Technology Reader

Anaerobic Digestion

Version Date: 14-05-2025

File No.: 20250514_Technology Reader Summary

Contents

Summary

The primary objective of anaerobic digestion is to convert the input feedstock materials into a more stable product. Segregation is the first and most critical step in the anaerobic digestion process, as it determines the efficiency and quality of the entire operation. When municipal solid waste reaches the facility, it is a mixed stream of organic and inorganic materials. Through a combination of manual sorting and mechanical systems like trommel screens and magnetic separators, non-biodegradable items such as plastics, metals, glass, and cardboard are removed. This ensures that only the clean organic fraction moves forward into the digestion process, where it is biologically broken down to produce biogas and nutrient-rich compost. Meanwhile, the recovered recyclables are collected separately and sent to appropriate recycling channels, where they are processed and reintroduced into the supply chain. This careful separation enhances process efficiency, protects equipment, improves compost quality, and supports a circular economy by converting waste into both clean energy and reusable materials. The full process can be seen in detail in the video linked here.

Anaerobic digestion (AD) is the series of processes to breakdown complex organic matter to biogas and CO_2. It involves 4 stages, hydrolysis, acidogenesis, acetogenesis and methanogenesis. It is also described as biological oxidation of biodegradable waste by microbes under anaerobic conditions or in the absence of air. In the content below we will provide an overview of the process, technologies, methodologies in which the above-mentioned AD process is done.

The incoming unsorted waste will be heterogeneous in nature and have impurities. In order to have a highly efficient AD process, these impurities need to removed and the feedstock needs to be homogenised. Pre-treatment processes and segregation processes will have to be carried out to achieve this. Mechanical and manual segregation of the waste will aid in separating unwanted impurities from the actual feedstock. Mechanical segregation starts with a grabber that puts the material into the hopper unloading the waste materials via conveyer belts to a hand pick station, where hand pickers physically segregate waste, and secondly through a drum screen and a magnet in which the separated organic fraction goes via a conveyor belt towards the digestion garage boxes. There are electro mechanical controls installed to monitor the operations.

After the feedstock is pre-treated and segregated the organic waste fraction goes into the digestion process where the waste is treated, broken down into simpler compounds, which aids the microorganisms to break down the material further releasing methane and CO_2. The technology adapted here is dry-fermentation. Dry-fermentation has various benefits over wet-fermentation, few major benefits are lower energy and water requirements. The most important benefit is that the dry digestion can handle impurities like plastic or big items like coconuts etc. The released gas is called biogas, a combination of methane, CO_2, and few traces of H_2S. The biogas is then passed through purification system where CO_2, H_2S and

other impurities are removed, hence the output gas have higher concentration of methane. This gas can be used as an alternative source for existing conventional fuels like CNG and gasoline. Apart from biogas, the AD process also produces bio-fertilizer via the system of windrow composting. Bio-fertilizer is high in fertilizer properties and can be a replacement or supplement for producing conventional fertilizers.

1 Introduction

The technology adapted is Integrated Mechanical Biological Processing Technology (MBT) System, it is one of the most innovative MBT process for the treatment and utilisation of residual household waste. This technology has been identified as Maximum Yield Technology (MYT) by Zweckverband Abfallbehandlung Kahlenberg (ZAK) Kahlenberg Waste Treatment Association.

The focus of MYT is on extracting the complete raw material and energy content from the municipal solid waste. Although the characteristic properties of MSW vary on a regional and international level, the key components are always the same. MYT innovative, perfectly synchronized multi-step process cascade gains the following four main components from the input MSW and extracts the maximum potential from them while utilizing synergies for each treatment step most effectively.

- Energy Sources (Biogas and CBG)
- Recyclables as Glass, Paper, Plastics, Metals.
- Minerals
- Bio-fertilizer

Anaerobic digestion is a Dry Batch Fermentation Technology where in the organic fraction, including impurities such as silt and sand is fed into specially designed reactors. The anaerobe digestions system presents a dry batch digester, which is a static digester, in which the feedstock will not be pumped or moved; hence the feedstock cannot block any pipe, or other mechanical part; the amount of sand and silt in the fermentation tank is fully controlled because the feedstock will be only touching the garage boxes. The digester can take waste with an average dry solid content between 25-35% with no or less water addition.

