7 ❖ COMPOSTING

Composting involves the aerobic biological decomposition of organic materials to produce a stable humus-like product (see Figure 7-1). Biodegradation is a natural, ongoing biological process that is a common occurrence in both human-made and natural environments.

Composting is one component in USEPA's hierarchy of integrated solid waste management, which is discussed in the introduction to this guidebook (see Figure I-1 in the introduction). Source reduction tops the hierarchy of management options, with recycling as the next preferred option. Grasscycling and backyard composting are forms of source reduction or waste prevention because the materials are completely diverted from the disposal facilities and require no municipal management or transportation. Community yard trimmings composting programs, source-separated organics composting, and mixed MSW composting are considered forms of recycling.

It is important to view compost feedstock as a usable product, *not* as waste requiring disposal. When developing and promoting a composting program and when marketing the resulting compost, program planners and managers should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, *not* a means of waste disposal.

This chapter provides information about methods and programs for composting yard trimmings (leaves, grass clippings, brush, and tree prunings) or the compostable portion of mixed solid waste (MSW), including yard trimmings, food scraps, scrap paper products, and other decomposable organics.

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7 HIGHLIGHTS

Composting is an environmentally sound recycling method. (p. 7-8)	Composting involves the aerobic biological decomposition of organic materials to produce a stable humus-like product. Compost feedstock should be viewed as a usable product, *not* as waste requiring disposal. Program planners should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, *not* a means of waste disposal.
Composting can significantly reduce waste stream volume. (p. 7-9 —7-10)	Up to 70 percent of the MSW waste stream is organic material. Yard trimmings alone constitute 20 percent of MSW. Composting organic materials can significantly reduce waste stream volume and offers economic advantages for communities when the costs of other options are high.
Developing and operating successful composting programs presents several challenges. (p. 7-10)	These challenges include the following: • developing markets and new end uses • inadequate or nonexisting standards for finished composts • inadequate design data for composting facilities • lack of experienced designers, vendors, and technical staff available to many municipalities • potential problems with odors • problems controlling contaminants • inadequate understanding of the biology and mathematics of composting.
The feedstock determines the chemical environment for composting. (p. 7-10 — 7-11)	Several factors determine the chemical environment for composting, especially: (a) the presence of an adequate carbon (food)/energy source, (b) a balanced amount of sufficient nutrients, (c) the correct amount of water, (d) adequate oxygen, (e) appropriate pH, and (f) the absence of toxic constituents that could inhibit microbial activity.
The ratio of carbon to nitrogen affects the rate of decomposition. (p. 7-12)	The ratio must be established on the basis of available carbon rather than total carbon. An initial ratio of 30:1 carbon:nitrogen is considered ideal. To lower the carbon:nitrogen ratios, nitrogen-rich materials (yard trimmings, animal manures, biosolids, etc.) are added.
Moisture content must be carefully monitored. (p. 7-12 — 7-13)	Because the water content of most feedstocks is not adequate, water is usually added to achieve the desired rate of composting. A moisture content of 50 to 60 percent of total weight is ideal. Excessive moisture can create anaerobic conditions, which may lead to rotting and obnoxious odors. Adding moisture may be necessary to keep the composting process performing at its peak. Evaporation from compost piles can also be minimized by controlling the size of piles.
Maintaining proper pH levels is important. (p. 7-13)	pH affects the amount of nutrients available to the microorganisms, the solubility of heavy metals, and the overall metabolic activity of the microorganisms. A pH between 6 and 8 is normal.

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Source reduction tops USEPA's composting methods hierarchy.

(p. 7-15)

Communities and individuals are encouraged to follow the hierarchy as listed below in order of preference: Grasscycling and home backyard composting completely divert materials from the MSW stream and should be adopted whenever possible.

Source-separated programs offer several advantages over mixed MSW programs, including: reduced handling time, less tipping space, and less pre-processing equipment. Mixed MSW composting offers fewer advantages over the long term.

1. Grasscycling (source reduction)
2. Backyard composting (source reduction)
3. Yard trimmings programs (recycling)
4. Source-separated organics composting (recycling)
5. MSW composting programs (recycling)

Planning a composting program involves these steps.

