***Pak. J. Bot*., 39(1): 271-277, 2007.**

MUNICIPAL SOLID WASTE COMPOSTING AND ITS ASSESSMENT FOR REUSE IN PLANT PRODUCTION

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Abstract

A pilot study was conducted to assess the feasibility of composting of source separated organic matter of municipal solid waste (MSW) generated in low, middle and high income areas of Karachi city with a population over 14 million. Results of MSW analysis indicate the presence of high percentage of biodegradable organic matter (71-74%), acceptable moisture content (40-50%) and C/N ratio (38-40:1). On windrow composting, not only the volume of waste was reduced but also produced a crumbly earthy smelling soil-like, compost material. All quality parameters in the compost samples were found to be within the acceptable limits set by international standard. The pH ranged between 6.8-8.1, soluble salts 3.90-5.10 mS/cm, organic matter 45-60% and have an acceptable amount of plant nutrients (Nitrogen 0.91-1.35%, Phosphorus 0.42-0.85%, Potassium 1.00-1.80%). The compost quality could further be improved by adding cow manure, poultry manure or yard waste etc. Its use in plant production or land reclamation may be helpful to maintain soil fertility and improve moisture holding capacity. MSW composting could be adapted country wide to recycle/reuse the organic residues as solid waste management option.

Introduction

Karachi, a mega city of Pakistan with a population >14 billion generates about 7000-8000 tons per day of municipal solid waste (Anon., 1993). Approximately 89% waste material is of recyclable nature, out of which 65-70 % is of organic type (vegetable, fruit waste, kitchen and garden waste) and decomposable in nature, the remaining 30-35% comprises of bones, tins, plastic, paper, glass, dirt etc. The existing system of solid waste management in the city is inefficient and inadequate to cope with the present and future need of increasing solid waste quantities. There are no planned disposal sites for the city. The current practice of the illegal dumping of solid waste in and around the city has created a serious environmental and public health problem. For sustainable development, it is essential to establish sound, economical and technical methods of solid waste management.

The bioconversion process is gradually emerging as a natural, promising, environment-friendly and potential microbial process to degrade environmental contaminants (Colwell, 1994). At present, the municipal solid waste composting is being encouraged in many countries of the world and researchers have experienced the benefits of using MSW compost in the field (Pokhrel & Viraraghavan, 2005; Abigail, 1998; Francis, 1997; John, 1997; Paul & Howard, 1997). Keeping in view the quantum of MSW generation in Karachi city and huge cost for its disposal, the present research study was conducted to select an appropriate system of solid waste management. A pilot study was designed to assess the feasibility of the MSW composting. The other objective was to evaluate the quality of finished compost as per requirement for soil conditioning/ fertilizer. This investigation is expected to minimize raw material wastage and may also help in the establishment of guidelines and regulations for the production and use of MSW compost. Moreover, in the present restrained economic situation in the developing countries like Pakistan, the efficient solid waste management plan including product recovery would serve as a best measure to reduce pollution.

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Materials and Methods

The research study was conducted at NED University campus in the month of December 2003 at ambient temperature ranging from 18 to 26ºC. Domestic solid waste samples were collected from 6 different localities of Karachi city, representing high, middle and low socio-economic areas. The organic material mainly vegetable, fruit and kitchen waste etc., were separated manually and subjected to windrow composting process. Scientific balance with capacity ranging up to 100 kilograms was used to determine the actual percentage of organic waste generated at various income groups. The total weight of introduced organic material for composting and the finished compost were calculated by weighing. The required operating conditions of moisture, temperature, air etc., were maintained throughout the composting process (Haug, 1980). Aeration typically in the pile was provided by manually turning of waste. The turning loosens, mixes and adds moisture to homogenized and aerated the material in the pile as well as reposition of the piles.

A pile of mixed solid organic waste of 3 feet high was placed on concrete surface/paved ground and was watered regularly to maintain moisture level between 45-50% and turned manually every 3-5 days for the first six weeks of composting cycle. From the seventh week, the moisture was allowed to drop when optimum biosolids decomposition was achieved. This process completed in about 8-9 weeks. After this period the compost was allowed to cure for additional three weeks without turning. During the curing period residual decomposable organic material were further reduced by fungi and actinomycetes. The finished compost was then screened out and weighed.

