Composting

- Composting is a process of controlled decomposition of the organic waste, typically in aerobic conditions, resulting in the production of stable humus-like product, i.e. compost.
- Composting is a biological process in which microorganisms convert organic matter into compost.
- Considering the typical composition of wastes and the climatic conditions, composting is highly relevant in India and should be considered in all municipal solid waste management (MSWM) concepts.

- Aerobic composting, which is carried out in the presence of air, is far more popular because it is much faster compared with the "trench" composting where direct access to air is denied.
- Processing of MSW by aerobic composting process yields humus rich compost (organic manure) along with macronutrients and micronutrients for plants.
- Composting is the third preferred choice in the ISWM hierarchy. It ensures that waste is processed appropriately to facilitate material recovery.

Benefits of Composting

- The real economic benefits of compost use include improved soil quality, enhanced water retention capacity of soil, increased biological activity, micronutrient content, and improved pest resistance of crops.
- Composting minimises or avoids GHG emissions from anaerobic decomposition of organic waste (such as in a large unturned heap).
- Composting increases the design life of other waste management facilities.
- Stringent design requirements and associated costs for catering to management of leachate from organic waste decomposition may be reduced in those landfills that do not receive organic waste.
- The use of compost reduces the dependency on chemical fertilisers for agricultural operations.

Constraints faced by the composting sector in India

- Compost quality standards (SWM Rules, 2016 and FCO series) are becoming increasingly stringent.
- Majority of the collection of MSW is in the form of mixed waste.
- Making quality compliant compost from mixed waste requires some equipment for refinement and quality control and higher production cost, but the yield is reduced as the quality standards are higher (10%–15%).
- All compost sold for application to food crops is mandated to be FCO compliant.
- Percentage of process rejects increases proportionally (30%–40%) unless the processing facility produces compost as well as refuse derived fuel (RDF).

- Lack of knowledge and practical experience among the various stakeholders responsible for planning, execution, operation and maintenance (O&M), and marketing leads to inadequately designed plants, inefficient equipment, improper operation, and shortcuts from equipment design to operational protocol.
- After the product is ready (called "finished compost"), cost is incurred for bagging, transport, marketing (commission of the chemical fertiliser company, dealers, etc.). The final cost to the farmer is normally almost twice the price received by the compost plant operator.
- As of 2015, the total cost to the farmer is about Rs.4,000–Rs.5,000 per ton of finished compost (distance being the main price variant). This price is too high for the average farmer.

The composting process

- During aerobic composting, microorganisms oxidize organic compounds to carbon dioxide (CO_2), nitrite, and nitrate.
- Carbon from organic compounds is used as a source of energy while nitrogen is recycled.
- Due to chemical reactions producing heat, temperature of the mass rises.
- Several biological, chemical, and physical processes contribute to the success of the aerobic composting.
- Understanding these processes is necessary for making informed decisions when developing and operating a composting plant.

BIOLOGICAL PROCESSES

- The two distinct biological process stages observed during composting are:
1) Thermophilic stage
2) Mesophilic stage
- **Thermophilic Stage** :
i. Moisture: 55%–60%
ii. Temperature: 55°C– 65°C
iii. Air voids: 20%–30%
iv. Microorganisms: thermotolerant fungi, thermophilic bacteria, actinomycetes
- **Mesophilic stage** :
i. temperature: moderate
ii. stabilisation of compost material occurs

- **Curing** :
i. Maturation Stage
ii. Lasts for 3-4 weeks
iii. Microbial species population increases drastically

CHEMICAL PARAMETERS

- Air Voids: Compost pile should have enough void space to allow free movement of air as aerobic conditions fasten the composting process by 10–20 times and reduce generation of foul smell.
- Moisture: Moisture is a critical factor in establishing stable conditions conducive for composting because the microbes need moisture for survival and growth.
- Aeration: The composting process requires adequate supply of oxygen for biodegradation by microorganisms. Under aerobic conditions, decomposition rate is 10–20 times faster than under limited oxygen supply or anaerobic conditions.
- Carbon-to-Nitrogen Ratio : C/N ratio of 30:1 is ideal for decomposition. C/N ratio below 25:1 results in foul smell while higher C/N ratio impedes decomposition

PHYSICAL PROCESSES

- Temperature: Under properly controlled conditions, temperatures are known to rise beyond 70°C in aerobic composting. Temperature plays a critical role in composting by increasing rate of biological activity resulting in faster stabilisation.
- Particle Size: The optimum particle size should have enough surface area for rapid microbial activity, but also enough void space to allow air to circulate for microbial respiration.

