COMPOSTING TECHNIQUES FOR DECENTRALIZED SOLID WASTE MANAGEMENT

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Abstract : In India, waste management has been neglected since long. Due to rapid industrial growth with urbanization, waste quantity is increasing. Poor waste management services and lack of technology available for treatment of solid waste, most waste ends up at landfill and thus produces more greenhouse gas which is harmful to the environment. More land is needed for the disposal of the solid waste. If waste is segregated and treated at source the transportation cost, fuel and emissions due to waste hauling to landfill can reduce. The new solid waste management rules by Government of India lays emphasis on involvement of users in waste segregation and process at source to an extent possible. For this effective technique of composting for decentralised solid waste treatment are being studied. For this paper, a process of literature study, selecting case studies, data collection, data analysis, conclusion is chosen. Qualitative as well as quantitative information for different waste treatment technologies are collected and analysed to give the indicative parameters for selection along with the assessment of sustainability aspect for different factors.

IndexTerms **- Decentralized, Solid-waste, India, Treatment Technologies, Waste to Compost, Zero Waste**

I. INTRODUCTION

Yearly worldwide waste generation represents 7-10 billion tons altogether, out of which roughly 2 billion tons are categorised as city solid waste (MSW)[1]. Urban India is confronting a regularly expanding test of giving infrastructural needs of a developing urban populace. As indicated by the 2011 census, the number of inhabitants in India was 1.21 billion; of this 31% live in urban areas. As indicated by Central Pollution Control board 1, 27,486 TPD (Tons every day) of Municipal Solid Waste was generated in India amid 2011-12, with a normal waste generation of 0.11 kg/capita/day. Of the aggregate waste produced, around 89,334 TPD (70%) of MSW was collected and just 15,881 TPD (12.45%) was handled or treated. Isolation at the source, accumulation, transportation, treatment and logical transfer of waste was to a great extent deficient prompting degradation of the earth and low quality of life [2].

Waste loads heaping up are a typical sight in a large portion of the urban areas and townships of India. Exploding populations and changing ways of life are creating enormous amount of waste. The quantum of waste produced changes between 0.2 - 0.4 kg/capita/day in urban areas and goes up to 0.5 kg/capita/day in metropolitan urban communities [3]. Civil organizations burn through 5 - 25% of their financial plan on MSW (Municipal Solid Waste) administration, which is Rs 75 - 250/capita/year. Regardless of the different measures to treat waste, the ULBs (Urban Local body) are at present unfit to agreeably satisfy their general obligations. This has brought about medical issues, for example, loose bowels, cholera, and intestinal sickness among the majority. Of the aggregate MSW created in India, 30 - 40% comprises of organic waste, 30 - 40% slag and fine earth, 3 - 6% paper while a small extent of under 1% represents plastics, glass, and metals [3].

The attempts to treat the waste at centralized facility and stop waste going to dumpsites have failed. There are concepts like Zero Waste campus and waste free cities being adopted. Various technologies and methods are used for treating the waste at the source or at decentralized facilities. Looking at the cases of implementation where efforts are made to successfully manage their waste. Decentralized systems reduce the cost of collection, transport and disposal of waste by local urban agencies [4]. Most people are unable to achieve 100% decentralized management due to lack of appropriate channels for managing rejects and sanitary waste [5].

Decentralised composting allows reuse of organic waste where it is generated, thereby reducing waste quantities to be transported as well as transport costs. This has a positive effect on the overall municipal waste management costs [6]. An integrated approach to solid waste management involving a mix of centralised and decentralised community-based alternatives such as recycling, re-use & recover (3Rs); composting and anaerobic biogas production could help to obtain sustainable waste management solutions [7]. The decentralization systems should be studied in terms of how they create a clean and hygienic environment free of garbage in the selected area, minimizing waste disposal, using waste as a source of wealth, converting biodegradable waste into organic fertilizer., to educate the community and increase their awareness of their roles and responsibilities, to involve the community in the management of solid waste. Therefore, there raise a need for a comprehensive study of managing solid waste with decentralised technology and its feasibility under different aspect.