(p. 7-17 — 7-18)

1. Identify goals of the composting project.
2. Identify the scope of the project—backyard, yard trimmings, source-separated, mixed MSW, or a combination.
3. Get political support for changing the community's waste management approach.
4. Identify potential sites and environmental factors.
5. Identify potential compost uses and markets.
6. Initiate public information programs.
7. Inventory materials available for composting.
8. Visit successful compost programs.
9. Evaluate alternative composting and associated collection techniques.
10. Finalize arrangements for compost use.
11. Obtain necessary governmental approvals.
12. Prepare final budget and arrange financing.
13. Construct composting facilities and purchase collection equipment, if needed.
14. Initiate composting operation and monitor results.

Short- and long-term waste management needs determine composting program goals.

(p. 7-18)

Program goals may include one or more of the following:

- achieving mandated waste reduction goals through increased recycling.
- diverting specific materials, such as yard trimmings, biosolids, or any high-moisture organic waste, from landfills and incinerators.
- using compost as a replacement for daily cover (soil) in a landfill. In this case only a portion of the material may be composted to meet the daily cover needs, and the quality of compost generated is not critical.
- use for erosion control on highways, reservoirs, etc.

Political support for a composting project is critical.

(p. 7-19)

It is important to inform elected officials and government agencies of the project's goals and the developer's plans for implementing the project. Winning approval from an informed public can also be important for obtaining public funding. Without public approval, composting programs are difficult to successfully implement.

7 HIGHLIGHTS (continued)

Assess the amounts and quality of feedstock available. (p. 7-19 — 7-20)	Successful planning must be based on accurate data about quantities and sources of available feedstocks. This data helps determine the size and type of equipment needed and space requirements.
Two-way communication with the public is critical. (p. 7-20)	An effective education program is crucial to winning full public support. New waste management practices require substantial public education. Providing information about the nature of composting may help dispel any opposition to siting the composting facility. Potential problems such as odor should be openly and honestly discussed and strategies for addressing such problems developed.
The composting method chosen should be compatible with existing systems. (p. 7-21 — 7-22)	The composting option chosen must be compatible with existing processing systems. Communities should consider these factors: • preferences of the community • collection and processing costs • residual waste disposal costs • markets for the quality of compost produced • markets for recyclables • existing collection, processing and disposal systems.
There are four types of technologies for composting. (p. 7-22 — 7-26)	The four composting technologies are windrow, aerated static pile, in-vessel, and anaerobic composting. Supporting technologies include sorting, screening, and curing. The technologies vary in the method of air supply, temperature control, mixing/turning of the material, and the time required for composting. Their capital and operating costs also vary considerably.
Compost is screened to meet market specifications. (p. 7-26)	One or two screening steps and possibly additional grinding are used to prepare the compost for markets. For screening to successfully remove foreign matter and recover as much of the compost as possible, the compost's moisture content should be below 50 percent.
Final compost use and markets are crucial for program planning. (p. 7-27 — 7-28)	A well-planned marketing approach ensures that all compost will be distributed. Accomplishing this requires producing a consistently high-quality compost to satisfy market needs. The quality and composition required for a compost product to meet the needs of a specific market depend on a mix of factors, including intended use of the product, local climatic conditions, and even social and cultural factors.
Several states are considering regulating composts. (p. 7-27)	One approach for establishing regulations is to rely on the federal standards for land application of biosolids. Metals content of the applied material is an important concern. Table 7-2 shows the maximum metals content for land application of biosolids.

