DECENTRALIZED MANAGEMENT OF SEGREGATED ORGANIC WASTE

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Contents

1. Introduction

Municipal solid waste (MSW) has become a serious concerns for emerging countries such as India because of expanding population, urbanization, economic development, and changing production and consumption habits. Existing studies and literature show that the Indian solid waste management system is expanding and is stochastic. As per the Central Pollution Control Board (CPCB) Annual Report (2018), there was exponential increase in city-wise generation of waste per capita perday (0.24–0.85 kg per person per day) during 2001–18 and this trend is anticipated to continue.

A significant fraction of MSW in India is organic waste, which can be defined as organic material that is readily biodegradable. According to a 2012 report by the National Environmental Engineering Research Institute (NEERI)[1] and the Indian Council for Research's Solid Waste Management in India report, 2018,[2] the organic fraction of urban MSW in India is approximately 55–65 per cent. The organic fraction in waste is considered a source of contamination of soil, water and air if disposed of indiscriminately and requires greater attention for efficient and effective resource recovery.

Most cities, however, either dispose of their waste in low-lying areas outside the city or dump it into landfills, the most common method of waste disposal, done without precautions or operational control. Reasons for this include minimum segregation of waste at source and dearth of land for waste processing. Limited understanding of technological options to manage segregated organic waste aggravates the problem. Further, most cities have adopted centralized systems for managing MSW. Their resources, technology and human capital are best designed and executed at the city level.

A centralized management system has the advantage of processing and treating the bulk of the waste at once at one place with single monitoring points. The system, however, also comes with limitations, including:

- It needs large plots of land. This remains an ever-increasing challenge;
- Availability of funds to support capital expenditure (capex) and operational expenditure (opex) is too high;
- Any failure in a centralized system leads to the whole system of waste processing

coming to a standstill;

- Significant time is required to get clearances (i.e. consent to establish, consent to operate) for the project and the chance of environmental pollution is high if environmental regulations are not in place or monitored;

- Involves little public participation.

Decentralized waste management systems, on the other hand, reduce the burden of handling large volumes of MSW with lower requirements of capex and opex. Besides, adoption of appropriate home composting methods could help reduce the quantity of organic waste at source to foster a clean and hygienic environment. Therefore, considering the magnitude of current municipal solid waste and the problems accompanying current municipal solid waste management practices, it is critical to consider decentralized management and technology options as a matter of priority. The centralized option should be considered only if the possibility of adopting a decentralized system is ruled out due to a specific constraint. The Solid Waste Management (SWM) Rules 2016 also provide a clear policy advisory to cities to adopt community-based waste management and emphasize on decentralized waste management.

According to the 2016 Solid Waste Management (SWM) Rules:

- Biodegradable waste produced by all the bulk waste generators (i.e. those producing over 100 kg of waste per day) must be collected, handled and disposed of within the premises as much as possible by composting or biomethanation.

- Local authorities shall involve communities in waste management and promote home composting, biogas generation and decentralized waste processing on a community level.

- Local authorities shall make an application for authorization for setting up waste processing, treatment, or disposal facility, if the volume of waste exceeds five metric tonnes per day, including sanitary landfills from the state Pollution Control Board (SPCB) or Pollution Control Committee (PCC).

No authorization is required to set up a decentralized facility if the capacity is less than five tonnes per day. Further, to encourage decentralized organic waste processing solutions and promote city compost, the government has implemented policy. The Ministry of Chemicals and Fertilizers (MoC&F) released a notification on 10 February 2016 to promote city compost schemes.[3] Under this scheme, an amount of Rs 1,500 will be provided per tonne of city compost as MDA (Market Development Assistance) to the manufacturer or marketer of compost. This is in itself an enabling factor to encourage manufacturing and marketing of city compost.

This report explains treatment methodologies and ways to convert organic waste into resources and provides a basket of available decentralized treatment technologies for organic waste practiced at the household, neighbourhood, ward, cluster of wards or zone levels depending upon the quantity of organic waste.

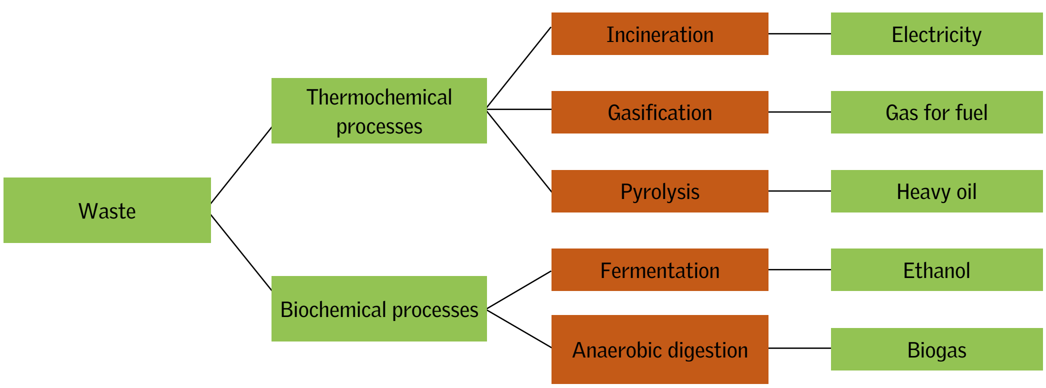
2. Treatment methods for organic waste in India

Municipal solid waste (MSW) primarily comprises biodegradable, non-biodegradable and inert fractions. Biological or thermal treatment of biodegradable and non-biodegradable waste can lead to recovery of valuable products such as compost or energy.

The selection criteria for these technologies are largely dependent on climate, techno-economic viability, availability of land, composition of waste, quantity and physiochemical characteristics of feedstock, preferred form of energy recovery, end-user requirements and environmental aspects.

Biochemical conversion processes are applied mainly to solid waste with high moisture content, an indication that the organic fraction of waste is more suitable for composting after separating the reusable and recyclable fractions. As a result, biochemical conversion processes are the most feasible in India. Several decentralized technologies are available for treating organic waste. These are addressed in detail in the following paragraphs.

Figure 1: Conversion processes for municipal solid waste



Source: CSE, 2021

What can be composted?

Do compost	Don't compost
• Fruits and vegetable, tops and bottoms included • Eggshells • Coffee grounds and teabags • Nutshells • Rice and grains • Cooked food if it does not have oil, dairy or meat • Yard trimmings • Flowers, sawdust, wood chips, newspaper and cardboard • Hair, fur and vacuum lint	• Bones • Plant trimmings with chemical pesticides, insects or diseases • Meat and fish • Dairy • Oil and butter • Cooked food with oil, dairy or meat • Pet waste • Coal or charcoal ash

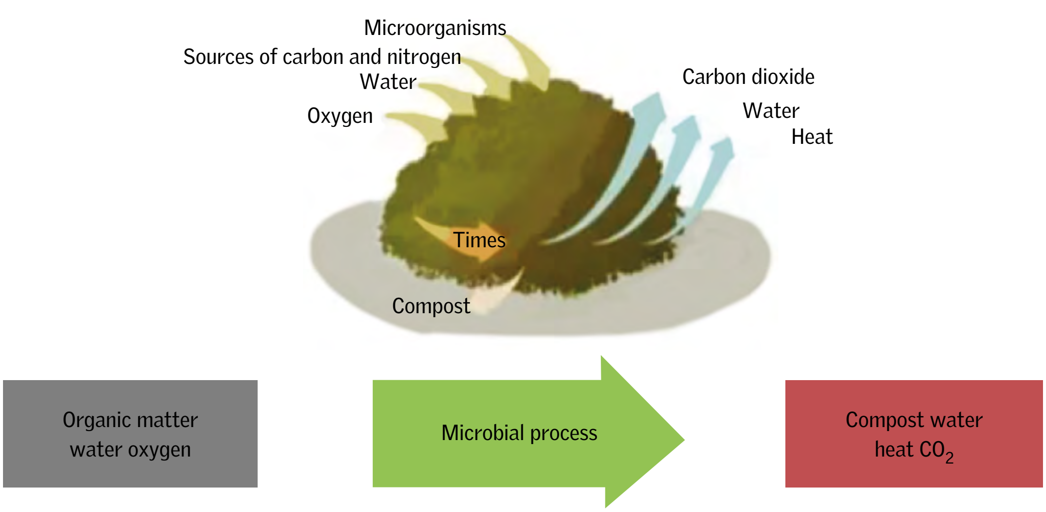
Source: CSE, 2021

2.1 Aerobic composting

Aerobic composting is the decomposition of biodegradable organic matter in a warm, moist environment by the action of bacteria and other organisms. Segregated organic fraction of solid waste is a suitable substrate for composting. As per the study, community-based decentralized composting can generally treat about 2–50 tonnes per day (TPD) of waste, depending on the size of the community and volume of compostable substances. Under ideal operating conditions,compost that contains essential plantnutrients and beneficial minerals for plant growth can be produced within three months.

Figure 2: Aerobic composting

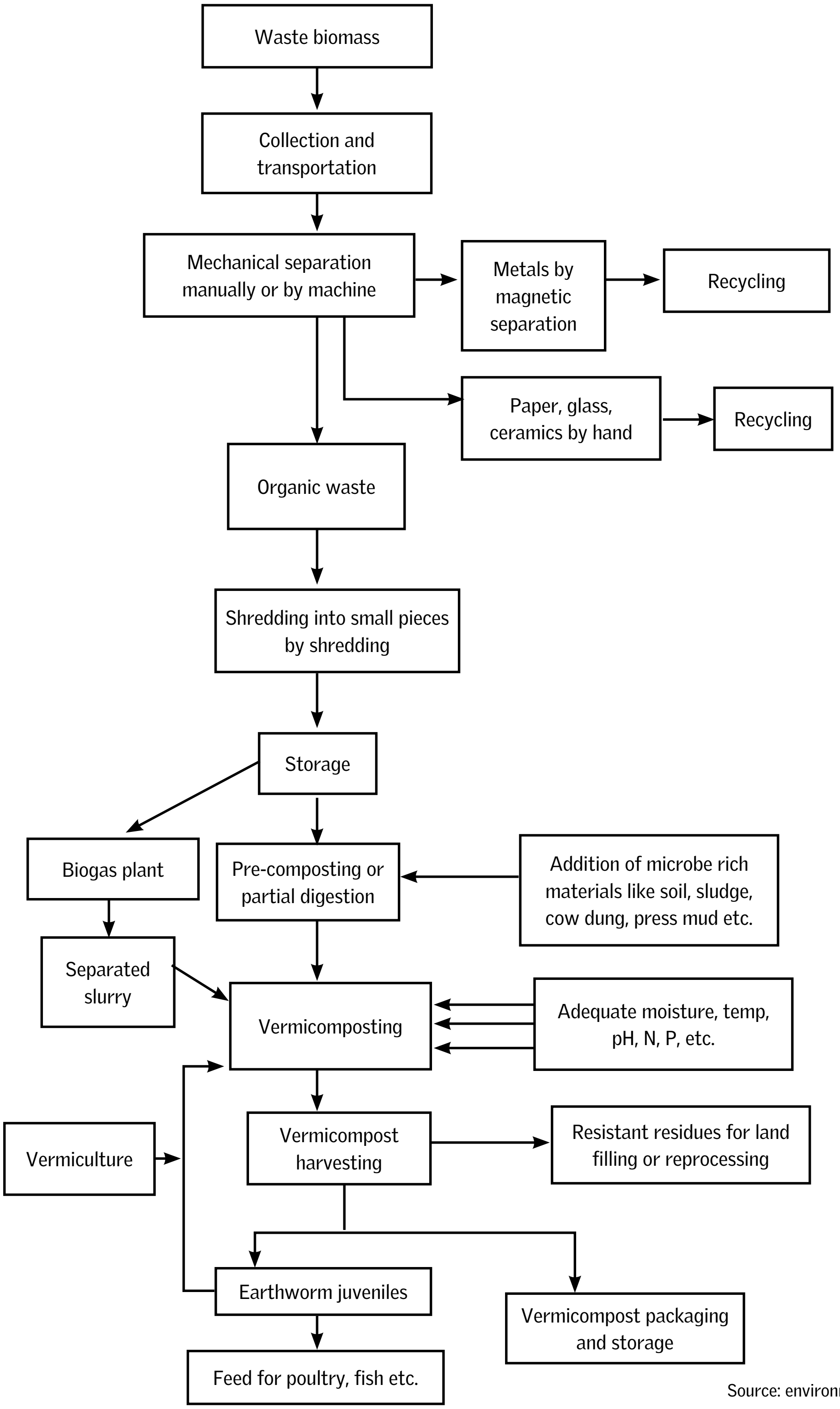
$$\text{Organic waste} + O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O + \text{Heat} + \text{Compost}$$



Source: CSE, 2021

2.2 Vermicomposting

Figure 3: Vermicomposting process



Source: environmentaljournal.org

Vermicomposting is an aerobic process of organic waste degradation and stabilization by interacting with microorganisms and earthworms under controlled conditions. Microbial communities help degrade biodegradable matter, and a high density of earthworms then feed on the waste and produceearthworm castings, also called vermicompost. Such vermicompost has been shown to have higher levels of nutrients than compost. Earthworms candegrade household waste, sewage sludge and organic waste.

