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Mitigating solid waste accumulation through composting process in Jaffna Peninsula, Sri Lanka

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Disposal of solid waste is a major environmental problem globally, at present. Solid waste accumulation in the environment is contentiously increased because of the population development and globalization. In Jaffna, disposal of municipal solid waste has become a serious problem and high portion of solid waste comes from domestic sector of the Jaffna peninsula. Hence, an attempt was taken to justify the nature of waste collection annually and its composition thus to develop centrally aerated compost digester with all facilities to convert the decomposable fraction of house hold waste into good quality compost with an intention of mitigating waste accumulation in the environment. The composition ratio of the waste from the municipal council was 79% of organic compounds, 11% of paper, 2% of plastic, 1% of glass, 1% of metal and 6% of others (sand, small stones) and there were no significant differences in collected waste among months of a year and in between years. Designed compost digester was compared with peripherally aerated digester and evaluated for its efficiency by fitting a model for oxygen consumption during decomposing process and maturity was determined by sieving through 4mm sieve. Maximum oxygen consumption rate in mg/hr per gram of solid waste in the digester was recorded for centrally aerated with water spraying unit, and peripherally aerated as 5.11 mg/hr/g, and 3.89 mg/hr/g respectively. This higher oxygen consumption rate in designed digester was due to the higher aerobic decomposition by the aerobic microbes inside the digester and 80% of decomposition was achieved by 35 days and 65 days for centrally aerated compost digester and peripherally aerated compost digester respectively. Therefore, this is the best option to dispose Municipal solid waste in an eco-friendly manner in Jaffna peninsula.

Introduction

The developing countries have now begun to acknowledge the environmental and public health risks associated with uncontrolled dumping of wastes which has occurred mainly due to inadequacy in the capacity building of personnel associated with the municipal solid waste and lack of guidelines for technical aspects of solid waste management. About 25% of the population in

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Sri Lanka lives in urban environment which accounts only 0.5% of the total area (Jayawardhana *et al*., 2000). In Sri Lanka, the quantity of solid waste has increased over the years with changes in consumption patterns. Waste generation per capita per day on the average was 0.85 kg in Colombo municipal council, 0.75 kg in other municipal council, 0.65 kg in other urban council and 0.40 kg in Piradeshiya sabhas. In Sri Lanka, daily waste collection by local authorities is estimated at 2683 tons. However, total municipal solid waste generated in Sri Lanka is around 6400 tons (United States Environmental Protection Authority, 1994). In Jaffna municipal council, 78,781 inhabitants (Statistical hand book, 2007) generating 9702 tons of solid waste per year (Jaffna Municipal Council (JMC) Report, 2007). In Jaffna, the collection and removal of municipal solid waste has become a serious problem. Local government authorities have been adopting various measures to mitigate this problem. Premachandra (2006) estimated that about 2900 tons of municipal solid waste is collected per day throughout the country among this collection about 60% of collection is from western province of Sri Lanka. The accumulation of the solid waste materials in the environment could be reduced by introducing appropriate strategy in the initial point of waste generation. Domestic sector is the prime source for the generated waste within the JMC limit (JMC Report, 2007). JMC has already introduced compost bin to promote home level composting but that bin is having some design defects such as poor aeration gradient, odor generation, no leacheate collection system and no water circulation unit to convert house hold waste into home compost. Hence, an attempt has been taken to develop centrally aerated compost digester for producing compost at home level with the intention of mitigating waste accumulation in the environment.

Materials and methods

Background of the study

Public health engineering division of the JMC is responsible for the collection and disposal of garbage generated within its limit. The waste is generated from homes, streets and in other commercial, industrial, agricultural operations within the municipal council limit. Domestic waste mainly consists of kitchen waste, rejected food. So, these decomposable waste materials could be converted into compost by compost digester. This is possible only when waste generation is stable throughout the year. Therefore, an attempt was made to justify the stability of waste collection within JMC limit and to design centrally aerated compost digester for mitigating waste accumulation in the environment through composting process.

