33 26682916, E-mail:swapan2009sajal@gmail.com
Co-authors' e-mail address: bidyut53@yahoo.co.in

Some technologies are more suitable than others, depending on the composition and quantities of organic material to be treated (Sokka et al., 2007; Fortuna and Diyamandoglu, 2016). The acquisition of a good knowledge of the community's on organic waste stream, including composition, quantities and sources, is an essential first step in the planning process (Das and Bhattacharyya, 2014; Sukholthaman and Sharp, 2016). One of the common organic waste management methods is incineration (Moy et al., 2008; Nixon et al., 2103). However, incinerating organic waste is not efficient either as the moisture content in organic waste can be as high as 90% and thus would require additional amounts of energy to combust. This results in increasing CO_2 emissions (Kuo et al., 2011; Yang et al., 2012; Förster et al., 2016).

An alternative to the above mentioned methods, the organic waste may be send to composting facilities. In composting facilities the organic waste can actually be broken down quickly and be turned into compost, a valuable resource (Gautam et al., 2010; Zheng et al., 2013; Naroznova et al., 2016). The main aim of this research is to investigate the MSW decomposition process. For that purpose, the organic fraction of MSW was segregated from different sources and was composted through controlling conditions. The properties of the compost were compared with the Environmental Protection Agency (EPA) standard in terms of physicochemical characteristics and quality.

MATERIALS AND METHOD

The present investigation entitled "Selective organic fraction degradation under controlling composting conditions" involved preparation of normal composts from different organic residues. Finally the evaluation of its manurial value was carried out at Duttcon industrial research and development lab, Kolkata, India during the financial year of 2013-2014. Organic waste makes up about 48% of the residential waste in Kolkata (Hazra and Goel, 2009). Municipalities cannot realistically reach diversion targets greater than 60% of organic waste without segregation at sources of residential organics in separate collection programme. The proper utilization of sources segregation process, municipalities able to collect biodegradable organics (up to 82%) from residences, markets, hotels and restaurants (Das and Bhattacharyya, 2014).

After the classification and characterization of municipal solid waste, the feedstock is delivered to a reception area, where it makes into heaps then commonly formed into windrows of 3 to 4 metres in height for a process known as biodegradation or decomposition, aided by mechanized controls. Temperature, moisture, and oxygen content are monitored closely to maximize the rate of biodegradation. Heaps temperature and oxygen level need to be observed by a site operator with handheld monitoring tools. Heap turning introduces oxygen, accelerates physical degradation of feedstock and provides an opportunity to adjust the moisture content to the optimum level. Many windrow turners have a watering attachment, which enables moisture to be added to the heap while turning. The total composting time is managed by the aggressiveness of the turning regime. More frequent turning breaks particles down more quickly, and provides an opportunity to optimize composting conditions, thus accelerating the composting process. This enables a windrow composting facility to increase its annual throughput capacity.

Segregation of Municipal Solid Waste

In composting systems, there are three objectives for materials separation: a) recover recyclable or combustible materials as marketable by-products, b) reduce the levels of visible inert materials, and c) reduce the levels of chemical contaminants. Many of the separation technologies now applied to MSW composting were originally developed to recover recyclable or combustible materials from solid waste. While some of these technologies have been adapted for reduction of inert materials, they have rarely been optimized for reducing chemical contaminant levels. But the source- separated MSW involves the significant role in maintaining the quality of compost product. Therefore, it is necessary to segregate the MSW at source for producing a high – quality, marketable compost. Because the quality of the end product is depends on the type of materials that are being composted. Further, inadequate separation of materials can adversely affect compost quality (Silva et al., 2014; Kupper et al., 2014).

Sampling and Analysis of the Segregated Materials

Table 1 shows the compostable waste characteristics which includes (organic matter content, calorific value and heavy metal concentrations). The values presented in Table 1 were analysed in the financial year 2013-2014.

