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Compatibility analysis and cost economics study of decentralized solid waste management of Kolhapur city, India

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Abstract

This paper studies the various factors that manage the suitability of a decentralized solid waste system within Kolhapur city of Maharashtra state in India. The main purpose of decentralization is to create hygienic environment free of garbage by utilizing waste as resource, minimizing of waste disposal, converting biodegradable waste into compost, generation of wealth from waste, to reduced cost required for solid waste management (especially on transportation), to educate the community and spread awareness about their roles and responsibilities about solid waste. The paper also summarizes the major findings of the study and suggests the suitable methods of decentralization techniques in the respective area. this paper refers, two decentralized methods which are best suitable are analyzed. i.e, bio-methanation and vermin-composting. And viability of replacting this decentralized methods at the city level is carried out.

Keywords: Bio-methanation, decentralization, solid waste, vermi-composting, waste disposal.

Introduction

Most of the Indian cities are facing a severe problem of solid waste management due to fast urbanization and are striving to find efficient responses to advance the living standard of people[1].

According to solid waste management rules (2016), every waste generator must segregate and stock up the waste generated by them in three separate containers namely bio-degradable, non bio-degradable and domestic hazardous wastes in appropriate bins and surrender segregated wastes to concerned waste pickers or waste collectors as per the order given by the local authorities from time to time[2].

The Kolhapur city is situated in Maharashtra state of India. As per the provisional census reports of India, population of Kolhapur in 2011 is 5,49,236. Kolhapur city generates 230 TPD of solid waste.

The ZOOM project was implemented for composting of solid waste generated in Kolhapur city. The project was shut in 2010. The treatment facility was stopped but the disposal of waste was going on without any treatment. Then, the KMC was allotted with a landfill site at Top Sambhapur for disposal of municipal solid waste but that also is pending due to the litigations over the landfill site. Thus, it was seen that the waste generated in the city is directly disposed off without treatment. Later on, KMC started two new projects for solid waste treatment with Bio methanation. One is at Kasaba Bawada of 30 MT where the segregation of the waste is done mechanically and another is at Puikhadi of 5 MT where there is manual segregation on the plant, the effectiveness of the treatment facilities is not yet seen due to lack of labors and no segregation of waste at source. The puikhadi facility was started in the year 2107 and it required 6 to 7 months to build the facility. Thus, most of the times the plants are not working efficiently.

Considering the graveness of the problems, it is imperative to undertake the decentralized solid waste management since the present centralized system is not suitable for waste with high organic content and is also expensive. It does not allow integration of informal waste workers. Wastes are not collected in efficient manner under this system.

Literature review: The paper studies the cost economics of the routes of municipal solid waste collection by using optimal routing techniques[3]. Decentralized composting, Initiatives of small and middle-size private sector, Accounting and transparency, Composting technique, Marketing, role of municipal authorities are studies in the paper[4]. The paper analyses sustainable development, Parameter analysis, physical composition analysis**,** Calculation of Energy Content[5]. The paper helps to understand technology and the technical expertise, managerial influence, economic viability, community support and influence of parallel government schemes[6]. Community initiatives, Decentralized composting, Municipal Solid Waste management, Replicability are studies in the paper[7]. The paper gives information about the Recycling of waste, Decentralized Composting, Pit Composting, Vermi Composting, Small Scale Anaerobic Digestion, Mechanical composting[8]. The paper studies the Recycling, Waste-To-Energy Combustion (WTE), Sanitary Landfilling, Composting or Mechanical Biological Treatment, RDF[9]. Parameter analysis, Vermicomposting is studies in the paper[10]. The paper refers to Material collection, earthworm species (red worm), Chemical analysis, Vermicomposting[11]. In the present study, an attempt has been made to provide a comprehensive review of the characteristics, generation, collection and transportation, disposal and treatment technologies of MSW practiced in India[12].

