Municipal Solid Waste Composting: Physical Processing
Fact Sheet 1 of 7

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The recent upsurge of interest in composting the organic fractions of municipal solid waste (MSW) builds on largely successful efforts with composting yard trimmings, agricultural wastes, and sewage sludges. While experience with these other materials is helpful in considering an MSW composting program, there are a number of challenges unique to MSW which need to be addressed. MSW contains materials which vary widely in size, moisture, and nutrient content, and the organic fractions can be mixed with varying degrees of non-compostable wastes and possibly hazardous constituents. Manufacturing a marketable compost product from this material requires a range of physical processing technologies in addition to the biological process management common to other types of composting.

Four tasks are central to the design of a modern MSW composting system: collection, contaminant separation, sizing and mixing, and biological decomposition. This fact sheet reviews the various technologies and options currently available for preprocessing MSW and accomplishing the first three tasks. Fact Sheet 2 discusses biological processing and overall system evaluation.

The first of the preprocessing tasks, collection, largely determines the processing requirements of the remaining tasks because they must be tailored to the characteristics of the incoming waste. Separation processes at the composting facility generate recyclable and reject streams, usually at several places in the process. Size reduction increases the surface area of the organic wastes, enhancing opportunities for biological activity, while mixing ensures that nutrients, moisture and oxygen are adequate throughout the material. Options for accomplishing these first three tasks are described below.

Collection

If we take the perspective that composting is a manufacturing process, the ideal input material for a compost product is a consistent and clean organic waste. This ideal is rarely reached, and even leaf composting facilities receive tennis balls, plastic bags, and street sweepings which can contain a variety of contaminants such as motor oil and asbestos. Moving across the collection spectrum from leaves and grass to "biowaste" (such as food scraps, yard trimmings, and selected other organics like soiled paper) to totally mixed MSW, the types and volumes of non-compostable contaminants increase. These include visible materials such as plastic and glass, and chemical contaminants, such as Household Hazardous Wastes (HHW). Both physical and chemical contaminants can have a negative impact on the marketability of the finished product, and their removal forms a large part of the expense of modern MSW composting facilities.

Some composting programs require source separation of organic compostables by articipating residents and businesses, while others accept a mixed stream and separate non-compostables at a centralized facility. 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 described below. One important modification to traditional collection techniques is the establishment of a HHW collection program. To be effective at reducing the contaminants of concern in MSW compost, such programs must emphasize heavy metal sources such as batteries and consumer electronics. The remaining mixed waste (less any separately collected recyclables and HHW) then serves as feedstock for the composting facility, where centralized separation of non-compostable materials will occur. With this approach, 60 to 70 percent of the solid waste stream is typically processed into compost. The remaining 30 to 40 percent includes recyclables as well as rejects destined for the landfill or an incinerator and landfill.

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. However, two other important factors, the overall system cost and the quantities of materials recovered for recycling and composting, have not yet been adequately researched or evaluated. For further discussion of the trade-offs between these two collection approaches, and a detailed analysis of their effect on compost quality, see Fact Sheet 3 in this series.

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 and HHW). Many of the separation technologies now applied to MSW composting were originally developed to recover recyclable or combustible materials from solid waste. While some of these technologies have been adapted for reduction of inerts, they have rarely been optimized for reducing chemical contaminant levels. Reduction of inerts and chemical contamination will be highlighted in the discussion below.

A wide range of technologies are available (see Table 1), and many facilities use a sequence of steps employing different processes. While this discussion attempts to cover these technologies in a logical sequence of processing steps, individual facilities may omit some options or may choose to arrange them in a different order. Facility designers can select among them based on expected feedstock characteristics, finished product quality specifications, and the options for marketing separated by-products. For recovered recyclables, as with the compost product itself, a knowledge of local market conditions and specifications should be central to facility design.

