Solid waste treatment-Composting

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Composting

- Composting is the process by which the organic, biodegradable portion of MSW is microbiologically degraded under aerobic conditions.
- During the process of degradation, bacteria are used to decompose and break down the organic matter into water and CO_2, which produces large amounts of heat and water vapor in the process.
- Given sufficient oxygen and optimum temperatures, the composting process achieves a high degree of volume reduction and also generates a stable end product called compost that can be used for mulching, soil amendment, and soil quality enhancement.
- Four tasks are central to the design of a modern munciple solid waste (MSW) composting system:
  - Collection
  - contaminant separation
  - sizing and mixing
  - biological decomposition

Collection

- Separate collection of compostable materials programs can include everything from yard and food waste to soiled paper products, and in some cases have recovered 45 to 50 percent of the entire solid waste stream for composting.
- However, even when organic compostables are separately collected, a small fraction of non-compostable wastes will need to be removed at the composting facility.
- Educational programs are a critical aspect of source separated composting systems, since such programs depend on residents to accomplish much of the separation.
- Composting programs which accept a mixed waste stream accept material more or less as it is currently collected, relying on the facility separation techniques.
- There are several trade-offs between source separation and centralized separation of compostables.
- It is clear that source separation can produce a higher quality, less contaminated compost, as well as maximize the recycling of glass and paper.
- And while source separation is generally less convenient for the waste generator, pilot programs are finding that many generators like to do it.

Centralized Separation

- In composting systems there are three objectives for materials separation:
  1) recover recyclable or combustible materials as marketable by-products,
  2) reduce the levels of visible inert materials (e.g., plastics and glass), and
  3) reduce the levels of chemical contaminants (e.g., heavy metals).

Table 1. MSW Composting - Centralized Separation Technologies

TECHNOLOGY	MATERIALS TARGETED
Screening	Large: film plastics, large paper, cardboard, misc. Mid-sized: recyclables, organics, misc. Fines: organics, metal fragments, misc.
Hand Picking	Recyclables, inerts and chemical contaminants
Magnetic Separation	Ferrous plus contaminants associated with ferrous met
Eddy Current Separation	Non-ferrous metals
Air Classification	Lights: paper, plastic Heavies: metals, glass, organics
Wet Separation	Floats: organics, misc. Sinks: metals, glass, gravel, misc.
Ballistic Separation	Light: plastic, undecomposed paper Medium: compost Heavy: metals, glass, gravel, misc.

...Centralized Separation

Screening (Figure 1): Fine materials, including soil, grit, and much of the organic wastes, fall through the screen as "unders".

- Plastic films and large paper products are retained on the screen as "overs" and may possibly be recycled or marketed as a refuse derived fuel (RDF), which is burned for energy recovery.

Manual Separation: With materials segregated to a relatively uniform size, it becomes much more practical to hand separate recyclables and contaminants as they move along conveyor lines.

Magnetic Separation: utilize magnetic belts, rollers or overhead magnets to separate the ferrous metals from the rest of the stream.

Eddy current separation (Figure 2): This technology works by exerting repulsive forces on electrically conductive materials.

- Aluminum is the primary metal recovered from MSW, although some copper and brass will also be separated.

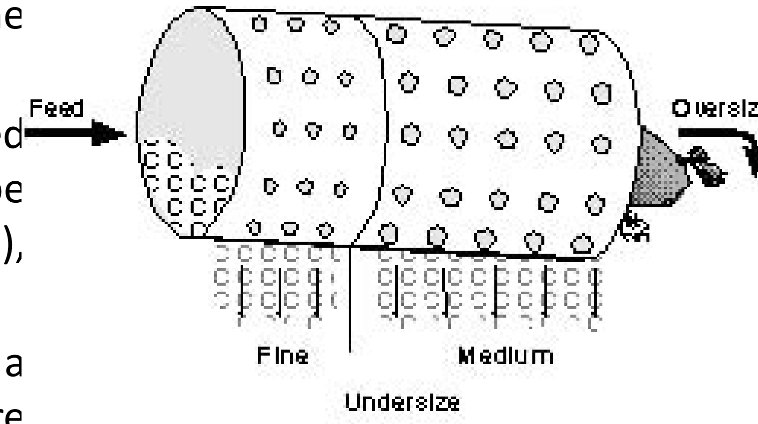


Figure 1.