Dry fermentation has advantages over wet fermentation, like

- easily scalability,
- highly flexible with different types of feedstocks,
- low electricity and water consumption and,
- stable fermentation residue
- no issues with impurities like plastics and for example coconuts (big pieces)

2 Anaerobic Dry Digestion

2.1 Description of the Dry AD process

Dry anaerobic digestion is a modular system where every garbage box is an independent reactor. This provides very high reliability to the system because, should a failure occur to one of the units, the other garbage boxes can continue operating. Continuous operation is the key factor in a waste treatment plant where incoming waste flows cannot be stopped without major inconveniences.
Dry anaerobic digestion is also a very low operational cost system because the waste does not need any costly pre-treatment before entering the digesters. For the same reason, also maintenance is simple. OPEX are low also because the digestate does not require solid/liquid separation as it would occur when compared to a wet digestion system.

As soon as one of the Anaerobic Digestion (AD) garage-boxes is ready to be filled, the wheel loader retrieves the material from the temporary storage and feeds the garage-box.

AD garage-box doors

Each AD garage-box consists of a sealed concrete structure equipped with a special door provided with a pressurised rubber seal. The concrete floor houses a series of parallel PVC pipes which are lengthwise incorporated in the floor. These pipes are provided with tapered plastic nozzles (spigots) and are connected via pneumatic valves to two high pressure blowers which are used for the following purposes:

- Recirculate air in the first phase of the process to increase the material temperature by a short aerobic stage aiming also at consuming the oxygen in the garage-box before starting the anaerobic process;
- Recirculate gas through the material during the AD process;
- Flush the gas from the material at the end of the AD process;
- Keep the spigots open during the loading phase of the garage-box.

Each garage-box outlet is then equipped with a series of pneumatic valves which are used for the following:

- Open/close the gas flow from the garage-boxes to the fermentation tanks and to the biogas upgrading
- Open/close the exhaust air flow heading to the air treatment system
- Open/close the recirculation circuit flowing through the spigots via the high-pressure fan

Please note that, based on the latest design, all the technological system is supplied on prefabricated and pre-tested SKIDs where all the equipment required for the process is installed. There will be a SKID dedicated to each AD garage-box, a central air/gas SKID, a central water system SKID, a central heating system SKID and a central compressed air SKID. It goes without saying that the SKID configuration minimizes the site assembly time and allows for most of the testing to be conducted already at workshop, before delivery.

The garage-boxes are also equipped with a sprinkling system which recirculates the liquid contained in the fermentation tanks. The sprinkling system is massively used in the beginning of the process to activate anaerobic process by inoculating the fresh material with the bacterial activity present in the fermentation tanks.

Technical outfit AD garage-box

The fermentation tank and percolation perform multiple actions in the process:

- Act as a hydraulic buffer
- Act as a temperature/heat buffer
- Wash out the acids from hydrolysis of a freshly filled garage-box
- Contribute substantially to the biogas production
- Represent a storage of biology
- Inoculate fresh garage-box (no need for recirculation of digestate)

In the AD garage-boxes, a slightly positive pressure (3-5 mbar) is maintained throughout the process to prevent air to enter the garage-boxes during the anaerobic phases. Each garage-box is also equipped with an over/under pressure protection valve which activates in case of excessive under/over-pressures and having outlet outside the building.

As soon as the material is fed to the AD garage-boxes and the door is closed the blower starts to recirculate the garage-box air through the spigot floor. This induces a preliminary aerobic process which rises the temperature quickly to the mesophilic (or if required Thermophilic) level required in the AD process. Furthermore, the oxygen level in the air is dropping leading rapidly the process to anaerobic conditions.

After this first stage, the gas valve opens allowing the gas to be extracted from the garage-boxes. The gas is reaching the storage volume and mixes up with the gas coming from the other garage-boxes. During the process, the blower alternatively recirculates the gas through the spigot pipes in the material to optimize gas production and homogenize the process conditions in the whole batch of material.

