DESIGN OF AN MSW COMPOSTING FACILITY

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ABSTRACT

This paper addresses the design requirements of an aerobic composting facility to process unsegregated municipal solid waste into a compost product suitable as a soil conditioner in nonfood crop applications. The facility around which the paper is written is located in Portland, Oregon, and is designed to process 185,000 tons per year.

INTRODUCTION

The design of most processing facilities centers around the material to be processed and its properties and flow rates. A facility processing MSW is quite different in that the properties of the material varies hourly, actually truckload-to-truckload, seasonally and, in these times of increased recycling, from year-to-year. Flow rates are extremely cyclic throughout each day of operation. These wide fluctuations in waste character and flow present a unique challenge to the designers of an MSW composting facility.

THE COMPOSTING PROCESS

The decomposition or stabilization of organic matter by biological action has been taking place in nature since life first appeared on our planet. In recent times, man has attempted to control and directly utilize the process for sanitary disposal and reclamation of organic waste material, and this process has been termed "composting."

Generally speaking, there are two processes: *(a)* aerobic decomposition and stabilization; and *(b)* anaerobic fermentation. In these processes bacteria, fungi, molds and other saprophytic organisms feed upon organic materials such as vegetable matter, animal, mineral, night soil, and other organic refuse and convert the waste to a more stable form.

When an organic material is decomposed in the presence of oxygen, the process is called "aerobic." In aerobic stabilization many organisms which utilize oxygen feed upon the organic material and develop the cell protoplasm and the nitrogen, phosphorous, some of the carbon and other required nutrients. Much of the carbon serves as a source of energy for the organisms and is burned and respired as carbon dioxide. A large quantity of water vapor is also released by the process.

The aerobic process is most common in nature and is the one which takes place on ground surfaces such as the forest floor where the droppings from trees and animals are converted into a relatively stable humus or soil manure. There is no accompanying nuisance (odor) where there is adequate oxygen present.

A great deal of energy is released in the form of heat in the oxidation of the carbon to carbon dioxide and the hydrogen to water vapor. If the organic material is in a pile or is otherwise arranged to provide some insulation the temperature of the material during fermentation can rise to over 158°F (70°C). If the temperature exceeds 149°F (65°C) to 158°F (70°C), however, the bacterial activity is decreased and stabilization is slowed down. When the temperature exceeds 113°F (45°C), thermophilic organisms which grow and thrive in this temperature range develop and replace the mesophilic bacteria in fermenting the material. Only a few groups of thermophiles carry on any activity above 149°F (65°C). Oxidation in thermophilic temperature takes place more rapidly than at mesophilic temperature, and, hence, shorter time is required for stabilization. Temperatures above 55°F will destroy pathogenic bacteria and protozoa, hookworm eggs and weed seeds, which are detrimental to health and agriculture when the final compost is used on the land.

DESIGN CONSIDERATIONS

Plant Feed Stock

Unlike most industrial processes that convert raw materials into finished products, municipal solid waste (MSW) is a very nonhomogeneous material. It arrives at the plant, having been collected from a variety of residential and commercial sources. As a result, particle size and densities of individual loads vary widely. The character of MSW varies, from region to region, country to country, seasonally and from year-to-year within the same region. It is abrasive, and contains a variety of materials that can cause special materials handling problems. Items such as dimensional lumber, plastic and metal extrusions can create blockages and make directional changes of conveyors difficult. Textiles, sheet plastics, magnetic tapes, and women's hosiery can wrap up in rotational machinery or form balls or ropes. Heavy items such as rocks, bricks, and blocks will create impact loadings on feed hoppers and belts of conveying systems. MSW can also contain hazardous materials such as paint thinners, pesticides, motor oils, etc. These items can create special problems for plant personnel, the process, and the quality of the finished product.

Characteristics of MSW

The results of a typical waste characterization study is shown in Table 1 [1]. This study was performed on MSW in the metropolitan area of Portland, Oregon, from August 1986 to July 1987. The study involved four seasonal waste stream sampling periods at three separate waste disposal sites. During the course of the study, a total of nearly 200,000 kg (440,000 lb) of refuse was sampled. This study and its results provided the basic data used to design the facility. This study is probably more detailed and complete than many studies of this type. Many communities do not have studies of such detail and, therefore, any design for waste processing must accommodate significant variations in its character.

Flexibility

Any facility processing MSW must be as flexible as possible. At this time, waste disposal is a very dynamic industry. As sanitary landfills are filled up, and new sites develop, the cost of waste disposal is increasing dramatically. This change not only makes alternatives to landfilling, such as composting, economically viable, but it also provides incentives for recycling efforts. These efforts can and do change the character of the MSW stream, and can have significant impact on the mass flow through the plant. For example, an increase in the amount of plastics or metal recycled prior to arrival at the plant will increase the percentage of compostable material in the MSW stream. In a plant designed to process a given number of tons of MSW per year, a higher tonnage of compost could be expected to be produced. Conversely, if recycling efforts of paper products reduce the amount of paper in the MSW arriving at the plant, the amount of compost produced would be smaller. Reasonably large variations in the make-up of the waste stream must be considered when sizing major components of the composting process.