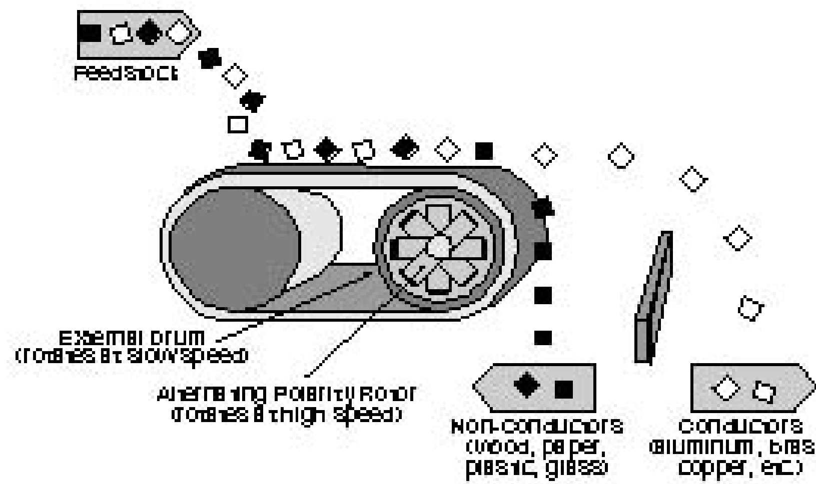


Figure 2.

...Centralized Separation

Air classification: The heart of an air classification system is an air column or "throat", into which the waste stream is fed at a gradual rate.

- A large blower sucks air up through the throat, carrying light materials such as paper and plastic, which then enter a cyclone separator where they loose velocity and drop out of the air stream.
- Heavier materials, such as metal, glass, and food waste, fall directly out of the throat (Figure 3).

Wet separation: take advantage of the density differences as air classifiers, use water rather than air as the floating medium.

- After entrainment in a circulating water stream, the heavy fraction drops into a sloped tank where it moves to a removal zone.
- The less dense org. matter floats and is removed from the recirculating water by screening systems.

Ballistic separation: takes advantage of both density and elasticity differences to separate inert and organic constituents.

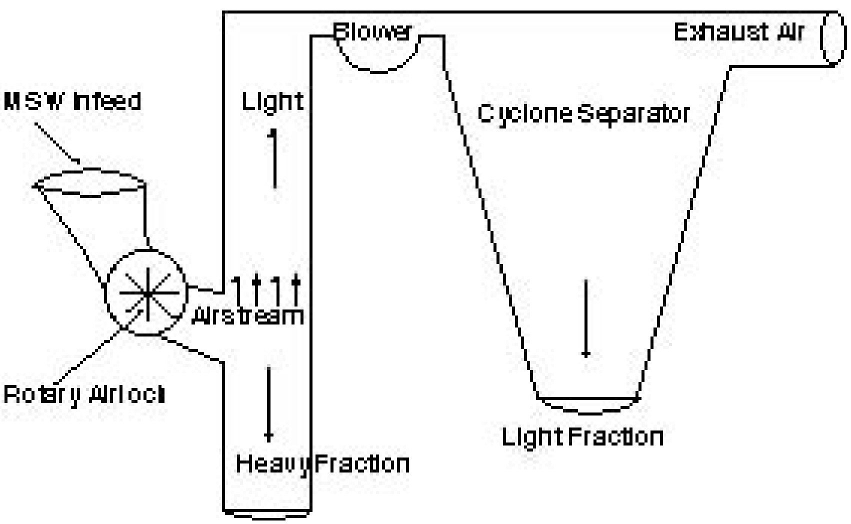


Figure 3.

Size Reduction and Homogenization

- Even after the removal of much of the non-compostable material, municipal solid waste needs further processing before composting. Large pieces of paper, cardboard, food and yard waste will break down slowly if not reduced to a smaller size.
- Reducing particle size increases surface area, enhancing composting rates because the optimum conditions for decomposition occur on the surfaces of organic materials.
- However, reducing particle size also reduces the pore size, limiting the movement of oxygen required for composting.
- Thus for any composting system and material there is an optimum range of particle sizes, and for MSW this is usually between 0.5 and two inch diameters (1.2 - 5 cm).
- There are three major types of size reducing devices available for municipal waste processing: hammermills, shear shredders, and rotating drums.
- **Shear shredders** usually consist of a pair of counter-rotating knives or hooks (each of which is several centimeters thick), which rotate at a slow speed with high torque.
- The shearing action tears or cuts most materials, although thin flexible items like film plastic may slip through the gaps between the knives.