At the end of the process, when the gas production lowers, the fresh air valve opens, and the blower starts to purge the garage-box from gas. Flushing is performed with air or, as explained in following section, in case of biogas upgrading flushing is with CO_2. The gas mixture that is produced is first utilized in the central gas system and when the methane concentration lowers below a certain threshold the gas is stored in a "lean gas" additional holder. This is provided to maximize gas exploitation and minimize gas emissions during transient phases. The lean gas holder collects the gas mixtures which are not directly usable in the generators or upgrading systems but can be slowly introduced in the utilization during all phases where the methane concentration allows for that.

Subsequently, when the gas quality decreases even more, the lean gas is flared in a special flare. Support biogas is required when methane concentration drops below 10-15%. As soon as the gas quality is below the LEL (Lower Explosion Level) of methane, the exhaust gas mixture is further diluted with air coming from the halls and is then transferred to the biofilter.

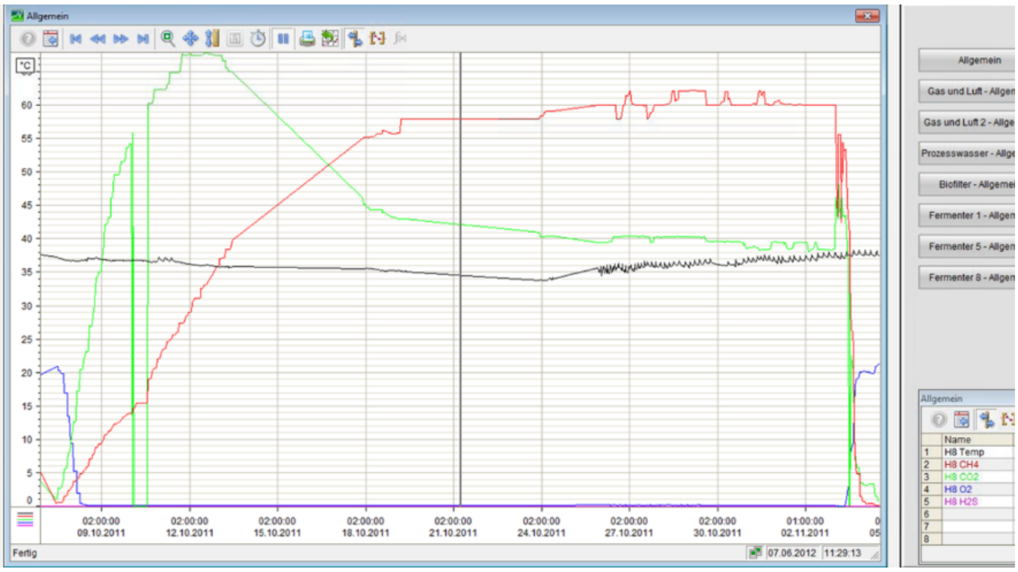
Gas flare and fermentation tank incl. gas holder (L) with mixer shown (R)

When the analysing system indicates that the methane content in the garage-box atmosphere is below the LEL, the door safety interlock opens, and the garage-box can be opened. The material is retrieved from the AD garage-boxes with the wheel loader and transferred to the aerobic section.

The residence in the AD garage-boxes is set to 22 – 24 days. Experience shows that this retention time optimizes the gas productivity and leaves sufficient organic load to the material to be actively participating to the following aerobic process steps.

2.2 Biogas production cycle

The biogas production and the methane concentration will vary along the whole process. A typical diagram is shown in the following screenshot (CH_4 concentration indicated by red line):