II. METHOD OF STUDY

The main objective of this study is to explore the composting methods and techniques that could be used for Decentralised Solid Waste Treatment, in light of the challenges and prospects. In doing so, Pertinent literature will be explored to understand the waste processing and in particular decentralized one. The methods and technology implemented and available today are studies for similar case study and what could be potentially be exploited for solid waste management. The cases are chosen to elaborately cover the aspect that are drivers to conceive decentralized solid waste treatment, parameters of selection and sustenance. Four decentralized facilities are being closely studied to understand the efficiency and performance. Data was collected by visiting the site and getting information from the owners and operators of the facilities. Then primary analyzing the selection of waste processing technologies on the criteria of Quantity of waste generation, land availability, Market for the products, Capital investment, O&M (Operation and Maintenance), Siting criteria was done. Issues are discovered in each case and suggestions are written for same. Technical aspects, financial aspects are also consolidated and then the information to be further analyzed for writing the conclusion.

III. WINDROW COMPOSTING

Windrow is the general term for an elongated pile of stacked raw materials. The pre-sorted and shredded organic waste is mixed mechanically with additives known as bio-cultures. This mixture is piled around a pyramid shape or straight windrows. Piles need to be small with the size having maximum footprint area of 1m*1m and high not more than 1m. The pile need to be porous enough for air to pass through them over a long period of time. The total composting process lasts 20 days, which can be described by a thermophilic phase (8-9 days at 45–70 ◦C) and a mesophilic phase (8-9 days at 30–45 ◦C) as shown in 'Chart 1: Flowchart of Windrow composting process using shredder and mechanical mixing'. During the thermophilic phase, which initiates very rapidly, the compost piles are turned frequently to regulate their temperature and ensure an equal decomposition level throughout the pile. After this the compost is spread on a flat paved surface for 2 day to dry and aerate properly before finally being packed.

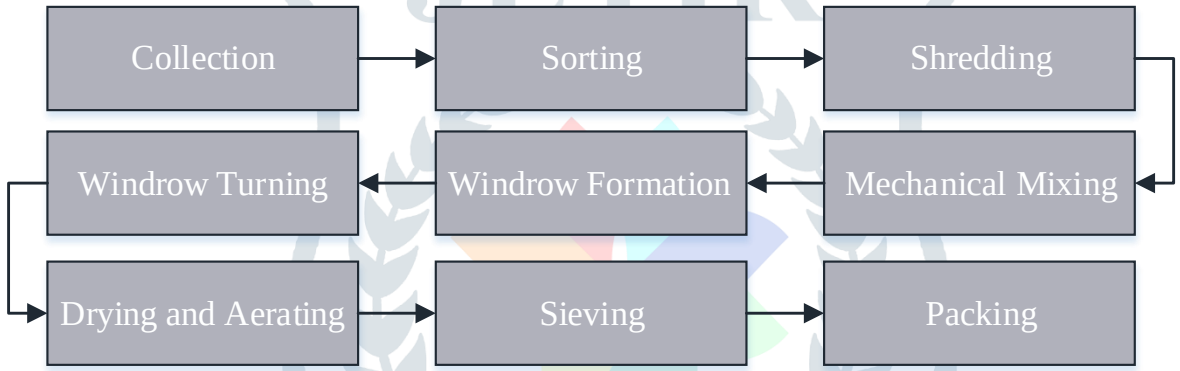

Chart 1: Flowchart of Windrow composting process using shredder and mechanical mixing

Project Overview: (2) Garden Composting Unit

This facility was set up by Urban Local Body which is municipal cooperation of the city. The facility process waste from ABC Garden as well as the flowers which are worshipped during different festivals in the city. This location was in close proximity to all the bridges in Ahmedabad where people come to worship. This flowers and other materials are collected in a bin over all seven main bridges in Ahmedabad. This garden location was also strategically in the centre to use the waste from the Garden over the riverfront and also from the different zones of city in 15Km proximity.

Key Success factors

Tendering was done on design, built and operated basis for 5-years period. This eliminated the responsibility of the urban local body to develop expertise for procurement and operation. No market for the compost was searched as this was internally sold off to the garden department of the urban local body.