Location of the study

The JMC is the biggest organization and heart of the Jaffna district. There are 78,781 people living in the 20.2 km^2 in the JMC (statistical information, 2007). In addition to population, hotels, markets, teaching hospital and slaughter houses are also contributing for the waste generation. The JMC topography is almost flat and there is no any steep gradient within the limit. At present, refuse is collected daily from house to house by hand cards from seven collecting zones and deposited at 42 temporary collecting points. At present tractors and trailers are collecting the garbage from these points. The solid waste is transported to dumping yards within the city which are low lying areas. Kakaitheevu is one of the biggest dump sites and a private dumpsite at Vannarpannai is called as Chippitharai. At Kalundai dumpsite (50 acre) toilet waste, poultry litter and hospital wastes are disposed. Highly contaminated hazardous hospital waste is burnt in the large pits at Kalundai dumpsite to avoid environmental contamination (JMC report, 2007). Toilet waste and Slaughter house waste materials are buried in the soil at the dumpsite. But these two ways are not good because there are habitats around the area. The dumping of solid waste is causing health problems and polluting the environment, influencing climate changes and global warming. Now the Kakaitheevu dumpsite is facing trouble because that area has now been occupied by Colonies. Table 1 showed the division of collection points for easy management. Normal solid waste dumping is creating the environmental pollution as such solid waste have to be collected and dumped in a systematic manner to keep the city clean. Several International Non Governmental Organizations carried out the public projects to motivate the public in such a manner that they have introduced three colour bins for the segregation of the solid waste at collecting points. This project was not success because of the war situation .Further, the compost making was carried out at kaakaitheevu for two years but this was not functioning due to the war situation. All the wastes generated from the temporary collecting points are transferred to three main collecting points such as Vannarpannai, Nallur, and Ariyalai from where the waste is transferred to Kakaitheevu and Kalundai dumpsites which belongs to Sandilipai A.G.S Division. (JMC report, 2007). There is no special separation of waste materials according to the nature of waste. Only, the approach of mixed municipal solid waste collection is carried out. At present generation of waste materials was done according to two categories such as combustible (green leaves, paper) and Non combustible (sand, plastic, glass, metal).

Table 1. Zonalized collecting points.

	Zone	Temporary collecting points
1	Gurunagar	Main street, Veembadi veethi, Achukooda veethi, St.peeter's lane, Aainth maadi, Fourth cross street junction
2	Bazaar	Kannathedi lane, Rasavin toodam, Kinnar lane, Stanly road.
3	Paasajoor	Eechamodai lane, Veethanaiyar lane, Paandiyanyhlvu, Kuruso road.
4	Ariyalai	Moothavinaijakar junction, Saathitijar road, Nayanmaar road.
5	Vannar pannai	Oodumadam veethi, Sivakutunathar veethi, Saapapathi veethi, Saavakaddu, Thalaijali lane.
6	Naavanthurai	B.A.Nambi lane, Navanthurai market, Jina road, Seeni vasam road, Kaacherei lane, Kacherei south lane, Kaadukanthor lane.
7	Nallur	Nallur public toilet, Rasa pathi junction, Sadanather road, Sankilian road, Sivan new road, Pallam veethi, Sedthiteru.

Data collection

Total waste generated from JMC from 2005 to 2008 in monthly basis was collected as secondary data. The real value of the period 2008 December was not marked because of the effect of "Nisha" Cyclone and the average value from the other years was used to indicate December 2008. Discussion was made with Officers to gather the information about transport system used and the difficulties faced during the generation period.

Sampling and separation

Separation was done manually by visual inspection of waste with the help of fork, mammoty, baskets & steel plates. Sampling was done perfectly by collecting random samples from every three collecting points Nallur, Ariyalai, and Vanarpannai located at Jaffna municipal council limit. Those samples were mixed thoroughly and the composition of 10 kg of waste was analyzed. This was done in several times. Finally the composition of glass, plastic, paper, metal, organic waste and others were estimated as percentage of weight basis.