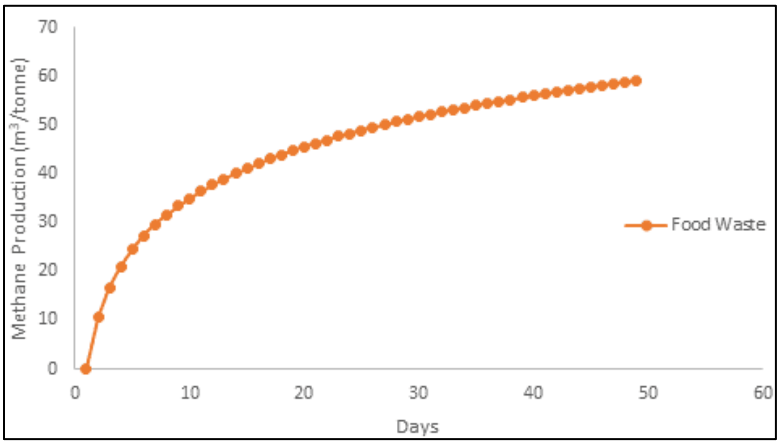
A typical biogas composition graph over a 28-day process period

As it can be seen, methane concentration starts from "0" at the beginning of the process and returns to zero at the end.

The same cycle occurs in all the garage-boxes, however with a certain time lag depending on the garage-boxes filling schedule. This overlap of production will therefore induce a more constant diagram.

The biogas produced in all garage-boxes is flown to the gas holder and is here mixed with the gas produced in the fermentation tank itself. The latter provides a constant contribution to the biogas production and methane concentration and guarantees that the CHP or the upgrading system is fed with the suitable gas quality.

A typical cumulative methane production curve is shown in the following picture. This includes both the CH_4 produced in the garage-boxes and in the fermentation tanks and shows that extending too much the process beyond 3 weeks is not meaningful.



A typical overview of the cumulative gas production

2.2.1 Process control system

The control system supplied consists of a computer that takes care of visualization. The computer visualizes the complete composting process. On the visualization, the operator can see the status of the installation, evaluate, and adjust process parameters, if needed. The computer monitors the composting process and is connected to a PLC that controls the process. The control parameters for the PLC are entered via the visualization.

The software in the PLC operates the process air and process water of all garage-boxes. The control software sets temperature, moisture level and oxygen level of the composting material to optimum conditions. However, only qualified personnel should operate the computer.

The parameter settings of the control software do not need to be changed after the composting installation has been started. The visualization is equipped with modem and communication software for quick support in case of problems.

2.2.2 Gas recirculation

The batch Dry AD process is a static one. This means that the material is not stirred or anyway moved during the whole process duration. If on one hand, the absence of stirring limits the process efficiency, on the other hand this brings the big advantage of making the system very reliable, maintenance friendly and able to accept highly contaminated waste.

To compensate for the absence of stirring, the technology provides the feature of recirculating biogas during the process blowing it back through the spigot floor.

This provides the following benefits:

1. keeps the material porous enough to facilitate good percolation, which is of utmost importance in this type of process, as already mentioned
2. promotes the biogas development in the whole batch of material
3. maintains homogeneous temperature and moisture conditions in the whole batch of material.

Gas recirculation is performed by the ATEX proof high pressure fan installed in the system.

2.2.3 No digestate recirculation to the AD process

In the system, the anaerobic process is inoculated via the liquid phase therefore avoiding material recirculation in the garage-boxes. The system is provided with a large fermentation tank where all the percolate is directed. There is water level management system in fermenters to monitor the water level and recirculation in the fermentation tank. The fermenting liquid is recirculated to the anaerobic garage-boxes most of all in the beginning of the process to bring the suitable bacterial life allowing the anaerobic process to be started also without recirculating digestate material mixed to the incoming stream. This allows for a substantial reduction in the volume required in the garage-boxes.

2.2.4 Sensor and Data Management

The process is monitored based on pressures, level measurements, temperatures, flow rates, CH_4, CO_2 and O_2 percentages (possibly H_2S). These values are read by the PLC, used to control the process based on the software and sent to the SCADA for visualization. The SCADA stores this data, this can be done locally on the SCADA PC, or somewhere else such as a NAS. All these parameters are supervised by SusBDe's technology providers.

2.2.5 Absence of obstacles in the AD garage-boxes

The AD garage-boxes are designed to prevent that any obstacle can interfere with the operation of the wheel loader in the unit. This is of utmost importance both to eliminate costly and time taking repairs to damaged parts but also to facilitate the loader operation making the garage-box loading and unloading phases easier and quicker. For example, percolation is performed via the spigot floor avoiding steel meshes retaining the material in the unit.

