We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

5

Composting Barrel for Sustainable Organic Waste Management in Bangladesh

Md. Azizul Moqsud
Institute of Lowland Technology, Saga University
Japan

1. Introduction

Inadequate collection and uncontrolled disposal of solid waste cause a serious health hazard to inhabitants and environment (Goyal et al., 2005). So, solid waste management has become a major environmental problem confronting urban areas in developing countries (Pfammtter & Schertenleib, 1996). Sujauddin et al. 2008 shows that household solid waste can be converted from burden to resource in developing countries. Like other developing countries, the major portion (about 84%) of the total solid waste is organic in Bangladesh (Moqsud et al., 2005a). In composting process, the organic portion of wastes is converted into stable end product of compost by bio-degradation (Hong, 2005; Rahman, 1993). As a result, the volume, weight and moisture content are reduced; the potential odor and the pathogens minimized, and nutrients are available for agricultural production (Witter, 1998; Shinha, 2001). The spread of diseases is minimized due to the destruction of some pathogens and parasites at elevated temperatures (Golueke, 1972, Vesiland & Rimer, 1981, Bhide & Sundarsan, 1983).

Like any tropical and subtropical regions, Bangladesh has got a large amount of rainfalls and considerable sunlight throughout the year. But it is important to maintain limited amount of moisture content in the compost process for effective composting operations.

At moisture content > 65 %, anaerobic condition and generation of bad odors as well as the depletion of the aerobic bacteria will be induced (Goyal et al., 2005). At moisture content < 40%, bacterial activity for decomposition is reduced (Rahman, 2004). Hence, it is necessary to design a special type of composting reactor to cope with the heavy rainfall in these regions for composting. The in-vessel composting reactor requires small area for installation and operation which is essential in the densely populated urban areas (Iyengar & Bhave, 2005). The problems of fly breeding, odor generation, and rodents are eliminated because of the enclosed aerobic design of the reactor (Chang, et al., 2006). The conventional steel barrel, (Figure 1 a), has not become popular as a composting reactor in Bangladesh as it can not skip over the bad odor generation and also takes a longer time to complete the composting process (Moqsud, 2004). So a modification is needed to overcome these drawbacks of the conventional composting barrel. This chapter presents an assessment of a modified steel barrel used as a composting reactor in Bangladesh, which is suitable, eco-friendly and effective in the typical sub-tropical monsoon climate. Field tests were performed in order to examine the effectiveness of the proposed in-vessel composting reactor. Benefit-cost ratio of this modified barrel composting plant is analyzed to ensure the financial viability.

Source: Waste Management, Book edited by: Er Sunil Kumar,
ISBN 978-953-7619-84-8, pp. 232, March 2010, INTECH, Croatia, downloaded from SCIYO.COM

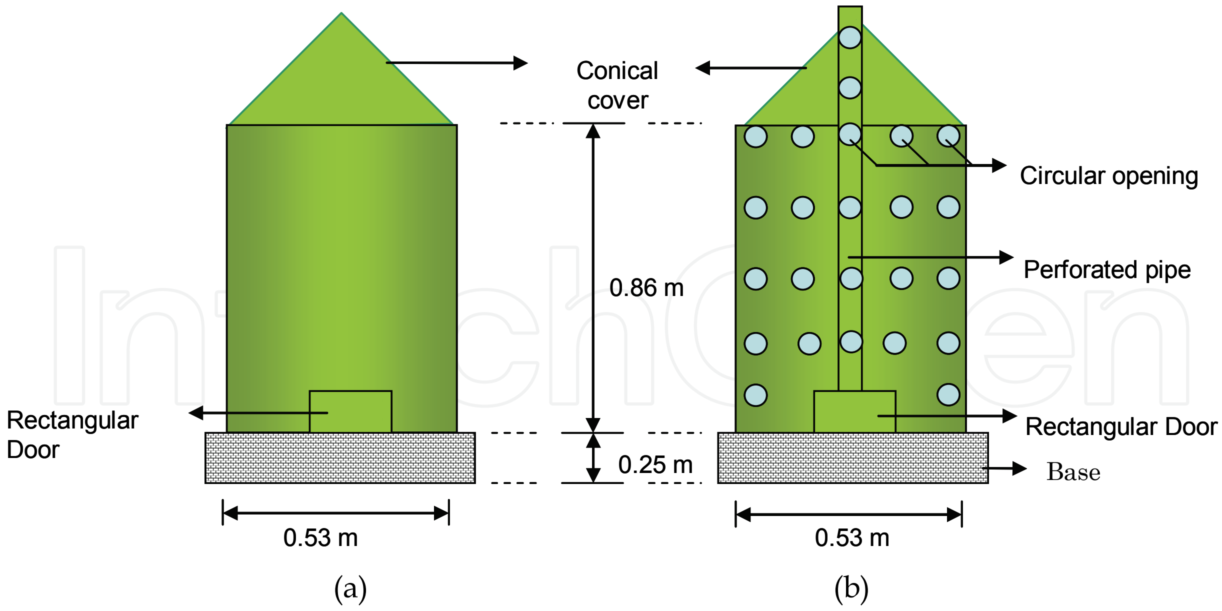

Fig. 1. Schematic of a composting barrel: (a) conventional type (b) modified type