In addition to variations of the characteristic of the waste stream, seasonal effects can have significant impact on the design as well. For example, in Portland, yard debris varies from about 10.5% to 14.5% of the waste stream in the fall, spring and summer months. During the winter, this percentage drops to less than 3% of the total waste stream.

Finally, the flow rate of material into the plant can vary greatly during the day. Early morning and late afternoon hours are periods of peak activity when the majority of the day's delivery can be expected. Receiving areas and handling equipment must have adequate surge capacity.

Process Flow

Once a representative characterization of the waste stream has been established, the processing of each major category of material within the waste stream

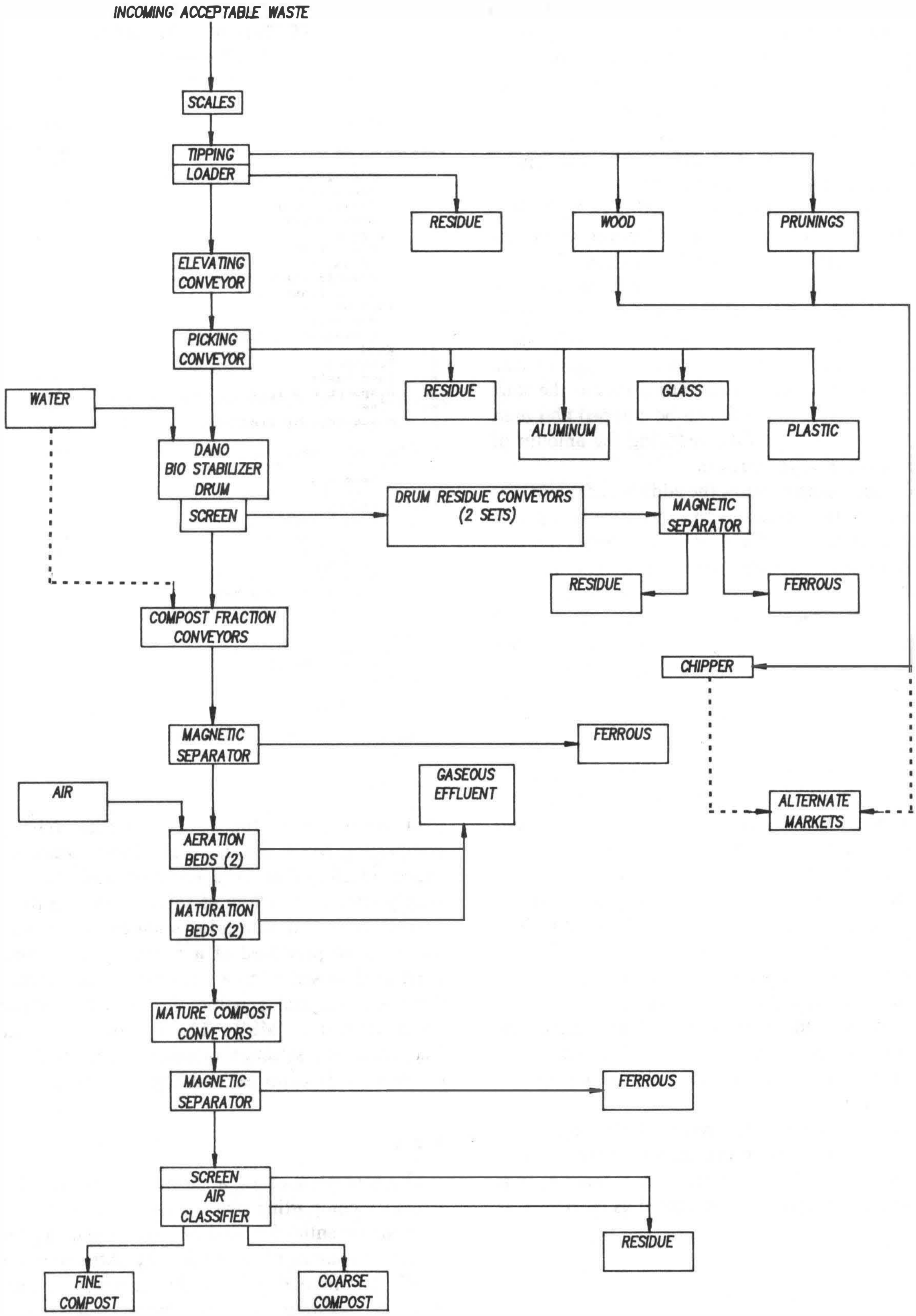

FIG. 1 TYPICAL PROCESS FLOW DIAGRAM

can be determined. One way to do this is by means of a mass balance diagram, constructed from a process flow diagram, shown in Fig. 1. The mass balance diagram is based upon the waste characterization study, Table 1, and a knowledge of the processing capabilities at each diversion point in the diagram. The mass balance diagram also shows the sequence of and type of processing utilized within the facility.