Limitations of the technology / treatment facility

Windrows are made in open so the composting is not possible during rains. This created problem for the neighbouring houses as there is no buffer and dwellings are adjacent to composting unit. There is a problem of odour, waste displacement in neighbouring houses when windrows are turned upside down.

For an operation contract which is in isolation to collection and transport always has stakeholder dispute. This is because the collection and transport agencies are paid on the collection and trips of waste and not on the organic or compostable waste. As this incentive is missing they tend to collect waste which could not be processed and trips it to the facility. The waste has to be segregated again manually and the remaining waste part has to be further transported to dump site.

Recommendation

Inter-stakeholder dispute could be solved by giving a single contract from collection to processing in case of decentralized facilities.

IV. IN-VESSEL COMPOSTING

Bin composting refers to a group of methods that contain composting materials in building, container, or vessel. The methods in the vessels are based on variously forced aeration and mechanical overturning techniques to speed up the composting process. Many methods combine the techniques of windrow and pile methods to try to overcome the deficiencies and exploit the attributes of each method [8]. There are a variety of in-vessel methods with different combinations of vessels, aeration devices, rotation mechanisms. The few methods discussed here have been used or proposed for urban composting. They are also good examples of the types of decentralized systems used in Indian urban context.

V. BIN COMPOSTING

Bin composting is perhaps the simplest in-vessel method. The materials are contained by walls and usually a roof. The bin itself may simply be wooden slatted walls (with or without a roof), a grain bin, or a bulk storage building. The buildings or bins allow higher stacking of materials and better use of floor space than free-standing piles. Bins can also eliminate weather problems, contain odours, and provide better temperature control [8].
Essentially, bin composting methods operate like the aerated static pile method. They include some means of forced aeration in floor of the bin and little or no turning the materials. Occasional remixing of material in the bins can invigorate the process. If several bins are used, the composting materials can be periodically moved from one bin to the next in succession [8].

Project Overview: (4) Science College

This Bin is a designed product, that compost the kitchen and garden waste. This is made out of reinforced fiberglass material; therefore, it is corrosion proof and definitely long-lasting. The unit can be easily wheeled around and most importantly no electricity or drying/churning is required. The nutrient-rich liquid manure is collected in a separate drawer. This process is built on a continuous flow system method. 110 Litres(0.11m3) in volume bin will ensure each everyday waste (of up-to 2 kg) can be dumped. In 30-40 days moderately loose, crumbly and the colour of dark brown/ black, granular, lightweight Compost is ready for harvesting. The liquid manure tray collects the water-soluble nutrient rich light golden coloured liquid fertilizer.

For this project, the initial cost was funded by an external private entity under CSR (corporate social responsibility). Also with the capital cost being funded by the external party, the campus is contractually being bound by the responsibility of decentralised waste processing.

Key Success factors

Developed an Integrated system for campus solid waste management. In this system is not one person's or one department's duty and scope to make the campus Zero Waste. Therefore, the bins were implemented after student's initiative of segregation awareness drive. The bins were implemented in phases even after they were procured all at once. Background of students in science stream played an important role in experimenting with different mix promotion of water namely sorting it into food waste and tree waste of different trees in different quantities. This helped to discover how an optimum time to compost waste and make the best end product.

Limitations of the technology/treatment facility

Composting takes a very long period of time even with the addition of prescribed additives. Usually, in all composting process, the yield is directly promotional to the time taken. Here using bin composting the batch which is delivered after 45 days is maximum of 70kg when feed with ideal waste composition, therefore, it gives lesser yield taking more time. User education and awareness is crucial for implementing this system as to monitor each bin individually in long run become a cumbersome job.

VI. ORGANIC WASTE CONVERTOR(OWC)

OWC (Organic Waste Converter) is a Decentralized Waste Management System to turn large amounts of organic waste such as kitchen waste, garden waste, food processing waste and other organic waste into compost. The system is designed to eliminate odour and also to remove the problem of irritants such as flies and rats. This system is a bio-mechanical Composting System which consists of the OWC machine, Curing System and a number of optional accessories for specific waste challenges as shown in Figure 1: Plan of composting facility using organic waste convertor with external curing system'.