MUNICIPAL SOLID WASTE FEEDSTOCK FOR COMPOSTING

- MSW feedstock for composting should essentially include the segregated wet fraction of waste.
- Vegetable market waste and yard waste, being rich in organic content, are a preferred feedstock.
- MSW feedstock should be delivered at a well-defined area within the plant. This area is essential for overall smooth functioning and regulated flow of MSW feedstock into the processing area.
- The tipping area should have adequately sized shed (sides open) to receive predetermined quantities of waste daily.
- Storage area should be large enough to handle daily and weekly variations in waste quantity and should be provided with sheds to cater to wet weather conditions.

- MSW *segregation* and *pre-processing* are essential for composting.

- **PRE-PROCESSING OF MIXED MUNICIPAL SOLID WASTE** :
- Typically, mixed MSW received at the compost plant consists of 40%– 50% non-biodegradable material.
- Pre-processing of mixed MSW is crucial for preparing FCO-compliant compost.
- Pre-processing has a high economic value as it recovers recyclables, reduces contaminants, lowers processing costs and also ensures quality of compost.

- **Pre-processing serves the following purposes:**
i. separation of the mixed material into different streams, which are suitable for specific products—biodegradable for composting, combustible dry material for RDF, separation of recyclable material on sorting belt (glass, metal, etc.).
ii. reduction of cross-contamination of the material to make different products.

Pre-processing technologies :

- **Screening**- controls the size of feedstock
- **Magnetic separation**- removes ferrous metals
- **Eddy-current machines-** separates aluminium and other nonferrous metals
- **Air classifiers-** removes heavier fractions like glass and ceramics
- **Ballistic separation**-Ballistic or inertial separation separates constituents based on density and elasticity differences.
- **Additional inoculum**- Inoculum (bacterial culture) is also added to the feedstock to improve efficacy of the process. Adding inoculum may be an issue because of its cost implications. However, inoculum enhances composting process and also helps in suppressing foul odour.

COMPOSTING TECHNOLOGIES

Technologies for composting can be classified into the following general categories:

1) Windrow composting
2) Aerated static pile composting
3) In-vessel composting
4) Decentralised composting (bin and box composting)
5) Vermicomposting

1) WINDROW COMPOSTING

- Windrow composting process consists of placing the pre-sorted feedstock in long narrow piles called windrows that are turned on a regular basis for boosting passive aeration.
- The turning operation mixes the composting materials and enhances passive aeration.
- Compost yield of 10-15% is more common from mixed municipal solid waste.

UNIT OPERATIONS IN WINDROW COMPOSTING

Compost pad (platform):

- The pre-processed MSW is transferred onto the compost pad into windrows.
- The compost pad is an area where the windrows are stacked.
- The compost pad must be stable, durable, and impervious, so it is constructed with an appropriately designed combination of reinforced cement concrete (RCC) and plain cement concrete (PCC).
- The compost pad shall have a slope of about 1% to drain the excess water (storm water or leachate) from the windrows into a leachate collection tank.

The following factors have to be considered in the location and design of the composting pad:

- The base has to provide a barrier to prevent the percolation of leachate and nutrients to the subsoil and groundwater.
- The surface has to facilitate equipment movement even during wet weather conditions.
- The surface area has to accommodate waste for 5 weeks, with sufficient room for equipment to maneuver and an area to establish a static pile for curing compost.