In addition to showing the processing of MSW into finished compost, the mass balance diagram, when constructed, also indicates expected quantities of recyclables. Most of the recyclables shown are obtained through manual sorting of the waste stream early in the process. Ferrous metals, however, are to be separated magnetically. The mass balance diagram also shows separation of wood and yard debris at the start of the process. This material can be chipped and used as ground cover or as a fuel, reducing the amount of material into the reject stream.

MSW composting requires the addition of significant amounts of water, elevating the moisture content of the organic fraction. Unfortunately, it is rather difficult to determine the moisture content of each component within the organic fraction and, also, there is a wide variation in moisture contents between one material and another. For example, food waste can be expected to have a moisture content in the range of 80% while paper, a significant segment of the organic fraction, may have a moisture content in the range of 15%. Although the waste characterization study for Portland indicated an average moisture content of the combustible fraction of 34.1%, no breakdown of moisture by commodity was available. Data obtained from plants of similar design in Europe was used to estimate the amount of water required to raise the organic fraction to the optimum. The amount of water added is a very large quantity in the range of 800–1000 lb/ton of MSW (400–500 kg/t) and has a significant impact upon the amount of compost that can be produced. Sources of water supply should be carefully considered since it can be a major cost item. Fortunately, the process water does not have to be potable and, therefore, sources outside of the public water supply system can be considered.

Rejects (residue) are the result of the separation processes occurring within the facility. Since this material must usually be transported to a landfill, it is important that equipment be designed as efficiently as possible.

Durability

Of prime importance to the operation of a composting plant is the requirement to minimize unscheduled maintenance time. Communities relying on composting MSW for disposal of their waste stream expect a facility that is rugged and reliable. One cannot simply shut off the flow of solid waste into the plant during times of unscheduled maintenance; waste continues to be produced at a relatively fixed rate and must be disposed of on a continuous basis. Generally, there are financial penalties for failure to process a given amount of MSW. The approach to sizing of equipment and selection of components must include the flow range expected and high reliability.

Image

The maintenance of a clean environment in and around a composting plant is essential, both to minimize the potential for odor generation and to promote public acceptance of such a facility. Attention to such details as minimizing ledges for accumulation of material, floor drains and operational requirements for daily sweeping and wash down of critical areas are some of the ways to keep unprocessed MSW from

TABLE 1 PORTLAND WASTE CHARACTERIZATION PERCENTAGE SUMMARY (Wet Weight Basis)

COMPONENT	Municipal Waste Disposed (Percent)	
Combustibles	83.4	
1. Paper	34.8	
Corrugated Board/Kraft Paper		9.9
Newspaper		4.3
Office Paper		4.7
Other Paper		15.9
2. Plastics	7.9	
Milk Jugs		0.4
Containers		0.9
Durable Plastic		0.8
Other Plastics		5.8
3. Yard Debris	10.0	
Prunings		3.0
Leaves/Grass Clippings		7.0
4. Wood	8.0	
5. Textiles	3.8	
6. Food Waste	8.8	
7. Disposable Diapers	1.5	
8. Fines	2.0	
9. Miscellaneous Organics	6.7	
Non-Combustibles	16.2	
10. Recyclable Glass	3.6	
Beverage		2.1
Other Recyclable Glass		1.6
11. Aluminum	0.9	
Food Containers		0.3
Other Aluminum		0.6
12. Ferrous Metal	6.0	
Food Containers		2.1
Other Ferrous Metals		3.9
13. Other Non-Ferrous Metals	0.2	
14. Miscellaneous Inorganics	5.5	
Other	0.5	
15. Reusable		0.4
16. Hazardous Waste		0.1
17. Other		0.1
Total		100.0

Moisture content of combustibles: 34.1%

collecting. The use of doors to enclose loading and unloading operation minimizes the possibility of wind-blown litter and discourages birds. Light colors and a good landscaping plan help to promote a good image to the public, essential for acceptance.

THE FACILITY

The Portland facility is divided into two major functional areas, the MSW processing area and the composting area.

MSW Processing Area

Receiving of the MSW, separation for recyclables and pulverizing of the organic fraction are carried out within a single building, the receiving building. MSW is delivered to the receiving building and dumped on the tipping floor. The floor is large enough to accept up to three days delivery of MSW, about 1800 tons (1636 t). After some initial sorting of loads that may contain high percentages of recyclables, paper or wood, for example, the MSW is loaded by front-end loader into two apron feeder conveyors. These conveyors are 4 ft (1.2 m) wide and elevate the MSW approximately 25 ft (7.6 m) vertically at the rate of 30–60 fpm (0.15–0.30 m/s). As the material is transported up the conveyor, bag breakers open trash bags to expose the contents.