Example of a clean spigot floor

2.2.6 Biogas Characteristics

The biogas produced in the Anaerobic Digestion has the following typical composition:

- CH_4 50 – 55%
- CO_2 45 – 35%
- N_2 0 – 6%
- O_2 0 – 1.5%
- H_2S 500 – 3.000 ppm (MSW)
- H_2S 100 – 1.000 ppm (biowaste)
- H_2O saturated

This biogas will require treatment to reduce the H_2S content (AC filters, scrubbers) and chilling at ca. 5°C to reduce the water content. After this pre-treatment, it follows an upgrading process able to separate the methane (CH_4) from the other gasses (mainly CO_2).

2.3 Garage-box construction

An anaerobic garage-box consists of a sealed concrete structure provided with a special door equipped with a rubber sealing. The concrete floor houses a series of parallel PVC pipes which are lengthwise incorporated in the floor. These pipes are provided with tapered plastic nozzles called spigots and are used to distribute the air evenly over the garage-box. In this way, the process can be controlled properly, and the conditions can be maintained in the complete batch of material being processed.

Garage-box partly filled with organics

2.3.1 Anaerobic Garage-boxes and gas system

The following Parameters are measured at each garage-box:

- CH_4
- O_2
- H_2S
- CO_2

- Temperature
- Pressure
- Water temperature (inlet)
- Water temperature (outlet)

The following Parameters are controlled at each garage-box:

- Irrigation valve
- Air and gas valves
- Heating valves

The following Parameters are measured in the central gas system:

- CH_4
- O_2
- H_2S
- Gas flowrate
- Air flowrate
- Heating water temperature
- Air and gas pressures
- Process water levels

The following Parameters are controlled in the central gas system:

- Gas / air blower flowrate
- Heating water flowrate

Additionally, the following measurements are displayed

- Water level in the leachate water pits/tanks
- Water quantity used for the garage-box humidification system

3 Biogas Upgradation System

The biogas upgradation technic is based on membrane separation, which can produce Fuel Grade Methane(FGM). The upgradation process starts with purifying the biogas with H_2S scrubbers. The purified gas is sent to the membrane upgradation system to produce high quality biogas.

3.1.1 H_2S Scrubbing

Scrubbing is a common method used to remove hydrogen sulfide from biogas. The process uses the sparger-based gas liquid contact for removal of hydrogen sulphide from the gas. The liquid and raw gas are injected into the scrubber vessel from the bottom. The process is based on the red-ox reaction of chelated polyvalent metal ion, where iron in chelated form in an aqueous medium is used for scrubbing H_2S from biogas stream. Iron which exists as both Fe3+ and Fe2+ form, works as a catalyst to scrub the gas of H_2S. The gas coming out of the scrubber, which is free of hydrogen sulfide, is then scrubbed with water for cleaning any minute quantities of chemical carried over. The clean gas thus obtained is fit for the end application.

The sulfur component in the hydrogen sulfide is precipitated as elemental sulfur. The scrubbed solution containing sulfur is then taken to the re-generator and regenerated with air using an ejector-based air liquid contact process. The regenerated solution containing sulfur is passed through filter press for sulfur removal. The clear filtrate is then re-cycled back to the scrubber.

3.1.2 Biogas Upgradation System - Membrane separation

Biogas is compressed and fed into modules which contain thousands of porous, hollow fibre membranes. Fast gases permeate the membrane walls while slow gases exit the hollow tube.

This is a passive technology requiring minimal supervision. The system can be scaled by adding or reducing the number of modules online. Multiple stage membrane separation system can produce 99% pure methane. This technology is efficient at removing water vapor and performs for a period of 8 to 12 years.