Table 1. MSW Composting - Centralized Separation Technologies

Many of these technologies are mechanically sophisticated, but for the reduction of chemical contaminants the most effective systems use human beings. While machines can do a reasonably good job of separating by size, density, or electromagnetic characteristics, we have yet to invent a pattern recognition device as good as the human brain. Manual separation can occur at several points in the process, starting at the tipping floor where large bulky items such as mattresses, carpets, appliances and hazardous materials such as propane cannisters are removed.

Screening: Most MSW composting facilities first convey the waste into a bag-opener and screen or trommel to separate different sizes of waste (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. But the main purpose of size segregation in a composting plant is to facilitate further separation. It is much easier for either people or machines to further separate materials of a similar size, as small items are not buried under large ones. Size fractionation also takes advantage of the size distribution properties of different waste components, generating streams in which certain recyclables or contaminants are concentrated.

Figure 1. Trommel

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. As manual separation of MSW can be an unpleasant task, worker comfort and safety are very important. Ergonomic design can help workers function at their best, and issues such as conveyor speed, reach, placement of containers, flooring material, lighting, ventilation and dust control should all be considered.

Here, as throughout the plant, it is recommended that workers wear safety glasses, gloves and adequate clothing to protect against injury from sharp objects, and hearing and respiratory protection wherever appropriate (see Fact Sheet 5).

Conveyors and other materials handling machinery are critical to the operation of a plant. While this equipment may seem mundane, proper materials handling can minimize downtime and cleanup, and contribute to the overall efficiency of the facility.

Steady materials flow will improve the efficiency of all the separation devices described below.

Magnetic Separation: As materials are conveyed from one separation system to another, the conveyors can utilize magnetic belts, rollers or overhead magnets to separate the ferrous metals from the rest of the stream. Magnetic separation efficiency is sensitive to the depth of waste, as small ferrous items will not stick to the magnet if they are buried in non-ferrous materials, while larger ferrous items can drag non-ferrous items like paper and plastic along. Air classification to remove the light paper and plastic fractions prior to magnetic separation minimizes the contaminants in the scrap ferrous. Pre-shredding and screening can also enhance ferrous recovery. Because magnetic separation is relatively inexpensive, it can sometimes be found at several locations in the composting facility. A minimum of two stages of magnetic separation are usually needed to achieve efficient ferrous recovery. Magnetic separation is effective with iron and most steel, but does not separate aluminum, copper, and other non-ferrous metals. Consumer electronics can be difficult to separate magnetically, depending on the ratio of ferrous to non-ferrous materials.

Eddy current separation systems have been developed to separate non-ferrous metals. This technology works by exerting repulsive forces on electrically conductive materials. These systems should be located after magnetic separation to minimize contamination by ferrous materials. Aluminum is the primary metal recovered from MSW, although some copper and brass will also be separated. Cans literally jump off the conveyor into a waiting bin (Figure 2). Eddy separators, while they do not achieve perfect removal of aluminum, do produce a relatively marketable aluminum by-product.

Figure 2. Eddy Current Separator

Air classification is an additional separation technology used in some MSW composting facilities, and is commonly used to generate a marketable RDF. This technology has been used in the combustion industry for many years. The heart of an air classification system is an air column or "throat", into which the waste stream is fed at a gradual rate. The air column is usually oriented vertically. 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). These two streams tend to be different sizes as well as densities, facilitating further separation. Glass and metal can be sorted out of the heavy fraction by systems such as the wet separator described below. The light fraction can be marketed directly as an RDF, or sorted for recyclable paper or plastic prior to composting.

Figure 3. Air Classification

Wet separation technologies, while taking advantage of the same sorts of density differences as air classifiers, use water rather than air as the floating medium. These units are usually used to separate particles of glass, sand, and other heavy particles from organic materials prior to composting. A hammermill or other size reducer is needed prior to wet separation to minimize the potential for air pockets in the heavy fraction. After entrainment in a circulating water stream, the heavy fraction drops into a sloped (and sometimes vibrating) tank where it moves to a removal zone. This heavy fraction may be marketable as an aggregate substitute in construction applications. The less dense organic matter floats and is removed from the recirculating water using screening systems similar to those employed by wastewater treatment facilities. Wet separation is particularly effective at removing glass fragments and other sharp objects, which tend to be heavier than organic materials.