Consider marketing to large-scale compost users. (p. 7-28)	Large-scale users of composts include the following: • farms • landscape contractors • highway departments • sports facilities • parks • golf courses • office parks • home builders • cemeteries • nurseries • growers of greenhouse crops • manufacturers of topsoil.
Marketing success depends on a number of factors. (p. 7-28 — 7-29)	Understanding the advantages and limitations of a given compost is important for marketing success. Marketers should focus on the qualities of the specific compost products, how they can meet customer needs, and what the compost can and cannot do. To target the right markets, you must know the potential uses of compost.
Major U.S. compost markets include those listed here. (p. 7-28 — 7-30)	Major U.S. compost markets include the following (see Table 7-3): • landscaping • topsoil • bagged for retail consumer use (residential) • surface mine reclamation (active and abandoned mines) • nurseries (both container and field) • sod • silviculture (Christmas trees, reforested areas, timber stand improvement) • agriculture (harvested cropland, pasture/grazing land, cover crops).
The quality of a compost product directly impacts its marketability. (p. 7-31 — 7-33)	Quality is judged primarily on particle size, pH, soluble salts, stability, and the presence of undesirable components such as weed seeds, heavy metals, phytotoxic compounds, and undesirable materials, such as plastic and glass. (Table 7-4 summarizes compost quality guidelines based on end use.) The marketability of a compost can be controlled by selectively accepting feedstock materials. Feedstock material should be carefully controlled to ensure consistent compost quality.
Backyard composting programs can significantly reduce the volume of MSW. (p. 7-35 — 7-39)	In some communities, 30 or more percent of the MSW generated during the growing season is yard trimmings. Grasscycling and backyard composting programs reduce the need for collecting, processing, and disposing of the composted materials. Yard trimmings can be composted in piles or containers located in yards. Effective education and appropriate incentives are necessary to successfully implement community-wide backyard composting programs.

7 HIGHLIGHTS (continued)

Community-wide yard trimmings composting programs are another option. (p. 7-39 — 7-42)	Community-wide yard trimmings composting programs divert significant quantities of materials from land disposal facilities. Grass and leaves make up the bulk of yard trimmings produced. Other materials include tree limbs, trunks and brush; garden materials such as weeds and pine needles; and Christmas trees. Both drop-off and curbside collection are possible.
Direct land-spreading of yard trimmings is an alternative. (p. 7-45)	This approach bypasses the need to site and operate composting facilities. Direct land-spreading programs do have advantages, but they require careful management to avoid soil fertility problems if the carbon:nitrogen ratio is too high.
Source-separated organics composting programs are increasing. (p. 7-45 — 7-46)	The definition of source-separated organics can include food scraps, yard trimmings, and sometimes paper. The advantage of source-separated organics composting is the ability to produce relatively contaminant-free compost. Accomplishing this depends on the conscientious efforts of generators and an effective collection program. A contaminant-free feedstock is important for producing a high-quality compost.
Mixed MSW composting also diverts materials from landfills. (p. 7-47)	The source of feedstock for mixed MSW composting is usually residential and commercial solid waste. These programs do not require additional education and are more convenient for residents since special handling is not needed. The quality of the feedstock and consequently the compost product is enhanced when potential contaminants, such as household hazardous wastes, are segregated from the input stream through household hazardous waste programs (at the curb or facility).
Several technologies are available for composting mixed MSW. (p. 7-47 — 7-51)	A two-stage process is often used: aerated static pile, in-vessel, or aerobic processes are usually the first stage and turned windrow or aerated static pile is the second-stage curing technology. The combination of technologies depends on the process selected, space and odor considerations, economics, and operating preferences.
Concerns about mixed MSW compost must be addressed. (p. 7-51)	One of the primary concerns is the presence of heavy metal compounds (particularly lead) and toxic organic compounds in the MSW compost product. Measures, including source separation, can be taken to prevent problems and produce a high quality compost. Testing for chemical constituents must be carefully planned and executed to ensure production of a consistently high-quality product.
Leachate at composting facilities must be contained and treated. (p. 7-52)	Even well-managed facilities generate small quantities of leachate. The facility's design should include a paved floor and outdoor paved area equipped with drains leading to a leachate collection tank or collection pond. For outdoor compost piles, attempts must be made to minimize leachate production by diverting any surface-water runoff from the up-slope side of the piles.