2. Materials and methods

Figure 1 (b) shows the conventional as well as the proposed modified barrel used in this study. The modified barrel made of steel has a circular shape with a diameter of 0.53 m and height of 0.86 m. This barrel, generally available in the market to store oil and chemicals, was collected from the recycle shops and modified. The modification include:

- 0.0125 m diameter openings throughout the surroundings to ensure aerobic digestion inside the barrel

The conventional composting barrel has no opening in the surroundings and it has no perforated PVC pipe in the middle portion of the barrel which caused almost anaerobic condition inside the barrel, and consequently a bad odor generation during the composting operation (Moqsud, 2004). A conical-shaped cover made of steel is set at the top to avoid infiltration of rain water and to protect from excess heat and sunlight into the organic waste both in the conventional and the newly modified composting barrel. A 0.25 x 0.30 m rectangular opening with a hinge system was made at the bottom side for collecting the composting mass from the barrel both in the conventional and the proposed modified barrel (Figure 1). The both barrels were placed on a raised base to manage leachate resulting from the composting process (Moqsud, 2003). The outside of the barrel was painted green for aesthetic and corrosion protection. The average cost of each conventional and modified barrel was around US$25 and US$29, respectively. As the modification was done by using the recyclable PVC pipe and created the openings by using the hand drill machine the cost for modification is not so prominent. The organic waste was separated and collected from the source of generation in the study area. This biodegradable waste comprised of mainly kitchen garbage of raw vegetables and some cooked food waste. There were some biodegradable paper waste as well as fruits leftovers which were homogenized by cutting to approximately 0.05-0.08 m in length (Iyenger, Bhave, 2005; Moqsud, 2003). The large size organic wastes are pulverized into small pieces for quick composting process (Chang et al., 2006; Hong, 2005). Then these homogenized organic solid wastes were deposited in the composting barrel by removing the conical cover shown in Figure 1.

The basic physico-chemical properties of the organic wastes of the study area are summarized in Table 1.

Bulk density of the collected waste (kg/m^3)	300
Mean daily waste generation rate (kg/person/day)	0.27-0.38
Moisture content (%)	56 %
pH	7.2
C/N ratio	21

Table 1. The basic properties of the collected organic wastes in the study area

The change in waste volume, temperature, pH and moisture content were monitored during composting. After 45 days, the decomposing organic wastes were collected from the bottom rectangular opening of the barrel and layered in the sunlight for maturing for one week.

One of the main objectives of composting is to reduce the volume of the organic waste. Waste reduces volume from its initial value during the composting process. The total volume of the waste was calculated everyday by measuring the height of the waste and was compared with the previous day's volume.

Temperature is an important controlling parameter for proper composting operation (Sundberg, 2004). Variation in temperature was measured daily during composting by inserting thermometer (range 0^0 to 100^0 C) 0.1 m above from the bottom through the circular side-openings in the barrel. The reading was equilibrated for 5 minutes.

Measurements of pH in the compost were done by adding 0.010 kg of compost sample (taken from 0.10 m above the bottom of the barrel) in 0.0001 m^3 distilled water and mix thoroughly for several minutes (Sundberg, 2004; Jackson, 1973). The pH was measured by a digital pH meter (JENWAY -3051) by inserting the probe into the water-compost mix solution.

The variation of moisture content was determined by gravimetric procedure of weighing samples before and after the water is removed. The sample was weighted first to get its wet weight. Then it was dried for 24 hours in a 110ºC oven. After weighting the sample and subtracted the weight of the container the dry weight was achieved. The difference between the wet and dry weights was the weight of the water that the sample originally contained. By dividing this water weight by the wet weight gave the moisture content as a fraction. The following equation (1) was used for determining the moisture content of the compost.

$$\text{Moisture content (\%)} = \{(\text{wet weight-dry weight})/ \text{ wet weight}\} \times 100 \quad (1)$$

The nutrient content of the finished compost sample was determined by standard methods of chemical analysis (Goyal, 2005; Sundberg, 2004; Jackson, 1973). Nitrogen content was determined as total Nitrogen by Kjeldhal's method. Phosphorus content was measured as total Phosphate (acid digest) using vanadomolybdophosphoric acid method, and Potassium (acid digest) from various compost samples were determined using flame photometry (Systronics) fitted with element specific filters.