The yearly mean moisture content of the compostable waste is 45%. Kolkata has a tropical wet-and-dry climate. As Kolkata is near the sea, the city has uniform temperature throughout the year. The temperature ranges from 14-25°C in the winter and 23-36°C in the summer. Annual rainfall is around 160 cm. Humidity level can be very high in the summers. However, the climate of Kolkata in favour of municipal solid waste windrows composting. Because optimum moisture content for windrow composting is in the range of 40-50%. Therefore windrow composting may be considered for handling the compostable waste so the moisture content would not be a problem and need not be removed.

The yearly mean value of pH of the compostable waste is 7.75 (test method IS: 1390-1983 RA 2004). In its optimum range this value of pH is considered to be 6-8.

Table 1. The physicochemical characteristics of the raw material used in composting

Parameter	Results obtain	Test method
Total Sulphur (S)	0.11% w/w	IS: 1350 (Part II) 1970 RA 2000.
Total Cadmium (Cd)	0.75% w/w	IS: 13963 (Part I) 1994 RA 2003.
Copper as Cu per 100 gm of Sample	8.97 mg	IS: 4667 (Part II) 1969 RA 2003.
Lead as Pb	Less than 10 ppm	IS: 12074-1987 RA 1998.
Nickel as Ni	Less than 5 ppm.	IS: 13318-1992 RA 2003.
pH	7.75	IS: 1390-1983 RA 2004.
Ash Content	13% w/w	IS:4311-1967 RA 2000
Moisture	42.46% w/w	IS:16052 (Part 6) 2013
Carbon	24.28% w/w	IS:1350(Part IV/Sec I)1974 RA 2000
Hydrogen	5.87% w/w	IS:1350(Part IV/Sec I)1974 RA 2000
Nitrogen	0.75% w/w	IS:1350(Part IV/Sec II)1975 RA 2000
Oxygen	12.96% w/w	IS:228 (Part 18) 1987
C:N Ratio	32	-
Total Organic Solid	82.32% w/w	IS:3025 (Part 18) RA 2002
Total Inorganic Solid	13.45% w/w	IS:3025 (Part 18) RA 2002
Total Inert Material	4.23% w/w	IS:3025 (Part 18) RA 2002

The pH affects the amount of nutrients available to the microorganisms, the solubility of heavy metals, and the overall metabolic activity of the microorganisms.

A study, performed during a session of 2013-2014 and the heavy metal concentrations in the compostable waste is Copper as Cu per 100 gm of sample 8.97 mg, Sulphur (S) 0.11%, cadmium (Cd) 0.75%, Lead (Pb) less than 10 ppm and Nickel (Ni) less than 5 ppm. During the chemical characterization of compostable waste it is found that total organic solid is 82.32%, total inorganic solid is 13.45% and the total inert material is 4.23% (the percentage are weight basis). IS: 3025(Part 18) RA2002 testing method is followed during chemical characterization of municipal solid waste.

Estimating the Quantities of Compostable MSW

The residential sector generates food scraps in a relatively constant quantity all year around, but fluctuates according to the season and the type of area (i.e., the nature of local activities, food habits, cultural traditions, socio-economic factors and climatic conditions). On average, a common household generates between 50 and 60 kilograms (kg) per person of compostable waste annually. Some of the largest generators of compostable wastes include municipality markets, food packaging and distribution companies, hotels, restaurants, cafeterias and convention centres, and supermarkets. If these large contributors are being considered for inclusion in a compostable waste recovery program, they should be analysed, since the nature and quantities of organic waste produced may vary considerably from one to another. Table 2 shows the compostable waste quantity generated in various municipalities under Kolkata metropolitan city area, based on waste parameters.

In order to properly plan diversion programs and design facilities, accurate estimates of organic waste quantities in the MSW stream are required. Material that is already separated and diverted can be quantified through direct measurement. Determining the relative quantities of the different waste types in mixed MSW is sometimes achieved by conducting a waste composition study.