Table 3: Salient features of aerobic composting processes

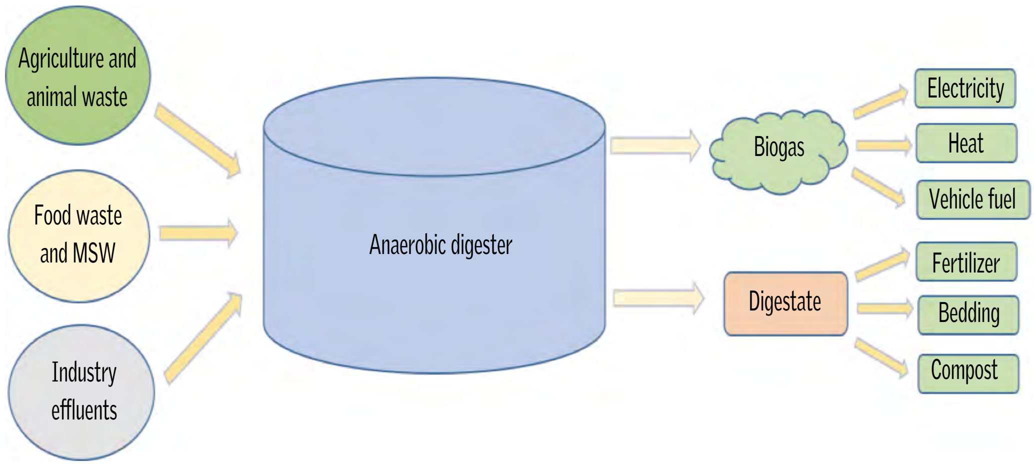
Parameters	Composting	Vermicomposting
Type of process	Three stages: Mesophilic, thermophilic and cooling and maturation stage	Single stage: Mesophilic
Organic waste characteristics	Stored organic waste, combination of waste with similar decomposition rate	No hard, oily, acidic or alkaline compounds
Organism involved	Microorganisms and macro-invertebrates	Mostly earthworms
Stocking density	–	27–35 worms/kg feed
Feed rate	–	1.25 kg feed/kg worm
Initial C:N ratio	20–50	25–30
pH	5.5–7.5	5–8
Moisture content	Coarse organic waste: 70–75% Fine organic waste: 55–65%	Coarse organic waste: 70–90%
Product characteristics	The texture is coarser and may contain heavy metals	The texture is more refined and heavy metals accumulate in earthworm bodies

Source: Compiled from Lim S.L., Lee L.H., Wu T.Y. (2018) Sustainability of using composting and vermicomposting technologies for organic solid waste biotransformation: Recent overview, greenhouse gases emissions and economic analysis. J Clean Prod 111 (Part A).

2.3 Anaerobic composting

Anaerobic digestion, also referred to as biomethanation, is a robust, well-proven engineered process to biochemically decompose both liquid and organic matter by various bacterial activities in an oxygen-free environment. The anaerobic digestion process occurs naturally in many anoxic environments, such as watercourses, soils and landfills. Anaerobic digestion has previously been associated with treatment of sewage sludge from aerobic wastewater treatment and animal manure. Over time, the main fields of anaerobic digestion usage moved from municipal sewage sludge to liquid (mainly industrial) wastewater, followed by the municipal organic fraction of solid waste and agricultural residues.

Figure 4: Anaerobic composting



Source: CSE, 2021

Table 4: Comparative overview of treatment methods for biodegradable waste

Parameters	Composting	Vermicomposting	Anaerobic digestion
Input feedstock	Biowaste (C/N: 20–50; TS: 55–75%)	Biowaste (C/ N: 25 – 30; TS: 70–90%)	Biowaste (C/N: 16–25)
Conversion operating conditions	The process needs moisture and aeration. Low ambient temperatures (~15°C) slow the process.	Bedding layer, moisture aeration and shading are needed. Ambient temperature of 10–35°C ideal.	30–40°C. Anaerobic, atmospheric pressure
Resource requirements	Water is needed during the process. Avoid water saturation by rainfall—energy for shredding feedstock, turning and aeration of windrows, and sieving of compost. Space of 200–250 m^2/ tonne daily input	Water is added in hot arid climates. Energy for shredding feedstock. Space of 800 m^2/ tonne daily input or 200 m^2 when assuming four to five vertical stacks of treatment bins.	Depending on technology and feedstock, some water may be required Wet AD: TS—15% Dry AD: TS—15% Land use depends on system type
Processing time	90 days for mature compost	45–60 days for vermicompost, which also includes 15 days pre-treatment by composting.	30 days
Hygienization	Inactivation of pathogens and weed seeds by temperature	No complete inactivation of pathogens and weed seeds	No complete hygienization
Emissions	CO_2 and water vapour, leachate control	CO_2 and water vapour, leachate control	Methane leakage may occur—low amounts of toxic H_2S (if not combusted)

Parameters	Composting	Vermicomposting	Anaerobic digestion
Skill requirement	Only simple labour skills required	Simple labour skills required	Technical skills for building gas-tight digester. Trained technicians for operation and maintenance
Output value products	Compost: Nitrogen: 1–2%; P: 0.4–4%; K: 0.5–2.5% (depends on feedstock and technology)	Vermicompost (30% of input in wet weight) and worms (3–10% yield of stocking density per week). Nitrogen: 1–2%; P: 0.4–4%; K: 0.5–2.5% (depends on feedstock and technology)	Biogas (55–60% CH_4, 35–40% CO_2), digestate (nutrient content depends on feedstock and retention time)
Product yield	50% compost in dry weight or 30% in wet weight	50% compost in dry weight or 30% in damp weight	Rule of thumb: 10 kg biowaste = 1 m^3 biogas (and 22 MJ). Methane yield: 0.36–0.53 m^3 CH_4/kg VS of feedstock. Liquid digestate (input and output)
Comments	Compost quality is influenced by feedstock quality. The amount of salt and metals in the soil and crops may affect	Worms avoid tannins and oily, salty, acidic and alkaline compounds	Lignified material not suitable. Smaller particle size accelerates the process. Biogas requires ample storage space if not continuously used on-site (e.g. for cooking or generator)

Source: Compiled from Ali U., Sajid N., Khalid A., Riaz L., Rabbani M.M., Syed J.H., Malik R.N. (2015) A review on vermicomposting of organic wastes. Environmental Progress and Sustainable Energy 34(4).

2.4 Factors affecting composting

Like those of any other biological process, the chemical and physical characteristics of the substrates are vital to the viability of the process. The complexity and function of the substrate's molecular structure are significant because these characteristics influence the assimilation of nutrients by different microorganisms. Composting is an organic matter bio-oxidative microbial degradation process. The ideal moisture content in the starting material depends on the physical state and size of the particles and the composting method used. The key factors affecting the composting are furnished below.

Table 5: Major factors affecting the composting

Factors	Optimal range during various stages	Comments
Oxygen concentration	13–18%	Maintaining higher oxygen concentration in a compost pile is complex and may lead to other problems, like low moisture content.
Particle size	A mixture of particles 3–50 mm	Smaller particles have a greater surface area relative to their volume, which means more material is exposed to microorganisms. They adversely affect the free air space (FAS) within a material.
Structure	Enough of the particles in the composting pile maintain their structural properties throughout the composting process	If all the particles have poor structural characteristics (like cardboard, which becomes wet and loses its initial rigidity), FAS within the composting pile falls.
C:N ratio	30:1	If the C:N ratio is too high (excess carbon), decomposition slows down. If the C:N ratio is too low (excess nitrogen), you will end up with a stinking pile.
Moisture content	40–60%	At lower moisture levels, microbial activity is limited. At higher levels, the process is likely to become anaerobic and foul-smelling.
Temperature	55–60°C	Temperatures within compost piles affect microbial growth and activities, and hence the rate at which the raw materials decompose. Higher temperatures result in the faster breakdown of organic materials, destroy weed seeds, and kill pathogens. However, excessively high temperatures (>65˚C) can inhibit microbial activity.
pH	5.5–8	Microorganisms cannot survive in environments that are too acidic or alkaline. When the pH is >9, nitrogen is more readily converted to ammonia and becomes biologically unavailable, increasing the C:N ratio and slowing the process.

Source: Compiled from various relevant literature

2.5 Factors affecting anaerobic digestion

In anaerobic digestion, the control is mainly undertaken by the microorganisms. However, operational conditions such as temperature, pH, essential nutrients,and toxicants can play a significant role in modifying the reaction rates of individual sub-processes. The anaerobic digestion's energy performance depends mainly on the biogas production technology, raw materials andgeographic location (ambient temperature) (see *Table 6: Key factors affecting anaerobic digestion*).

Table 6: Key factors affecting anaerobic digestion

Factors	Optimal range during various stages	Comments
Moisture content	Less than 60%	The system will not work if the moisture content is not in the suitable range.
pH	6–7 for a single-stage digester. In two-stage digesters however it is 5–6 in the hydrolysis stage and 6.5–8 in the methanogenic stage.	Low pH slows down the process and may lead to death of microorganisms.
Alkalinity	More than 100 mg/L	Alkalinity will speed up the acidogenic stage faster than the methanogenic stage, which can lead to process upsets.
Volatile fatty acids (VFAs)	Less than 4,000 mg/L	Higher concentrations of VFAs can be toxic to the microorganisms in the digester.
Temperature	Mesophilic digesters: 30–38°C and Thermophilic digesters: 50–60°C	Thermophilic breakdown proceeds much faster than mesophilic. Therefore, a thermophilic reactor can yield a higher rate of biogas production in a shorter period.
Retention time	14–40 days but it strongly depends on technology.	If the retention time is too short, the entire degradation process will not be achieved. The SRT is too long, biogas recovery efficiency suffers, and the digester vessel will not be efficiently used.
C:N ratio	30:1	Excess nitrogen can lead to the accumulation of ammonia in the digester. Lower nitrogen can affect the cell growth of microorganisms.
Ammonia	200 mg/L	Excess ammonia leads to substrate/ product toxicity and hampers the digestion process.
Sulphide	Less than 50 mg/L	The presence of high sulphide (as H2S) levels inhibits methane generation, most likely due to the increased loading of sulphur compounds, including proteins.

Source: Compiled from various relevant literature

Most of the microorganisms for composting are readily available in the solid waste itself. They tend to multiply rapidly in favourable conditions, and the number of bacteria is rarely a limiting factor in composting, provided all otheraforementioned factors are appropriate. There are various inoculums on the market that claim to speed up the composting process and locally available products that can be used as alternatives to commercially patented inoculums,such as fresh cow dung, which can be used in place of patented inoculum, bio-inoculum or culture. Cow dung added in excess to the waste will not affect the quality of the compost. For aerobic digestion, it is essential to keep the overall moisture content of the mixture 45–55 per cent by weight.

In anaerobic digestion, cow dung will be added in slurry form for initial seeding. The slurry can be made by mixing fresh cow dung with water in the ratio of 1:1, and other additives such as jaggery and yeast can be added to the slurry, based on the requirement.

The second alternative is sour buttermilk or curd, which can be used to accelerate aerobic composting. The proportion of sour buttermilk or curd to waste varies depending on the characteristics and quantity of waste to be processed.

The third alternative is a sludge of the sewage treatment plants (STPs) and digesters, which can be used as the source of microorganisms in aerobic or anaerobic composting processes. It may however be noted that sludge from STPs, which uses aerobic treatment processes, will be helpful only for the aerobic composting process. The sludge of the digester will be only beneficial for seeding the anaerobic processes.

The fourth alternative is panchagavya, which consists of nine ingredients, i.e. cow dung, cow urine, milk, curd, jaggery, ghee, banana, tender coconut and water. It has the potential to promote growth and provide immunity in plant systems.

Several composting inoculants are available at varying prices in the market. They make many claims, and users are unsure of statements made by inoculant vendors. As a result, the idea of developing compost-specific standards and promoting quality requirements to help the compost industry and aid the growth of new markets is slowly gaining traction across the country.

2.6 Compost quality standards

Compost quality standards have been set as per the Solid Waste Management Rules, 2016, Fertilizers Control Order (FCO) 2009 and FCO 2013 (see *Table 7: Compost quality standards).*

New Delhi-based Indian Agricultural Research Institute (IARA), also known as Pusa Institute of Technology, carries out scientific experiments for comparative performances of inoculants available in the market, with IARI inoculate the baseline. The institute also has facilities to carry out quality testing of city compost as per Fertilizer Control Order norms. Without such distinguishing features, government rules, guidelines and decision-makers' interventions, compost sales may lag and eventually fail one of the purposes of decentralizing the treatment system.

Table 7: Compost quality standards

S. no.	Parameter	Organic compost FCO* 2009	Phosphate-rich organic manure FCO (PROM) 2013
1	Arsenic (mg/kg)	10.001	10
2	Cadmium (mg/kg)	5	5
3	Chromium (mg/kg)	50	50
4	Copper (mg/kg)	300	300
5	Lead (mg/kg)	100	100
6	Mercury (mg/kg)	0.15	0.15
7	Nickel (mg/kg)	50	50
8	Zinc (mg/kg)	1,000	1000
9	C/N ratio	<20	Less than 20:1
10	pH	6.5–7.5	(1:5 solution) maximum 6.7
11	Moisture, % by weight, maximum	15.0–25.0	25.0
12	Bulk density (g/cm^3)	<1.0	Less than 1.6
13	Total organic carbon, % by weight, minimum	12.0	7.9
14	Total nitrogen (N), % by weight, minimum	0.8	0.4
15	Total phosphate (P_2O_5), % by weight, minimum	0.4	10.4
16	Total potassium (K_2O), % by weight, minimum	0.4	–
17	Colour	Dark brown to black	–
18	Odour	Absence of foul odour	–
19	Particle size	Minimum 90% material should pass through 4.0 mm IS sieve	Minimum 90% material should pass through 4.0 mm IS sieve
20.	Conductivity (as dsm-1), not more than	4.0	8.2

Note: * FCO: Fertilizer Control Order; Tolerance limits as per FCO: Compost: The sum of nitrogen, phosphorus and potassium nutrients shall not be less than 1.5 per cent in compost. For PROM: No such directive

Table 8: Vermicompost standards

S. no.	Criteria		Value
1	Moisture % by weight		15–25
2	Colour		Dark brown to black
3	Odour		Absence of foul smell
4	Particle size		Minimum 90% material should pass through 4.0 mm IS sieve
5	Bulk density		0.7–0.9
6	Total organic carbon, % by weight, minimum		18.0
7	Total nitrogen (N), % by weight, minimum		1
8	Total phosphates (P_2O_5), % by weight, minimum		0.8
9	Total potassium oxide (K_2O), % by weight, minimum		0.8
10	Heavy metal content (mg/kg) by weight, maximum		
	a.	Cadmium (Cd)	5
	b.	Chromium (Cr)	50
	c.	Nickel (Ni)	50
	d.	Lead (Pb)	100

Note: Tolerance limit for vermicompost: The sum of nitrogen, phosphorus and potassium nutrients should not be less than 2.5 per cent in the case of vermicompost.