In an OWC, the batch of waste which is operated for food and garden waste has to be shredded in an even size particle. There are different processes in organic waste convertor available depending upon the size of waste to be treated. This collected evenly sized batch is added to OWC where it is mixed mechanically with Bio-Culture. The requirement of the bio-cultures being added to each batch differ from batch size and composition of Bio-Culture. In one-process as shown in 'Chart 2: Flowchart of composting process using organic waste convertor', after mixing of waste with bio-culture for about 10-15 minutes the batch is collected and kept in curing tray. In the curing tray facility for moisture and partial control of temperature is made with sprinklers. In another process, the whole batch remains in a controlled environment. Here the batch is converted to compost directly in 24-36 hours. This process is accelerated with temperature going up to 70-90°C. Therefore, no extra space for curing is required in this type of organic waste converter.

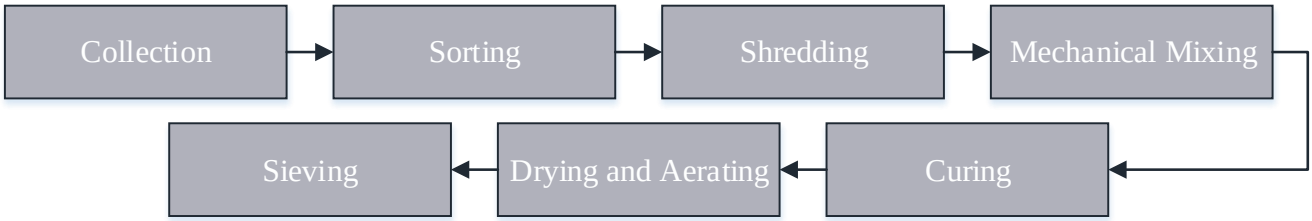

Chart 2: Flowchart of composting process using organic waste convertor

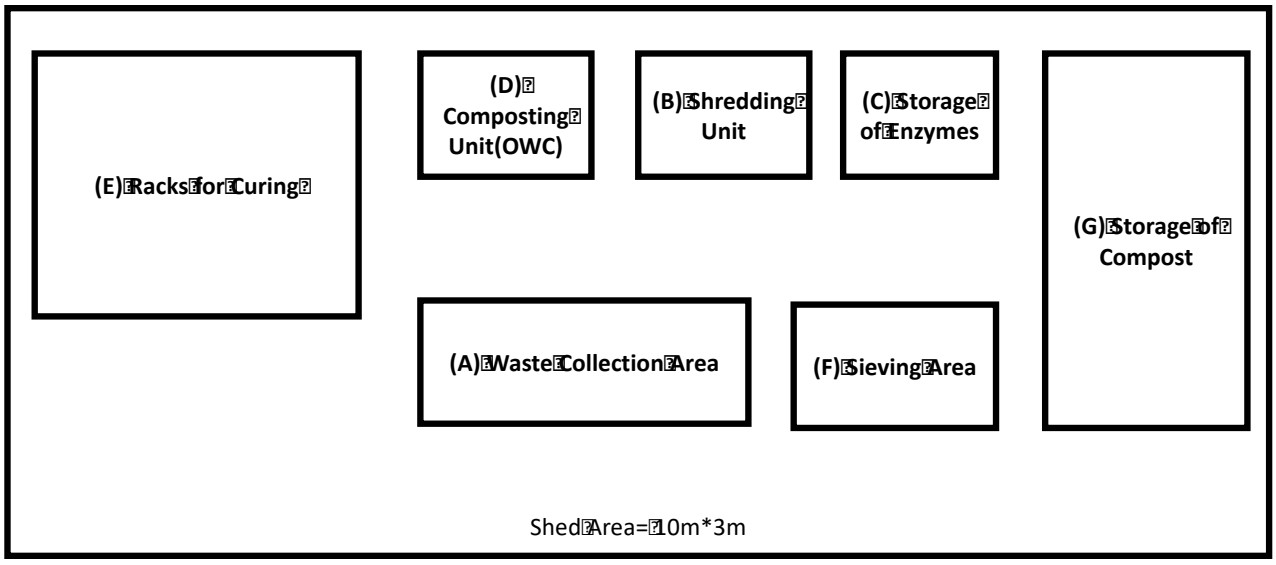

Figure 1: Plan of composting facility using organic waste convertor with external curing system