During such a study (season 2013-2014), representative samples of solid waste from various sources (e.g., residential and market, hotel and restaurants) are obtained and manually sorted into major fractions (e.g., paper, plastic, metals and food waste). The weights of the various compostable wastes are tabulated, and the overall composition of the waste is calculated on a percentage basis. From the analysis of municipal solid waste, the estimated compostable

Table 2. Compostable waste quantity generated in various municipalities under Kolkata metropolitan city area

Sl No.	Municipality	Location	Quantity (MT/Day)	Compostable waste parameters	Compostable percentage	Compostable quantity (MT)
1	RajarhatGopalpur	North Kolkata	220	Moisture > 35%, Organic > 60 %, C/N Ratio- 25-35	40%	88
2	Dum Dum		65			26
3	South Dum Dum		170			68
4	North Dum Dum		260			104
5	Baranagar		138			55.2
6	Kamarhati		130			52
7	Kolkata Municipal corporation	Centre Kolkata	3520			1408
8	Bidhannagar Municipal Corporation		200			80
9	RajpurSonarpur	South Kolkata	134			53.6
TOTAL			4837			1934.8

waste percentage is 40% on a weight basis, taking compostable waste parameter moisture more than 35% (moisture content maintain by spraying of water during turning of heap in windrow process), organic greater than 60% and the C/N ratio between 25-35. On the basis of compostable waste parameter (Table 2), we can segregate from various sources around 1935 metric tonne per day of compostable waste in the Kolkata metropolitan city area.

OPERATION AND TESTING

Steps of the Composting Process

The proposed scheme flow chart of the windrow composting process is presented in Fig. 1. The composting process occurs in two major phases. In the first stage, microorganisms decompose the composting feedstock into simpler compounds, producing heat as a result of their metabolic activities. The size of the composting pile is reduced during this stage. In the second stage, the compost product is "cured" or finished. Microorganisms deplete the supply of readily available nutrients in the compost, which, in turn, slows their activity. As a result, heat generation gradually diminishes and the compost becomes dry and crumbly in texture. When the curing stage is complete, the compost is considered "stabilized" or "mature". Any further microbial decomposition will occur very slowly.

Composting Process Control

Incoming waste is directly unloaded at the windrow decomposition area and then forming the windrow heaps. The windrow decomposition facility includes the yard for the windrow heaps turning. The windrow decomposing facility is designed based on the number of windrow compost heaps in accordance with the amount of incoming waste and turning days. Fig. 2 shows the practical implementation of the windrow composting process under controlling composting conditions. The dimension of windrow heaps of 3 to 4 meters in height shown in Fig. 2(a) and Inoculum is added to the windrows at 1 kg per ton (kg t^{-1}) of garbage and water is sprayed by pipes. The windrows are turned five times (one turning per week) by pay loaders. The temperatures inside the windrows are found to be 50–60 °C during the initial 5–7 days, which kills most of the pathogenic bacteria. In some cases, a rise in temperature up to 70 °C is noted. After almost a month, the windrows are broken down and the total contents dried and shifted to a maturation yard.

Removal and Collection of Composting End Product

Once the compost has reached maturity (about 6 weeks), final processing can be performed. After partial maturation for a certain number of days, the compost is placed on a conveyor belt by a small pay loader; it transfers to tumble for 40 mm screening. Above 40 mm materials in the form of refuse materials are transported to landfill sites. Below 40mm materials transfer through conveyor for 20mm screening. Again the above 20mm materials are also going to refuse site and below 20mm are stored in a semi finish godown. The storage area is designed for the amount of compost produced in 15 days. Finally, after 15 days of maturity in semi finish godown without turning, the finished compost is conveyed by bucket elevator to 4 mm vibrating screens. The screening process of matured compost is shown in Fig. 2 (b). The oversized material joins other residue for consolidation and disposal and below 4mm is considered as a composting end product which is transferred for weighing and packaging (50 kg per bag). The residue generated in this process is disposed at a landfill site.