Design of the compost digester

Compost digester was designed with central aeration technology to promote house hold composting from the kitchen waste to avoid waste accumulation in the environment. The following materials 50 lit plastic bucket, PVC pipes of ¾ inch diameter, Reducing socket, End cap, Electric driller, Plastic pipes, Hand sucker and Steel round and stand were used in designing of compost digester**.**

Design procedure of compost digester

The plate 1, 2, 3 showed the designed compost digester and the internal arrangements of the bin. The 50 litter of bucket was taken. Bottom center of the plastic bucket was holed (¾ inch diameter) to insert the pipe for the central aeration system. The holes were made spirally on the surface of the central pipe (0.5 cm). The plastic pipe was taken and it was fitted by reverting it on the inner surface of the bucket with the evenly spaced holes (0.4 cm diameter). The same size holes were made by power driller. The extruded potion was fitted at the bottom to promote the entry of the air current into the bin. One end of the plastic pipe jointed internally was coupled with hand sucker to spray water if necessary (plate 2). Stand was made with steel round (36 cm diameter) and it was mounted on both sided rotating threaten rod. This whole set up was mounted on a stand which made by the steel pipes. Stand is mainly for agitation and easy removal of the inner compost.

Plate 1: Designed compost digester.

Plate 2: Internal arrangements.

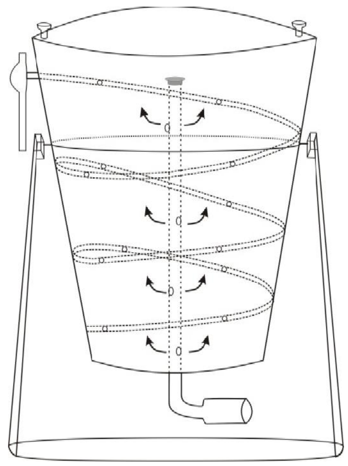

Plate 3: Line diagram of compost digester.

Experimental set up

Two same capacity plastic buckets were taken. One bucket was developed as compost digester with central aeration technology and water circulation unit. Other bucket was also developed as the compost bin with peripheral aeration technology introduced by JMC. Uniformly mixed household waste of 20 kg with higher percentage of organic fraction (89 %) was placed in each compost digester with compost starter.

Placement of wastes and maintenance of waste digesters

Compost starter (dry cow dung: fresh cow dung is 3:1) of 1 kg was placed at the bottom of the compost digesters to initiate the composting process. Three liters of water were sprayed on the waste material on daily basis.

Measurement of compost facilitating parameters

Temperature was measured at three points (top, middle, bottom) of compost digesters by standard soil thermometer and they were averaged to get real temperature profile. This temperature was correlated with oxygen consumption rate (mg/hr/g of solid waste) to check the activity of aerobic micro organisms. There has been considerable amount of work on measuring oxygen consumption rate. The oxygen consumption rate, y, in mg/h per g of volatile solids, is related to the temperature, T°C, by the equation of the form $y = a.\ 10^{kT}$ Schulze, calculated the constants to be a = 0.1 and k = 0.028 within the temperature range of 20 to 70°C. Compost maturity was determined by sieving through 4mm sieve. After ten days the samples were taken in every seven days interval from three points (top, middle, bottom) of composting mass. When the residue is lesser than 2% through 4 mm sieve, it can be concluded that the compost has reached its maturity.

Rating of decomposition

Based on the particle size though 4 mm sieve, the compost maturity was determined.Color of the final samples (humus color) was also compared for all the treatment combination and ranked.

Results and discussion

The total waste generated from JMC limit was shown in Fig. 1. There was no significant different within the years in collection of waste. But in 2005, the waste was collected effectively because amount of around 2,000 tones waste was collected more than other three years. Technical efficiency could be improved to generate waste in other years. The number of collecting points had been reduced from 53 to 42 at the Jaffna municipal council limited to minimize the health hazards and environmental pollution. This is due to the scavengers working on the waste heaps and placing the dirt inside the wells and also the heaped waste disturbs the publicity of the town. Therefore, to avoid this trouble, the waste collecting points were reduced and deposited wastes are transported immediately to the dumpsites. Survey revealed that the waste management problem is aggravated due to high density population and limited per capita land area issues. Available tractors and trailers for transportation, availability of man power and lack of technical staff in this field were identified as reasons for low efficiency. The monthly variation of waste collection in JMC was shown in Fig. 2. There was no significant variation among monthly waste generation. Normally the collection of waste could be revealed higher at April and May because at that time the trees would shutter their leaves. Also there is a higher collection of waste at October, November and December because of the tree cuttings from the houses. Implementation of the stable waste management system in the JMC is possible since there was no significant difference between the collected wastes among the years and within the months of the years. The everage composition of waste collected from the JMC was shown in Fig. 3. Organic fraction around 79% was observed in all samplings in 2008. Since the organic fraction was higher in the collected waste and there was no any significant difference among the months, stable composting is suitable economic method for the waste management. The organic fraction was 83% during 1999 (Prabharan, 1999) and it was 80% during 2002 and at present in 2008 it was 79% which indicates the reduction of organic fraction in JMC. Recycling of paper, glass, polythene is not practiced in Jaffna. There is no market for collected material. This type of materials are usually burnt and buried.