Odor and dust control are crucial when operating a compost facility. (p. 7-52 — 7-53)	The source and type of odor should be identified. The degree of odor control needed depends in part on the facility's proximity to residences, businesses, schools, etc. Siting a facility at a remote location provides a large buffer zone between the facility and any residents and helps to alleviate odor-related complaints. Operators should be aware of *Aspergillus fumigatus*, a fungus naturally present in decaying organic matter. Workers susceptible to respiratory problems or with impaired immune systems are not good candidates for working in composting facilities.
Routine testing and monitoring is an essential part of any composting operation. (p. 7-53)	At a minimum the following should be monitored: • compost mass temperatures • oxygen concentrations in the compost mass • moisture content • particle size • maturity of the compost • pH • soluble salts • ammonia • organic and volatile materials content.
Keeping records is essential. (p. 7-54)	Periodically evaluating records helps identify where improvements are needed and provides information necessary for making the operation more efficient. All employees should understand the importance of keeping good records. Records should be kept on employee safety training, facility and employee safety procedures, and health monitoring at the facility.
Communication with community leaders and facility neighbors should be ongoing. (p. 7-54 — 7-55)	To ensure good relations, the public should be informed of the types of materials accepted and prohibited and the collection schedules. Periodically remind residents that composting is an effective management tool. A complaint response procedure is also important. Document and respond to complaints promptly.
Composting facilities may require approvals or permits. (p. 7-56)	The requirements for permitting composting facilities may vary among states. In addition to state-level permits, local permits may be required, such as building permits, zoning variances, or special land use permits.
Financing is an integral part of planning a composting project. (p. 7-56)	The most common methods of financing a large-scale composting project (e.g., to service a municipality) are through bond sales or bank loans. A financing professional should be consulted.

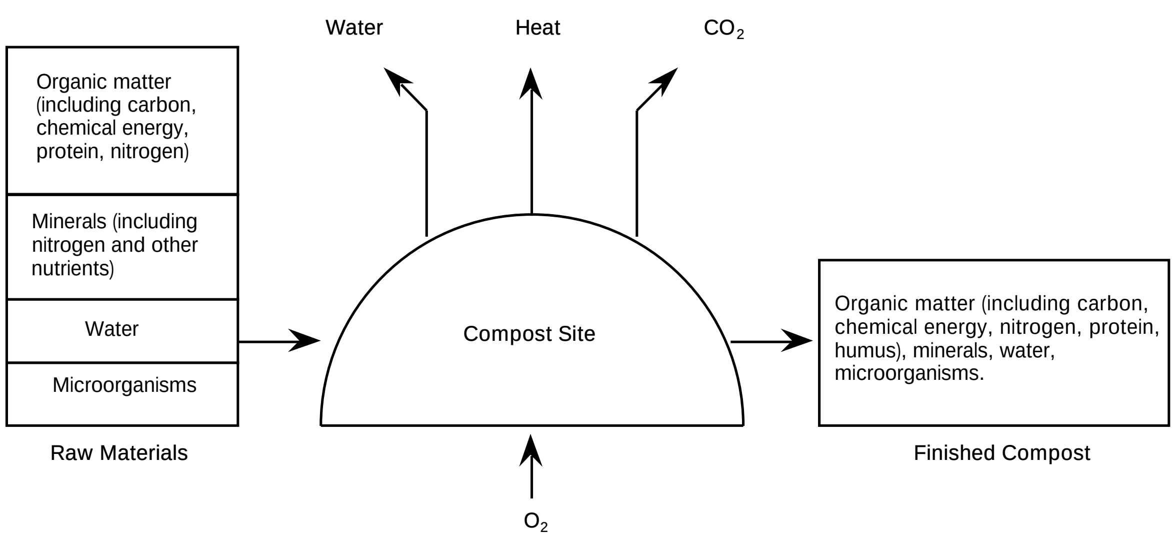
7 COMPOSTING

WHAT IS COMPOSTING?

Composting as a Biological Process

Composting involves the aerobic biological decomposition of organic materials to produce a stable humus-like product (see Figure 7-1). Biodegradation is a natural, ongoing biological process that is a common occurrence in both human-made and natural environments. Grass clippings left on the lawn to decompose or food scraps rotting in a trash can are two examples of uncontrolled decomposition. To derive the most benefit from this natural, but typically slow, decomposition process, it is necessary to control the environmental conditions during the composting process. Doing so plays a significant role in increasing and controlling the rate of decomposition and determining the quality of the resulting compost.

Figure 7-1
The Composting Process



The carbon, chemical energy, protein, and water in the finished compost is less than that in the raw materials. The finished compost has more humus. The volume of the finished compost is 50% or less of the volume of raw material.