Analysis of the Produced Compost

The compost prepared from MSW is black brown in colour. It is crumbly in nature with an earthy odour. The

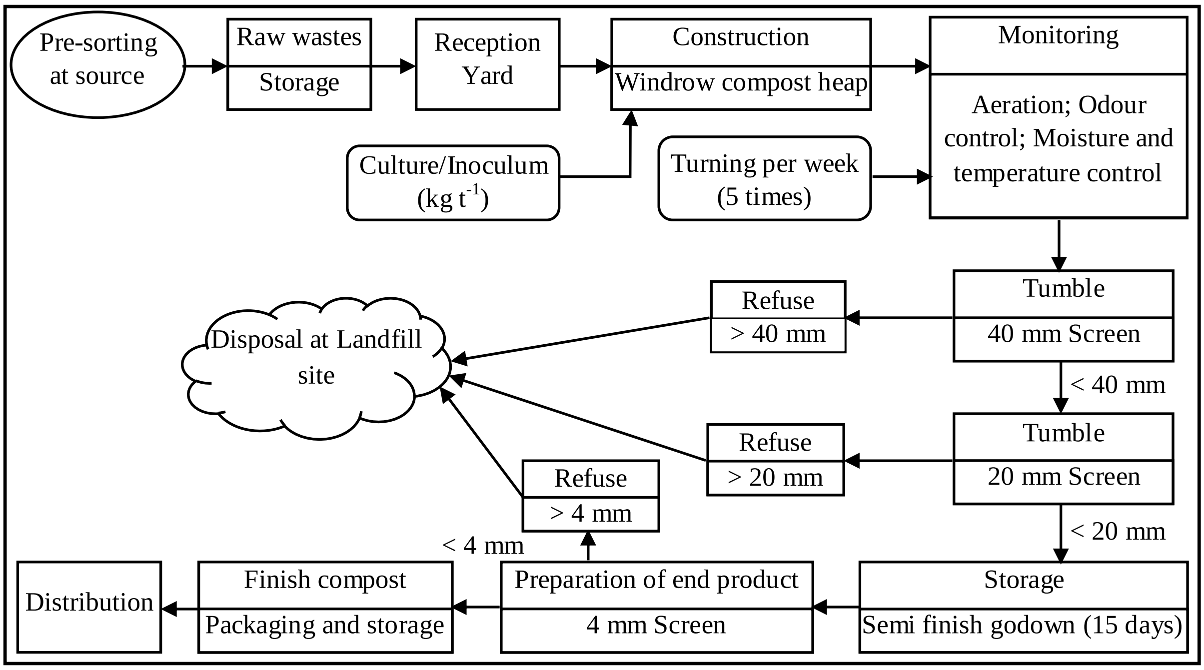
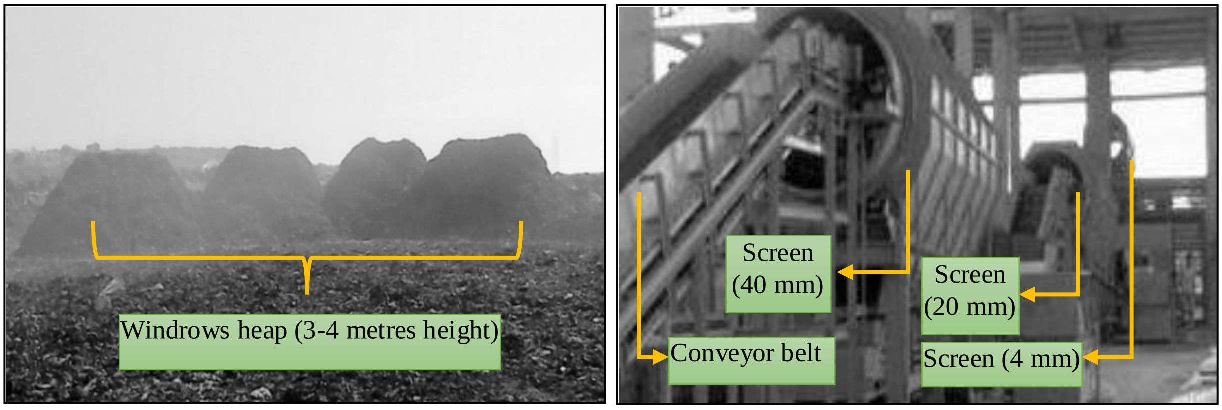


Figure 1. Proposed scheme flow chart of windrow composting process.