Methodology

Typical areas were surveyed from Kolhapur city like nagala park, shivaji peth, kasaba bawda, shivaji udyamnagar, rajarampuri to understand present solid waste management practices. And it is been analysed that Nagala park is the area suitable for implementing proposed decentralized disposal practices.

Hence, generation, composition and characteristics of the solid waste were studied like organic matter, paper, plastic, glass, metal and other waste. Per capita waste generation was calculated from the results and the various parameters such as pH, temperature, density were identified. With respect to composition and amount of solid waste generation prototype models like Bio-methanation plant, Vermicomposting plant and composting plant are prepared for checking viability and compatibility of each. Appropriate area, cycle time, no of plants will be determined on the basis of results obtained. The segregated plastic and glass are recycled and feasibility is checked. And per capita solid waste management charges were identified. Feasibility and economical comparison is carried out of conventional and decentralized waste disposal option for Kolhapur city.

Questionnaires were distributed in the selected areas like Nagala park, Junabudhwar peth, Kasaba bawada, Rajarampuri and Shivaji Udyamnagar which includes information like number of family members, annual income, amount of waste generated per day, tentative composition, segregation of waste at source, dumping facility of waste nearby etc. Based on the questionnaires, following results were identified. Based on the following results, selection of the appropriate decentralized disposal practice is to be selected. According to the composition of waste, the methods of decentralized disposal practices can be used are bio-methanation, vermicomposting and composting for the selected area. Prototype models were constructed for the disposal of solid waste.

Table-1: Per capita waste generation.

Category	Weight
High income people	0.312 gm
Medium income people	0.290 gm
Low income people	0.170 gm

Table-2: Composition of solid waste in %.

Content	High Income (%)	Medium Income (%)	Low Income (%)
Organic	48.3	20.62	45.94
Paper	10.83	22.14	14.95
Plastic	13.19	26.80	7.47
Glass	8.01	6.41	2.13
Metal	1.41	4.66	5.34
Garden waste	3.77	9.9	13.88
Other	12.25	5.2	16.82

Table-3: Parameter evaluation.

Test	Sample Waste
pH	6.5-7.5
Temperature	26- 32
Density	240-280

Bio-methanation: Two cylinder PVC tanks of volumes 0.28 M^3 and 0.19M^3 are used as gas holders and digesters of waste respectively. For the tank of volume 20 liters, the provision was made at bottom to remove sludge by using valve. PVC tank of volume 0.06m^3 was facilitated with two separate holes for feeding waste and gas outlet having 2 and ½ inches respectively at the bottom. A pipe of 4 feet in length was inserted through hole of diameter 2 inch so as to maintain anaerobic condition. And ½ inch valve used as gas outlet. This tank is kept upside down into the digester tank in floating position.

The population of the area selected was 1200. The prototype model was used for 1 building out of the 12. The average per capita waste generation is found out to be 0.250kg/day. Per day generation of waste is 300kg. As the organic matter in waste was 45% on an average, it was observed that 26% of that waste was cooked food and hotel waste, 14% was vegetables leftover and fruits and 5% was other waste (these observations are based on 10 days study). Out of which the biomethanation is most suitable for the waste obtained from cooked food and hotel waste. Hence a prototype model of biomethanation plant was used for the building.

In the beginning, the culture was developed in the model by using fresh cow dung. A 15 days cycle was implemented and the feeding of waste was done respectively.

Figure-1: Bio-methane model.

Table-4: Feeding details.

Duration	Proportion (%)	Rise in height cm	Volume (M^3)
20Dec-30Dec culture development	50 H_2O + 50 cow dung	2.2	0.0041
1 Jan-15 Jan	70 waste + 30 cow dung	1.7	0.0032
16 Jan-31Jan	80 waste + 20 cow dung	1.9	0.0036
1 Feb-15 Feb	90 waste + 10 cow dung	2.0	0.0038
15 Feb-24 Feb	100 waste	2.2	0.0041
25 Feb-20 Mar	100 waste	2.1	0.0039

After the analysis of the waste, it was observed that the drum becomes full of waste in 14 days and started to overflow. Hence, it was understood that the cycle time required for completion of gas formation process should be increased to achieve better efficiency.