3. Results and discussion

The variation of volume change of organic solid waste is shown in Figure 2. It is seen that after composting was completed in about 35-40 days, the volume of the organic waste

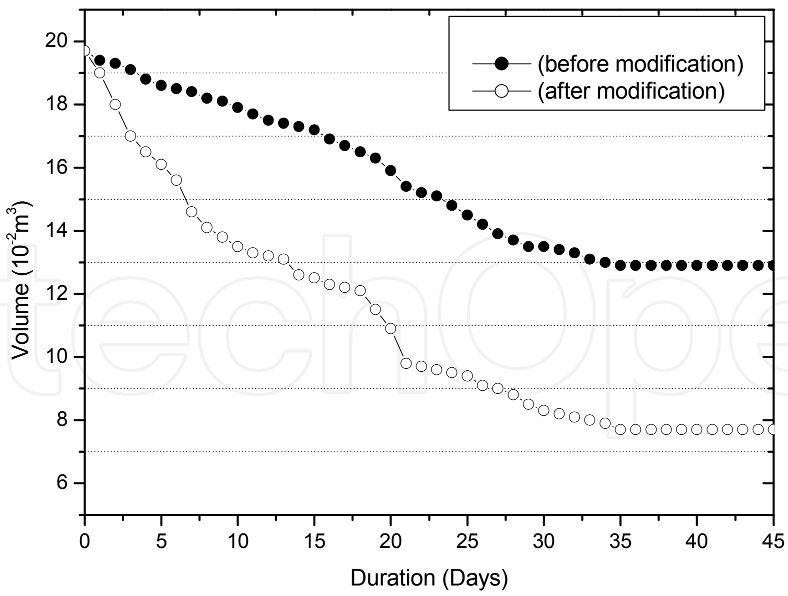

Fig. 2. Variation of waste volume during composting before and after the modification of the barrel

became 50-70 % of the original volume. The volume reduction was quicker, when the modified composting barrel was used.

After 4 weeks, the volume became 70% and 50% less of its original volume for the case of after and before modification, respectively. This is so as the aerobic condition was maintained in the middle as well as the surroundings of the new modified barrel. Microorganisms reproduced very rapidly at early stage of composting due to the abundance of easily-degradable organic matter. For this, the rate of volume reduction is usually fast (Zheng, 2004).

Figure 2 shows that during the initial days (3-7 days), the rate of volume reduction was quick, while after 14 days it became slow and almost constant after 21 days and 35 days in the modified and conventional barrel, respectively. This observation is mainly due to the quantity of nutrients for the bacteria were depleted, and thereby the rate of decomposition became slower in the later stage. In the case of conventional barrel, the volume of the organic waste reduces slowly. This is due to the lack of aerobic condition inside the barrel and the presence of excess amount of moisture content (Figure 4).

The temperature variation during composting is illustrated in Figure 3. It shows that temperature rises from the initial day to the maximum at 21 days and then it begins to fall and became constant after 37 days.

The broad range of optimum temperatures for composting process is from 45 to 65^{0}C (Sundberg, 2004).This allows a large variety of micro-organisms to participate in the process. However, if the peak temperature is more than 72^{o}C, some useful bacteria, which are responsible for the aerobic decomposition, will die (Ahmad, 2000).

The temperatures generated by the mesophilic and thermophilic bacterial activity lead to the destruction of diseases causing microorganisms. During the initial days, the increased temperature in the composting barrel was mainly caused by the more exothermic reactions associated with the respiratory metabolism of the microorganisms involved in the composting operation (Sundberg, 2004; Tchobanglous, 1977). But at that time, the moisture content is high, which prevents to reach at the peak temperature. Again, it is found that after the modified composting barrel generated a peak temperature of 69ºC in contrast to 60ºC before modification.

In case of the conventional barrel, moisture content is generally high as there were not much available openings to remove or evaporate the moisture of the leachate and thereby lowering the temperature inside the reactor. The durations of the optimum temperature for composting are about 22 days and 28 days for the case of before modification and after modification of the barrel, respectively. The longer length for the modified one would be favorite to the composting process, even though it has a drawbacks in terms of temperature >65ºC.