(a) (b)

Figure 2(a). Windrow decomposition yard (Dhapa, Kolkata, India); (b) Screening of matured composed.

pH of composting product is neutral, though slightly acidic or alkaline pH within the range of 6.7-8.2. The compost can neither be completely dry nor be lumpy and water does not come out of the mass when squeezed. The Nitrogen, Phosphorous and Potassium (NPK) contents are 1.26%, 0.89% and 1.23% respectively. The Nitrogen is in the form of Nitrates for proper utilization by the plants. The C/N ratio is in between 10 to 15.

One of the primary concerns, is the presence of heavy metal compounds (particularly copper, lead, cadmium) and toxic organic compounds in the MSW compost product. To date, where problems have occurred with mixed MSW compost, we have been resulted from immature composts, not metals and toxic organics. The measures, including further separation by generators at source, can be taken to prevent problems and produce a high quality compost. Table 3 shows the physicochemical parameters of the compost product. The influence of source separation on lead content is readily apparent. The composition of mixed MSW compost is influenced by feedstock characteristics, collection method, processing steps, and composter operating procedures.

Testing of compost for chemical constituents is carefully planned and executed in Duttcon industrial research and development lab as per standard methods of Bureau of Indian Standards. Wide variations in metal concentrations within the same compost heap have been reported. However, three samples collected for analysis of chemical. From sampling and testing programs for mixed MSW

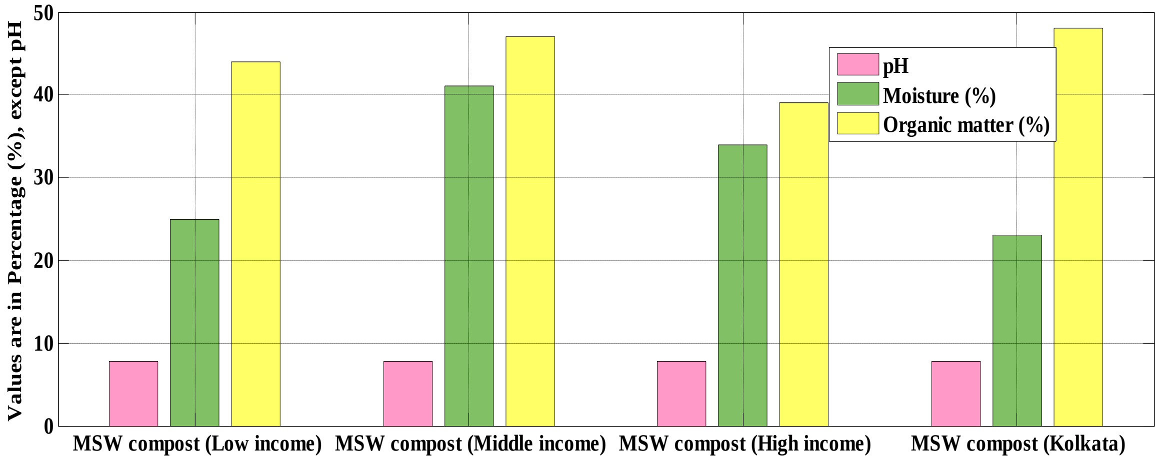


Figure 3. Comparative average values of pH, moisture content and organic matter (%) in fertilizer samples.