3. DECENTRALIZED TREATMENT OF ORGANIC WASTE

Composting of biodegradable solid waste can be conducted at different levels, i.e. household, community, ward and zone level, using technology and mechanization. Small-scale home composting is most frequently performed in bins or open heaps, relying on a passive aeration process. Medium- and large-scale composting facilities rely more on mechanization with regular turning or active aeration and the use of bins or in-vessel composting reactors. Small- or medium-scale decentralized composting can be operated by suitable technology and executed at decreased investment and operating costs. Manual composting in decentralized plants is more simply integrated with the overall Indian level of development and socioeconomic background as it involves labour-intensive processes. It also offers additional employment opportunitiesand a source of income to the underprivileged in Indian society.

Various on-site and decentralized composting methods can be implemented for multiple household sizes and other premises or establishments. Any strategies for handling smaller waste capacity, however, can manage more waste simply by increasing the number of units. As a result, cost comparisons and space requirements should always be calculated before choosing an acceptable method based on need and financial capability and material availability, climate, techno-feasibility, land availability, waste composition, quantity, physico-chemical characteristics, feedstock, end-use requirements and environmental factors.

The following decentralized composting methods can be used as a reference by multiple stakeholders for managing their solid waste at the source at different levels, i.e. household, community, ward and zone levels. It should be noted that the capital costs, as well as the operating and maintenance costs, of the decentralized organic waste treatment methods listed here are subject to vary depending on location.

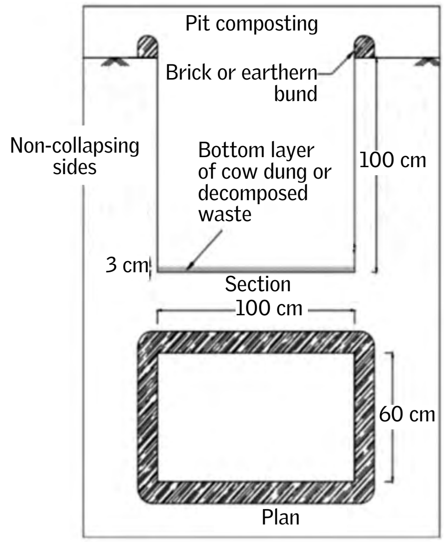
3.1 Decentralized compositing ideal for individual households

1. Pit composting

Technology	**Aerobic composting**
Description	• Two pits required, each of size 1 m x 0.6 m x 1 m. • Bigger pits for bigger families, according to requirements. • Each pit can cater to biodegradable waste continuously for about five to six months. • At the bottom, spread a layer of cow dung slurry before filling the waste for composting and spread the waste uniformly over the cow dung layer. • Waste should be shredded into small pieces for better decomposing. • A layer of dry leaves or soil may be spread over the waste daily to avoid a foul smell from the pit. • Turn the waste every five to seven days for proper aeration. • Repeat the procedure until the first pit is filled; close the pit by spreading a 15-cm layer of soil. • Once the first pit is closed, use the other pit in the same way. • Once the compost is ready, empty the pit, store it in a cool, dry place for seven days and then use it.
Land area required	2 m^2 for pits and 1 m^2 for working space.
Coverage	One household for a family of five or six members
Waste treated/day	Up to 1 kg (up to 30 kg/month)
Processing time	Four months
Compost production	20 per cent of the total waste feed into the pit
Workforce	Earthen pit: Can be easily managed by household Brick or concrete pit: Rs 2,000–3,000 per labour
Capital cost	Nil (if earthen pit) Approx. Rs 10,000 (if brick or concrete pit)
O&M cost	Nil (as no manpower required for O&M)
Monitoring of composting process	• Choose an elevated area to avoid water clogging. • Waste of bigger sizes is to be cut into small pieces (1 inch) for easy decomposing. • Spread the waste over the decomposed waste layer. • Sprinkle water above the layer to maintain the moisture content. • More browns than usual should follow the addition of oily, gravy or liquid items to enhance composting. • Once the pit is filled, close it by spreading over it a layer of soil. • Cover the pit with a green mesh sheet to keep rodents away.
Indicator of quality of compost	Temperature: Mature and stable compost has a moderate temperature in accordance with the outside air temperature. If the compost feels hot, it indicates that it still generates heat due to decomposition. Colour: Should be medium to dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved in a 4 mm sieve. Structure: A crumbly structure is desired; unfavourable composting conditions may result in a dusty appearance. Moisture content: One should be able to squeeze the compost into a ball in the hand without water dripping out, and the hands should feel moisture inside the compost. When releasing the compost, there shouldn't be much left in the hand.
End use	Compost can be used as manure in home gardens.
Where this technology has been implemented	Lal Bagh, Bangalore This technology is cost-effective and feasible for households where space is available inside the boundary.

Earthen pit

Source: https://www.harajeevan.org



Section and plan of pit for composting

Source: reasearchgate.net

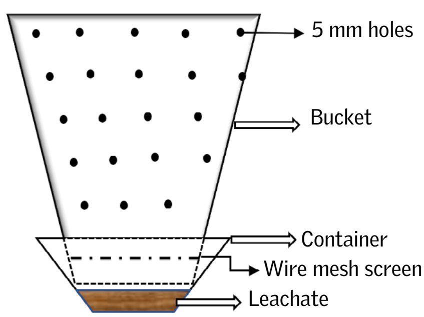
2. Home composting buckets

Technology	**Aerobic composting**
Description	• Three buckets of 60-litre size with lids are required. • Each bucket can cater to waste for 30 days. • Drill 5 mm holes in a straight line along with the bucket at a distance of 6 cm around the bucket and 8 mm holes at the bottom and lid. • Place a wire mesh screen (platform) at the bottom of the bucket. • Apply a thick layer of prepared bio-compost over the platform. • Now spread the shredded waste over the bio-compost layer and spray diluted bio-culture mixture (bio-culture to water 1:50) over the waste and add browns. • Before covering the bucket, repeat the above process of waste daily. • From the fourth day onwards, properly mix the old waste layer for proper aeration before placing fresh waste on the top. • Repeat the procedure until the first bucket and second bucket are filled. • Once the second bucket is filled, start using the third bucket until it's filled. Once the third bucket is filled, remove the compost from the first one, dry it and use it.
Land area required	1.5 m^3 for the buckets and 1 m3 for the working space.
Coverage	One household for a family of five or six members
Waste treated per day	Up to 1 kg
Processing time	60 days
Compost production	20 per cent of the total waste feed into the bucket
Workforce	Can be easily managed by household
Capital cost	Rs 2,000 for 60-litre buckets (three) Rs 500 for wire-mesh screen (three)
O&M cost	Rs 200 for 2-kg bio-compost (can be used for five to six months) Rs 200 for 1-kg bio-culture (can be used for five to six months)

Technology	Aerobic composting
Monitoring of composting process	• Waste of bigger sizes is to be cut into small pieces (of 1 inch) for easy decomposing. • Place the wire-mesh screen so that it does not touch the bottom of the bucket. • Make sure that water used for dilution of bio-culture does not contain chlorine. • More browns than usual should follow addition of oily, gravy or liquid items to enhance composting. • Do not use excess water. • The holes at the bottom of the buckets are made to create passage for leachate. • Place a container under the bucket to collect the leachate. • The leachate collected can be diluted with water and used as manure for trees and plants. • Cover every day's waste with a thin layer of compost or browns. • During the rainy season, cover the buckets to protect it from rain.
Indicator of quality of compost	Temperature: Mature and stable compost has a moderate temperature as per the outside air temperature. If the compost feels hot, it indicates that it still generates heat due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved in a 4 mm sieve. Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: Should be able to squeeze the compost into a ball in your hand without water dripping out, and your hands should feel the moisture inside the compost. When releasing the compost, there shouldn't be much left over on the hands.
End use	For home gardens, compost can be used as manure.
Where this technology has been implemented	Copernicus Marg, New Delhi This technology is cost-effective and feasible for households where space is a constraint.

Bucket composting

Source: shudh-labh.com

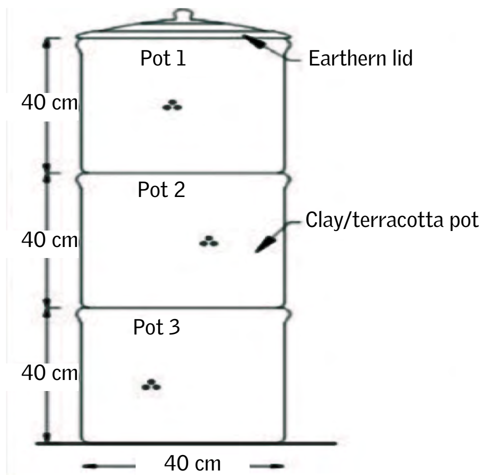


Section diagram of bucket composting

3. Tri-pot composting

Technology	**Aerobic composting**
Description	• Three pots of 40-cm height and 40-cm girth with lids are required. • Each pot can cater to waste for 25 days. • Drill holes (of 20-mm diameter) on the sides. The holes will allow air to circulate. • Also, make large holes (of 50-mm diameter) at the bottom of the pots. These holes will allow the leachate to drain leachate. Make sure you leave the third pot without a hole in the bottom. • Place a plain sheet of paper at the bottom of the first and second pots to create a platform. • Apply a thick layer of prepared bio-compost over the platform. • Spread the shredded waste over the bio-compost layer and spray diluted bio-culture mixture (ratio of bio-culture to water is 1:50) over the waste. • Before closing the pot with the lid, repeat this process daily. • From the fourth day onwards, mix the old waste layer properly for proper aeration before placing fresh waste on the top. • Once the first pot is filled with the waste, interchange it with the second pot and repeat the process. • Once the second pot is also full, tear the paper of the first pot and let the partially decomposed waste move to the third pot. • Then, place the first pot in the middle of the second pot and continue the process as before. • When all the pots are complete, the partially decomposed waste inside the bottom pot will have already become compost. • Now empty the third pot and repeat the process as usual.
Land area required	0.5 m^3 for the pots and 1 m^3 for the working space.
Coverage	One household for a family of five or six members
Waste treated per day	Up to 1 kg
Processing time	45 days
Compost production	20 per cent of the total waste feed into the pot
Workforce	Earthen pot: Can be easily managed by household
Capital cost	Rs 1,500 for three pots Rs 200 for 2 kg bio-compost (can be used for five to six months) Rs 200 for 1 kg bio-culture (can be used for five to six months)
Monitoring of composting process	• Waste of bigger sizes is to be cut into small pieces for easy decomposing. • Don't place regular newspaper as the ink will run. • Make sure that water used for dilution of bio-culture does not contain chlorine. • Do not use excess water. • More browns than usual should follow the addition of oily, gravy or liquid items to enhance the composting. • Cover every day's waste with a thin layer of compost or browns. • During the rainy season, cover the pots to protect them from rain.

Technology	**Aerobic composting**
Indicator of quality ofcompost	Temperature: Mature and stable compost has a moderate temperature in accordance with the outside air temperature. If the compost feels hot, it indicates that it still generatesheat due to decomposition. Colour: Should be medium to dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved in a 4 mm sieve. Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: One should be able to squeeze the compost into a ball in the hand without water dripping out, and the hands should feel the moisture inside the compost. When releasing the compost, there shouldn't be much left in the hand.
End use	Compost can be used as manure in home gardens.
Where this technologyhas been implemented	South Goa This technology is feasible for households with little space availableinside the boundary.



Tri-pot composting

Source: https://www.instructables.com/Terracotta-home-composter/

4. Pipe composting

Technology	Aerobic composting
Description	• Four pipes of 10-inch diameter and 5-foot height, medium size and medium thickness with end caps are required so that rodents cannot damage them. • Each pipe can cater to waste for 15 days. • Drill five 5-mm holes in a straight line, then drill three more lines of holes and space them evenly around the pipe. Dig a pit up to one-foot deep, place the pipe vertically in the pit and fix it firmly. This can be placed in a planter on a balcony or terrace. • Add two handfuls of crushed leaves into the pipe to create a bed at the bottom, or add soil. • Add kitchen waste followed by an equal amount (by volume) of browns. If crushed dry leaves or standard coco peat is used as browns, add diluted sour curd or cow dung slurry to accelerate composting. • Please note that the addition of soil makes compost processing difficult. • Once the first pipe is filled, start using the second pipe, and repeat the same procedure in the third pipe. • Once the third pipe is filled, take out the first pipe from the ground carefully. Take out the compost from inside the pipe using a rack, dry it for some time, then use it.
Land area required	1 m^3 for the pipes and 1 m^3 for the working space.
Coverage	One household for a family of five or six members
Waste treated per day	Up to 1 kg
Processing time	30 days
Compost production	20 per cent of the total waste feed into the bin
Workforce	Can be easily managed by household
Capital cost	Rs 1,000 for 6 m x 0.25 m (diameter) pipe
O&M cost	Rs 300 for coco peat (5 kg) (can be used for five to six months)
Monitoring of compostingprocess	• Do not overload the pipe with kitchen waste; instead, layer it properly with enough browns. • Waste of bigger sizes are to be cut into small pieces (1 inch) for easy decomposing. • Do not use excess water • More browns than usual should follow the addition of oily, gravy or liquid items to enhance the composting. • Cover every day's waste with a layer of browns.
Indicator of quality of compost	Temperature: Mature and stable compost has a moderate temperature in accordance with the outside air temperature. If the compost feels hot, it indicates that it still generates heat due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved in a 4 mm sieve. Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: One should be able to squeeze the compost into a ball in the hand without water dripping out, and the hand should feel the moisture inside the compost. When releasing the compost, there shouldn't be much left in the hands.
End use	For home gardens, compost can be used as manure.
Where this technology has been implemented	Jamshedpur, Jharkhand This technology is an effective and proven method for treating organic waste and is feasible for households where space is a constraint.

Pipe composting

Source: soilandhealth.in

3.1.1 FAQs about aerobic composting

1. **There is a white fungus in the compost bin. Is that bad?**
No, the white fungus is not harmful—it means your composting process is active. You can continue to layer your kitchen waste with coco peat and dry leaves. If the fungus is not white, there is something wrong. We recommend discarding the contents.