Project Overview: (5) Management Institute, Ahmedabad

Institution's top management has emphasis for waste management within the premises and in such a way that no organic waste must leave the campus area. Intact motive to cater to this goal from top management to execution team, where at last one person responsibly runs the operation from preparing a batch for composting, curing it, sieving it and stacking it for approx. for 500kg per day food waste. Treating the waste costs, whether done within the premise or centrally for the city. When done in one's own decentralised facility directly benefit is the user.

Key Success factors

The motivation of the management and dedicated endeavours of individuals engaged with the genuine execution is the key success factor. Project of treating the organic waste with Organic waste convertor is financially viable with IRR of 10% as calculated for the net cash flows of the project.

Limitations of the technology / treatment facility

Bulk garden waste cannot be processed directly when the whole process is planned to be completed in 10 Days. This 10days composting process is calculated taking ideal food waste for composting. Waste that is sourced should be segregated well and only the intake of the organic substance to be taken. Equipment gets damaged like shredder and turning blades easily in the OWC when struck with metal or other heavy substance. Moisture content has to be manually adjusted. If excess moisten waste is added then it has a problem in operation itself with turning and mixing as well as in composting.

Recommendations

For institutes/premices which has ample quantity of garden waste should have the facility to store it instead of dumping it in any proportion as it crucial component in making the compost with food waste. Storing the garden waste for year-round using the passive aerate bin method. This gets partially composted and then using it with daily food waste reduced the demand for the sawdust as consumable. This increases the productivity of same equipment and aid to financial viability.

VII. DRUM COMPOSTING

Drum composting is a low-cost technology to facilitate rapid composting. This is done with the waste being feed in a rotating drum which is aerated with holes in it. Further to accelerate the process, bio-cultures which aids the growth of microorganism and their activities is being used. After the batch is ready with the bio-culture mixed the drum has to be manually rotated each day for 2-5minutes. For the absorption of moisture saw dust or dry leafs from the horticulture waste is to be used. With this process food waste from the kitchen takes at most 10-12 days for final compost to be ready. Pictorial flow chart of the process in shown in 'Chart 3: Flowchart of composting process using manually operated drum composter'.

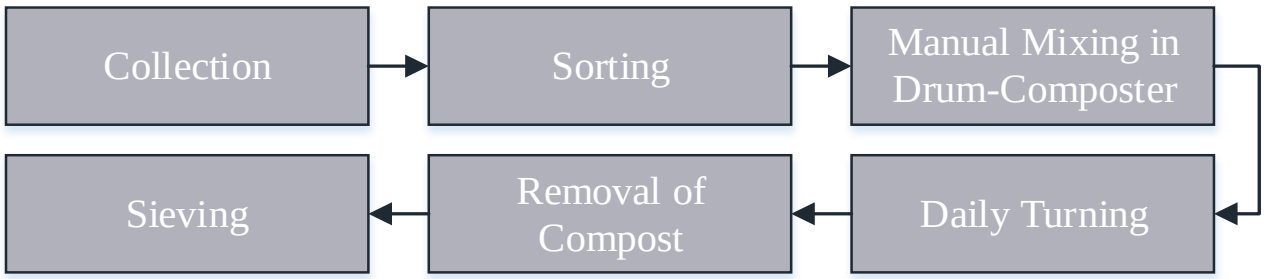

Chart 3: Flowchart of composting process using manually operated drum composter

Project Overview: ABC Club Ltd

Treating the waste at source is a big challenge for the establishment like clubs, institution and hotels. Enthusiasm of clubs managing committee for ZERO WASTE Management concept lead to setting up a composting facility in-house. It benefits directly by production of valuables like composting of organic waste and the environment as a whole. For this particular project, an external agency was hired to Audit, aware and execute on design, built and operate basis. Organic portion of dry waste and wet waste at source is treated in a cost-effective way by suing simple drum composting technology. This is not seen as monetary benefits but a step-in direction of Zero Waste campus.