The assessment of gas was done by using the ORSAT gas analyzer. The results obtained from the analysis as follows: CH_4- 55%, CO_2- 40%, other gases- 5%.

Table-5: Analysis of parameters.

Parameters	Results
Organic matter	1.11 %
Organic Carbon	0.645 %
Nitrogen (N)	2380 mg/l
Phosphorous (P)	211.42 mg/l
Potassium (K)	760 mg/l

Vermi-composting: From the 45% organic matter, 14% includes the vegetables leftover and the fruits. For one building out of the 12, a prototype model of vermicomposting is used. The per day generation of waste suitable for vermicomposting is seen to be 2.5 to 3.5kg. A vermibed is used made up of tarpaulein material of the size 4x2x2 ft. 30kg cattle manure was introduced in the vermibed to produce the culture. A daily waste of approximate 2.5kg was introduced in the vermibed for 7 days from the apartment. The earthworm species used for vermicomposting is eisenia fetida. This is an Australian breed of earthworm which is commonly used for vermiculture as its efficiency is good. Moisture is maintained in the vermibed by sprinkling water daily.

For the daily feeding of the waste, it was observed that the efficiency was not achieved so it was understood that a gap of 5 to 7 days should be maintained for proper decomposition of the waste so 6 beds are required for proper and efficient functioning of the model so that the waste is dumped in the vermibeds after a gap of 5 to 7 days.

A cycle time of 42 days was analyzed and the results were obtained.

Figure-2: Vermi-bed.

Table-6: Analysis of parameters.

Parameters	Results
Organic matter	1.76 %
Organic Carbon	1.02 %
Nitrogen (N)	4676 mg/l
Phosphorous (P)	325 mg/l
Potassium (K)	1360 mg/l

Cost analysis: Population of Nagala park is 6560. The total waste generation is 1600kg/day. It contains 45% organic waste.
Total organic waste generated per day= 1600 x 0.45=720 kg/day

It was seen that around 26% of it was cooked food which can be used for bio-methenation, 14% of it was vegetable leftovers which can be used for vermin-composting and remaining 5% was leaves and garden waste that can be used for composting.
For bio-methenation = 1600 x 0.26 = 416 kg/day
For vermin-composting = 1600 x 0.14 = 224 kg/day
For composting = 1600 x 0.05= 80 kg/day
From the total waste generated, 35% can be used for recycling as it is dry waste
For recycling = 1600 x 0.35 = 560 kg/day
For landfill = 1600x 0.15 = 240 kg/day
As per the above results, 2 locations for vermicomposting beds are allocated, 1 for bio-methenation and 1 for composting are allocated.

Design of bio-methenation plant: For bio-methenation plant, the capacity of the plant should be at least 2 MT to achieve good efficiency and proper working of the plant.
Hence, waste to be treated per day= 2000 kg.
Volume of waste= 7.69 m^3/day
Considering, retention period of 21 days.
Volume required = 7.69 x 21=161.51 m^3
Consider 15% contingency
Volume of tank= 185.75 m^3
Methane gas generation= 120 m^3/day
Electricity generated (1.5units/ m^3 of methane) = 180 units/ day
Manure generated= 200 kg/day (90% volume reduction)

Design of vermin-composting plant
Total waste to be treated= 224kg/day
Two locations are identified for construction of pits
Total waste to be treated per day at each location= 112kg
Thus, area required for one pit= 44.85 m^2
If we consider 3 days input cycle and retention period of 21 days,
Area of one pit= 44.85x 3= 134.52 = 135 m^2
Total number of pits required in one location = 9 pits

5 x 3 m	5 x 3 m	5 x 3 m
5 x 3 m	5 x 3 m	5 x 3 m
5 x 3 m	5 x 3 m	5 x 3 m

Figure-3: Plan of vermin-bed.

Table-7: Cost estimation for recycled waste.