Size Reduction and Homogenization

Hammermills consist of rotating sets of swinging steel hammers through which the waste is fed (Figure 4).

Rotating drums mix materials by tumbling them in a rotating cylinder (Figure 5).

- Internal flights or vanes lift material up the sides of the rotating drum where they fall to the base by gravity.
- Drums take advantage of gravity to tumble, mix, and homogenize the wastes.
- Dense, abrasive items such as glass or metal will pulp the softer materials, resulting in considerable size reduction of paper and other cellulosic materials.
- While some of these drums can also function as biological reactors, typical residence times of less than 36 hours allow only the beginnings of microbial decomposition.

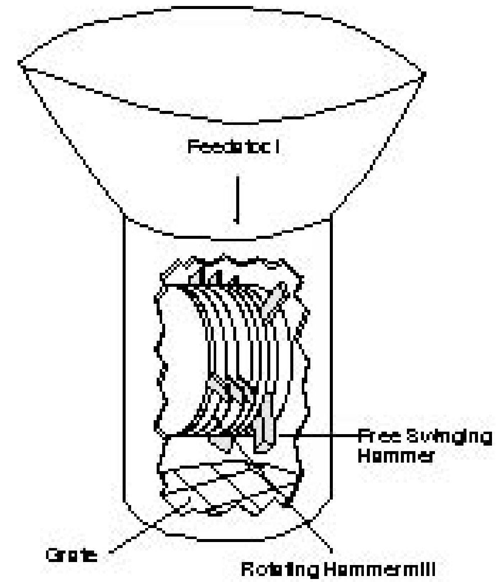


Figure 4.

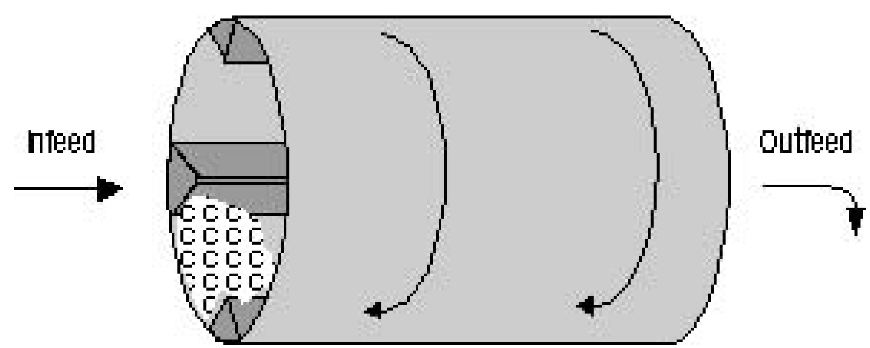


Figure 5.