Analysis

The physical and chemical characteristics of various compost samples were carried out in the laboratory using standard procedures. Similarly, samples of cow dung as organic fertilizer and commercial fertilizer were also analyzed to compare its quality with compost. Accuracy in the results were obtained by analyzing each sample 8-10 times for each parameter. Representative samples were first ground to homogenous powder in a miller apparatus and then analyzed. Soluble salts and pH were measured in a suspension of 10 gm in 100 ml of distilled water using Hach Portable Conductivity Meter and Orion pH-meter. Moisture content was determined by drying well mixed samples in an oven at 105^{o}C for 24 hours and expressed as a percentage of total weight. The volatile solids content of organic matter was determined on the dried sample taken for the moisture content test by measuring loss on ignition at 550^{o}C for 3 hours using a muffle furnace. The weight loss represented organic content that were expressed as a percentage of dry solids (Anon., 1990). Phosphorus was analyzed by spectrophotometer and the concentration of potassium in the samples were measured using flame photometer. The details of the analysis are presented elsewhere (Anon., 1990; Brawn, 1990). Total Kjeldahl Nitrogen was estimated by ASTM method of analysis (Anon., 1990). Carbon percentage in the samples were calculated according to the New Zealand formulae (Anon., 1951), in which percent organic matter present in the sample was divided by 1.724.

Table 1. Composition of municipal solid waste in high, middle and low socioeconomic localities.

Components	High (% by weight)	Middle	Low
Food wastes	74.10	73.45	71.15
Paper & Cardboard	9.30	6.92	4.33
Plastic & Polythene	6.00	9.50	13.72
Textile	1.50	2.73	5.40
Rubber & Leather	1.10	1.30	-
Metals & Tin	3.60	1.90	-
Glass	4.40	3.10	1.60
Miscellaneous	-	1.10	3.80

Table 2. Average chemical composition of municipal solid waste.

Parameters	Average values	*Standard values suitable for composting
pH	6.4	5.5-8.0
Moisture (% dry basis)	36	< 50
Organic matter (% wet basis)	57	> 20
Nitrogen (% dry basis)	0.81	> 0.6
Carbon (% dry basis)	33	No specs
C/N ratio (total dry weight)	40:1	25-50:1

*Standard (Zucconin & deBertoldi, 1987),

*Data was produced during author's association with NED University of Engineering & Technology, Karachi.

Results and Discussion

Presence of high percentage of biodegradable organics (73%) and comparison of the average values of C/N ratio (40:1), pH (6.4), organic matter (57%), and moisture content (36%) of the MSW samples against those of standards value (Anon., 1987), shown in Table 1 and 2 indicate that the organic fraction of refuse is suitable for composting process. The refuse generated in India, Mexico and Great Britain is compostable in nature (Flintoff, 1976), as also established by PCSIR study (Khatib *et al*., 1990), and confirmed during the present research study. However, to obtain good quality compost, the C/N ratio of the waste can be adjusted to an optimum level by adding cow manure, poultry manure, garden waste etc. As several researchers have drawn attention that successful preparation of MSW composts depended upon the nature of the organic materials, the proportion of nitrogenous compound to carbohydrates, the temperature of decomposition and the microbial population involved in the process (Babyranidevi & Bhoyar, 2003; Xi *et al*., 2003)**.**

The composting procedure used during the pilot study was aerobic windrow type. The advantages of windrow process over other composting process lies into its simplicity, low level technology and involvement of unskilled labor that is usually employed in running the process. Therefore windrow process can be easily managed in rural and urban areas of developing countries including Pakistan. Moreover, it has been established that the capital, operational and maintenance costs for windrow composting are relatively low (Technobanoglous, 1993; Haug, 1980; Gotass, 1956). This method is best suitable for the tropical climate like the climate of Karachi city, where the temperature remains moderate with mean minimum and maximum temperature ranging between 20 and 32^{o}C and humidity between 49 and 75%. Summer season last long for eight-month extending from end of March to October and the winter season is not very cold. Process data such as temperature, moisture content, and mass reduction etc., were monitored during the composting and curing period. During the process, the initial mix of organic waste was watered regularly to maintain optimum moisture content of about 45-50%, and aeration rate was increased by frequent turning of the waste every 4-5 days to homogenize the material and to maintain adequate temperature to support the accelerated microbial growth typically required for composting environment. It was observed during the process that the mixture heated up rapidly, reaching a temperature of 48^{o}C after one day of composting. By maintaining the temperature of 48-50^{o}C for initial 3 days of the process, the frequency of turning and mixing of the waste was increased to obtain temperature between 35-40^{o}C, (an optimum level for microbial degradation). During composting, the mass reduction was estimated by weighing the waste under process from time to time. It was noted that the weight loss gradually became more pronounced during 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 8-10 weeks, whereas in summer season it took only about 4-6 weeks. The weight reduction in winter season was found to be more than 60%, where as in summer it was above 70%. Similar findings were observed by (Andrea *et al*., 1998).