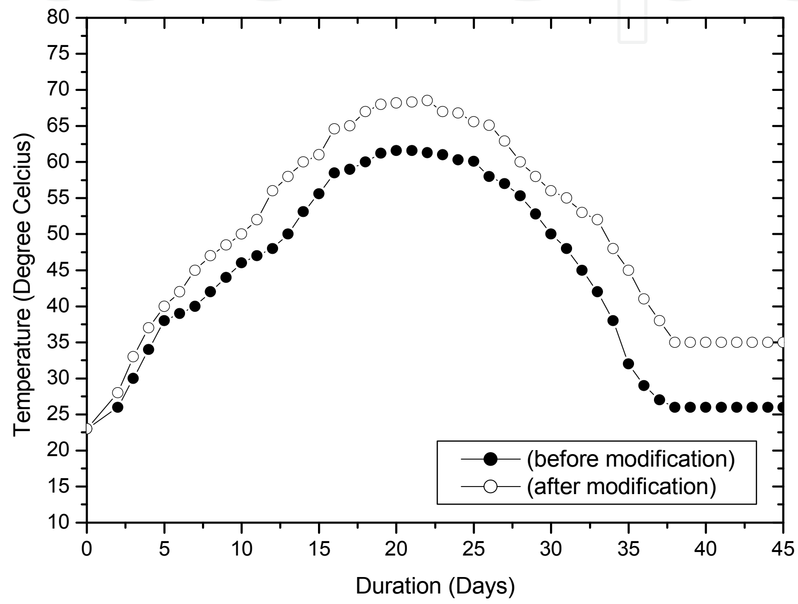

Fig. 3. Variation of temperature during composting before and after modification of the barrel

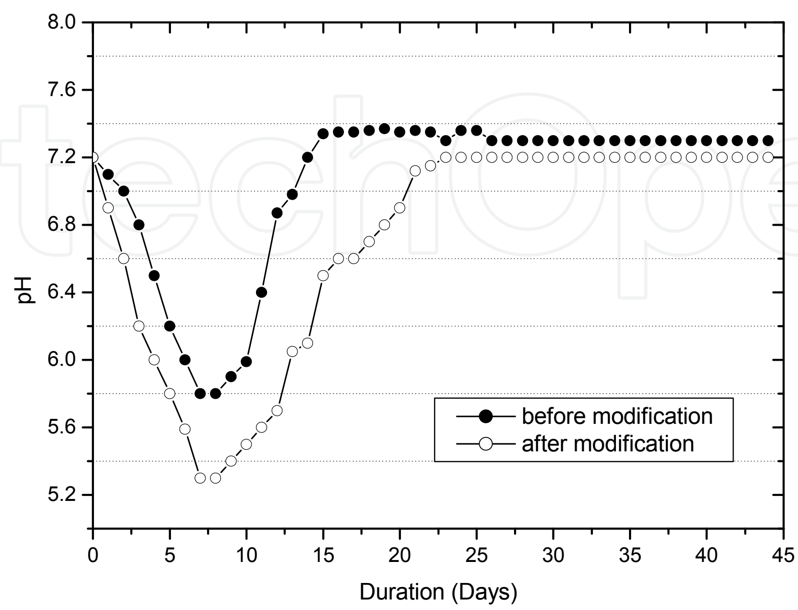

Fig. 4. Variation of pH during the composting before and after the modification of the barrel

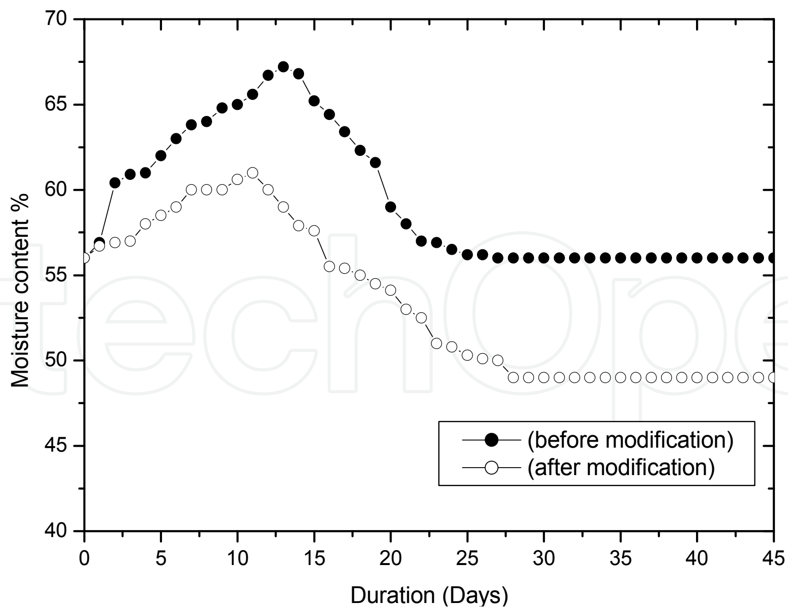

Fig. 5. Variation of moisture content during composting before and after modification of the barrel

The variation of pH with time during the composting process is plotted in Figure 4. This variation directly indicates the extent of decomposition within the compost mass. The optimum pH range for most bacteria is between 6.0 and 7.5 (Parks et al., 1988). During the initial period (first 2 to 7 days), pH decreased to 6.0 or less during the initial phase of temperature rise.