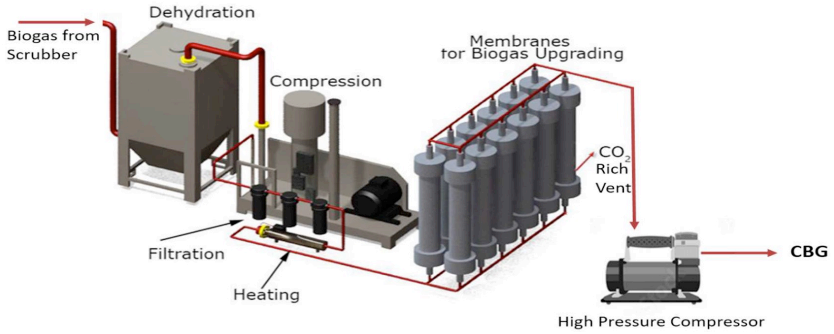
Technology:

Biogas upgradation Module is based on Hollow Fibre Membrane Technology to upgrade Biogas to Bio-CNG ensuring the national statutory standards for Auto Fuel, Cooking gas and Gas grid connectivity.

The biogas is a mixture of CO_2, methane, and the typical by-products. It is first desulfurized with active carbon, filtered, and pre-dried. The pre-cleaned gas is then drawn in with a compressor, compressed to 12 - 16 bar and upgraded in several membrane stages to give biomethane and a CO_2-rich off-gas stream. By judicious combination of membranes, methane of a purity higher than 99% can be obtained. The only equipment needed is a compressor. The methane concentration is obtained in natural gas quality.

Gas separation membranes work on the principle of selective permeation through a membrane surface. The driving force for permeation of the gas through the membrane is the difference between the partial pressures of the gas on the potentate side (the interior of the hollow fibre) and the permeate side (the exterior of the hollow fibre). The membranes have the highest selectivity and provide a superior technology for processing of crude biogas.

In a separation of Biogas between carbon dioxide and methane, permeation of carbon dioxide through the membrane is much faster while methane is retained within. The pre-filtered and de-sulphurised biogas is compressed to 12 - 16 bar pressure for the separation process.



Biogas Upgradation System

The throughput passes through the cooling process, resulting free condensate is separated from the raw gas, oil filters and coalescing filters for clean gas. The Biogas stream passes through a 2-stage constructed membrane-gas processing plant and with CH_4 separated up to 98% meeting the requirements of vehicular fuel (as per SATAT Scheme and Grid injection norms).

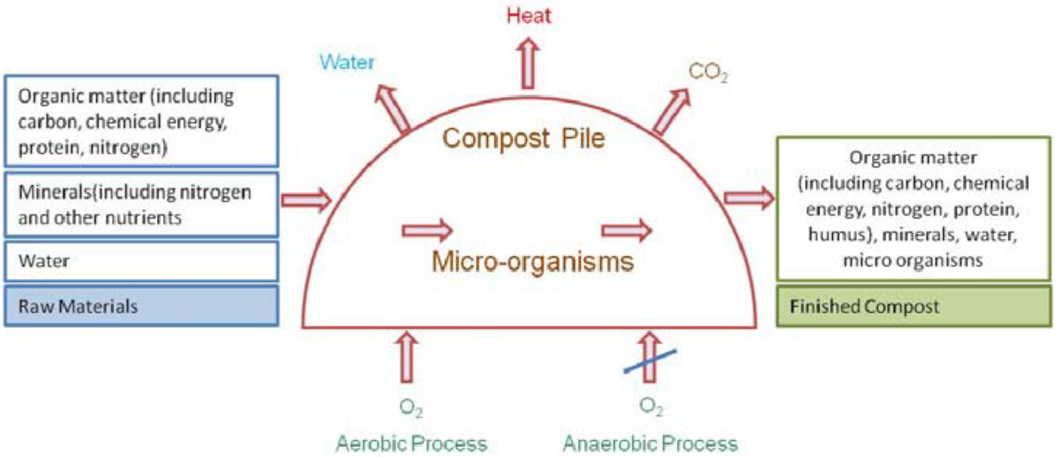
Benefits of membrane separation system:

- Low methane slip (loss)
- High methane yield of up to 99% can be obtained, which means maximum added value for the operator
- Highest energy efficiency for upgrading (<0.2 kWel/Nm3 raw biogas, <0.4 kWel/Nm3 biomethane)
- No additional ancillary materials or consumables such as water or sorbents (amines, glycols) are required, so no emissions into the environment
- Easily regulated for changes in flow rate or composition
- Following the upgrading process with membranes, the biomethane is already dry and satisfies the dew-point requirement for feeding into the grid
- Starting and stopping of the plant is possible at short intervals, ensuring high flexibility; therefore, ideally suited for operation of a biomethane filling station at the site
- The simple, easy-to-handle set-up takes up less space in the upgrading plant.
- The continuous separation process results in very high energy efficiency.