In Jaffna, combined collection at mixed solid waste is practiced and the waste has separated manually. In case of Jaffna municipal waste, comparatively low amount of non – combustibles are visible. Motivation of the people to put refuse in separate bins will improve the system more. Since the Jaffna municipal solid waste is having higher traction of bio degradable organic waste, this waste is suitable for stable compositing. Earlier composting studies revealed that the low ratio of carbon to nitrogen and high percentage of sand.

Hence the enrichment of nitrogen source is imperative to increase the ratio of carbon to nitrogen in compost.

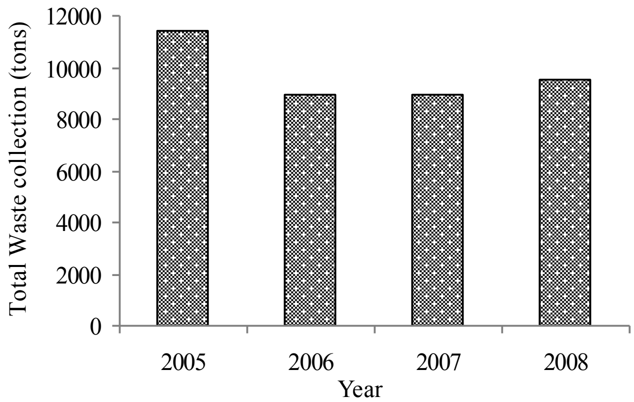

Fig. 1. Total waste collection in JMC from 2005 -2008 in tons (JMC report 2008).

Design evaluation of compost digester

The efficiency of the compost digester was evaluated by fitting a temperature model in relation oxygen consumption that is direly correlated with microbial activity. There has been considerable amount of work on measuring oxygen consumption rate. Schulze, 1962 postulated that the oxygen consumption rate, y, in mg/h per g of solids, is related to the temperature, T^oC, by the equation of the form $y = a.\ 10^{kT}$ Schulze, calculated the constants to be a = 0.1 and k = 0.028 within the temperature range of 20 to 70^oC. These values were obtained from runs on an intermittently rotated drum containing about 7.3 kg of fresh ground garbage at 50 to 60% moisture content. The other researchers obtained values of oxygen consumption rates for different phases of composting. The consumption appears to increase logarithmically with temperature to a maximum within the range $45\text{-}55^oC$ and then falls, also logarithmically, as the thermophilic fungi are killed off (maturation phase) and spore-forming bacteria and actinomycetes assume the dominant role (Basnayake, 2001).

The oxygen consumption pattern of three different digesters namely centrally aerated with water spraying unit (a), and peripherally aerated compost digesters (b) was shown in Fig. 4. Maximum oxygen consumption rates in mg/hr per g of solid waste in the digester, as calculated by the equation for centrally aerated with water spraying unit and peripherally aerated as 5.11 mg/hr/g, and 3.89 mg/hr/g respectively. Higher oxygen consumption rate that is 5.11 mg/hr/g was recorded for the digester which is centrally aerated with water spraying unit. This higher oxygen consumption rate may be due to the higher aerobic decomposition by the aerobic microbes inside the digester. Therefore the centrally aerated compost digester is good for home composting than peripherally aerated compost digester since it had produced good quality compost in 35 - 40 days whereas peripherally aerated compost digester produced compost in 65-70 day. Higher oxygen consumption was recorded within first 10 days of the composting process this may be due to the activity of the aerobic bacteria which faster aerobic decomposition.