The duration of pH > 6.0 for the case of modified barrel is longer than the conventional barrel. Therefore, it may imply that modified barrel has higher performance. From day 12, pH value of the compost began to rise to about 7.4. Initially, the microorganisms reproduced very rapidly because there was large portion of easily-degradable organic matter in the wastes. With the activity of the microorganisms, considerable amount of organic acids (acetic acid, butyric acid etc.) were produced, and consequently, the pH value of the compost decreased (Li & Zhang, 2000). With volatization of the organic acids, the pH value of the compost increased as more decomposition of organic matter had occurred (Fang & Wong, 1999).

Moisture content was determined by weight loss of compost samples, which were oven dried at 110 ºC for 24 h (Dresboll & Kristensen, 2005). At moisture levels above 68 %, water begins to fill the interstices between the particles of the wastes, reducing the interstitial oxygen and causing anaerobic conditions with a resultant offensive odor (Rahman, 1993; Tachobanglous, 1977). When the moisture contents drop much below 40%, the composting process becomes slow (Goyal et al, 2005). Figure 5 shows the variation of moisture content with duration of composting.The maximum moisture content reached nearly 67% before modification and about 60% after the modification of the barrel. So, by ensuring the aerobic condition in the middle and the surroundings of the barrel, the peak moisture content can be maintained at the optimum level for proper composting. As in the initial stage (5-12 days), the bacterial activities and the decomposition of organic waste were more significant. The values of moisture content were also high in that period and it decreased after some days (15-25 days) as the bacterial activities decreased at that time. However, the moisture content

in the conventional barrel is higher than the desired moisture content due to lack of aeration in all stages of the composting operation than that of the modified barrel.
The result of chemical analysis of compost sample is presented in Figure 6.