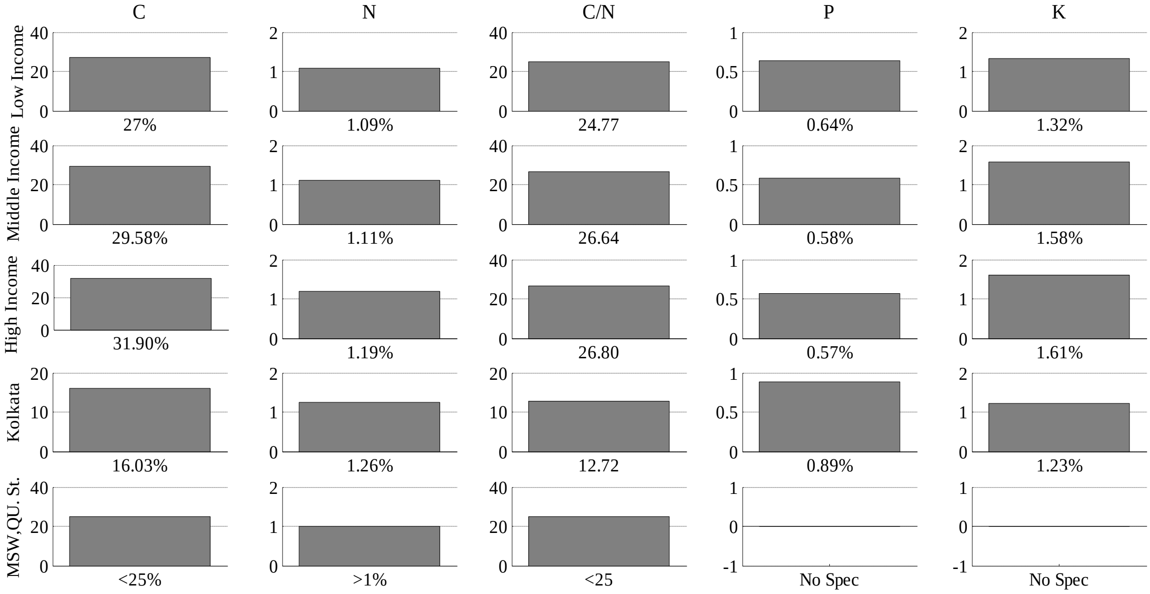


Fig. 4. Comparative average nutritional values and C/N ratio of composts.

compost we also found total sulphur. The program must recognize (S) 0.02 mg/Kg, total cadmium (Cd), 0.006mg/kg, nickel as Ni less than 5 ppm and lead as Pb less than 10 ppm.

RESULTS AND DISCUSSION

The windrow composting process that have been performed focus on the compost quality characterization and on the effects of unit operational conditions on the efficiency of the composting process, as well as on the end product quality. The evaluation and the conclusions that have been made are based on the comparison of the experimental results with literature references on the operational and quality parameters that influence composting process and the quality of the end product.

Presence of high percentage of biodegradable organics (82%) and comparison of the average values of the C/N ratio (32:1), pH (7.75), organic matter (48%), and moisture content (42%) of the MSW samples), shown in Table 1 indicate that the organic fraction of refuse is suitable for composting process. The composting procedure used during this study was an aerobic windrow type. The advantages of windrow process over other composting process lies into its simplicity, low level technology and involvement of unskilled labour that is usually employed in running the process.

Process data such as temperature, moisture content, and mass reduction, etc., was monitored during the composting and curing period. It was noted that the weight loss gradually became more pronounced during the first week of the test, as microbial activity increased to maximum. It was observed that, in winter season, the composting process was completed in about 7-9

Table 3. Physicochemical parameters of the compost produced in windrow composting

Sl no.	Parameter	Results obtain
1	pH	6.7-8.2
2	Carbon	16.03% w/w
3	Nitrogen	1.26% w/w
4	Phosphorous	0.89% w/w
5	Potassium	1.23% w/w
6	C:N Ratio	12.72
7	Total Sulphur	0.02 mg/kg.
8	Total Cadmium (Cd)	0.006 mg/Kg.
9	Copper (Cu)	28.78 mg/Kg.
10	Lead (Pb)	Less than 10 ppm.
11	Nickel (Ni)	Less than 5 ppm.
12	Hydrogen	0.44% w/w
13	Oxygen	1.30% w/w
14	Moisture	23.02% w/w
15	Ash Content	82.58% w/w

weeks, whereas in summer season it took only about 6-7 weeks. The weight reduction in winter season was found to be more than 60%, whereas in summer it was above 70%.