Ballistic separation takes advantage of both density and elasticity differences to separate inert and organic constituents. This method can be used in either initial processing or in the refinement of the final compost product. Compost is dropped on a rotating drum or spinning cone, and the resulting trajectory differences bounce glass, metal and stones away from the compost.

Compost refining refers to separation processes which occur after biological processing (see Fact Sheet 2). These can include screening, ballistic, and/or magnetic separation, and are important in preparing a visually attractive product. Contaminant separation at this late stage has a limited effect of chemical contaminants (see Fact Sheet 3), but can significantly reduce inert materials like plastics, glass, and stones.

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).

Size reduction and mixing processes usually occur after initial separation and removal of non-compostables. However, some separation processes, including wet separation, air classification and magnetic separation can achieve greater levels of removal after size reduction. Proper sequencing of these materials preparation processes can have a significant impact on system performance.

There are three major types of size reducing devices available for municipal waste processing: hammermills, shear shredders, and rotating drums. Hammermills consist of rotating sets of swinging steel hammers through which the waste is fed (Figure 4).

Tub grinders use a rotating tub to feed a horizontal hammermill, and are a common item at large yard waste composting facilities. Hammermills are energy and maintenance intensive, with hammers requiring frequent resurfacing or replacement. In MSW processing applications they must be housed in specially designed chambers as propane tanks and other flammable materials can cause serious explosions. And once batteries or other contaminants pass through a hammermill, they are pulverized and much more difficult to separate.

Figure 4. Hammermill

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. This tearing may help open up the internal structure of the particles, enhancing opportunities for decomposition. Shear shredders consume less energy and are less destructive than hammermills, but still can break apart contaminants and make subsequent recovery difficult.

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 may be set on a slight incline from horizontal, although this is not always necessary to carry the material through the drum from the feed end to the outlet. 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. To the extent that decomposition does occur in a rotating drum, it is important that aeration is adequate.

Excessive anaerobic activity can lead to low pH (<5.0), which may result in ammonia volatilization, corrosion of the drum, and leaching of metal contaminants.

Figure 5. Rotating Drum

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. Rotating drums are the least destructive size reduction technology, and many solid contaminants can more readily be separated after passing through the drum. While it is not known how much abrasion and leaching in the drum will affect the effectiveness of subsequent contaminant removal, even in this relatively gentle size reduction technology some cross contamination of compostable materials is likely to occur.

The last stage of processing before the active composting stage is usually the incorporation of water. If it includes a large paper fraction (with a high carbon to nitrogen ratio), MSW also benefits from mixing with nitrogen-rich materials such as sewage sludge or septage (see Fact Sheet 2). Size reduction and blending homogenizes the compostable materials, achieving greater uniformity of moisture and nutrients. Thorough mixing is important for rapid decomposition, and a variety of devices are available. The drum-type wet pulverizers described above commonly serve as a mixing and blending device. Some mixers have been adapted from agricultural feed mixer designs, and may contain counter-rotating augers or a reel. Pug mills can also be used, which blend by means of slowly counter-rotating hammers.

Summary

Separation, size reduction and mixing/homogenization are all prerequisites to the biological process of composting. The individual physical processes described above must be selected and linked together with biological processing technology to form a complete composting system. In evaluating a system design, several criteria stand out as particularly important to these physical processing steps, including cost (capital, operations and maintenance), market specifications for compost and recyclable by-products, and the flexibility of the system to respond to a changing MSW feedstock.

Cost is clearly an important criterion for any solid waste management option. While complex systems that separate many recyclable by-products and reduce contaminants may appear attractive, their overall costs may not be competitive. The economic analysis of a composting facility must not only evaluate other competitive options such as landfilling or incineration, but must also examine different ways of achieving the same goal with a composting program. The economic trade-offs between source separation and centralized separation for recyclable recovery and contaminant removal are not well defined, but need to be examined on a case by case basis to develop the best system for a particular community.