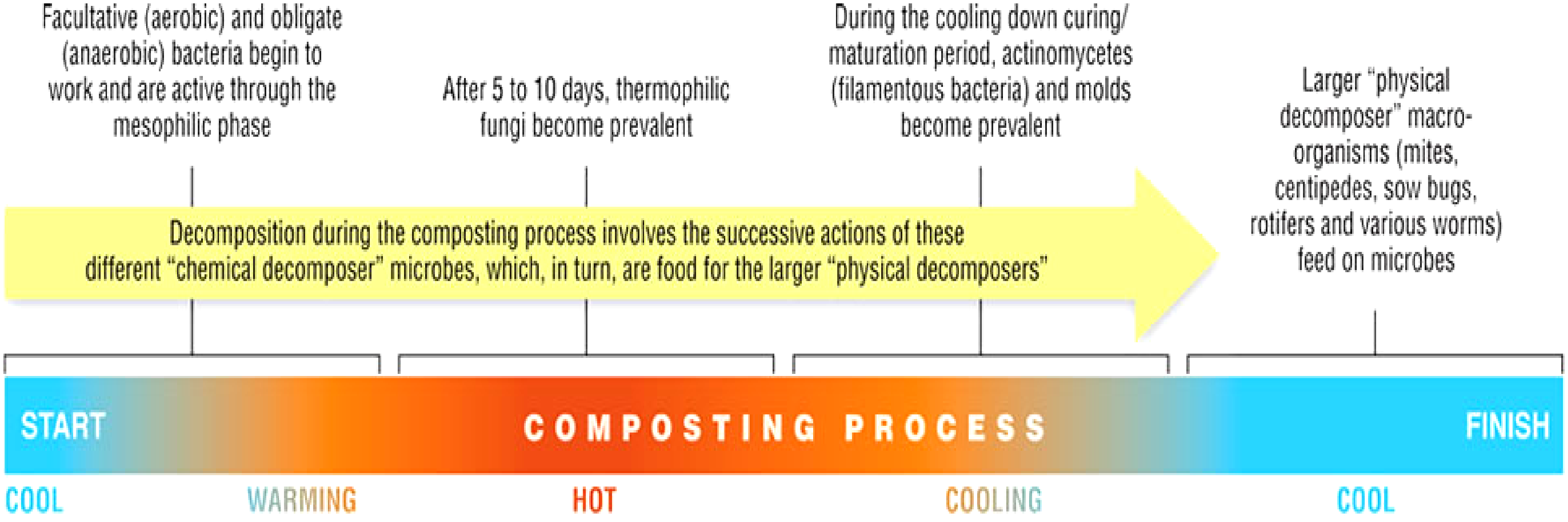
Biological process of composting

- **Carbon and nitrogen:** are the two most important elements in the composting process.
- If nitrogen is limiting, microbial populations will remain small and it will take longer to decompose the available carbon.
- Excess nitrogen, beyond the microbial requirements, is often lost from the system as ammonia gas or other mobile nitrogen compounds and can cause odors.
- While the typically recommended C:N ratios for composting MSW are 25:1 to 40:1 by weight.
- Nitrogen is usually the limiting element in MSW, and additives such as manure, clean sewage sludge (biosolids), septage and urea can be used as a supplemental nitrogen source.
- **Moisture:** is essential to the decomposition process, as most of the decomposition occurs in thin liquid films on the surfaces of particles.
- Excess moisture fill many of the pores between particles with water, limiting oxygen transport.
- If too little oxygen gets to the center of the compost, anaerobic decomposition will result.
- While anaerobic activity normally occurs to a limited extent in the interior of particles within an otherwise aerobic system, high levels of anaerobic metabolism can generate a wide range of unpleasant and pervasive odors and other by-products.
- A moisture content of 50- 55 % is usually recommended for high rate composting of MSW.
- During the active composting phase, additional water usually needs to be added to prevent premature drying and incomplete stabilization.
- MSW compost mixtures usually start at about 52 percent moisture and dry to about 37 percent moisture prior to final screening and marketing.

... Biological process of composting

- **Oxygen and Temperature:** Both fluctuate in response to microbial activity, which consumes oxygen and generates heat.
- Aeration both resupplies oxygen as it is depleted and carries away excess heat.
- Rapidly decomposing wastes can use up the oxygen introduced by turning within a matter of minutes.
- Oxygen concentrations in the large pores must normally be at least 12-14 % (ideally 16-17 %) to allow adequate diffusion into large particles and water filled pores.
- Most MSW composting systems used a forced aeration system with blowers and distribution pipes to supply oxygen during the initial phases of active composting.
- Passive diffusion and natural convection help supply oxygen to windrow systems between turning events.
- Heat is a by-product of decomposition, and is important in raising and maintaining temperatures for efficient decomposition.
- Temperatures of 45 to 59°C (113-138°F) provide the highest rate of decomposition, with temperatures above 59°C (138°F) reducing the rate of decomposition due to a reduction in microbial diversity.
- Since temperatures in excess of 55°C (131°F) for several days are usually required for pathogen control, the ideal temperature operating range is relatively narrow.
- Temperature also can affect odor, with odor generation rates for many compounds peaking between 56 and 70°C (132-158°F).