Particular	Composition %	Waste generation/month	Rate of Recycling	Income/ Month	Income/ annum
Paper	17	272x31=8432kg	6rs.	50,500/-	6,06,000/-
Plastic	13	208x31= 6448kg	3rs.	19500/-	2,34,000/-
				Total	8,40,000/-

Cost estimation for collection & transportation of solid waste
One auto tipper: 3,00,000rs
Hand tools: 6000rs.
Labours: 1 driver, 1 helper, 4 labours= 4,32,000rs.
Fuel required: 4500rs/ month

Cost estimation for bio-methenation for 2MT
Consider cost of construction= 25,000/m^3
Volume of tank= 185.75m^3
Total construction cost= 46,43,750rs
Labours: 4 x 8000= 32000 rs
Payment of labours/ annum= 3,84,000rs.
Hand tools= 20,000 rs.

Cost estimation for vermi-composting
Construction cost of one unit= 5,00,000rs
Total cost for 2 units= 10,00,000rs.
Payment of labours= 8 x 8000= 64000rs
Payment /annum= 7,68,000rs.
Initial setup cost= 1,00,000rs.
Hand tools= 50000rs.

Cost estimation for composting
Total waste treated= 80 kg
Waste treated/ annum= 29.3 T
Consider 10% of compost treated= 2.9 T
Composting pit size= 8x2x2
Construction cost= 10,000/-
Labor charges= 8000/-

Results and discussion

From the above analysis, the revenue generated is calculated from each decentralized facility according to the waste generated in the facility and the total revenue is calculated per annum.

The Table-9 describes the total cost required for construction of the decentralization facility, the operation and maintenance cost required per month and the per capita cost for solid waste management.

Table-8: Benefits from the models.

Plant	Compost/year	Electricity/ year	Rate/ unit	Total rs
Bio-methanation (0.5 MT)	-	16425 units	6rs.	98,500/-
	12 T	-	4rs	48,000/-
Vermin-composting	16.5T	-	8rs.	1,32,000
Composting	2.9T	-	4rs.	11,600
Recycling	-	-		8,40,000
			Total	11,30,100

Table-9: Total cost estimation for decentralized SWM.

Particulars	Amount
Capital investment	
Cost of collection vehicle & transportation	3,06,000
Construction cost of bio-methanation	9,85,700
Construction cost of vermi-composting	11,00,000
Total capital investment	24,91,700
O & M per month	
Cost of transportation	4500
Labour salary	1,40,000
Lump sum	20,000
Total per month O&M	1,64,500
Per annual O & M	19,74,000
Total annual revenue	11,30,100

Table-10: Per capita cost of solid waste management.

Particulars	Amount
Total per annum per person capital investment fees for 5 years	76.00/-
Total per annum per person O&M fees= (o & m charges – revenue) / population	129.00/-
Per capita per annum cost of solid waste management for first 5 years	205.00/-
Per capita per annum cost of solid waste management after 5 years	129.00/-
Actual per capita per annum SWM cost of KMC	680.00/-

Per capita cost of solid waste management
Total per annum per person capital investment fees for 5 years = 75.96 = 76 rs
Total per anum per person O and M fees = (o and m charges – revenue) / population = 128.64 rs.
Thus, per capita per annum cost of solid waste management for first 5 years = 76 + 129 = 205 rs.
Thus, per capita per annum cost of solid waste management after 5 years = 129 rs.

As per the following results, the total per annum per person capital investment fees for five years is calculated as 76 rupees and the total per annum per person O and M fees is 129 rupees. Therefore, the per capita per annum cost of solid waste management for first 5 years will be 205 rupees and after 5 years it will be 129 rupees.

Conclusion

Decentralized solid waste treatment & disposal practice will not only solve the problem of unscientific dumping but also reduces the cost on solid waste management by 81%. It will help to follow prevent, reduce, reuse, recycle, recover, treatment & disposal pattern for solid waste management as per the rules. Most of the waste can be used as resource.

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