In order to assess the compost maturity, the compost sample was placed in a sealed bag for a week. After a week, the seal was broken and the odor was smelled, which was found to have earthy smell, indicating the quality of stable and mature compost. The screened compost samples were drawn and analyzed in the laboratory for the parameters such as pH, soluble salts, organic matter, essential plant nutrients (nitrogen, phosphorus, potassium) and C/N ratio. The results of the analysis are shown in Table 3 and 4 and also compared against those of International Standards set for good quality compost**.** The pH value (6.8-8.1) and soluble salts (3.90–5.10 mS/cm) were found to be within the acceptable limits. A high organic matter content ranging from 45–60% was found, whereas the C/N ratio (26-27.0), lies within the acceptable limits but inclined towards the higher values meaning the compost may need supplements to increase its nitrogen value. The low nitrogen value could further be improved by adding phosphoric acid in the waste (Dinel *et al*., 2004). It prevents the excessive volatilization of ammonia during the meso and thermophilic phases of composting. These findings are in accordance to the previous study where it is reported that usually the nitrogen concentration in the compost sample is less available than the nitrogen in the feedstock from which the compost is made due to volatilization of ammonia (Dinel *et al*., 2004; Paul & Jessie, 1997). Therefore, it is important to balance the feedstock or to add phosphoric to ensure the loss of nitrogen during composting. With regard to agronomic parameters, the quantities of essential plant nutrients, especially nitrogen content (0.91–1.35%), phosphorus (0.42-0.85%) and potassium (1.00-1.80%), were found within the acceptable limits as required for soil conditioning (Abigail, 1998).

According to standard, excellent quality compost generally contain high concentration of nitrogen but no specific value set for phosphorus or potassium The MSW compost prepared during the present study was found to be as good as cowdung and chemical fertilizer (Table 4). Therefore, its use in Karachi sandy soil, may add humus and improve the aeration, aggregation and water holding capacity. It is reported that good quality compost can increase the crop yield as much as 10% (Poincelot, 1975). Further, its use helps to prevent erosion, supplies slow release of nutrients and can control numerous soil born diseases (Abigail, 1998; John, 1997). The present study would suggest that MSW composting and the quality of compost could further be improved by adding inoculating agent in the waste and the volatilization of nitrogen in the form of ammonia could be reduced by phosphoric acid treatment during composting.

Table 3. Comparative average values of pH, soluble salts, organic matter content of MSW compost, cow dung and chemical fertilizer samples.

Sample type	pH	Soluble salts (mS/cm)	Organic matter (%dry basis)
MSW compost (High income)	7.50 ± 0.32 (6.8-7.8)	4.19 ± 0.22 (3.90-4.50)	58 ± 1.4 (56-60)
MSW compost (Middle income)	7.42 ± 0.27 (7.1-8.0)	4.72 ± 0.15 (4.35-4.82)	56 ± 1.32 (54-58)
MSW compost (Low income)	7.78 ± 0.03 (7.0-8.1)	4.83 ± 0.12 (4.72-5.10)	48 ± 1.79 (45-50)
Cow dung (Organic fertilizer)	7.91 ± 0.18 (7.6-8.2)	4.81 ± 0.04 (4.75-4.88)	50 ± 1.5 (48-52)
Chemical fertilizer	6.95 ± 0.11 (6.8-7.1)	5.67 ± 0.13 (5.40-5.80)	38 ± 0.71 (37-39)
Proposed Italian Standard	5.5-8.0	<5	>20

*Data was produced during author's association with NED University of Engineering & Technology, Karachi.

Table 4. Comparative average nutritional values and C/N ratio of composts, cow dung and chemical fertilizer samples.

Sample type	Org. Carbon (%)	Nitrogen (%) dry basis	Phosphorus (%) dry basis	Potassium (%) dry basis	C/N Ratio
MSW Compost (High income)	31.90 ± 1.40	1.19 ± 0.14 (0.94-1.35)	0.57 ± 0.10 (0.42-0.70)	1.61 ± 0.22 (1.30-1.80)	27.03
MSW Compost (Middle income)	29.58 ± 1.32	1.11 ± 0.08 (0.95-1.18)	0.58 ± 0.09 (0.45-0.72)	1.58 ± 0.22 (1.20-1.80)	26.64
MSW Compost (Low income)	27.80 ± 1.79	1.09 ± 0.11 (0.91-1.20)	0.64 ± 0.09 (0.55-0.85)	1.32 ± 0.19 (1.00-1.50)	25 50
Cow dung (Organic fertilizer)	29.00 ± 1.50	1.19 ± 0.16 (0.95-1.50)	0.55 ± 0.07 (0.43-0.65)	3.81 ± 0.44 (3.10-4.40)	24.37
Chemical fertilizer	22.00 ± 0.71	0.86 ± 0.09 (0.73-0.98)	0.75 ± 0.21 (0.55-1.00)	0.18 ± 0.02 (0.16-0.20)	25 58
MSW Compost Quality Standard	>25	>1	No Spec	No Spec	<25

*Parenthesis shows the range.
*Data was produced during author's association with NED University of Engineering & Technology, Karachi.