2. **There is water vapour under the lid. What should I do?**
Water vapour below the lid is a good sign. It means the aerobic microorganisms are working, and composting is in progress. You can wipe the lid with a dry cloth and put it back.

3. **How to avoid fruit flies around my cabin?**
Fruit flies are one of the most common problems, and there are multiple solutions to avoid them. You can place a bowl of water and add four to five pieces of camphor on the compost bin or cover the kitchen waste completely with crushed dry leaves or coco peat. You can add two to three drops of aromatic oil such as eucalyptus, lemongrass or lavender oil. You can also cover the compost bin with a mosquito net or a thin cotton cloth around the compost bin. Placing a newspaper or cotton cloth on the compost pile will also reduce food flies.

4. **How to get rid of maggots inside the bin?**
Flies and maggots come out if the compost pile is too wet. So avoid rain or water splash on the compost bed. Kitchen waste is high in moisture—to ensure the compost is not too wet, add an equal proportion of grounds like crushed dry leaves and coco peat.

5. **How to manage black liquid under my compost bin?**
If black liquid accumulates at the bottom of the bin or leaks from the bin, it is an indication that the amount of browns added is not enough and that your compost is too wet—all the water content from your kitchen waste is not absorbed. To fix the leaky bin, use a pipe or a stick to dig for holes in the pile and add coco peat or compost so that the compost can absorb excess moisture. Remember to drain the water content from food like sambar and rasam and add solids like vegetables, greens or pulses.

6. **What to do if the material inside the bin is not decomposing?**
There are several possible reasons for this such as not enough nitrogen, oxygen or moisture in the waste. All three ingredients help in the composting process. To accelerate the composting process, add enough nitrogen-rich sources such as manure, grass clippings or food scraps. Mix the material regularly and add water to moisten the pile.

7. **How to avoid foul smells from the bin?**
Foul smell is another common problem that occurs due to anaerobic conditions or lack of air circulation in the compost bin. To avoid bad smells, do not add big lumps of cooked food or whole vegetables into the bin. If you have rotten vegetables or fruits, cut them into small pieces and spread them in the compost bin. If the decomposed waste smells like rotten egg, turn the waste at smaller intervals to get rid of the smell. Turning the waste frequently helps in aeration. Add straw, hay or dry leaves to absorb excess moisture. If the waste emits a smell of ammonia, add browns or coco peat.

7. **What to do if the dry leaves and browns are not decomposing?**
Poor aeration due to self-compaction, mainly when the material is wet, results in this. To remedy the situation, loosen the material with a rake, avoid adding thick layers of the same material and shred the material before mixing.

8. **What to do if my compost is dry?**
Compost getting dry indicates that the moisture is too little to complete the process of decomposition. This can slow down the process. To avoid this, sprinkle water on the decomposed waste, turn it and mixed it with the waste properly.

9. **Which foods should be avoided?**
In aerobic composting, oil, fat and non-veg items are avoided because they attract insects, flies, and rodents. These items can however be processed in

anaerobic composting. Also, stiff woody branches, stems or roots should also be avoided as it takes too much time to decompose.

10. **How to speed up my composting during the monsoon period?**
During the monsoon, the speed of composting can slow down due to the high moisture content in the atmosphere. To accelerate the composting process, add inoculums such as curd or cow dung slurry and keep the container in a dry place.

11. **What is the ideal green to brown ratio for composting?**
At the beginning of the composting process, the ratio of green waste and browns should be maintained 1:1, which means that browns and green waste should be of the same quantity. Once the system is stabilized, however, the ratio for mixing can be 2:1, which means that the quantity of browns needs to be half the quantity of green waste.

12. **How do I know my compost is ready?**
Your compost should smell like moist soil—there should be no foul smell. You and should be able to squeeze the compost into a ball in your hand without water dripping out, and your hands should feel the moisture inside the compost. At the time of releasing the compost, there shouldn't be much left in the hand.

5. Bokashi

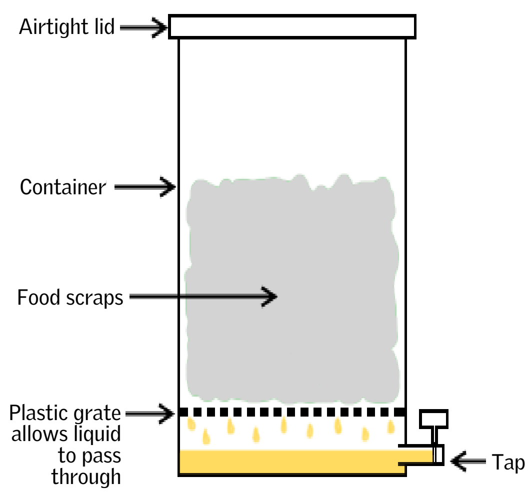
Technology	Anaerobic digestion
Description	• The volume of the container is 0.06 m^3 (0.4 m x 0.4 m x 0.4 m). Also, you can use a barrel or bucket with a lid that seals it perfectly. The container should have a tap at the bottom to collect our nutrient-rich compost tea once or twice a week. • Two containers are required. Each container can cater to waste for 45 days. • First, place about 20–30 gm of jaggery or molasses at the bottom of the container. This accelerates the fermentation process and is a food for microbes. • Then place the plastic grate at the bottom of the bucket with the knob facing upwards. About 3 inches of space is required for the fluid to collect at the bottom, which we drain out as the bokashi tea. Make sure the tap is closed, and place a piece of newspaper over it. • Bokashi powder. Bokashi bran is vegan and contains essential microorganisms to perform the composting process quicker than the conventional method of composting • In the first layer, sprinkle two tablespoons of bokashi bran (i.e. bokashi powder) over the bottom. Then add a 1–2-inch layer of kitchen waste over this. For every 1–2-inch waste, sprinkle at least two tablespoons of bokashi bran. Add 1 – 2-inch kitchen scraps and sprinkle bokashi powder again. Make sure you chop large chunks of waste into smaller pieces for faster composting. Finally, crush and add eggshells.

Technology	Anaerobic digestion
	Compress the layers as and when you are adding the waste layer by layer. It will displace out the air pockets, which may be present between the waste. It is also an essential step for successful smell-free composting. After finishing up multiple layers, add a thick layer of bokashi powder (about 3 tablespoons) and take an extra step to keep it air-tight. Place a piece of cardboard on top of the layers and press it. Finally, close the lid properly to make sure no air can enter. The composter can be kept indoors or in any location where there is no sunlight. Bokashi tea must be collected every three or four days to avoid the foul smell and composting failure. This tea can be used as a liquid fertilizer for your plants. It must be diluted with water at a ratio of 100:1, i.e. 100 parts water to 1 part bokashi juice, or approximately 2 teaspoons of juice for every litre of water. Mix well and water your plants to give them an instant supply of nutrients. Leave the composter undisturbed for at least 15 days before you harvest. Don't forget to collect the bokashi tea twice a week.
Land area required	0.12 m^3 for the container and 1 m^3 for the working space.
Coverage	One household for a family of five or six members
Waste treated per day	Up to 1 kg
Processing time	40 days
Compost production	20 per cent of the total waste feed into the bin
Workforce	It can be easily managed by household
Capital cost	Rs 3,600 for two containers
O&M cost	Rs 300 for bokashi powder (1 kg) (can be used for one to two months)
Monitoring of composting process	• Do not overload the pipe with a lot of kitchen waste; instead, layer it properly with enough browns • Waste of bigger sizes are to be cut into small pieces (1 inch) for easy decomposing • Do not practice using the excess water • More browns than usual should follow the addition of oily, gravy or liquid items to enhance the composting. • Cover every day's waste with a layer of browns. • If the composter is used correctly, its contents do not emit any smell. Certain conditions however—the lid not closed correctly, the top layer of waste not covered with enough bokashi powder, or waste not tightly pressed together, leaving air pockets—cause bad smells to be emitted from the composter. • The composter should be emptied into the garden, and after proper washing with water only, it should be started anew to avoid any unpleasant smell.

Technology	Anaerobic digestion
Indicator of quality ofcompost	Temperature: Mature and stable compost has a moderate temperature in accordance with the outside air temperature. If the compost feels hot, it indicates that it still generatesheat due to decomposition. Colour: Should vary dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved in a 4 mm sieve. Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: One should be able to squeeze the compost into a ball in your hand without water dripping out, and your hands should feel the moisture inside the compost. At the time of releasing the compost, there shouldn't be too much left in the hand.
End use	For home gardens, compost and brew can be used as manure. The bokashi liquid is full of microorganisms and nutrients, and considered an excellent fertilizer. It can be diluted with water and used for watering potted and garden plants. It should only be used in a diluted form only for garden plants. Undiluted bokashi liquid however can be used in the toilet, sink or washbasin, as microorganisms dissolve toilet paper, fat and remains of detergents or washing powder and prevent fat accumulation and other substances in the siphons.
Where this technology has been implemented	Bengaluru, Karnataka This technology is an effective and proven method for treating organic waste and is feasible for households where space is a constraint.

Bokashi composting

Source: https://deepgreenpermaculture.com

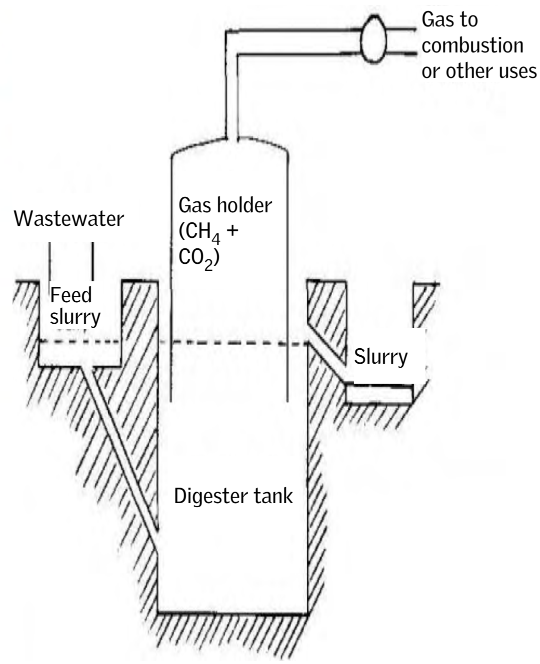


Bokashi composting bin

6. Anaerobic digestion (biogas)

Technology	**Anaerobic digestion**
Description	• The main components of the waste-based biogas plant are: a. Digester tank b. Gas holder tank c. Feeding pipe (110 mm diameter) d. Slurry outlet pipe (63 mm diameter) e. Gas outlet pipe (25 mm diameter) f. Bricks for additional load g. Control valve • The gas holder tank is kept inverted above the digester tank to collect the gas generated from the process. The water jacket model is mainly used in households. • The volume of the container for feeding the waste should be 0.25 m^3 for the household. The material of the digester and gas holder tank is fibre-reinforced plastic. • The digester tank can receive waste continuously once the unit is stabilized. • To start with a new biogas plant, fill 70 per cent of the digester tank with slurry from another plant or fresh cattle-dung. • Remove the straw and waste fodder from the dung, then mix it thoroughly with water to prevent separation of solid and liquid within the digester. • The amount of cattle dung should be 2–3 per cent of the total slurry for initial loading—it can be diluted with water. As a thumb rule, 1 kg of dung requires 10 litres of water; hence 20 kg of cow dung will be required along with 200 litres of water to prepare the initial slurry. • Leave the tank intact for 14 days. Collect the methane gas from the gas holder tank and use it for cooking. • From the fourteenth day onwards, waste from the kitchen and other degradable waste can be fed in the digester tank in a slurry form through the feeding pipe. • The waste should be chopped into pieces of 1-inch length for fast digestion, and the plant must be fed regularly to achieve regular gas production. • The overflowing slurry must be removed from the slurry outlet pipe. Otherwise, it can block the flow, and the gas pressure inside the digester might increase until it escapes through the gas inlet pipe or blows off the water trap. • It should be collected in a bucket and feed to the plants as it has excellent nutritional values. • The methane gas generated can be supplied to the households with the help of a gas outlet pipe and can be used in the household for cooking purposes.
Land area required	0.5 m^3 for the tank and 1 m^3 working space
Coverage	Two households for a family of eight to ten members
Waste treated per day	Up to 2 kg
Processing time	14 days
Gas and slurry production	2 kg of waste gives around 0.2 m^3 of methane gas which can be used for cooking for up to 20 minutes on a single burner. The quantity of waste feed into the tank in slurry form gives the same quantity of slurry in the form of liquid fertilizer
Workforce	The work can be easily managed by a household

Technology	**Anaerobic digestion**
Capital cost	Infrastructure: Rs 15,000
O&M cost	Rs 200 per annum
Monitoring of digestion process	• The substrate should have to be free of impurities to avoid scum formation and blockage of the inlet and outlet pipes. • A mosquito net to cover the unit will prevent the breeding of mosquitoes around the unit as water is used. • The slurry channel and outlet must be washed and should be covered from directsunshine. • Flooring: A concrete floor (anti-skid) with a proper slope at the main entrance may be constructed. • The gas distribution pipes should be regularly monitored. • Fire extinguishers should be kept within the facility. • The digester must be leak-proof. • The C:N ratio must be maintained appropriately
Indicator of quality of products	Alkalinity: Alkalinity will speed up the acidogenic stage more than the methanogenic stage, which can lead to process upsets. C:N ratio: Excess nitrogen can lead to the accumulation of ammonia in the digester. Lower nitrogen can affect the cell growth of microorganisms. Ammonia: Excess ammonia leads to product toxicity and hampers the digestion process. Volatile fatty acids (VFAs): Higher concentration of VFAs can be toxic to the microorganisms in the digester. Sulphide: The presence of high sulphide (as H_2S) levels inhibits methane generation, most likely due to the increased loading of sulphur compounds, including proteins. pH: Should be between 6-7 as low pH will slow the process and may lead to the death of microorganisms. Also, high pH refers to the digested material has a high buffer capacity. At that time, the CO_2 gradually decreased, and methane production gradually increased to balance the process in the digester. Moisture content: Should be less than 60 per cent. The system will not work if the moisture content is not in the suitable range.
End use	The slurry generated from the plant can be directed towards the plants as a liquid fertilizer. The methane gas generated can be used for cooking purposes.
Where this technologyhas been implemented	Thiruvananthapuram, Kerala Methane gas obtained can be used for cooking, which is why this technology is ideal for households. In addition, this technology has almost negligible operation and maintenance.
Limitations	Orange, lime, pickles, disinfectants, soap water, plastic, woodpieces, metal, sand and lignified material should not be put in the digester.