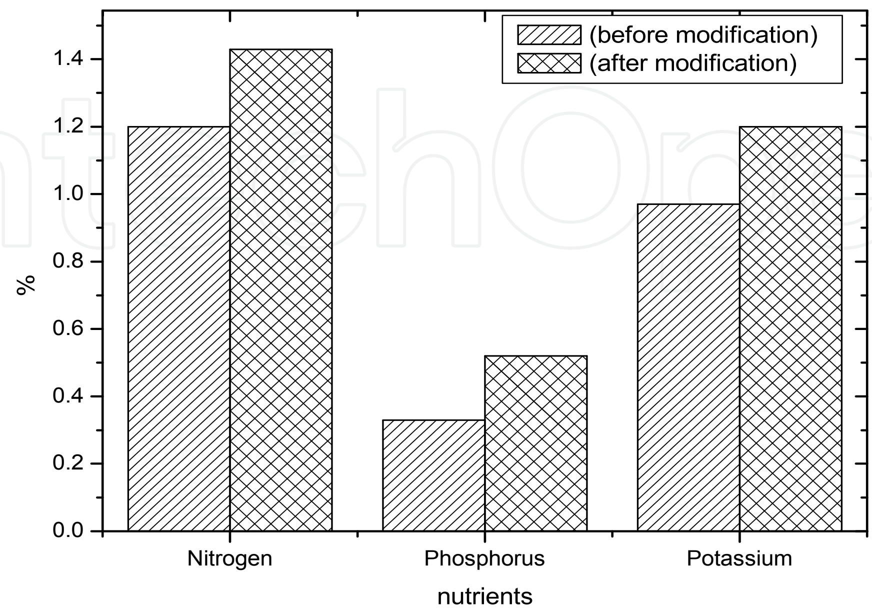

Fig. 6. Quantity of different nutrients present in the compost sample

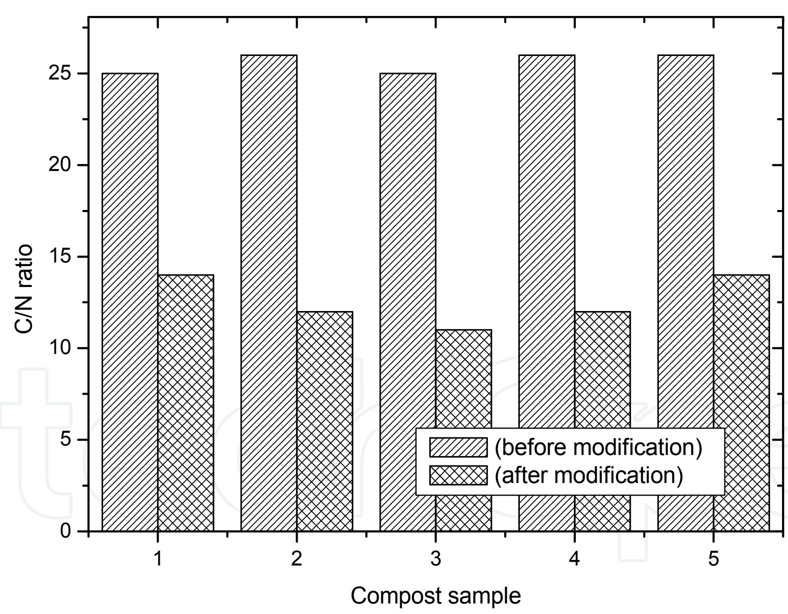

Fig. 7. Carbon- Nitrogen ratio of ready compost samples

As the ultimate goal of the composting of organic solid waste is to use the compost as a soil conditioner and also as a fertilizer in the agricultural field, it is important to examine the values of different nutrients. All chemical analyses were performed according to the standard methods of soil and compost analysis (Goyal, 2005; Sundberg, 2004; Jackson, 1973). It is observed that the values of nutrients i.e. Nitrogen, Phosphorus and Potassium (NPK) were very much similar as reported in other countries (Asija et al., 1984). The NPK values

were lower than the ideal values (N=1.5%, P=1.2%, K=0.8%) when the conventional barrel was used because of the lack of aeration during the composting (Verma et al., 1999).
Decomposition of organic matter is brought about by microorganisms that use the carbon as a source of energy and nitrogen for building cell structure. More carbon than nitrogen is needed. If the excess of carbon is too great, decomposition decreases when the nitrogen is used up and some of the organisms die (Nakasaki et al., 2005, Polprasert, 1996). The stored nitrogen is then used by other organisms to form new cell material. Figure 7 shows that the carbon-nitrogen (C/N) ratio of the ready compost varies from 11 to 14 in different samples in the study area after the modification. In the case of conventional barrel reactor the C/N ratio was found to be higher (above 24) than the recommended values (12-16). The compost from the conventional barrel would not be suitable for agricultural land application since the excess carbon would tend to utilize nitrogen in the soil to build cell protoplasm, consequently resulting in loss of nitrogen in the soil on which it would be applied.

4. Financial assessment of modified barrel composting project

The generation of solid waste was found to increase almost linearly with increasing of per capita income. Figure 8 shows the variation of the waste generation rate with the variation of per capita (person) income of selected low and middle-income family in the study area. When the per capita income per month is US$6-8, per capita waste generation is about 0.27 kg/day and when per capita income per month is US$67-75, per capita waste generation is about 0.38 kg/day.
Three different revenues were assessed from the modified composting barrel plant. These are

- fees charged by the collection scheme to the service beneficiaries (households) on a monthly basis (approximately US$0.3).
- revenues from the sale of compost (US$0.08 /kg) and revenues from the sale of recyclable materials like hard plastics, card board, glass and metals.

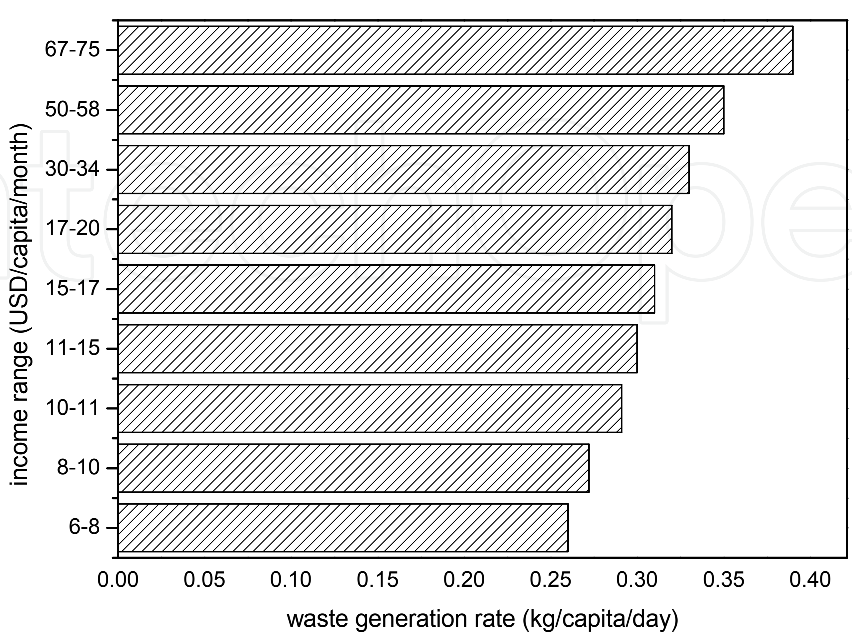

Fig. 8. Variation of per capita waste generation rate with respect to per capita income

Item *Cost*	*US$/year*	*Item* *Revenue*	*US$/year*
Depreciation cost for collection Investment (life time 5 years)	2422	Collection fees	3000
		Compost sales	12458
Operation cost for collection and composting	10152	Recyclables	333
Total	12574	Total	15788