Based on the study it can be concluded that municipal solid waste is suitable for composting because of the presence of high percentage of biodegradable organic matter, acceptable moisture content and C/N ratio in the waste. However, the composting process and compost quality could further be improved by adding inoculating agent like cow manure, poultry manure, yard waste etc in the municipal solid waste. Further, the nitrogen content in compost could be increased by adding phosphoric acid which prevents the volatilization of ammonia during composting process.

Since Karachi soil is sandy, erodible, low water holding capacity with little organic matter and nutrient content, the application of compost would be an investment in the long-term for the health of soils and plants. Finally, it is concluded that a module of this type for the recovery of valuable and economical organic fertilizer- the compost, can be adapted country wide to recycle the organic residues as waste management option.

Acknowledgement

The research project was funded by NED University of Engineering and Technology, Karachi, Pakistan.

References

Abigail, A.M. 1998. Using municipal solid waste compost in nursery stock production. *Bio. Cycle. J*., 39(5): 63-65.

Andrea, C., S. Salvia and Z. Gianni. 1998. Efficiency of Backyard Composting. *Bio. Cycle. J*., 39(6): 76-78.

Anonymous. 1951. Inter department committee on utilization of organic waste. Second interim report NZ Engg. 6(11-12), New Zealand.

Anonymous. 1990. American society for testing and material, 11.04, *Env. Technology*, E778-87, ASTM, Philadelphia.

Anonymous. 1990. APHA, AWWA, WPCF. Standard method for the examination of water and wastewater. (17 Edition). Washington DC.

Babyranidevi, S. and R.V. Bhoyar. 2003. Feasibility of some treatment for improving the composting of municipal solid waste. *Indian J. Environmental Health*, 45(3): 231-4.

Boopathy, R. 2000. Factors limiting bioremediation technologies. *Bioresource Technol*., 74: 63.

Braun, R. and O. Jaag. 1990. *Method of sampling and analysis of solid waste*, EA WAG, CH-8600, Dubendoof, Switzerland.

Colwell, R.R. 1994. Scientific foundation of bioremediation and gaps remaining to be filled. *Res. Microbiol*., 145: 40.

Dinel, H., T. Marche, M. Schnitzer, T. Pare and P. Champagne. 2004. Co-composting of paper mill sludge and hardwood sawdust under two types of in-vessel processes. *J Environmental Science and Health. Part B–Pesticides, Food Contaminants and Agriculture Wastes*, B39(1): 139-151.

Flintoff, F. 1976. *Management of solid wastes in developing countries*. WHO regional publication of south east asia. Serial No. 1. WHO, New Delhi.

Francis, R.G. 1997. New profit in organic recycling. Bio. Cycle. J., 38(9): 61-62.

Gotaas, H.B. 1956. *Composting- Sanitary Disposal and Reclamation of solid Waste*. WHO. Geneva.

Haug, H.B. 1956. *Composting–sanitary disposal and reclamation of solid waste*. WHO Geneva.

John, H. 1997. Apply compost and mulches to control erosion. *BioCycle. J*., 38(5): 63-65.

Khatib, R., N.F. Usmani and S.S. Husain. 1990. Evaluation of recycling material in municipal solid waste from Karachi. *Biol. Wastes*, 31: 113-22.

Lee, L.B. and H.B. Mat. 1998. Biodegradation of lubricating oil by locally isolated bacterial species-microbial identification and degradation potential study. In: *Proceedings of the 10th National Biotechnology Seminar*. 27-28 October, SIRIM Bhd. Malaysia. 1998, p. 80.

Paul, R. and L. Howard. 1997. Using urban organic in agriculture. *BioCycle. J*., 38(4): 86-90.

Paul, V.W. and O.S. Jessie. 1997. Measuring process parameters at an enclosed composting facility. *BioCycle. J*., 38(5): 58-61.

Poincelot, R.P. 1975. *Connection agriculture experiment station*. New Haven, Bulletin 754.

Pokhrel, D. and T. Viraraghavan. 2005. Municipal solid waste management in Nepal: practices and challenges. *Waste Manag*., 25(5): 555-62.

Tchnobanoglous, G., H. Theisen and S.A. Vigil. 1993. *Integrated Solid Waste Management: Engineering Principles and Management Issues*. New York. Mc Graw Hill.International Editions.

Xi, B., W. Meng, G. Huang, H. Liu, G. Zeng, X. Yuan, Q. Wang and Q. Bai. 2003. Composting technology of municipal solid waste with inoculating agent. *Huan Jing Xue*., 24(1): 157-60.

Zucconi, F. and M.de. Bestoldi. 1987. Compost specification for the production and characterization of compost from municipal solid waste, In: *Compost production, quality and the use*. (Eds.): M.de. Bestoldi, M.P. Ferranti, P.L., Hermite and F. Zucconi. Elsevier Applied Science Publishing Co., Inc., New York.

(Received for publication 20 June 2006)