Portable household biogas plants

Source: http://sanitation.kerala.gov.in/bio-gas/

3.1.2 FAQs about anaerobic digestion

1. Can we add fresh cow dung to prepare the initial slurry?

Fresh cow-dung should never be used to prepare the initial feeding slurry as it has a very high temperature inside, which can destroy the micro-organisms inside the digester. Therefore, it is always advisable to use cow dung after a minimum of seven days to prepare the slurry.

2. Can we add more waste than the required capacity into the digester?

Waste other than the required capacity should never be added to the digester as it will replace an equal amount of slurry from the system, which hampers the overall process.

3. Why does the cooking gas give insufficient heat?

The gas—generated during the process of anaerobic digestion—is a mixture of methane, H_2S, CO_2, and water vapour passing through the pipeline to the burner. For this reason, the gas doesn't have a high calorific value. After proper cleaning of the flue gas using H_2S and CO_2 scrubber and a condenser to remove the water vapour, however, the calorific value of the gas can be increased. But using a scrubber and condenser at the household level is not possible. Inverting the pipe to a U-shape helps control the water vapour inside the gas.

4. Why is my system not producing enough gas?

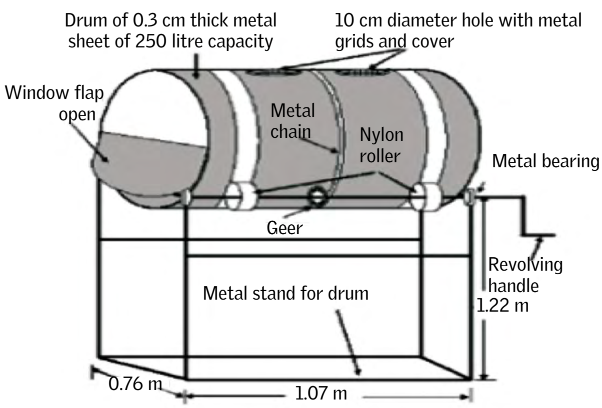
If your system is not producing the required amount of gas even after feeding the correct quantity of waste, it might be due to insufficient microorganisms inside the digester or leaks in the digester or gas collection chamber. Hence measurement of feeding to prepare the initial slurry for the digester is essential, and it should be strictly followed. With regard to system leaks, it is essential to recheck the whole system before feeding waste into the system. A leaky system also results in a decrease in the temperature inside the digester.

3.2 Decentralized compositing ideal for neighbourhoods (RWAs, medium-sized communities, bulk-waste generators)

1. Rotary drum composting

Technology	Aerobic composting
Description	• Three 200-litre drums are required, which should be covered with an anti-corrosive coating, and it is mounted on four rubber rollers and attached to a metal stand horizontally. • Each drum can cater to waste for 18 days. • The drum is manually rotated to ensure proper waste mixing, and two adjacent holes are drilled at the top of the drum to remove excess water. • Waste is shredded to a size of about 1 cm and then mixed with bio-culture inoculum solution to provide better aeration and moisture control. • The waste is manually turned by the handle clockwise once a day, which ensures proper mixing. Sometimes two to three rotations are made to ensure that the material on the top moves to the centre, where the temperature is higher. • For proper aerobic condition, open the side-window flap.
Land area required	1 m^3 for the composting units, 1 m^3 working space
Coverage	Five households
Waste treated/day	Up to 5 kg
Processing time	20 days
Compost production	20 per cent of the total waste feed into the drum
Manpower	1 semi-skilled labour
Capital cost	Composting units (3): Rs 30,000 Hand-held sieve: Rs 500
O&M cost	Salary (for three to four hours): Rs 5,000 5 kg bio-culture (can be used for two or three months): Rs 300

Technology	Aerobic composting
Monitoring of composting process	• Waste of bigger size is to be cut into small pieces for easy decomposing. • Maintain the moisture content throughout composting. • More browns than usual should follow the addition of oily, gravy or liquid items to enhance composting. • The drums should take place above the ground with the help of a stand. • The area should have a covered top.
Indicator of quality of compost	Temperature: Mature and stable compost has a moderate temperature in accordance with the outside air temperature. If the compost feels hot, it indicates that it is still generating heat due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved in a 4 mm sieve. Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: One should be able to squeeze the compost into a ball in the hand without water dripping out, and you should be able to feel the moisture inside the compost. When releasing the compost, there shouldn't be much left in the hand.
End use	Compost is used as manure in gardening.
Where this technology has been implemented	Chas, Jharkhand This technology is ideal for small-sized establishments, where space is a constraint, and vegetation is within the boundary. In addition, schools and offices can use it.



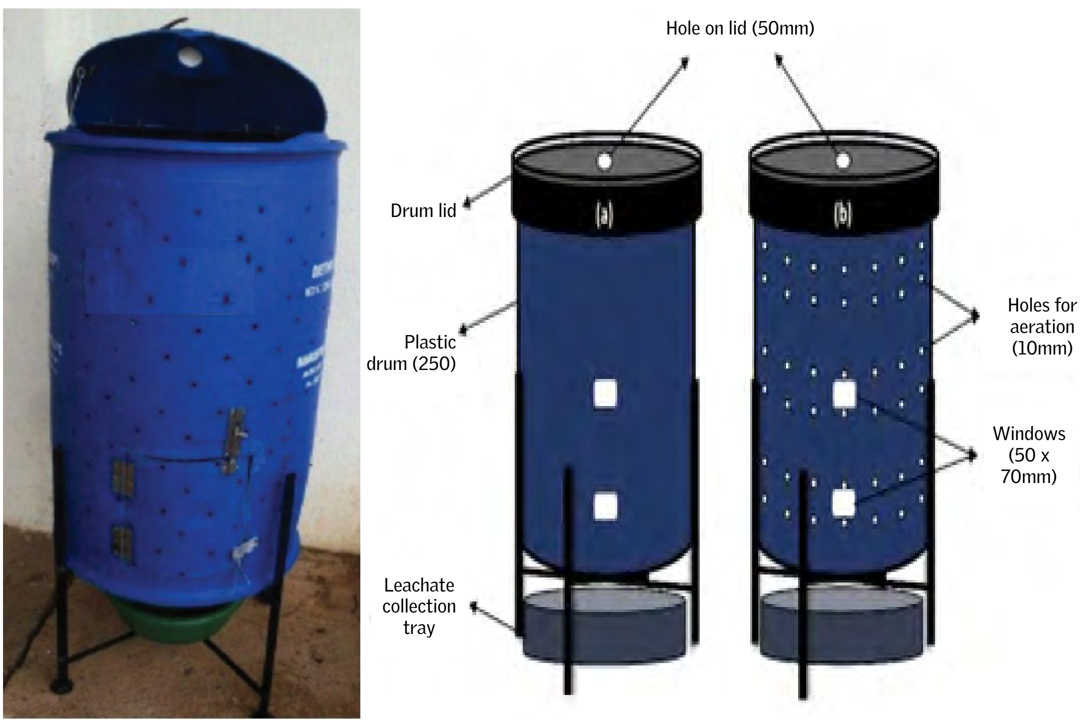
Rotary drum for composting

Source: Advisory on On-site and Decentralized composting of Municipal Organic Waste

2. High-density polythelene (HDPE) compost digester

Technology	**Aerobic composting**
Description	• Three 250-litre perforated drums with a hole each at the bottom to collect the leachate and a small opening to take out the compost are required. These should be placed on a stand vertically. • Each drum can cater to waste for 25 days. • Initially, at the bottom, add a 2-kg block of coco peat, half a bucket of dry leaves, and 0.5 kg of compost before filling the waste for composting. • To adequately segregated and shredded kitchen waste, add inoculum solution along with coco peat and some browns and mix it properly. • Layer the mixture uniformly throughout the drum. • Once the first drum is filled, use the second drum in the same manner. • After 45 days, take out the first drum and dry out the compost for a day or two in the shade. • Once the compost is dry, sieve the compost. Store the finely sieved manure in a dry placeaway from direct sunlight and use the same in gardening. • Collect the rest leftover from the sieving and feed it into the ongoing drum once again.
Land area required	1 m^3 for the composting units, 1 m^3 working space
Coverage	Eight households
Waste treated/day	Up to 8 kg
Processing time	45 days
Compost production	20 per cent of the total waste feed into the drum
Manpower	One semi-skilled
Capital cost	Construction: ₨ 5,000 Handheld sieve: Rs 500 Rack: Rs 100
O&M cost	Salary (for three to four hours): Rs 6,000 5 kg bio-compost (can be used for two to three months): Rs 500 5 kg bio-culture (can be used for two to three months): Rs 300
Monitoring of composting process	• Waste of bigger size to be cut into small pieces (of 1 inch) for easy decomposing • Once every week, soak a handful of neem powder in water and sprinkle this water into the digester to keep away flies, insects and bad odour. • Maintain the moisture content throughout composting. • More browns than usual should follow the addition of oily, gravy or liquid items to enhance the composting. • The drums should be kept above the ground on a stand. • The leachate collected at the bottom should be appropriately diluted before applying it to the raw waste. • The area should have a covered top.

Technology	Aerobic composting
Indicator of quality of compost	Temperature: Mature and stable compost has a moderate temperature in accordance with the outside air temperature. If the compost feels hot, it is generating heat due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved to determine different fractions. Structure: A crumbly structure is desired. Unfavourable composting conditions may resultin a dusty appearance. Moisture content: One should be able to squeeze the compost into a ball in the hand without water dripping out, and one should be able feel the moisture inside the compost. When releasing the compost, there shouldn't be much left in the hand.
End use	Compost is used as manure within establishments.
Where this technology has been implemented	Kanakapura Road, Bengaluru This technology is ideal for medium-sized establishments, where space is constraint and there is vegetation inside the boundary.



High-density polyethylene (HDPE) drums for composting

Source: shudhlabh-sol-ltd/aboutus.html

3. Byobin

Technology	Aerobic composting
Description	• Byobins have a capacity of 300–600 litres. They work in pairs. • A 600-litre Byobin can cater to waste for 25 days. • A net is provided at the bottom to separate the leachate and waste. • Above the net, apply a layer of ready compost to enhance the composting process. • Apply wet waste mixed with inoculum powder daily and spread it uniformly. • Spread a layer of dry leaves over wet waste to reduce maggots and moisture content in the compost. • Once the first bin is filled, leave it for composting and use the second bin. • The leachate gets collected at the bottom tank. • For proper aeration, lay four perforated pipes from below the net inside the bin.
Land area required	1.5 m^3 for Byobin units and 1 m^3 working space
Coverage	20 households
Waste treated/day	Up to 20 kg
Processing time	25 days
Compost production	20 per cent of the total waste feed into the bin
Manpower	One semi-skilled
Capital cost	Two Byobins: Rs 45,000 Handheld sieve: Rs 500 Rack: Rs 200
O&M cost	Salary (for six hours): Rs 8,000 5 kg bio compost (can be used for two to three months): Rs 500 5 kg inoculum powder (can be used for two to three months): Rs 300
Monitoring of compostingprocess	• Waste of bigger sizes is to be cut into small pieces (of 1 inch) for easy decomposing. • Once every week, soak a handful of neem powder in water and sprinkle this water into the digester to keep away the flies, insects and bad odours. • Maintain the moisture content throughout composting. • More browns than usual should follow non-veg items as well as oily, gravy or liquid items to enhance composting. • The bins should be placed above the ground on a stand. • The leachate collected at the bottom should be appropriately diluted before applying it on the raw waste. • The area should have a covered top. • The compost should not be stored in an airtight container.

Technology	**Aerobic composting**
Indicator of quality of compost	Temperature: Mature and stable compost has a moderate temperature in accordance with the outside air temperature. If the compost feels hot it is generatingheat due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved to determine different fractions. Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: Should be able to squeeze the compost into a ball in your hand without water dripping out, and your hands should feel the moisture inside the compost. When releasing the compost, there shouldn't be much left in the hands.
End use	The compost is used as manure within establishments.
Where this technologyhas been implemented	Alappuzha, Kerala This technology is suitable for medium-sized establishments, where space is a constraint.