From the elevating conveyors, MSW is then transferred to a horizontal sorting belt. Recyclers on each side of the belt manually remove up to six commodities for recycling. Recyclables taken from the picking belt are dropped into chutes alongside the recyclers, falling into portable bins on the floor below. These bins are emptied as necessary, and the recyclables are stored for removal and sale.

The recycling room is separated from the tipping area to minimize infiltration of dust present from the tipping operation. Adequate clothing, along with good ventilation, is provided. Recyclers are trained to recognize and intercept hazardous materials such as paint products, oils, and batteries.

Belt speeds in the recycling room are variable from 30–60 fpm (0.15–0.30 m/s) and are synchronized with the apron feeder to provide a uniform distribution on the sorting belt to promote the best potential for sorting of recyclables.

Upon leaving the sorting belt, MSW falls into a hydraulically operated charger for deposit into DANO biostabilizer drums. These drums, approximately 12 ft (3.66 m) in diameter and over 80 ft (24.4 m) in length, rotate as speeds between 1½ and 4 rpm. As shown in the mass balance diagram, water is added to the material in the drum, bringing the moisture content to desired levels for optimum processing. The drums, weighing approximately 400 tons (364 t) when loaded, are supported on two live rings and are hydraulically driven through a large ring gear.

During the retention time in the drum, the MSW is macerated and the organic material is broken down into relatively small particles. Trommel screens at the end of the drums separate the material by size, performing the function of segregating the organic and inorganic fractions into two streams. The organic fraction, now termed raw compost, compostable fraction, or fines, contains a percentage of glass, plastics, ferrous metal, and other inorganics. With the exception of ferrous metal, this material is left in the raw compost, as it won't harm the process and actually enhances the subsequent composting process by allowing a freer passage of air.

Residue

The noncompostable fraction, or residue, is conveyed away from the trommel screen for ultimate disposal in a landfill. As it is conveyed to the loading area, the material is passed under a magnetic separator which removes most of the ferrous material. The residue is then conveyed into a waste compactor for consolidation into containers for shipment to a landfill.

Raw Compost Stream

The raw compost is conveyed past magnetic separators (for ferrous material removal) and on into the composting area. While in transit, random samples are removed from the stream for testing to assure the material will meet the operational and technical requirements.

Composting Area

Within the composting area, the three stages of the composting process are accomplished. These areas are the aeration beds, the maturation beds, and finished compost processing. Although at the Portland facility the composting area is adjacent to the MSW processing area, the composting area can be located miles away, trading hauling costs for land costs. The composting area, about 7.5 acres (3.0 hectares) in size, contains nearly two-thirds of the total area of the facility.

Aeration Beds

The organic fraction is conveyed to the aeration beds and deposited to a depth of approximately 6 ft (1.8 m). Deposition of the material is accomplished by a shuttle conveyor mounted on a bridge conveyor that straddles the beds. The Portland facility has two identical beds, each 130 ft (39.6 m) in width and approximately 345 ft (105 m) long. These areas are sufficient to process a 3 week throughput of compost, with a retention time of 21 days on the aeration bed.

Aerobic composting requires a regulated flow of air through the composting mass. This is accomplished by a specially designed bed, perforated with a large number of openings through which air is introduced. Air is supplied individually to each bed by large-capacity blowers. Part of the inlet air to these blowers is air that has been exhausted from the Receiving Building, thus helping to ensure that any odors in the fresh MSW is forced into the composting mass.

Since air requirements vary during the 21 day cycle, air flow to each segment of the aeration bed can be controlled.

Compost Maturation

At the end of the 3 week retention time on the aeration beds, the remaining material is removed by front-end loader and deposited in the maturation area. It is retained for another 3 weeks, drying and completing the composting process. It should be noted that since the process of composting by the method described is a batch process, recovery of toxic or hazardous materials identified during process testing is easily accomplished.

Finished Compost Processing

Once the compost has reached maturity (about 6 weeks), final processing can be performed. The compost is transported by front-end loader from the maturation beds to a hopper feeding the conveyor that elevates the material to a vibratory screen. The oversized material joins other residue for consolidation and disposal. The mature compost, still containing small pieces of glass, rocks and nonferrous metals, is presented to an air classifier for removal of the denser objects.

The finished compost product is stockpiled by a radial stacker adjacent to the air classifier. Compost is loaded into trucks for distribution to users by a fixed conveyor fed by front-end loaders.

REFERENCE

[1] SCS Engineers. "Waste Stream Characterization Study." December 1987.

Key Words: Aerobic; Composting; Design; Separation