Part of that economic analysis must include a market assessment, both for recyclable by-product streams as well as the compost product itself. A composting facility must function as a manufacturing facility, where quality control and product specifications determine the facility operation and design. If markets require a higher grade recyclable product than a particular technology will produce, then the facility will be in serious trouble. Designing for product quality is difficult, in part because information on the effects of combining technologies are scarce. But this critical challenge must be met if an MSW composting facility is to succeed.

Finally, MSW composting facilities must be designed for flexibility. Changes in the regulatory environment, in market specifications, and in the waste stream itself are likely to be significant in the coming years. As with any new technology, "state of the art" is likely to have ephemeral meaning for MSW composting facilities. This is particularly true with the physical processing steps, where changes in the amount and type of waste collected and the product quality required are likely to significantly impact optimal facility design. An MSW composting facility must be able to adapt if it is to play a long term role in responsible waste management.

References

See the fully referenced article in a special issue of Biomass & Bioenergy (Vol. 3, Nos 3-4, pp. 163-180, 1992), from which this fact sheet is extracted. A copy of that journal containing 11 articles on MSW composting can be obtained through the Composting Council, 114 S. Pitt St., Alexandria, VA 22314, for $30.

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Municipal Solid Waste Composting: Biological Processing

Fact Sheet 2 of 7

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Composting is in essence a biological process. This fact is sometimes obscured by the wealth of sophisticated technical options available (see Fact Sheet 1). But proper design and management must be based on the needs of microorganisms if the process is to be a success. Neglect or misunderstanding of biological process control can lead to serious problems at composting facilities, and has contributed to facility closings.

Composting is defined by human intervention into the natural process of decomposition. With a combination of proper environmental conditions and adequate time, microorganisms turn raw putrescible organic matter into a stabilized product.

Through composting, readily available nutrient and energy sources are transformed into carbon dioxide, water, and a complex form of organic matter compost. Process management can be optimized for a number of criteria, including the rate of decomposition (to reduce residence time in reactors and thus minimize facility size requirements), pathogen control, and odor management. The key parameters are the available carbon to nitrogen (C:N) ratio, moisture, oxygen, and temperature.

Carbon and Nitrogen

Carbon and nitrogen are the two most important elements in the composting process, as one or the other is normally a limiting factor. Carbon serves primarily as an energy source for the microorganisms, while a small fraction of the carbon is incorporated in their cells. Nitrogen is critical for microbial population growth, as it is a constituent of protein which forms over 50 percent of dry bacterial cell mass. 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 or other environmental problems. While the typically recommended C:N ratios for composting MSW are 25:1 to 40:1 by weight, these ratios may need to be altered to compensate for varying degrees of biological availability. While wood chips have a high C:N ratio, most of the carbon in a large wood chip will not be available to microorganisms during the time frame of typical composting processes. Increasing the surface area of wood and other organic particles through size reduction (grinding or shredding), can increase carbon availability and accelerate decomposition if adequate nitrogen is available. 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

Moisture management requires a balance between these two functions: microbial activity and oxygen supply. Moisture is essential to the decomposition process, as most of the decomposition occurs in thin liquid films on the surfaces of particles. However, mixtures can be too wet, thereby reducing the oxygen supply. Excess moisture will fill many of the pores between particles with water, limiting oxygen transport. Oxygen diffusion, the movement of oxygen due to differences in concentration, is 10,000 times slower in water than in air. If too little oxygen gets to the center of the compost, anaerobic (without oxygen) 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.

Decomposition slows dramatically in mixtures under 40 to 45 percent moisture, which can lead facility operators to prematurely assume compost is stabilized and ready to sell. A minimum moisture content of 50 to 55 percent is usually recommended for high rate composting of MSW. MSW collection programs which include paper are often drier than this, and water or sludge should be added to bring moisture into the optimum range. The heat and airflow generated during composting evaporate significant amounts of water and tend to dry the material out. 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.