Composting process



Composting: microbial succession

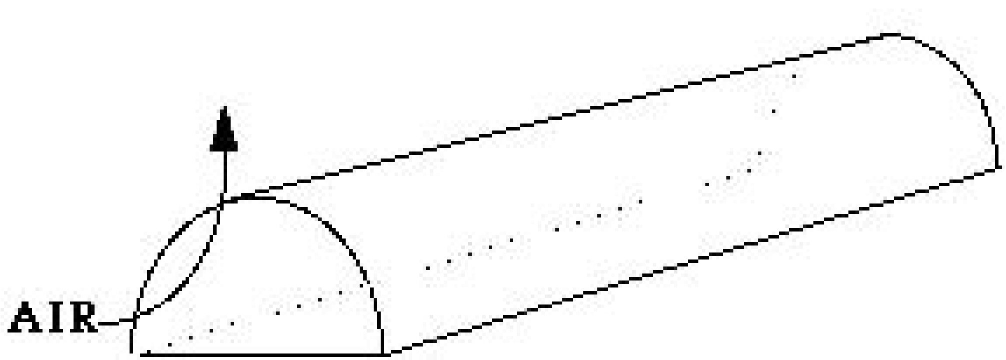
- A typical microbial succession has been described in the following terms: First, facultative (aerobic) and obligate (anaerobic) bacteria begin to work and are active through the mesophilic phase.
- The initial mesophilic temperatures are produced in the early stages of bacterially-dominated decomposition by species such as *Pseudomonas sp., Streptococcus sp., Azobacter sp., Proteus sp., Bacillus sp*.
- Then, after 5 to 10 days, thermophilic fungi become prevalent.
- Thermophilic decomposition is enhanced by fungi such as *Aspergillus, Emericella,* and *Penicillium*, among others.
- Following this period, during the cooling down curing/maturation period, actinomycetes (filamentous bacteria) and molds become prevalent.
- Decomposition within the compost involves the successive actions of these different "chemical decomposer" microbes, which, in turn, are food for the larger "physical decomposer" macro-organisms (mites, centipedes, sow bugs, rotifers and various worms).
- The numbers of each group of microorganisms present in compost:
  - Bacteria 1,000,000 – 1 billion present per gram of compost.
  - Actinomycetes 100,000 -100 million in a gram of compost.
  - Fungi 10,000 -1,000,000, fungal cells per gram of compost.

Methods of composting

- The method of choice depends on the volume of waste to be composted and the availability of space for composting.
- Three most common methods of MSW composting are:
  - Windrow
  - Static aerated pile
  - Closed in-vessel
    - Vertical reactors
    - Horizontal reactors

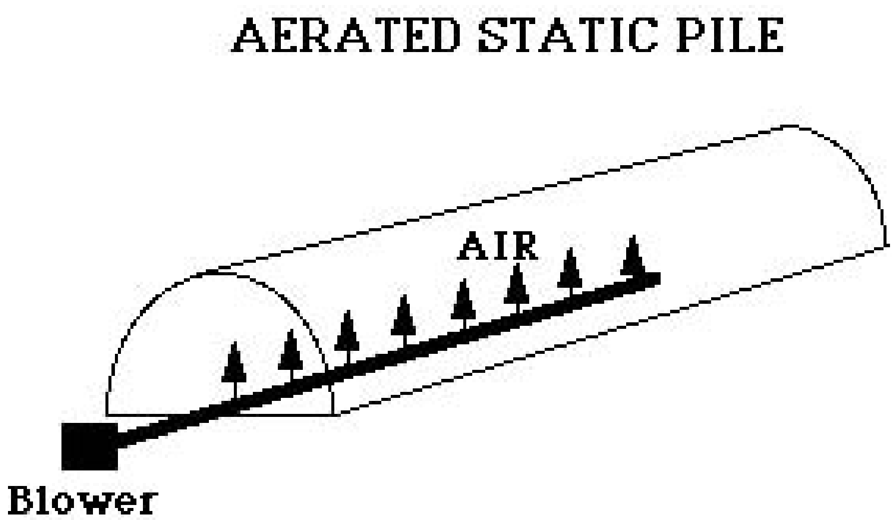
Windrow method

- This type of composting involves forming organic waste into rows of long piles called “windrows” and aerating them periodically by either manually or mechanically turning the piles.
- The ideal pile height is between four and eight feet with a width of 14 to 16 feet.
- This size pile is large enough to generate enough heat and maintain temperatures.
- It is small enough to allow oxygen flow to the windrow's core.