Table 2. Yearly costs and revenues of modified composting barrel plant (including collection)

Table 2 gives the summary of costs and revenues for a modified composting plant of capacity of 1.865 tons/day on a yearly basis. It is seen that the plant is financially viable when operating at 1.865 tons/day. It is evident that the revenues from the collection fees are partly cross-subsidizing the composting activities. Hence, it seems advisable to combine composting activities with neighborhood waste collection to ensure a viable operation of the scheme. An additional advantage of a combination of waste collection and composting is the direct influence on improving waste composition for composting in the collection area, as continuous contact with the customers is available and appropriate information may be disseminated (e.g. promoting source separation and separate collection). The depreciation was calculated using a lifetime of 5 years and interest rate of 15%. The cost items comprise barrel modification plant set up, salaries and uniforms of the employees both for collection and in the composting plant, maintenance of collection vehicles, and expenses for electricity and water. Total revenues from the sale of the recyclables such as hard plastics, cardboards, glass and metal are US$333. The benefit-cost ratio of the modified composting barrel plant is > 1. Financial analysis confirms the results of other investigations on decentralized urban composting plants, showing that small-scale plants struggle with their economic viability if all costs have to be covered by the plant revenues (Lardinois & Furedy, 1999). However, our results show that a plant of capacity 1.865 ton/day may be viable in the study area where the rent for land is relatively smaller than the capital city as land acquisition in urban areas is always one financial key obstacle for initiating a composting plant. The decentralized waste collection and composting activity relieves a certain burden from municipal budgets in the study area (Zurbrugg et al., 2005). The municipal waste transportation and landfill costs can be reduced approximately by US$9500 per year. This estimate takes into account that the composting plant reduces the amount of waste, which needs to be transported by municipal trucks as well the reduction of the municipal expenses for its final disposal. With or without municipal support, any composting plant should however focus on long-term financial feasibility where operational costs are covered by revenues. Therefore, marketing strategies and the development of a market for compost are crucial for the long term success of a composting plant (Zurbrugg et al., 2005).

5. Conclusions

Reduction of waste volume was faster in the modified composting barrel than the conventional barrel reactor. The volume becomes 50% and 70% of its original volume before and after modification of the composting barrel, respectively after 4 weeks. The barrel composting was operated in the mesophilic and thermophilic temperature bend, which was very effective for proper composting operation. The quality of compost in terms of C/N ratio is better in the modified composting barrel than the conventional barrel. Nutrient concentrations of compost, produced in the modified composting barrel, were also satisfactory. The biochemical quality of the compost produced in the modified composting barrel was found suitable. The benefit-cost ratio for large scale modified composting barrel plants is more than 1. Thus, the modified composting barrel can be an eco-friendly, efficient and a sustainable solution of organic waste management alternative in Bangladesh.

6. References

Ahmed, M. F., Rahman, M. M., 2000. Water Supply and Sanitation: Rural and low income urban communities, ITN-Bangladesh, Center for Water Supply and Waste Management, BUET, Dhaka, Bangladesh.

ASija, A. K., Pareek, R. P., Singhania, R. A., Singh, S., 1984. Effect of method of preparation and enrichment on the quality of manure. Journal of Indian Society of Soil Sci. 32, 323-329.

Bhide, A. D., Sundersan B. B., 1983. Solid waste management in developing countries, Indian National Scientific Documentation Center, New Delhi.

Chang, I. J.; Tsai, J. J.; Wu, H. K., 2006. Thermophilic composting of food waste. Bioresource Technol. 97, 116-122.

Dresboll, B. D., Kristensen, K. T., 2005. Delayed nutrient application affects mineralization rate during composting of plant residues. Bioresource Technol. 96, 1093-1101.

Fang, M., Wong, J. W. C., 1999. Effect of lime amendment on availability of heavy metals and maturation in sewage sludge composting. Journal of Environmental Pollution. 106(1), 83-89.

Golueke, C. G., 1972. Biological Reclamation of Solid Wastes. Rodale Press, Emmanus, USA.

Gantzer C., P. Gaspard, L. Galvez, A. Huyard, N. Dumouthier, J. Schwartzbrod. 2001. Monitoring of bacterial and parasitological contamination during various treatment of sludge. Wat. Res. 35(16), 3763-3770.

Goyal, S., Dhull, S. K. and Kapoor, K. K., 2005. Chemical and biological changes during composting of different organic waste and assessment of compost maturity. Bioresource Technology, 96, 1584-1591.

Hong, J. H., Park, K. J., 2005. Compost biofiltration of ammonia gas from bin composting. Bioresource Technology, 96, 741-745.

Iyengar, R. S., Bhave, P.P., 2006. In-Vessel composting of household wastes. Waste Management. 26, 1070–1080.