Oxygen and Temperature

The remaining key environmental parameters, oxygen and temperature, are linked by the decomposition process. Both fluctuate in response to microbial activity, which consumes oxygen and generates heat. Oxygen and temperature are also linked by a common mechanism of control: aeration. Aeration both resupplies oxygen as it is depleted and carries away excess heat. This dual purpose makes aeration management a central feature of biological processing, as it controls these two parameters.

Inadequate oxygen levels lead to the growth of anaerobic microorganisms which can produce odorous compounds. While adequate oxygen can minimize these odors, it is important to note that anaerobic pockets will exist in a heterogeneous material like MSW, and some odors including ammonia and some organic compounds can be generated even under generally aerobic conditions. Thus, while proper oxygen supply can minimize odors, it may not completely eliminate them. And since some of the odors causing problems at MSW composting facilities originate at the tipping floor with raw waste prior to composting and aeration, most MSW composting facilities are likely to require odor treatment to maintain good neighbor relations. Odor treatment options include biological, chemical, and thermal technologies.

Just a few of the many pre-processing steps described in Fact Sheet 1 are normally adequate to provide reasonably aerobic conditions as the feedstock enters the composting system, but additional oxygen must quickly be supplied. 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 percent (ideally 16-17 percent) 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.

There are several trade-offs related to optimizing temperature control. 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).

Biological Process Control

Most composting systems reconcile these trade-offs between reaction rate, pathogen reduction, and odor generation by an attempt to control temperatures to a narrow range near 55 to 60°C (131-140°F). To maintain this temperature range, heat gains from microbial activity need to be balanced against heat losses, which occur primarily through evaporation of moisture and heating the aeration air. Temperature, like oxygen supply, is usually managed by an aeration system: the same air which supplies oxygen can carry away excess heat. During most of the active composting stage, several times as much air is needed to remove heat as to supply oxygen, so maintaining proper temperatures will usually also keep oxygen levels in the proper range.

Forced aeration systems are commonly used during this stage of composting, using temperature sensors to control blowers.

Eventually, as readily available compounds are decomposed, the rate of composting slows, with less oxygen required and less heat generated. This slower stage is called curing, and while it requires less management than active composting, it is important to compost quality,

Windrow composting usually relies on natural convection and diffusion for oxygen supply. Pile size and turning frequency are used to balance heat loss in managing temperature control

(Figure 1).

Figure 1. Natural Air Circulation in a Compost Windrow

The effectiveness and penetration of oxygen supply in a windrow system varies with the rate of microbial activity and porosity of the pile. Anaerobic zones can be minimized by decreasing pile size or increasing its porosity, although in practice fully aerobic conditions are difficult to achieve in windrows during the active composting phase. Pile size may be increased in extremely cold weather or when decomposition slows as compost matures. Mechanically turning the pile releases heat and moisture and can temporarily increase the porosity. Agitation can also help break up clumps of material and thereby increase oxygen transfer.

Management of convection and diffusion through pile size and turning frequency can be a cost-effective strategy, although decomposition is generally not as rapid as with forced aeration systems.

Materials Handling

The process control strategies described above regulate temperature and oxygen to encourage microbial decomposition. Much of the scientific literature on composting focuses on these options for process control, but in the practical world of industry and government the emphasis, expense and hotly debated differences among systems have more to do with materials handling. Materials handling technologies mix, macerate, and move the compost through the facility. A variety of technologies have been adapted for use with MSW, which can be roughly divided into four groups: windrows, static piles, and vertical and horizontal reactors. Each of these composting materials handling technologies is described below.