4 Composting

4.1.1 Influencing Parameters and Stages of Composting Process

Composting is an organic method of producing compost manure by decomposition and stabilization of organic matter. Composting process is a commonly used method and results in the production of stable compost product reduced in size (when compared to initial size) and free from offensive odours. Compost is particularly useful as organic manure which contains plant nutrients (nitrogen, phosphorous and potassium) as well as micronutrients which can be utilized for the growth of plants. Composting can be carried out in two ways - aerobically (with the presence of oxygen) or anaerobically (without the presence of oxygen) or vermi-composting or by any other biological mechanism.



Composting Process

Several factors – physical, chemical, and biological influence the process of composting. By controlling some of these influencing factors, natural composting process could be accelerated. These influencing factors also have impact on quality of compost produced. Some of the important physical and chemical factors in the composting process are temperature, C/N ratio, phosphorous, sulphur, moisture, particle size, oxygen flow, etc.

C/N ratio: Optimum C:N ratio is to be maintained for maximizing the compost yield. To bring down the ratio, sewage and sludge are usually added. Optimum C/N ratio lies between 25-30 : 1.

Phosphorous: One of the essential nutrients for plant growth and determines the quality of compost. Phosphorous concentration might increase as composting proceeds.

Sulphur: Presence of Sulphur in sufficient quantities can lead to the production of volatile, odorous compounds. The major sources of Sulphur are two amino acids (cysteine and methionine). Under well-aerated conditions, the sulfides are oxidized to sulfates, but under anaerobic conditions, they are converted to volatile organic sulfides or to H_2S, leading to a bad odour. Some compounds like carbon disulfide, carbonyl sulfide, methyl mercaptan, diethyl sulfide, dimethyl sulfide, and dimethyl disulfide might also lead to bad odours. The site is located away from the human habitation.

Moisture: Optimum moisture content maintained is 50 to 60%. Very high moisture content will result in anaerobic condition. Higher moisture content is essential for mechanical operated system and the waste contains high percentage of fibrous material.

Temperature: Optimum temperature for aerobic composting 65–70 °C. This temperature results in increased rate of biological activity and faster stabilization of the material and also helps in destruction of pathogens and parasites.
Particle size: Smaller particles produce a homogenous particle size which helps to maintain optimum temperatures. But too fine particles may not allow air to flow into the piles. As observed from the sieve analysis, maximum portion of compostable material falls in the range of 10-20 mm size.
Oxygen and aeration: Aerobic process helps to decompose the organic matter at a faster rate. However, care must be taken not to provide more oxygen which might dry the system and slow down the composting process.

Biologically influencing parameters are microorganisms which breakdown organic matter and produce carbon dioxide, water, heat, and humus. This humus forms the end product as compost. The general composting process consists of four decomposition phases when a suitable environment is provided.

- *Mesophilic Phase (I):* In this phase, slightly rotten material exists, in which mainly bacterial degradation of easily degradable substances takes place. The microorganisms rapidly consume sugars, fats, starches and proteins and heat is given off, where the temperature up to about 42°C. This stage lasts for two to three days.
- *Thermophilic phase (II):* In this phase, active composting takes place where fresh compost is produced by further degradation of easily degradable materials as well as degradation of cellulose, caused by thermophilic fungi and bacteria. As the organic matter degrades, particle size is reduced. The temperature in this phase rises to 65°C which causes self-limitation or decrease in reproduction of microorganisms. This state lasts for few weeks.
- *Cooling phase (III):* Finished compost is produced in this phase, where degradation of cellulose by fungi and bacteria, and formation of humus substances takes place. A decrease in microbial activity and temperature occur in this phase.
- *Maturing phase (IV):* Matured compost is produced in this phase, with further decrease of temperature compared to the surrounding temperature. Very low microbial activity with further formation of humus substances and stabilization take place.