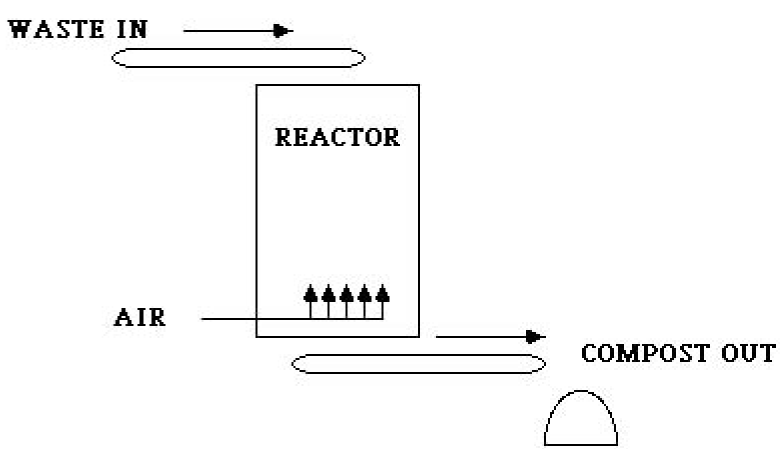
Static aerated pile

- In static aerated compost piles, the MSW piles are not physically agitated, rather air is supplied and excess heat is removed by a system of sensors and pipes within the pile.
- Piles are often covered with a layer of wood chips or mature compost to insulate the active compost from ambient temperatures and/or provide some odor treatment.



Vertical reactor

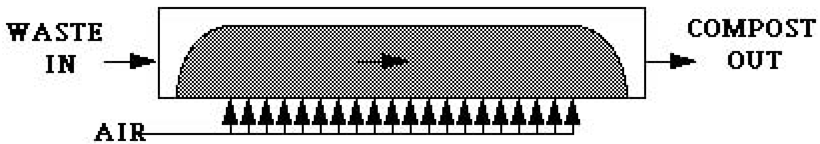
- Vertical composting reactors are generally over 4 meters high.
- Organic material is typically fed into the reactor at the top through a distribution mechanism, and flows by gravity to an unloading mechanism at the bottom.
- Process control is usually by pressure-induced aeration, where the airflow is opposite to the downward materials flow.
- Neither temperature nor oxygen can be maintained at optimal levels throughout the reactors, leading to zones of non-optimal activity.
- Some manufacturers have minimized these difficulties by enhanced air distribution and collection systems, including changing the airflow direction from vertical to horizontal between alternating sets of inflow and exhaust pipes.
- Tall vertical reactors have been successfully used in the sludge composting industry where uniform feedstocks and porous amendments can minimize these difficulties in process control, but are rarely used for heterogeneous materials like MSW.



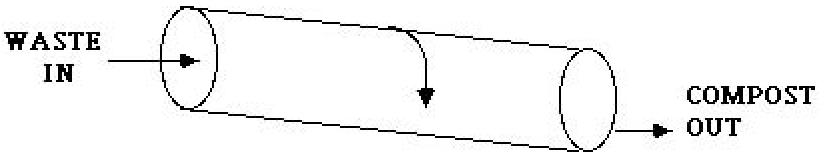
Horizontal reactors

- Horizontal reactors avoid the high temperature, oxygen, and moisture gradients of vertical reactors by maintaining a short airflow pathway .
- They come in a wide range of configurations, including static and agitated, pressure and/or vacuum-induced aeration.
- Agitated systems usually use the turning process to move material through the system in a continuous mode, while static systems require a loading and unloading mechanism.
- Aeration systems are usually set in the floor of the reactor, and may use temperature and/or oxygen as control variables.
- Systems with agitation and bed depths less than two to three meters appear effective in dealing with the heterogeneity of MSW.

Hotizontal bed reactor



ROTATING DRUM



Questions

- What is composting? Explain the four tasks are central to the design of a modern municipal solid waste (MSW) composting system.
- What are the different methods of composting? Explain biological degradation and composting in detail.
- Write short notes on:
  - Composting and its importance
  - Microbial succession during composting
  - Factors effecting composting
  - Types of composting