Windrows (Figure 2) are defined as regularly turned elongated piles, shaped like a haystack in cross section and up to a hundred meters (yards) or more in length. Process control is normally through pile management as described above, although forced aeration can also be used. The cross-sectional dimensions vary with feedstock and turning equipment, but most MSW windrows are 1.5 to 3 meters (yards) high and 3 to 6 meters (yards) wide. Individual windrows may be constructed over a period of several days or weeks, but are usually each managed as a single batch. Windrows composed of MSW are usually required to be located on an impermeable surface, which greatly improves equipment handling under inclement weather conditions. Windrows can be formed with a front-end loader, dump truck, or conveyor. A variety of specialized turning machines are available, although front-end loaders can also be used if operators are adequately trained. Windrow turners should perform several functions: increase porosity of the pile, redistribute material to enhance process uniformity, and break up clumps to improve product consistency. Some machines also perform a shredding or macerating function, which may partially substitute for other processing steps and can accelerate decomposition.

Figure 2. Windrow

Static piles can be shaped much like windrows or in an elongated pile or bed (Figure 3). The essential difference is in the name; static piles are not mechanically agitated. Once constructed by conveyor, loader or truck, the piles remain in place until the decomposition slows. The lack of agitation requires the maintenance of adequate porosity over an extended period of time. When composting fine materials like sludge, a coarse stable substrate such as wood chips is often incorporated in the mix. Inert materials or slowly degrading cellulosic substrates like cardboard or leaves may help supply that stable porous structure in MSW, but this needs to be considered in the preprocessing system design. Process control is normally through pressure and/or vacuum-induced aeration, with either temperature or oxygen as the control variable. Blower piping can be temporary plastic or metal in a bed of coarse material at the base of the pile, or recessed into the composting pad under perforated plates. 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. Both windrows and static piles are often outside and exposed to weather, but can be covered with a roof to minimize the impacts of weather and provide an opportunity for odor capture and treatment.

Figure 3. Aerated Static Pile

Vertical composting reactors (Figure 4) are generally over 4 meters (yards) high, and can be housed in silos or other large structures. 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. The height of these reactors makes process control difficult due to the high rates of airflow required per unit of distribution surface area. 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. As with static pile composting, a stable porous structure is important in vertical reactors which usually lack internal mixing. 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.

Figure 4. Vertical Reactor

Horizontal reactors avoid the high temperature, oxygen, and moisture gradients of vertical reactors by maintaining a short airflow pathway (Figure 5). 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. Materials handling equipment may also shred to a certain degree, exposing new surfaces for decomposition, but excessive shredding may also reduce porosity. 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 (yards) appear effective in dealing with the heterogeneity of MSW.

Figure 5. Horizontal Bed Reactor

Horizontal and vertical reactors are commonly referred to as in-vessel systems as differentiated from open systems such as windrows and static piles. Because of the higher capital and operation costs associated with these contained systems, residence time in the reactors is rarely adequate for the production of mature compost. Instead, in-vessel composting technologies are often used to help get the material through the early stages of composting when odors and process control are most critical, and the material is then moved into a windrow or static pile system for the later stages of decomposition and curing.

Rotating drum reactors take the trade-off between reactor cost and compost residence time to an even further extreme than the horizontal or vertical in-vessel systems (Figure 6). These reactors (sometimes called digestors) retain the material for only a few hours or days. While the tumbling action can help homogenize and shred materials, the short residence time usually means the processing is more physical than biological, so rotating drums are covered more fully in Fact Sheet 1. While rotating drums can play an important role in MSW composting, they are normally followed by other biological processing, which may include in-vessel, static pile, and/or windrow systems.

Figure 6. Rotating Drum

The materials handling systems described above must be combined with a process control strategy to produce a workable composting system. Table 1 summarizes the common MSW composting technologies according to these categories.

Table 1.

All these examples of composting systems can be used for a variety of feedstocks, and may require modifications for the biological processing of MSW. Some important characteristics of MSW which may be different from other composting feedstocks include high carbon levels (mostly cellulose), low levels of moisture, and a weak porous structure. The high cellulose levels require longer curing than many other materials, so that it may take six months to achieve the degree of stability found after only two or three months in sewage sludge composting. Mixing can provide a way to add moisture and to renew porosity, as well as increase the compost uniformity. Whatever technology is utilized, operator skill is required in adapting to changes in the waste stream. Seasonal fluctuations in yard waste constituents (i.e. grass clippings) and even load-to-load variability with commercial or industrial wastes require competent and flexible management.