There are various methods of composting and the approach in selecting the appropriate method of composting depends on time required to complete composting. Details like the material and volume to be decomposed, space available, the availability of resources (labour, finances, etc.) and the quality of finished product also need to be considered.

4.1.2 Windrow Composting Aerobic composting

Windrow composting, which is associated with least possible odour issues is generally preferred. Windrow composting is widely used at a large scale as the

climatic conditions are semi-arid to arid. Windrow composting is the process of decomposing organic materials to form stabilized organic matter.
It is defined as the controlled, heat dependent, microbiological process of decomposing organic materials into a biologically stable, humus-rich material. Compost is used in agriculture, horticulture, home gardening, land reclamation, wetland mitigation, and erosion prevention to help rebuild soil organic matter and to provide a good medium for plant growth.

Compost Windrows and Compost Material

Windrow composting process consists of placing pre-processed waste in long narrow piles called windrows that are turned on regular basis for enhancing aeration. These windrows shall have impermeable base / platform called compost pad made from concrete of compacted clay of 40 to 50 cm thick. The permeability co-efficient should be less than 10-7 cm/sec. This compost pad serves as a barrier to prevent percolation of leachate to sub-soil and groundwater. A slope of 1-2% should also be maintained in the base to drain excess water called leachate from the windrows. The base should be circled with a lined drain for collection of leachate or surface runoff. This leachate would be reused for recirculation of nutrients and for maintaining moisture content in windrows. Sufficient space shall be left between windrows for movement of equipment/vehicle used for turning windrow. Windrow composting is basically including the following phases.

4.1.2.1 Phase I: Pre-processing / Mechanical screening of waste

- The plant will be receiving mixed MSW including waste from residential areas and market areas. Mixed waste is pre-processed at the waste management facility by manually / mechanically segregating and sorting recyclables/ glass/metals, etc.
- This segregated waste after being digested in ADD can be now used as a feedstock for the composting process.

4.1.2.2 Phase II: Compost Pad and Turning of Windrows

This phase starts with transferring the mechanically treated waste to a specific area designed especially for windrows. A coarse material is spread over that area to enhance ventilation and drainage at the bottom of the windrow pile, and to prevent saturation that might cause anaerobic conditions.

- Long and narrow triangular or trapezoidal windrows are made parallel to each other with sufficient distance in between. The length and the number of windrows would depend on the quantity of organic waste that the plant is receiving.
- Turning of waste and addition of water by special machine to maintain / provide oxygen and water necessary for aerobic decomposition. Air can be pumped into the waste for good ventilation (forced aeration). The waste remains in windrows for 5 weeks to decompose with turning and addition of water twice a week during the first three weeks and once a week for the remaining two weeks. Windrows should be covered with special cover to prevent evaporation but without preventing air intrusion. Turning of windrow pile also helps to rebuild the pore space in the pile that is lost by settling and reductions in particle size.
- Turning of windrow pile depends on season, climate, temperature, moisture content and porosity of pile.
- Temperature shall be monitored regularly and generally maintained within 55 to 60°C as variation in temperature slows down the composting process.
- The moisture content of the windrows is generally maintained at 45-55%.
- As the composting proceeds, volume of each windrow pile decreases.

4.1.2.3 Phase III: Curing

In this phase, the fresh compost produced in the first phase is transferred to another area and piled up and kept to mature for a period of two to four weeks. Unlike phase II there is no turning of the waste and water addition in this phase. Microbial activity takes place at a lower rate in this phase. Matured and dry compost with water content of 25 to 30% is produced.

4.1.2.4 Phase IV: Compost Refinement

The matured compost is sieved into fine and coarse fractions using a drum screen. The fine fraction, rich in organic matter, passes through an air density separator to remove sand and grit and is prepared for sale. The coarse fraction is reused in the composting of fresh waste to accelerate the decomposition process.