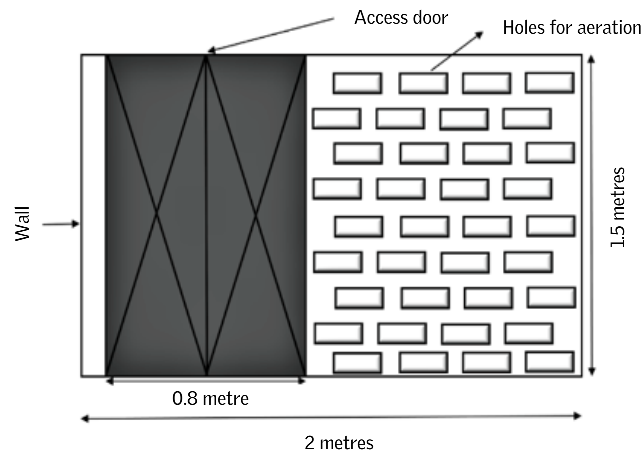
Byobin composter

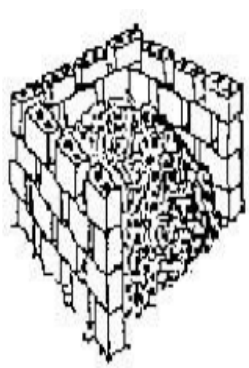
Source: https://savitahiremath.com/

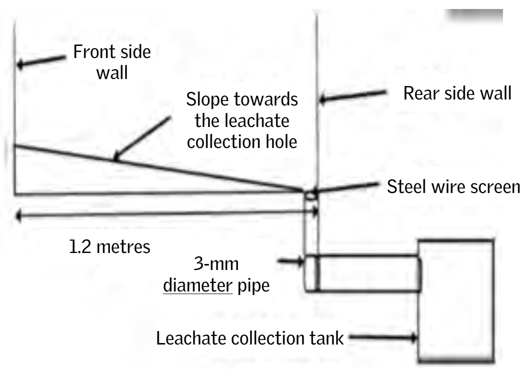
4. Concrete block composting

Technology	**Aerobic composting**
Description	• This system is composed of two numbers of brick wall blocks each of having 3.6 cum capacity. There are perforated holes at three sides of the wall and a leachate collectionpipe at the bottom. • Each block can cater the waste for 35 days. • The floor of each block shall be sloped to one side and have a drain point with a net to collect leachate. • Initially, spread a layer of cow dung slurry at the bottom for three to four days, then add one or two buckets of browns (dry leaves) before filling the waste for composting. • Add inoculum solution along with coco peat and some browns to the properly segregated and shredded kitchen waste, and mix it properly. • Layer the mixture uniformly throughout the block. • Once the first block is full, use the second tub in the same manner. • After 40 days, take out the compost from the first block and dry for a day or two in the shade. • Once the compost is dry, sieve it. Store the finely sieved manure in a dry place away from direct sunlight and use it in gardening. • Collect the rest leftover from the sieving and feed it into the ongoing block once again.
Land area required	8 m^3 for two blocks and 2 m^3 for working space
Coverage	100 households
Waste treated/day	Up to 100 kg
Processing time	35 days
Compost production	20 per cent of the total waste feed into the tub
Manpower	Two semi-skilled
Capital cost	Construction: Rs 3,50,000 Handmade sieve: Rs 5,000 Rack: Rs 500
O&M cost	Salaries (for five to six hours): Rs 12,000 5 kg bioculture (can be used for two months): Rs 300
Monitoring of compostingprocess	• Waste of bigger size is to be cut into small pieces (of 1 inch) for easy decomposing. • Once every week, soak a handful of neem powder in water and sprinkle this water into the block to keep away flies, insects and bad odours. • Maintain the moisture content throughout composting. • Addition of non-veg items, oily, gravy or liquid items should be followed by more browns than usual to enhance the composting. • The leachate collected at the bottom should be appropriately diluted before applying it to the raw waste. • The area should have a covered top. • Net to should be provided to avoid the attack of birds
Indicator of quality ofcompost	Temperature: Mature and stable compost has a moderate temperature as per the outside air temperature. If the compost feels hot, it indicates that it still generatesheat due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved to determine different fractions.

Technology	Aerobic composting
	Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: Should be able to squeeze the compost into a ball in your hand without water dripping out, and your hands should feel the moisture inside the compost. At the time of releasing the compost, there shouldn't be too much leftover on the hands.
End use	Compost is used as manure within the society or housing complex.
Where this technologyhas been implemented	Northeast Delhi This technology is ideal for large-sized establishments where space is not a constraint.







Side cross-section view

Concrete block composting

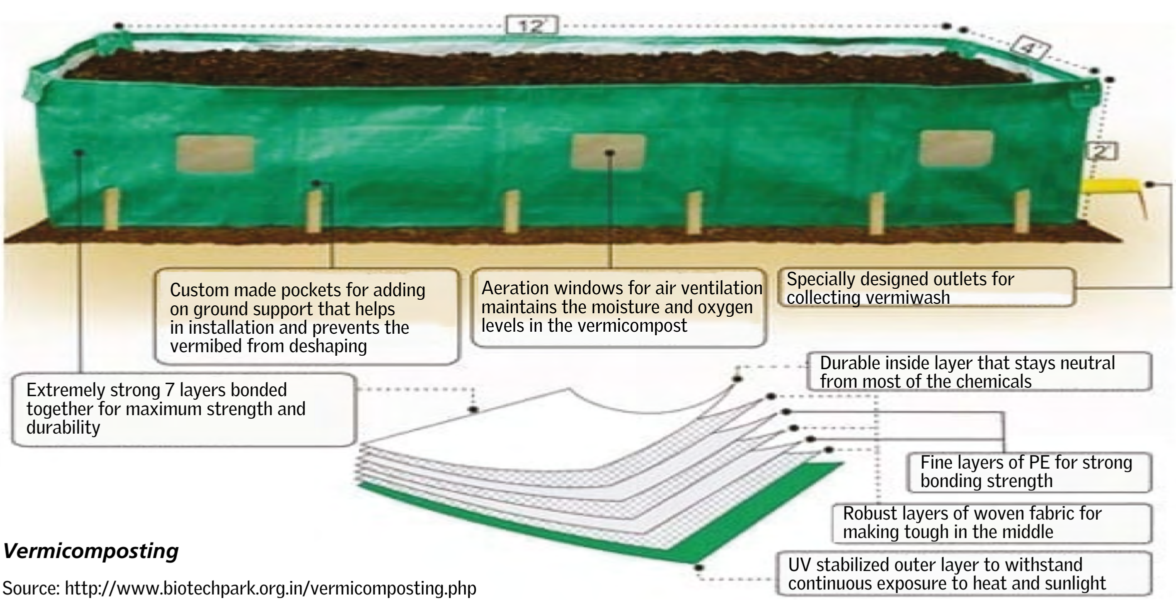
Source: CSE, 2021

3.3 Decentralized composting for ward level

1. Vermicomposting

Technology	**Vermicomposting**
Description	• The dimensions of the concrete tank should be 15 m in length, 1.5 m in width, and 0.6 m in height for a large-scale operations. Holes are to be provided at the bottom of the basin tank to drain leachate. • The bed for vermicomposting is a multilayered arrangement lined with either coarse sand or gunny bags, or straw at the bottom, above which a 15–20 cm layer of lightly moist composted cattle manure is placed. • Earthworms are introduced above the layer at 1–2 kg per square metre of bed on an average. • For large-scale operations, collect the organic waste and chop the larger pieces into 1-inch pieces with a cutter. Then, mix the waste with cow-dung powder. Also, prepare a cow dung slurry and sprinkle it on the heap for quick decomposition. • It is necessary to pre-compost the waste material so that the heat generated during the initial phase gets dissipated and the material cools down to ambient conditions. • The pre-composted waste can be directly put over the cattle manure in thin layers. The bed has to be loosely covered with wet gunny bags, serving to retain the moisture and darkness. • Initially, the earthworms move up from the lower layer to reach the waste which they consume as food, and as the process goes on they move towards the bottom layer. • In some cases, to remove the vermicompost, the basin or tank is exposed to sunlight for two to four hours. • The earthworms in the basin, pot or tank can be used for further composting of bio-waste.
Land area required	4,000 m^2
Coverage	5,000 households
Waste treated/day	Up to 5 tonnes
Processing time	45 days
Compost production	20 per cent of the total waste feed into the bin
Manpower	Two skilled and semi-skilled labour
Capital cost	Infrastructure: Rs 15,00,000
O&M cost	Salaries (for six to eight hours): Rs 55,000 Maintenance: Rs 10,000
Monitoring of composting process	• Waste of bigger size is to be cut into small pieces for easy decomposing. • A thick wet cloth or wet piece of gunnysack should cover the waste to protect the basin, pot or tank from rats, ants, etc. • Sprinkle a solution of cow dung or diluted curd into the waste to speed up the composting process. • It is essential to use surgical hand gloves while handling waste and manure. • Maintain the moisture content throughout composting at 50–55 per cent. • Avoid a sprinkling of water and stagnation of liquid at the bottom of the basin. • The vermi-basin, pot or tank should not be exposed to direct sunlight or rainfall. • Compost taken out should not be dried under sunlight. • Renew the base layer annually.
Indicator of quality of vermicompost	Moisture content percentage by weight: 15–25 per cent. Should be able to squeeze the compost into a ball in your hand without water dripping out. Colour: It should be dark brown to black.

Technology	Vermicomposting
	Odour: A mature compost should smell like forest soil. An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Non-degraded plant material: Non-degraded plant material in the compost (e.g. grass, trim branches etc.) indicates that the composting process is still ongoing. Particle size: Can be judged visually, but compost can also be passed through 4.0 mm IS sieve. Bulk density: Should be 0.7–0.9; low bulk density indicates low porosity and compaction. Structure: A crumbly structure is desired; unfavourable composting conditions may result in a dusty appearance. And your hands should feel the moisture inside the compost. At the time of releasing the compost, there shouldn't be too much leftover on the hands.
End use	The compost generated has a high value and is called black gold. It can be sold for around Rs 4.5–5 per kg with the help of an urban local body (ULB).
Where this technology has been implemented	Lucknow, Uttar Pradesh This technology is ideal for the ward level, where space is not a constraint. It is a low-cost technology with minimum operation and maintenance. The quality of the compost, however,has a high value.
Limitations	Non-veg items, oily, gravy or liquid items should be avoided.



Vermicomposting

Source: http://www.biotechpark.org.in/vermicomposting.php

3.3.1 FAQs about vermicomposting

1. **My compost emits a foul smell. Is there something wrong in the process?**

Vermicompost emits a foul smell due to overfeeding the waste or the system not getting enough air—which gives rise to anaerobic conditions—or the bed is too wet. To get rid of the foul odour, remove the excess food and remove the meat items, if any. Also, loosen the material and add bedding material such as dry leaves or straw to absorb moisture. One has to take care that any material containing toxic matter or heavy metals does not get into the vermin bed.

2. **How to get rid of flies and ants from my compost pile?**

Flies and ants are found on the compost pile when waste is exposed to the atmosphere. To avoid this, cover the waste completely with gunny bags. Also, use non-poisonous ant repellent around the compost pile.

3. **What should I do if mites are infesting my compost?**

Mites are often found in moist areas. Avoid adding high moisture content waste to get rid of such a situation.

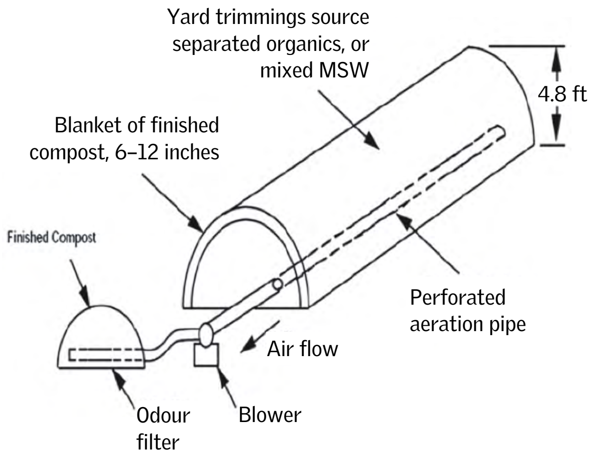
4. Is there something wrong with my process if the worms in the compost are dying or crawling away?

If earthworms try to escape a system, it indicates that something is wrong with their feed or environment. Worms die or crawl away from the waste pile because the bed is either too wet or dry. Other reasons may be due to excess temperature inside the pile or not getting enough air or food. Another reason may be that the waste pile is very tightly packed. Some things need to be taken care of: do not add water to the bed if it's too wet, and added required water to reach the required moisture level if it is too dry. If the temperature of the bed is high, then sprinkle water and add waste appropriately. Also, remember to turn the bed very carefully without harming the worms to make it fluffy.

2. Aerated static pile composting

Technology	Aerobic composting
Description	• Perforated pipes of 10 mm diameter and 20 m length are laid at the beginning with a distance of 1.5 m in seven rows. The pipes are connected to a blower with the help of nozzles for air circulation. • The properly segregated biodegradable waste is fed into a shredder, and sawdust and dry leaves along with the inoculum power mixed with the above mixture before feeding it into the shredder. • A layer of mulch is evenly applied over the aerated pipes • The shredded organic waste and mulch are mixed, which helps in better aeration, and are layered over the aerated pipe. • Each day's waste after shredding is converted to 2m x 1m x 1m heaps, and the next day's waste is placed in the same way behind the last pile. As a result, each day's waste is covered with 6–12 inches of finished compost. • The waste is then covered with a semi-permeable membrane composting cover made up of e-PTFE (polytetrafluoroethylene) material. • Composting cover is: the moisture and air are contained inside, heat is retained inside the system, odour and volatile organic components are contained and it helps as a weatherproof material. • For each pipe, six piles are made with 1 m distance from each other once the first pipe is completed, repeat the same for the other pipes. • Air is circulated using an electric blower through the pipes to the piles, which helps in aeration and maintains the piles' temperature. • The design provides maximum aeration to the waste, and at the outlet, leachate is collected. • The waste pile during the active phase (first 30 days) of composting is left undisturbed. After active composting, the cover is removed, the temperature starts declining, and the waste is left for stabilization and curing. After 42 days, the waste is taken out and sieved.
Land area required	350 m^2
Coverage	3,000 households
Waste treated/day	Up to 3 tonnes
Processing time	42 days
Compost production	20 per cent of the total waste feed into the bin
Manpower	Two skilled and three semi-skilled labour
Capital cost	Infrastructure: Rs 25,00,000 Shredder: Rs 6,00,000 Mechanical sieve: Rs 4,00,000 Electric blower: Rs 2,00,000
O&M cost	Salaries (for six to eight hours): Rs 55,000 Electricity: Rs 10,000 Maintenance: Rs 10,000
Monitoring of composting process	• Waste of bigger sizes are to be cut into small pieces for easy decomposing. • A thick wet cloth or wet sack piece should be used for covering the waste to secure steel wire mesh to prevent theactivities of rodents or mosquitoes. • Maintain the moisture content. • Addition of non-veg items, oily, gravy or liquid items should be followed by more browns than usual to enhance the composting.

Technology	Aerobic composting
Indicator of quality of compost	Temperature: Mature and stable compost has a moderate temperature as per the outside air temperature. If the compost feels hot, it indicates that it still generates heat due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: can be judged visually, but compost can also be sieved to determine different fractions. Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: Should be able to squeeze the compost into a ball in your hand without water dripping out, and your hands should feel the moisture inside the compost. At the time of releasing the compost, there shouldn't be too much leftover on the hands.
End use	The compost generated can be sold around Rs 3 per kg with the help of an urban local body (ULB).
Where this technologyhas been implemented	Panaji, Goa This technology is ideal for ward level, where space is not a constraint. Moreover, this technology hasgot optimum operation and maintenance.