The screened compost samples were drawn and analysed in the laboratory for the parameters such as pH, heavy metals, organic matter, essential plant nutrients (nitrogen, phosphorus, potassium) and C/N ratio. The results of the analysis are shown in Table 3 and also compared (Figure 3 and Figure 4) against those of international standards set for good quality compost. The pH value (6.7-8.2) was found to be within the acceptable limits.

A high organic matter content ranging from 45–60% was found, whereas the C/N ratio (10-15), lies within the acceptable limits. With regard to agronomic parameters, the quantities of essential plant nutrients, especially nitrogen content (1.26%), phosphorus (0.89%) and potassium (1.23%), were found within the acceptable limits as required for soil conditioning. According to the standard, excellent quality compost generally contain high concentration of nitrogen, but no specific value is set for phosphorus or potassium.

CONCLUSIONS

In Kolkata, the volume of discarded residues is increasing, but the area available for their disposal is becoming scarce. Therefore, the best solution for minimizing disposed waste volumes is the recycling of certain waste fractions. As a result, composting is becoming an attractive management option as a safe and effective way to manage a significant part of the MSW. Furthermore, compost can provide plant nutrients and organic matter, help control plant diseases, stimulate plant growth and increase water retention of the soils, and therefore could be valuable for agriculture.

Various techniques to collection, treatment and composting of MSW organic are exist. An important step would be the establishment of decentralised composting process in urban areas. Which will reduce the transportation cost tremendously. As a first step, should involve the establishment of systems for the handling of household wastes. Here, systems where the impurities are separated at the household level should be of priority. To determine how the organic fraction of MSW can be optimally separated from the other waste fractions, transported to the facility and then composted, practical tests need to be carried out and pilot projects established.

ACKNOWLEDGEMENTS

The authors wish to thank Eastern Organic Fertilizer Limited; and Duttcon Industrial Research & Development Lab for helping to collect practical data and improve the quality of the work.

REFERENCES

Capanema MA, Cabana H, Cabral AR (2014). Reduction of odours in pilot-scale landfill biocovers. Waste Management,34: 770–779.

Chowdhury M. (2009). Searching quality data for municipal solid waste planning. Waste Management,29: 2240–2247.

Corvellec H (2016). A performative definition of waste prevention. Waste Management,52: 3–13.

Cossu R. (2013). Groundwater contamination from landfill leachate: When appearances are deceiving!.Waste Management,33: 1793–1794.

Edjabou ME, Jensen MB, Götze R, Pivnenko K, Petersen C, Scheutz C, Astrup TF. (2015). Municipal solid waste composition: Sampling methodology, statistical analyses, and case study evaluation. Waste Management,36: 12–23.