JMC has introduced peripherally aerated compost digester to promote home composting in the Jaffna peninsula but this attempt was not successful due to its defects such as odor emission, low decomposition rate, dropping of leachate through bottom holes and no water circulation unit. But the designed centrally aerated compost digester over comes above short comings in the peripherally aerated digester. Centrally aerated compost digester is the enclosed unit with the peripheral water circulation system and it has leachate collection unit at the bottom and having the stand therefore it can be moved according to our convenience. Therefore this enclosed compost digester is best for home composting.

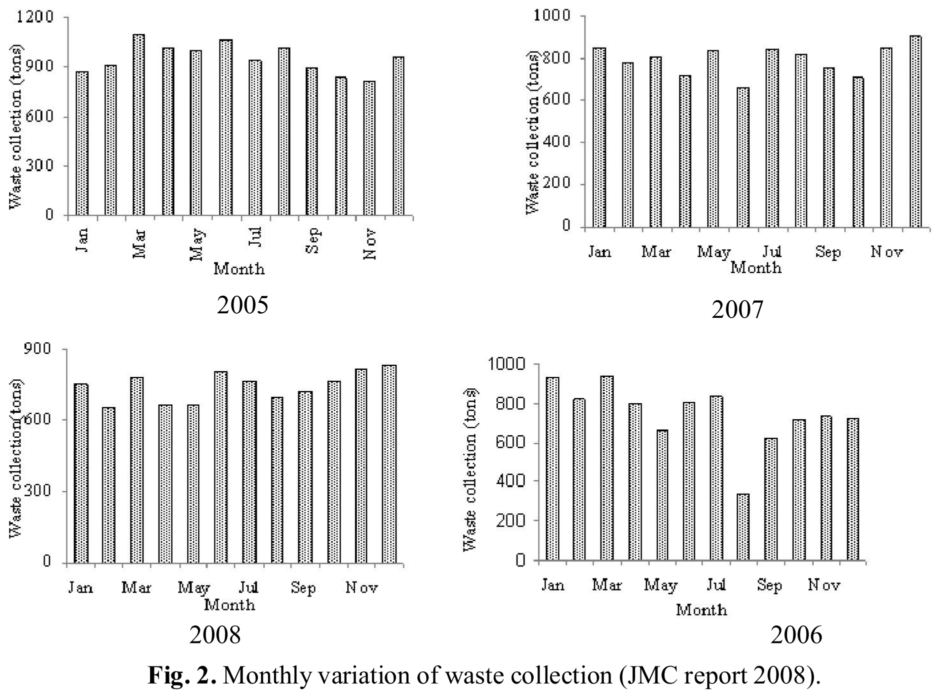

Fig. 2. Monthly variation of waste collection (JMC report 2008).

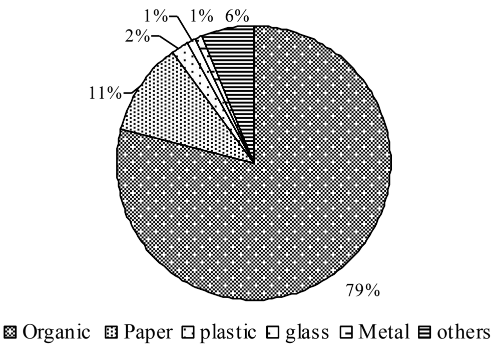

Fig. 3. Average composition of waste (JMC report 2008).

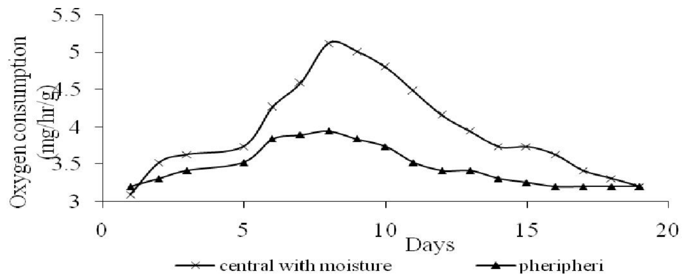

Fig. 4. Oxygen consumption pattern of three different digesters.

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