Aerated static pile composting

Source: CSE, 2021

3. Anaerobic digestion

Technology	**Anaerobic digestion**
Description	• The main components of the waste-based biogas plant are: a. Digester tank b. Gas holder chamber c. Feeding pipe (2 m diameter) d. Slurry outlet pipe (0.1 m diameter) e. Gas outlet pipe (5 cm diameter) f. Control valve • As this biogas plant is a bigger capacity unit, two units need to be installed to efficiently process the waste. The gas holder chamber is made up of either plastic or rubber bag. • The digester volume for feeding the waste should be 500 m^3 for household use. The digester tank can receive waste continuously once the unit is stabilized. • To start with a new biogas plant, fill 70 per cent of the digester tank with slurry from another plant or freshcattle dung. • The amount of cattle dung should be 2–3 per cent of the total slurry for initial loading; it can be diluted with water. As a thumb rule, 1 kg of dung requires 10 litres of water; hence 4,000 kg of cow dung will be required with 40,000 litres of water to prepare the initial slurry. • Leave the tank intact for 20 days, collect the methane gas from the gas holder chamber. From the twenty-first day onwards, waste from the kitchen and other degradable waste can be feed in the digester tank in a slurry form through the feeding pipe. • The waste should be shredded into small pieces of 1-inch length for fast digestion, and the plant must be fed regularly to achieve regular gas production. • The overflowing slurry must be removed from the slurry outlet pipe. Otherwise, it can block the flow, and the gas pressure inside the digester might increase until it escapes through the gas inlet pipe or blows off the water trap. • It should be collected in a tank and feed to the plants as it has excellent nutritional values. • The methane gas generated can be supplied to the nearest area within a 200-metre radius through a gas outlet pipe and used in the household for cooking purposes.
Land area required	2,000 m^2
Coverage	5,000 households

Technology	**Anaerobic digestion**
Waste treated/day	Up to 5 tonnes
Processing time	21 days
Gas and slurry production	Five tonnes of waste gives around 500 m^3 of methane gas, which is equivalent to 180–220 kg and can be used for cooking. This is equivalent to 550 units of power. The biogas may also be cleaned by removing CO_2 and H_2S. The plant gives approximately 6 KL/day of liquid fertilizer
Workforce	Three skilled, five semi-skilled labour
Capital cost	Infrastructure: Rs 1,76,00,000 Shredder: Rs 10,00,000 Pump: Rs 10,000
O&M cost	Rs 15,00,000 per annum
Monitoring of composting process	• The substrate should be free of impurities to avoid scum formation and blockage of the inlet and outlet pipes. • Use a mosquito net to cover the unit to prevent breeding of mosquitoes around the unit as water is used. • The slurry channel and outlet must be washed and should be covered from direct sunshine. • Flooring—Concrete floor (anti-skid) with proper slope at the main entrance may be constructed. • The gas distribution pipes should be regularly monitored. • Fire extinguishers should be kept within the facility. • The digester must be leak-proof. • The C:N ratio must be maintained appropriately
Indicator of quality of product	Temperature: Thermophilic breakdown proceeds much faster than mesophilic. A thermophilic reactor can therefore yield a higher rate of biogas production in a shorter period. Alkalinity: Alkalinity will speed the acidogenic stage faster than the methanogenic stage, leading to process upsets. C:N ratio: Excess nitrogen can lead to the accumulation of ammonia in the digester. Lower nitrogen can affect the cell growth of microorganisms. Ammonia: Excess ammonia leads to product toxicity and hampers the digestion process. Volatile fatty acids (VFAs): Higher concentration of VFAs can be toxic to the microorganisms in the digester. Sulphide: The presence of high sulphide (as H_2S) levels inhibits methane generation, most likely due to the increased loading of sulphur compounds, including proteins. pH: Should be 6–7 as low pH will slow down the process and could lead to the organism's death. Also, high pH indicates that the digested material has a high buffer capacity. At that time, the CO_2 gradually decreased, and methane production gradually increased to balance the process in the digester. Moisture content: Should be less than 60 per cent. The system will not work if the moisture content is not in the suitable range.
End use	The slurry generated from the plant can be directed towards the plants as a liquid fertilizer. The methane gas generated can be used for cooking purposes.
Where this technologyhas been implemented	Hyderabad Methane gas is obtained, which can be used for cooking. This is why this technology is ideal for households. In addition, this technology has the almost negligible operation and maintenance.
Limitations	Orange, lime, pickles, disinfectants, soap water, plastic, woodpieces, metal and sand should not be put in the digester.

Biogas plant

Source: https://www.thehindu.com/news/cities/Hyderabad/hyderabad-gets-its-first-bio-methanisation-plant/article29598605.ece

3.4 Decentralized composting ideal for a cluster of wards (zone level)

1. Multiple tubs composting

Technology	**Aerobic composting**
Description	• The unit will have 14 tubs with dimensions of 3.9 m x 1.8 m x 1.0 m in two trains of seven tubs in each train. Each tub size depends on the unit's capacity. • The floor of each tub will slope to one side and have a drain point with mesh to collect leachate. • Each tub's leachate drain points will be connected to underground pipes to form a leachate drainage network and is connected to a chamber for safe collection. • Each tub will have a sufficient number of holes on the side walls. The holes will be connected through pipes and have a cowl installed on the top to help proper aeration. • A digital weighing machine shall be installed to record the received waste, and a shredding machine with a conveyor belt shall be placed at the receiving bay to shred the waste. • The segregated organic waste along with rice husk and effective microorganism solution is feed into the shredder. • Before putting the shredded waste in the compost tub for the first time, bio-dozing has to be done by placing a layer of 2-inch-thick dry cow dung on the floor of each tub. • Turn the waste up and down once every five days for better aeration.
Land area required	600 m^2
Coverage	Two to three wards
Waste treated/day	Up to 5 tonnes
Processing time	40 days
Compost production	20 per cent of the total waste feed into the bin
Manpower	Two skilled, three semi-skilled

Technology	Aerobic composting
	• Put the first day's shredded waste in the first tub and continue this process, i.e. as for example, the seventh day's waste in the seventh tub. Then, again, put the eighth day's waste in the first tub and continue the same process as before for the 21 days. • Now leave the first train of tubs intact. The waste in all seven tubs in the first train will be turned up and down for aeration, but no fresh waste will be added. • Start using the second train of tubs, i.e. from the eighth to fourteenth tubs,for putting the waste from the twenty-second day onwards and repeat as for the first train of tubs. • After 40 days, take out the compost from the first tub and take it to the screening machine for sieving. The larger particles again can be feed into any of the tubs going for composting.
Capital cost	For infrastructure: Rs 50,00,000 For shredder: Rs 10,00,000 For mechanical sieve: Rs 7,00,000 For pump: Rs 10,000
O&M cost	For salaries (for eight hours): Rs 55,000 For electricity: Rs 10,000 For maintenance: Rs 10,000
Monitoring of compostingprocess	• Waste of bigger size is to be cut into small pieces for easy decomposing. • The addition of non-veg items, oily, gravy or liquid items should be followed by more browns or cow dung slurry than usual to enhance the composting. • Roofing—Truss with corrugated sheets for roofing may be used • Side wall—For proper ventilation and protection, wire mesh with appropriate gaping may be used. • Flooring—Concrete floor (anti-skid) with proper slope at the main entrance may be constructed • Maintain the moisture content. • Fly traps should be installed to control flies. • A separate space or room should be provided for storing the finished product.
Quality indicator of compost	Temperature: Mature and stable compost has a moderate temperature as per the outside air temperature. If the compost feels hot, it indicates that it still generatesheat due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved to determine different fractions. Structure: A crumbly structure is desired. Unfavourable composting conditions may result in a dusty appearance. Moisture content: One should be able to squeeze the compost into a ball in your hand without water dripping out, and your hands should feel the moisture inside the compost. At the time of releasing the compost, there shouldn't be too much leftover on the hands.
End use	With the aid of urban local bodies (ULBs), the compost generated can be sold for around Rs 20 per kg.
Where this technologyhas been implemented	Paradeep (Odisha) This technology is ideal for a cluster of wards where space is not a constraint. Further, this technology has optimum operation and maintenance.


Micro-composting centre, Paradeep, Odisha

Source: CSE, 2021

2. Windrow composting

Technology	**Aerobic composting**
Description	• Windrows are typically trapezoidal in the cross-section. • There should be sufficient space available (ideally 1–3 metres) between windrows for movement and windrow turning. • The composting platform should be a combination of reinforced cement concrete (RCC) and plain cement concrete (PCC). It should havea slope of about 1 per cent to drain the excess water (storm water or leachate) from the windrows into a leachate collection tank. • The leachate tank should ideally be placed in the lowest corner of the composting platform. • The waste should be transferred to the compost platform into windrows by bucket loaders. • The outer layers of piles are moved to inner layers by turning the windrows every week for five weeks. During the rainy season, more frequent turning (every three to four days) is necessary. • A turning should occur based on the rate of decomposition, moisturecontent, porosity of material and composting time. • Each windrow stays on the compost platform for 35 days. After that, the compost is ready for sieving. • Each windrow should be marked to identify the age of the waste. • Leachate stored in the leachate tank should be sprinkled during the turning process to maintain the moisture content.
Land area required	2,000 m^2
Coverage	Two to three wards
Waste treated/day	Up to 30 tonnes
Processing time	40 days
Compost production	20 per cent of the total waste feed into the bin
Manpower	One manager plus two skilled, five semi-skilled labour
Capital cost	Infrastructure: Rs 60,00,000 Shredder Rs 25,00,000 Mechanical sieve: Rs 15,00,000 Pump: Rs 30,000
O&M cost	Salaries (for eight hours): Rs 1,00,000 Electricity: Rs 30,000 Maintenance: Rs 30,000 Fuel: Rs 30,000 Rent of the JCB/hook loader and bobcat machine: Rs 20,000

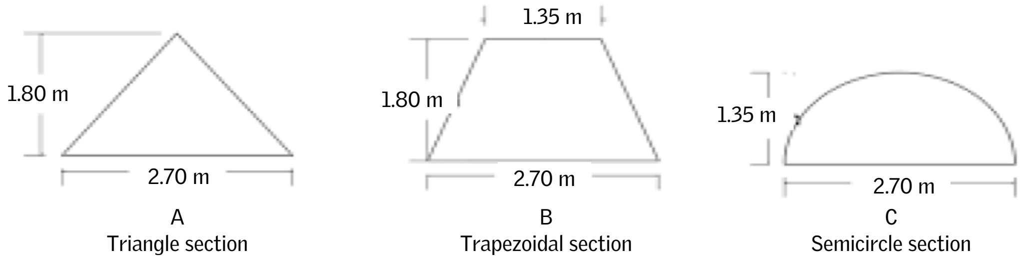
Monitoring of composting process	• Waste of bigger sizes is to be cut into small pieces for easy decomposing. • The addition of non-veg items and oily, gravy or liquid items should be followed by more browns or cow dung slurry than usual to enhance the composting. • Flooring—Concrete floor (anti-skid) with proper slope at the main entrance may be constructed. • Roofing—Truss with corrugated sheets for roofing may be used. • Maintain the moisture content. • A separate space or room should be provided for storing the finished product.
Indicator of quality ofcompost	Temperature: Mature and stable compost has a moderate temperature as per the outside air temperature. If the compost feels hot, heat is still being generated due to decomposition. Colour: Should vary between medium and dark brown. Odour: A mature compost should smell like forest soil (petrichor). An ammonia smell indicates a low C:N ratio or low moisture status, and an H_2S smell (rotten eggs) indicates anaerobic circumstances. Particle size: Can be judged visually, but compost can also be sieved to determine different fractions. Structure: A crumbly structure is desired. Unfavourable composting conditions may resultin a dusty appearance. Moisture content: You be able to squeeze the compost into the ball in the hand without water dripping out, and you should feel the moisture inside the compost. When releasing the compost, there shouldn't be much left in the hands.
End use	With the aid of urban local bodies (ULBs), the compost generated can be sold for around Rs 3 per kg.
Where this technologyhas been implemented	Okhla, New Delhi This technology is ideal for a cluster of wards, where space is not at all a constraint. This technology has got optimum operation and maintenance.

Incoming waste at compost yard

Rain shed

Primary screening

Bagging machine



Stages of windrow composting

Source: Advisory on On-site and Decentralized composting of Municipal Organic Waste

India has 279 composting plants, 138 vermicomposting facilities and 172 biomethanation processors.[4,5] Based on the numbers, composting technology is the most chosen and preferred technology for efficient organic waste management, among all other technologies. Composting has been practised in India for decades though the extent of its use has been surging.

Currently, waste management has become a significant challenge due to the unscientific practice of waste management observed in the past few decades.

The effectiveness of composting technology depends on its planning and execution. The financial sustainability of the operating plant is often affected by the management of decentralized smaller units and construction cost. Implementing larger composting plants usually needs great investments, and recovering invested amounts is difficult. Thus losses incurred may lead toclosure of plants. As a result, it is not incorrect to conclude that economic, social and technological factors all play a role in selecting decentralized treatment technologies. These parameters vary by location.

Composting is a mature and proven treatment technology in urban waste management. It is well-known to waste managers in high-, middle- and low-income settings as a simple and robust technology. Even so, in urban parts of the country composting is not as common as one would expect. Reasons may include a lack of segregated organic waste. Low-quality feedstock yields poor quality compost, which leads to poor acceptance by resident populations or lack of approval by potential compost users. Given the ease and robustness to process a wide range of biowaste types, it seems imperative that composting be given more attention as a means to waste management.

Vermicomposting systems are considered less energy-consuming, and more cost-effective and economically feasible treatment methods than conventional treatment technologies. In contrast, the expected barrier to vermicomposting can be seen in the requirement of substantial space. This can however be easily resolved by stacking feeding boxes on a vertical axis. The energy consumption is expected to be higher in the case of windrows composting than vermicomposting as less equipment is involved in the process, resulting in less carbon dioxide emission. It has been observed that windrow composting requires heavy equipment and high initial investment.