Fortuna LM, Diyamandoglu V (2016). A novel method

formaterial characterization of reusable products. Waste Management,52: 14–24.
Das S, Bhattacharyya BK. (2014). Estimation of Municipal Solid Waste Generation and Future Trends in Greater Metropolitan Regions of Kolkata, India. Journal of Industrial Engineering and Management Innovation, 1: 31-38.
Feo GD, Gisi SD (2014). Using MCDA and GIS for hazardous waste landfill siting considering land scarcity for waste disposal. Waste Management, 34: 2225–2238.
Förster H, Thajudeen T, Funk C, Peukert W (2016). Separation of nanoparticles: Filtration and scavenging from waste incineration plants. Waste Management, 52: 346–352.
Gautam SP, Bundela PS, Pandey AK, Awasthi MK, Sarsaiya S (2010). Composting of Municipal Solid Waste of Jabalpur City.Global Journal of Environmental Research, 4: 43-46.
Greene KL, Tonjes DJ (2014). Quantitative assessments of municipal waste management systems: Using different indicators to compare and rank programs. Waste Management, 34: 825–836.
Guerrero LA, Maas G, Hogland W (2013).Solid waste management challenges for cities in developing countries. Waste Management,33:220–232.
Hazra T and Goel S (2009). Solid waste management in Kolkata, India: Practices and challenges. Waste Management, 29: 470–478.
Ishii K, Furuichi T (2013). Estimation of methane emission rate changes using age-defined waste in a landfill site.Waste Management,33: 1861–1869.
Korucu MK, Erdagi B (2012). A criticism of applications with multi-criteria decision analysis that are used for the site selection for the disposal of municipal solid wastes. Waste Management, 32: 2315-2323.
Kuo JH, Lin CL, Chen JC, Tseng HH, Wey MY. (2011). Emission of carbon dioxide in municipal solid waste incineration in Taiwan: A comparison with thermal power plants. International Journal of Greenhouse Gas Control,5: 889–898.
Kupper T, Bürge D, Bachmann HJ, Güsewell S, Mayer J. (2014). Heavy metals in source-separated compost and digestates. Waste Management, 34: 867–874.
Mohareb AK, Warith MA, Diaz R (2008). Modelling greenhouse gas emissions for municipal solid waste management strategies in Ottawa, Ontario, Canada. Resources, Conservation and Recycling,52: 1241–1251.
Moy P, Krishnan N, Ulloa P, Cohen S, Brandt-Rauf PW. (2008). Options for management of municipal solid waste in New York City: A preliminary comparison of health risks and policy implications. Journal of Environmental Management,87: 73–79
Mueller W (2103). The effectiveness of recycling policy options: Waste diversion or just diversions?.Waste Management,33:508–518.
Naroznova I, Møller J, Larsen B, Scheutz C (2016). Evaluation of a new pulping technology for pre-treating source-separated organic household waste prior to anaerobic digestion. Waste Management, 50: 65–74.
Nixon JD, Wright DG, Dey PK, Ghosh SK, Davies PA. (2013). A comparative assessment of waste incinerators in the UK. Waste Management,33: 2234–2244.
Silva MEF, Lemos LT, Nunes OC, Cunha-Queda AC. (2014) Influence of the composition of the initial mixtures on the chemical composition, physicochemical properties and humic-like substances content of composts. Waste Management,34: 21–27.
Sokka L, Antikainen R, Kauppi PE (2007). Municipal solid waste production and composition in Finland—Changes in the period 1960–2002 and prospects until 2020.Resources, Conservation and Recycling,50: 475–488.
Sukholthaman P, Sharp A (2016). A system dynamics model to evaluate effects of source separation of municipal solid waste management: A case of Bangkok, Thailand. Waste Management, 52: 50–61.
Turan NG, Çoruh S, Akdemir A (2009). Ergun ON. Municipal solid waste management strategies in Turkey. Waste Management,29:465–469.
.Yang N, Zhang H, Chen, M, Shao LM, He PJ. (2012). Greenhouse gas emissions from MSW incineration in China: Impacts of waste characteristics and energy recovery. Waste Management, 32, 2552–2560.
Zawierucha I, Kozlowski C, Malina G (2013). Removal of toxic metal ions from landfill leachate by complementary sorption and transport across polymer inclusion membranes. Waste Management, 33, 2129–2136.
Zheng W, Phoungthong K, Lü F, Shao LM, He PJ (2013). Evaluation of a classification method for biodegradable solid wastes using anaerobic degradation parameters. Waste Management,33: 2632–2640.
Zhu-Barker X, Burger M, Horwath WR, Green PG. (2016). Direct green waste land application: How to reduce its impacts on greenhouse gas and volatile organic compound emissions?.Waste Management, 52:318–325.

Accepted 05 April, 2017

Citation: Swapan D, Bidyut B (2017) Selective organic fraction of municipal solid waste degradation under controlled composting conditions. Journal of Environment and Waste Management 4(1): 156-163.

Copyright: © 2017 Das et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are cited.