Jackson, M. L., 1973. Chemical analysis of soil. McGraw Hill Publications Company.

Li, G. X., Zhang, F. S., 2000. Solid waste composting and production of fertilizer. Chinese Chemical Industry Press, Beijing, P R China.

Moqsud, M. A., 2003. A study on composting of solid waste. A Thesis of Masters of Science in Environmental Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

Moqsud, M. A; Rahman, M. H., 2004. Composting of Kitchen garbage in Bangladesh. Proceedings of the sixth international summer symposium, Japan Society of Civil Engineering, Saitama, Japan, p. 413-416.

Moqsud, M.A; Rahman, M.H., 2005. Biochemical quality of compost from kitchen garbage of Bangladesh. Proceedings of the 20th International conference on Solid Waste Technology and Management, Philadelphia, p. 440-447, USA.

Moqsud, M.A, Rahman, M.H, Hayashi, S., Du, Y.J., 2005a. An assessment of modified composting barrel for sustainable waste management in tropical regions. 4th International conference on Environmental Informatics, July 26-28, Xiamen, China. p. 130-136.

Nakasaki, K.; Yaguchi, H., Sasaki, Y., Kubota, H., 1993. Effects of pH control on composting of garbage. Waste management and Research. 11(2), 117-125.

Pfammatter R., Schertenleib R., 1996. Non-governmental refuse collection in low-income urban areas. Lessons learned from selected in Asia, Africa and Latin America. SANDEC Report No.1/96.Water and sanitation in developing countries EAWAG/SANDEC, Duebendrof , Switzerland.

Polprasert, C., 1996. Organic waste recycling-technology and management. Wiley, Chichester, west Sussex, England.

Rahman, M. H., 1993. Recycling of solid waste in Bangladesh. The International Journal of Environmental Education & Information.UK, 12(4), 337-342.

Rahman, M. H., 2004. Composting of Solid waste in Bangladesh. Proceedings of the 19th international conference on Solid Waste Technology and Management, Philadelphia, USA p 45-49.

Sinha, A. H. M. M. and Enayetullah, I., 2001. Solid waste management with Resource recovery options. Proceeding of the International Conference on Professional Development Program 4, Center for Environmental and resource Management, Dhaka, 2-4 February, p. 32-37.

Sujauddin, M., Huda S. M. S, Hoque, R., 2008. Household solid waste characteristics and management in Chittagong, Bangladesh. Waste Management 28, 1688-1695.

Sundberg, C., Smars, S., 2004. Low pH as an inhibiting factor in the transition from mesophilic to thermophilic phase in composting. Bioresource Technol. 96, 746-752.

Tchobanoglous, G., 1977. Solid Waste: Engineering Principles and Management Issue, McGraw Hill Publications Company, New York.

Verma, L. N., Rawat, A. K., Rathore, G. S., 1999. Composting process as influenced by the method of aeration. Journal of Indian Society of soil sci. 47 (2), 368-371.

Vesilind, P. A., Rimer, A. E., 1981. Unit operations in resource recovery engineering, Prentice-Hall, Inc, New Jercy.

Witter, E., Lopeaz-Real, J. M., 1988. Nitrogen losses during the composting of sewage sludge and the effectiveness of clay soil, zeolite and compost in adsorbing the volatilized ammonia. Biological Wastes 23, 279-294.

Zheng, G. D., Chen, T. B., 2004. Dynamic of Lead specialization in sewage sludge composting. Journal of Water Sci. and Technol. 50(9), 75-82.

Zurbrugg, C., Drescher, S., Rytz, I., Sinha, A. M., Enayettullah, I., 2005. Decentralized composting in Bangladesh, a win-win situation for all stakeholders. Resources conservation and recycling. 43 , 281-292

Waste Management
Edited by Er Sunil Kumar

ISBN 978-953-7619-84-8
Hard cover, 232 pages
Publisher InTech
Published online 01, March, 2010
Published in print edition March, 2010

Solid Waste Management is one of the essential obligatory functions of the Urban Local Bodies/Municipal Corporation. This service is falling too short of the desired level of efficiency and satisfaction resulting in problems of health, sanitation and environmental degradation. Due to lack of serious efforts by town/city authorities, garbage and its management has become a tenacious problem. Moreover, unsafe disposal of garbage and wastewater, coupled with poor hygiene, is creating opportunities for transmission of diseases. Solutions to problems of waste management are available. However, a general lack of awareness of the impact of unattended waste on people's health and lives, and the widespread perception that the solutions are not affordable have made communities and local authorities apathetic towards the problems. The aim of this Book is to bring together experiences reported from different geographical regions and local contexts. It consolidates the experiences of the experts from different geographical locations viz., Japan, Portugal, Columbia, Greece, India, Brazil, Chile, Australia and others.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821