The maintenance cost of the vermicomposting plant is, in contrast, high. Also, the production of vermicompost takes longer (15 days extra). As a result, the selling cost of vermicompost is higher than that of windrow compost, potentially reducing the economic viability of vermicomposting. Vermicomposting needs more skill than composting as well as knowledge of the worm life-cycle and ideal processing conditions. Further, the advantages of anaerobic digestion are diverse and fit well into the broader sustainability debate as it transforms waste into a renewable source of energy while also preserving plant nutrients. To fully realize the value of goods and by-products, scientific, regulatory, and socioeconomic impediments should to be tackled, which requires interactions between scientists, regulators and end users. Many anaerobic digestion projects have faced severe operational problems or have failed due to inappropriate technology selection, poor design, inadequate operation, lack of ownership, maintenance by operators, lack of project monitoring, etc. Thus, a reconnaissance study of the concerned region and characteristics of the waste should be carried out before installing any decentralized technology.

4. Conclusion and recommendations

This report focuses on the best available decentralized treatment methods for the organic fraction of solid waste. Based on field study and literature review, it suggests decentralized treatment methods for organic waste at the individual, household, community, ward and cluster levels.

During the study, a wide range of treatment technologies for organic waste were observed to already exist and have been researched for decades. These treatment methods transform biodegradable waste into a variety of output products.

This analysis distinguishes between two types of composting methods—aerobic composting and anaerobic composting—and highlights their main characteristics.

Appropriate process steps and parameters can describe each technology to produce products with distinct properties. A waste manager's viewpoint regarding feedstock requirements might consider technologies that can treat the broadest range of organic waste feedstock type and quality, but investment and operational costs cannot be neglected.

A study of technologies for decentralized waste management indicates that every technology has limitations. Selection of suitable technology lies in the extent of waste segregation at source. Proper segregation of waste can improve the quality of compost and recycled materials recovered from municipal solid waste (MSW) and can solve marketing of products.

The policy does not indicate a plant's minimum output potential to qualify for the subsidy regarding existing government rules and regulations for promoting decentralized systems and city compost. If a city has several decentralized plants, the urban local body may register as a joint entity. The Market Development Assistance (MDA) guidelines, however, do not say anything regarding this. Further, the policy necessitates establishing an in-house testing facility, which is not feasible in small-scale decentralized facilities, and the subsidy application process is also comprehensive. As per the Mobile Fertilizer Management System (m-FMS) site, mostly centralized composting plants have opted for MDA. At the same time, we know that the decentralized facilities produce a better quality of compost, which has a higherdemand than more extensive facilities that are making compost from mostly mixed waste.

As per CSE's 2018 report, *Charting the Future of City Compost*, if all the organic waste from all the cities is composted we can generate only about 11.5 million tonnes of compost per annum. The compost can easily be marketed and utilized. But for this, demand must be created. Demand is determined by the quality of compost, which is indirectly linked to the necessary technology built for each city based on the composition and characterization of the waste. Poor implementation of supporting policies and governmental measures and limited marketing experiences often hinder the economics of composting. Therefore, to promote decentralized composting and its market, interventions need to be undertaken right from strengthening waste management systems to creating awareness for market linkages.

The following changes need to be incorporated to promote decentralized composting and create demand for high-quality compost.

1. Source segregation: According to Solid Waste Management (SWM) Rules, 2016, local government authorities must ensure that all cities and towns in their jurisdiction plan implement sustainable waste managementsystems. Local bodies should implement effective waste management systems focusing on source segregation, decentralized treatment of wet waste, recycling and reuse supported by the SWM by-laws. Source segregation is essential for better quality compost.

Urban local bodies should:

- **Give incentives and subsidies**: Local authorities may give incentives or subsidies to households by exempting them from paying user fees or by charging them a lower user fee based on the weight of thewaste to encourage segregation.

- **Revise contract:** The contract should pay for the quantity of waste processed and recycled rather than the quantity of waste collected. Such incentives shall ensure high-quality waste feed for composting as compost quality is primarily determined by the type of waste feed used.

- **Enact by-laws**: Local authorities should imposing penalties on RWAs (residential welfare associations) and BWGs (bulk-waste generators) that fail to comply with source segregation and on-site organic waste treatment as prescribed in SWM Rules, 2016.

- **Recognize best practices**: Local authorizes should recognize and felicitate model schools, ULBs, educational institutions, bulk-waste generators (BWGs) and resident welfare associations (RWAs) for practising adequate segregation and decentralized management of organic waste.

2. Comprehensive assessment: Barely any states have conducted comprehensive assessments to characterize the waste generated in their cities and towns. Thus, it is difficult for the authorities to select suitable processing technology for the waste produced for a particular region.

- The local government shall conduct proper feasibility assessments, including selecting technically, financially and environmentally appropriate technologies for the local context.

- This assessment shall also include a comprehensive overview of the various biowaste treatment technologies, the products they produce, and how they fit into the local market demand. The assessment will help the government provide critical information for making informed decisions about the most technically, financially and environmentally acceptable technology for the local context.

- Such a strategy shall emphasize community or stakeholder participation and inter-departmental coordination at the local-authority level to ensure implementation effectiveness.

3. Capacity-building programmes: The Ministry of Housing and Urban Affairs, Ministry of Chemicals and Fertilizers, Ministry of Agriculture and Farmer's Welfare and state authorities must ensure that all stakeholders are apprised of decentralized management of organic waste and promotion of city compost and are clear about their roles and responsibilities for Information Education and Communication (IEC) and awareness (see *Table 9: Role and responsibilities of various stakeholders*).

Table 9: Role and responsibilities of various stakeholders

Stakeholder	Role and responsibilities
State urban departments	Conduct periodic awareness campaigns for ULBs to encourage them to follow segregation and decentralized waste management models and the use of city compost in agriculturally dominated areas. Encourage theuse of manure in wasteland reclamation. Collaborate with the state agriculture department to create a valuechain for compost—at least 10 per cent to be procured by local fertilizercompanies. Build partnerships with local NGOs or waste-to-compost companiesto run composting facilities and market the final product with quality monitoring.
Urban local body (ULB)	With the help of the local expert, ULBs shall conduct periodic awareness campaigns at the ward level for households, RWAs and BWGs to encourage them to follow segregation and decentralized organic wastemanagement and the use of compost in gardening.
State education department	Conduct periodic awareness campaigns and training sessions for educational institutes to encourage students to follow segregation anddecentralized organic waste management.
Fertilizer companies	Collaborate with ULBs to run monthly composting workshops for farmers using their CSR funds in the state's agricultural areas. Device market linkages.
State agriculture department	Conduct regular tests to inform farmers about the value of city compost in improving soil quality. Agricultural departments in each district ensure that fertilizer companies sell compost alongside urea to farmers.
Compost manufacturers and marketers	Encourage ULBs to provide segregated waste and improve waste management. To ensure a higher quality waste feed, encourage moredecentralized composting plants. Device market linkages with ULB.

4. Central Pollution Control Board (CPCB) review: CPCB shall review through the State Pollution Control Boards or Pollution Control Committees, at least once a year, implementing prescribed environmental standards for organic waste treatment technologies.

- SPCB shall submitted the proposals to CPCB on using any new decentralized technologies for processing organic waste for monitoring purposes.

- The local authority shall prepare an annual report on the decentralized organic waste processing unit's operation and send it to the CPCB for record and evaluation. The report should be put out in the public domain and may include month-by-month waste obtained, waste processed at the facility, compost or biogas generated and end-user information.

5. Monitoring of the decentralized composting facilities: The local authority must register all decentralized units at the community, ward and zone levels, and must visit these units every quarter to inspect the composting unit's operation.

6. Amendments in current FCO norms for city compost: Measures are required to be undertaken to ensure robust quality assurance, distribution and marketing mechanisms. Hence, it is recommended that Fertilizers Control Order (FCO) norms inculcate that different categories of compost have different standards. Such amendments will lead to a reverse push from industry to provide better feed, i.e. source segregated waste and induce competitiveness in the ULBs to produce better quality compost.

- As new composting technologies emerge, parameters such as microbial composition, humus content and pathogen content must be monitored regularly, and both FCO norms and Bureau of Indian Standards (BIS) standards should be amended accordingly.

- There must be a precise synchronization between FCO norms and Indian composting standards.

7. Establishing testing frequencies for compost: Many vendors get one batch of compost tested and then sell subsequent batches based on the same results for months. The waste feed varies from batch to batch of compost, so it is essential to monitor it regularly. Compost testing is currently costly in India due to a lack of facilities and laboratories capable of performing the tests. Therefore, the government must establish a testing schedule based on the amount of compost processed and the level (community, ward, zone, etc.) at which the unit is being operated.

8. Subsidy for compost testing: To ensure that the maximum number of units gets their compost tested, the government shall provide a grant to pay for the tests. All the districts have a soil-testing laboratory in their agriculture department, and these labs can be updated with suitable systems for testing the compost with qualified personnel. The district agricultural officers shall monitor such laboratories regularly.

9. The goal for fertilizers companies: Fertilizer companies have not co-marketed city compost as mandated by the SWM Rules of 2016, but this is partly due to a lack of high-quality compost to replace urea. The government should set a target for compost sold based on the amount of compost generated in India to ensure marketing of compost, according to the SWM Rules, 2016. A ratio of three or four bags of compost per seven or eight bags of urea translates to around one compost bag per 1.75 to two bags of urea.

- Fertilizer manufacturers must aim for progressive goals. There should be a set amount of compost that fertilizer companies must co-market yearly based on their sales.

- They should market fertilizer in collaboration with a marketing or manufacturing organization. A contract with a private concessionaire and the fertilizer companies' compost procurement system shall be reduced to a single annual contract rate.

10. Adopt different models for promoting decentralized waste management and marketing of compost: The decentralized composting approach reduces transportation costs and uses low-cost technologies based mainly on manual labor. All the decentralized models are equally beneficial to the ULB by reducing overall waste management costs. Decentralized municipal solid waste management (MSWM) facilities can be funded through community-based cooperatives, local NGOs, private–public partnerships (PPP) models or municipal funds. Community ownership of decentralized systems is critical for their success and continued operation.

The following four models take a pragmatic approach to increasing, expanding and promoting the compost market (see *Table 10: Compost marketing methods)*.

Table 10: Compost marketing methods

Model 1: Municipality owned, community operated

Item	Description
Objective	▸ Community involvement in management of primary waste collection and treatment ▸ Capital cost borne by local body ▸ Local employment opportunity ▸ Entrepreneurship development ▸ Non-profit seeking model
Authority	Municipality, local community, NGOs and RWAs
Role of local authority	▸ Making capital investments ▸ Supporting communities in finding or allotting land ▸ Collection and disposal of residual waste ▸ Monitoring agency
Advantages	▸ Cost-saving in transportation and centralized processing and disposal ▸ Profitable use of waste ▸ Job opportunities for the unemployed youth ▸ Entrepreneurship development ▸ Reduction in municipal burden due to community participation ▸ Improvement of MSWM through voluntary participation ▸ Can have government representation from bodies such as MoHUA, SBM, DoF and others and convey the issues to them to improve the policy process

Model 2: Municipality owned, municipality operated

Item	Description
Objective	▸ Reducing the cost of transportation, centralized treatment, and disposal of waste in landfills ▸ Local employment opportunity
Authority	Municipality
Role of local authority	▸ Investment provider ▸ Implementing and monitoring agency
Advantages	▸ Cost-saving in transportation, centralized processing and disposal of waste ▸ Profitable use of waste ▸ Job opportunities for the unemployed youth ▸ Entrepreneurship development

Model 3: Municipality owned, privately operated

Item	Description
Objective	▸ Profit-seeking model ▸ Full cost recovery (from collection fees and compost sales) ▸ Cost reduction through lower transportation and disposal costs
Authority	Municipality, private sector, NGOs
Role of local authority	▸ Funding capital expenditure ▸ Identify and allot land for composting ▸ Contracts out the operation and maintenance ▸ Monitor performance of contractors
Advantages	▸ Reduction of the municipal burden of waste management through private sector participation ▸ Know-how and efficient management through private sector ▸ Partnership with private entrepreneurs ▸ Facilitates the establishment of compost collection centres in cities from decentralized facilities

Model 4: Privately owned, privately operated

Item	Description
Objective	▸ Profit-seeking enterprise based on compost market conditions (Income is generated through the sale of products. like compost and through a collection of charges)
Authority	Private sector
Role of local authority	▸ Selecting a private operator through a transparent process ▸ Formulation of transparent regulations for PPP ▸ Cooperation in supply of raw waste and disposal of residues ▸ Synchronizing centralized and decentralized systems
Advantages	▸ Reduction of the municipal burden of waste management through private sector participation ▸ Investment of funds and know-how through private investors ▸ Partnerships with private entrepreneurs ▸ Creation of employment and business opportunities ▸ Can use a registered trademark to establish their quality mark/seal.

The Indian government has proposed a policy to promote the market for city compost in India. It never gained much traction due to a lack of implementation, resulting in sporadic stakeholder involvement.

This report recommends a decentralized framework for handling organic waste and the size of such treatment units at different levels and policy changes to reinforce the current compost value chain. The activities will not only offer environmental benefits by reducing the burden of unscientific organic waste management but also confer social and economic benefits of the current compost value chain.

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In India, the share of organic waste in the total quantum of municipal solid waste ranges from 55-65 percent. The organic fraction in solid waste is traditionally a major source of soil, water, and air pollution if disposed indiscriminately, while this could easily be turned into resource in the form of organic manure or biogas. Considering the quantum of organic waste generated in India and the problems associated with the current management practices, it's critical to prioritize and adopt decentralized waste management system.

This study outlines decentralized organic waste treatment technology options practiced at various levels ranging from the household, neighbourhood, ward, and zone depending on the volume of waste. It further analyses the economics of each composting and bio-methanation technology option suitable for urban local governments and various stakeholders so that readers can choose the most appropriate method and technology for treating segregated organic waste.

The report also recommends specific regulatory reforms to promote decentralized technology to ensure sustenance of the value chain to augment a sustainable market for city compost. The Solid Waste Management Rules, 2016, emphasize decentralized over centralized waste management systems but a lot more needs to be done to ensure compliance.

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