Compost System Evaluation

A composting system is the sum of many parts. System designs are almost always unique, with evolving technology and modifications to suit a particular community and a particular waste. Choices abound in feedstock selection, materials separation, composting machinery and process control. Because choices in each of these areas impact the performance of the entire system, it is nearly impossible to evaluate different MSW composting systems in an unbiased way. Additional research on physical and biological processing technologies will be important in determining optimum configurations and designing effective and efficient systems.

Among the many criteria available for evaluating system performance, three stand out as particularly important for MSW composting: product quality, percent rejects, and recycling rate. Compost product quality can include aesthetic, functional, and contaminant characteristics, all of which are clearly critical to product marketability. Percent rejects and recycling rate both have an impact on the amount of rejected waste needing disposal and on compost quality by effecting contaminant concentrations.

Compost product quality should be among the primary goals of a composting facility. Some aspects of quality, such as product maturity and particle size, can be modified at the end of active composting through increased curing time or simple physical processing. Other aspects are more difficult to remedy in the aftermath of poor process management. Chemical contaminants in particular require attention in earlier processing steps, as discussed in Fact Sheet 3.

Recycling rates and reject percentages have been published for a limited number of facilities. At present most of the data is based on design values rather than actual measurement. Table 2 summarizes data reported from several facilities.

Table 2.

Actual operating data are likely to be different from some of these projected values: Glenn reports that the facility designed for 15 to 20 percent recycling was initially recovering only 8 to 10 percent, and some of the centralized separation facilities are having trouble marketing contaminated recyclables.

It is also possible to achieve high organic recovery rates from a source-separated organic collection. Fillmore Co., MN, has a three-stream system: recyclables, compostables, and landfill. All three streams are delivered to their facility, and after some additional manual separation 50 percent of the total waste stream is composted, with 15 to 20 percent recycled and 30 to 35 percent rejected to the landfill. Estimates of compostable recovery rates from source separation programs in Europe range from 25 to over 50 percent. While these values are not as high as the levels achieved by mixed waste composting facilities, when recycling recovery is added to the compostables the numbers for total amounts recovered through recycling and composting are close. A pilot study in Fairfield, CT, found source separation of compostable and recyclable material recovered 70 percent of the residential waste stream. Independent comparative research will be essential to better understand the trade-offs between source and centralized separation with respect to recycling and recovery potential.

While most MSW composting facility developers try to minimize reject rates and the related disposal costs, in the absence of highly targeted contaminant separation low reject rates are likely to result in higher levels of chemical contaminants. This trade-off arises in part from lack of knowledge of the effectiveness of source and centralized separation options at removing critical contaminants like lead (see Fact Sheet 3). An equally important variable is the acceptable level of contamination.

Regulations specifying very low contaminant levels push system designers toward more intensive separation, while more relaxed standards may require no separation at all (see Fact Sheet 6).

In this context of uncertainty, systems should be designed with flexibility in mind. There are a wealth of processing options available, and a combination can be assembled to suit almost any need. A successful MSW composting factory must be designed with strict attention to the finished compost; product specifications will determine requirements for both the incoming refuse feedstock and the physical and biological processes employed. Achieving low contaminant levels will be essential if MSW composting is to live up to its potential and recycle organic wastes.

References

See the fully referenced article in a special issue of Biomass & Bioenergy (Vol. 3, Nos 3-4, pp. 163-180, 1992), from which this fact sheet is extracted. A copy of that journal containing 11 articles on MSW composting can be obtained through the Composting Council, 114 S. Pitt St., Alexandria, VA 22314, for $30.

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For general questions about composting, please browse this and other composting websites, or make use of the compost listserves.

For specific comments related to this page, please contact: Sue Fredenburg (format and style), or Tom Richard (technical content).

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