Windrows :

- The height to base width ratio of the windrow depends basically on the angle of repose of the material.
- Windrows are typically trapezoidal in cross section.
- The space between windrows should be sufficient for movement of the windrow turning machine. Normally, it is 1–3 metres.
- Windrow composting is the most economical and widely accepted composting process.

Windrow Formation:

- The size, shape, and spacing of windrows depend on the equipment used for turning.
- Windrow dimensions should allow conservation of heat generated during composting process while also maintaining diffusion of air to the deeper portions of the windrow .

Windrow Turning:

- Windrows are turned frequently to maintain aerobic conditions inside the pile. Windrow turning is a mechanised operation.
- Windrows should be turned frequently, once a week over 5 weeks, to maintain aeration and porosity to enhance degradation.
- During the rainy season where the interstitial spaces are filled with water, more frequent turning is necessary (interval of 3–4 days).
- Frequency of turning depends on: ▪moisture content, ▪porosity of material, ▪rate of microbial activity, and ▪ desired composting time

Curing:

- Screened material coming out of the coarse segregation section requires further maturation and moisture control for producing a product that is beneficial for plants and soil.
- The degree of maturity is determined through either oxygen uptake or CO_2 production rate.
- Curing of screened material for at least 3 weeks in a covered area ensures complete maturation of compost.

Compost Refinement:

- At the end of composting phase, the material usually contains 30%–35% moisture.
- The composting is normally taken to be complete when the active decomposition stage is over and the carbon-to-nitrogen (C/N) ratio is around 20.
- Compost with either higher or lower C/N ratio is not beneficial to the soil.
- Final compost product should be less than 4 mm.
- Remaining material should be put on the incoming waste heap to hasten the composting process

Leachate Management:

- Leachate is generated during composting as the biodegradable matter is fermented.
- It is a thick liquid with strong odour with very high biochemical oxygen demand (BOD) and chemical oxygen demand (COD).
- However, it has moisture and nutrients, which can be put to good use like for moistening the waste heap
- Leachate can be treated biologically. Control of leachate is a very important part of operating a compost plant safely.

2) AERATED STATIC PILE COMPOSTING

- In the case of aerated static pile composting, forced aeration is used to spread excess air through the windrows unlike the aerobic windrow composting, where aeration is achieved by turning the windrows so that new cut sections are exposed to air.
- The composting piles are placed over a network of pipes connected to a blower, which supplies the air for composting.
- Air can be supplied under positive or negative pressure.
- When the composting process is nearly complete, the piles are broken up for the first time since their construction.
- The compost is then taken through a series of post-processing steps.
- Aerated static pile technology requires mechanical aeration of composting pile.
- As compost piles are not turned frequently, feedstock should be mixed with bulking agents like rejects from trommels, straw and wood chips to ensure air circulation.

- Pre-processing ensures porosity by removing thin plastics in the raw materials and hence facilitates efficient air circulation .
- Pre-processing involves: ▪Segregation ▪Size reduction ▪Blending with bulking agents
- Controlled mechanical aeration enables construction of large piles, thus reducing the demand for land.
- It is suggested to cover the top of the pile with finished compost or bulking agent to ensure insulation, destruction of pathogens and suppression of odours.
- A top layer of matured compost could also act as an odour filter.
- Height of pile helps in retaining heat and should be ideally at least 1.5 m to 2.5 m.
- Aerated static pile technology usually takes 6-12 weeks for producing mature compost .
- Post processing of compost involves separation of wood chips from the finished products through trommel screen.

3) IN-VESSEL COMPOSTING

- In-vessel composting systems enclose the feedstock in a chamber or vessel that provides adequate mixing, aeration, and moisture.
- There are several types of in-vessel systems available: drums, silos, digester bins, and tunnels.
- These vessels can be single or multi-compartment units.
- In some cases, the vessel rotates; in others, the vessel is stationary and a mixing or agitating mechanism moves the material around.
- Most in-vessel systems are continuous-feed systems, although some operate in a batch mode.
- In-Vessel composting is recommended especially for kitchen and canteen food waste.