Key Success factors

External agency which has the technical expertise in waste processing was appointed. Appointing a single agency which is responsible for all the phase of the project helps implement project effortlessness. This includes an assessment of waste profile, consulting the suitability of technology, providing the technology, collection of waste, appointing manpower for processing of waste. This makes the establishment of clubs who can afford the CAPEX and OPEX for in-house waste management hassle-free.

Limitations of the technology/treatment facility

Manual turning is required daily. The operations of manually operated drum composting are not as automatized as that of organic waste converter where the whole process takes place in a closed box. The premise has to be cleaned to maintain the better aesthetics of place and hygiene.

VIII. DATA ANALYSIS

Data analysis includes Quantitative and Qualitative analysis of different decentralized treatment technologies available. This analysis is done from the data being collected which was case specific. Financial data was collected from the bills of the contractor, books of account and informal interviews with the operators and owners for the case studied. This data was further analyzed to produce net cash flows for 10 years are derived from the CAPEX and OPEX of the facilities and IRR (Internal Rate of Return) has been calculated. Other indicative parameters were collected in a similar manner and depicted per unit of waste to be treated. Per unit of waste treated figures such as land requirement, CAPEX, OPEX, manpower could be used as an indicative parameter for selecting technologies as shown in '**Table 1: Indicative criteria for** the selection of decentralised composting technology'. Qualitative data which was inquired in the form of informal interviews was generalized for drivers and sustainability parameters. Drivers are the motivation that leads to setting up a decentralized solid waste treatment facility. Parameters such as environmental, institutional, legal, contractual, operational were also considered which are crucial for sustenance. This feasibility assessment gives an elaborate overview of the overall environment that leads to execution and operation of the decentralized treatment facility.

IX. RESULTS AND INFERENCES

Table 1: Indicative criteria for the selection of decentralised composting technology

Parameters	Windrow Composting	Bin Composting	Drum Comoosting	Organic Waste Convertor
Waste intake	Organic portion of municipal solid waste			
Requirement for segregation	Low	High	High	Very High
Cycle time (days)	20	45	10	15
C:N of Compost	17:1	16:1	16:1	16:1
Area requirement(m2)/ kg of daily waste treated	1	5.6	0.36	0.06
Market for by-product/ end product	Y	N	N	Y
Waste treated(kg/day)/semi-skilled	650	(-)	(-)	500
Waste treated(kg/day)/unskilled	325	(-)	50	(-)
Management intensity	Intermediate	Low	Low	Low
CAPEX in INR/total waste treated in kg in a day	1111	7500	2400	2120
Monthly OPEX in INR/ total waste treated in kg in a day	50	32.14	160	21
Commercial applicability	Y	N	N	Y
IRR for 10 years' cash flows of the case study for reference.	(-)	-23	(-)	10

The waste with the different organic composition of dry and wet waste could be used for composting. Windrow Composting could be used for city-level decentralized treatment or commercial projects. Windrow composting facility has to be set up with certain buffer from the adjacent dwelling units. This process is done in open and even after caution, there is always a menace of odor and waste reallocating in the neighborhood while turning windrows.

Technologies which are less capital intensive could be used at the household, community, institutional waste composting. Well designed unit of Bin composting could be used by individual households who want to make compost in the kitchen or house itself. This is not commercially viable as there are CAPEX and OPEX per yield of the compost compared to other technologies. Selection of technology is largely driven by the quantity of segregated organic is available. Another major factor for the selection of the technology is the sophistication in operating it. The organic waste converter is a versatile technology which has been largely used in urban areas by institution and townships. This is because of the lesser maintenance requirement and uncomplicated operations. Same is the case with drum composting when used with bio-cultures. The equipment used for drum composting is DIY (Do it yourself) to construct. This method also requires no skilled manpower and no maintenance.

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