- **Types of In-vessel reactors** :
  i. Vertical plug flow and horizontal plug flow: feedstock is loaded on a periodic basis.
  ii. Agitated bin: feedstock is loaded and agitated continuously.
- Composting takes place in an enclosed vessel, all environmental conditions can be controlled to enhance composting.
- Minimal odour and leachate generation are observed.
- The detention time in the vessel varies from 3–10 days.
- Curing period of 2–3 weeks is required after the active composting period.
- In vessel composting requires at least 12-14 weeks to produce mature compost.

4) DECENTRALISED COMPOSTING

- Colony level and ward level decentralised composting should be promoted by ULBs(urban local bodies) for source separated organic household waste from very small quantities.
- Decentralised composting is the composting of source separated organic waste in limited quantities from households, apartments, neighbourhoods, markets, gardens, or the entire ward.
- The decentralised composting approach reduces transportation costs and makes use of low-cost technologies based mainly on manual labour.
- Decentralised composting can be practiced in either box or bin depending on the quantity of waste feed and cost implications.

BIN COMPOSTING

- Depending on the quantum of input material, the size of the bin may be decided.
- A series of bins may be used to accommodate all incoming waste.
- The bottom of the bin should be covered with a thick layer (15 cm) of coarse material, such as twigs, broken pieces of stone, or mulch, if available.
- Over this drainage layer, the feedstock is to be placed in layers.
- The feedstock should ideally contain a mix of garden or yard waste, kitchen waste, dried leaves, and paper.
- Water may be sprinkled to keep the heap moist. Care should be taken not to add excess water; the heap should not be wet..
- Finished compost may be sprinkled on top to provide the required inoculum and to contain odour.
- This waste should be turned regularly to hasten the composting process.
- High temperatures are produced upon turning once every 5–10 days.
- This also helps to kill larvae and weed seeds, and provides a conducive environment for decomposer organisms.
- The composting process may take between 45 days and 6 months, depending on the feedstock and turning condition

BOX COMPOSTING

- Box composting is practiced at the local community level and can cater to wastes up to 3–5 tonnes.
- The total space requirements for box are lower than for the windrow technology.
- The slab on which the boxes are built should be sealed and sloped towards one side.
- Leachate collection channels should be constructed, leading the leachate away from the boxes toward a central collection point.
- To improve oxygen supply to the pile within the boxes, the box wall contains gaps between the bricks.
- The base of the box should be perforated and resistant to corrosion to ensure aeration and drainage of excessive water from the pile.
- Assuming an input load of 3 TPD of organic waste, two boxes are filled within 5–6 days.
- When the box is full, the waste is left for 40 days to go through a thermophilicmesophyllic composting process similar to the windrow system.
- Temperature and moisture are frequently monitored.

5) VERMICOMPOSTING

- Vermicomposting is the process of using earthworms and micro-organisms to turn kitchen waste into black and nutrient rich humus.
- Vermicompost is richer in plant nutrients compared with normal compost prepared from similar material.
- It has some cocoons which develop into worms when put in the soil and continues to do their work of conversion.
- Vermicompost draws better market price.
- Vermicomposting is typically suited for managing smaller waste quantities.
- It is an ideal technology for towns that generate up to 50 TPD of MSW which is thoroughly segregated either at source or in the plant.
- The worm species that are considered efficient for conversion of waste are Eisenia fetida, Perionyx excavatus, Lampito mauritii, Eudrilus eugeniae, Lumbricus rubellus, Pheretima elongata, etc.

- Vermicomposting takes place at 2030°C which is the most favourable temperature for ensuring survival of earthworms.
- Carbon-to-nitrogen (C/N) ratio of 15–35:1 is suitable.
- Typical density of earthworms should be 1–4 kg per m2 on average.
- Worm casting or vermicast should be stored in sacks for at least a month to ensure complete maturation before being applied to soil,
- Since earthworms are very sensitive towards heavy metals, it is very important to ensure that waste feed is not contaminated .
- Under Indian conditions, the entire cycle of vermicomposting takes about 10 weeks.
- In case of pre-composted material, about 7-8 weeks is required.