Source: Reprinted with permission from Rynk, et al., *On Farm Composting Handbook, 1992 (NRAES-54)*

Good-quality compost is devoid of weed seeds and pathogenic organisms, relatively stable and resistant to further rapid decomposition by microorganisms.

Compost is the end product of the composting process, which also produces carbon dioxide and water as by-products. Composts are humus, which is dark in color, peat-like, has a crumbly texture and an earthy odor, and resembles rich topsoil. The final product has no resemblance in physical form to the original waste from which the compost was made. Good-quality compost is devoid of weed seeds and organisms that may be pathogenic to humans, animals, or plants. Cured compost is also relatively stable and resistant to further rapid decomposition by microorganisms.

Composting and co-composting are two commonly used terms. Composting is a broader term that includes co-composting. While composting refers to the decomposition of any organic materials (also referred to as "feedstocks"), co-composting is the composting of two or more feedstocks with different characteristics—for example, the co-composting of biosolids in liquid/dewatered form with yard trimmings and leaves.

It is important to view compostable materials as usable, *not* as waste requiring disposal. When developing and promoting a composting program and when marketing the resulting compost, program planners and managers should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, *not* a means of waste disposal.

In the broadest sense, any organic material that can be biologically decomposed is "compostable." In fact, humans have used this naturally occurring process for centuries to stabilize and recycle agricultural and human wastes. Today, composting is a diverse practice that includes a variety of approaches, depending on the types of organic materials being composted and the desired properties of the final product.

Composting as a Component of Integrated Solid Waste Management

Composting is one component in USEPA's integrated solid waste management hierarchy.

Composting is one component in USEPA's hierarchy of integrated solid waste management, which is discussed in the introduction to this guidebook (see Figure I-1 in the introduction). Source reduction tops the hierarchy of management options, with recycling as the next preferred option. Grasscycling and backyard composting are forms of source reduction or waste prevention because the materials are completely diverted from the disposal facilities and require no management or transportation. Community yard trimmings composting programs, source-separated organics composting, and mixed MSW composting are considered forms of recycling. Each of these approaches to composting is discussed in the section later in this chapter titled "Composting Approaches in Detail."

This chapter provides information about methods and programs for composting yard trimmings (leaves, grass clippings, brush, and tree prunings) or the compostable portion of mixed solid waste (MSW), including yard trimmings, food scraps, scrap paper products, and other decomposable organics.

The Benefits of Composting

Composting organic materials can significantly reduce waste stream volume.

Municipal solid wastes contain up to 70 percent by weight of organic materials. Yard trimmings, which constitute 20 percent of the MSW stream, may contain even larger proportions of organic materials. In addition, certain industrial by-products—those from the food processing, agricultural, and paper industries—are mostly composed of organic materials. Composting organic materials, therefore, can significantly reduce waste stream volume. Diverting such materials from the waste stream frees up landfill space needed for materials that cannot be composted or otherwise diverted from the waste stream.

Composting owes its current popularity to several factors, including increased landfill tipping fees, shortage of landfill capacity, and increasingly restrictive measures imposed by regulatory agencies. In addition, composting is indirectly encouraged by states with recycling mandates that include composting as an acceptable strategy for achieving mandated goals, some of which reach 50-60 percent (Apotheker, 1993). Consequently, the number of existing or planned composting programs and facilities has increased significantly in recent years.

The benefits of reducing disposal needs through composting may be adequate to justify choosing this option even if the compost is used for landfill cover.

Composting may also offer an attractive economic advantage for communities in which the costs of using other options are high. Composting is frequently considered a viable option only when the compost can be marketed—that is, either sold or given away. In some cases, however, the benefits of reducing disposal needs through composting may be adequate to justify choosing this option even if the compost is used for landfill cover.

Composts, because of their high organic matter content, make a valuable soil amendment and are used to provide nutrients for plants. When mixed into the soil, compost promotes proper balance between air and water in the resulting mixture, helps reduce soil erosion, and serves as a slow-release fertilizer.

Composting Challenges

Despite the growing popularity of composting, communities face several significant challenges in developing and operating successful composting programs. These include the following:

- developing markets and new end uses
- inadequate or nonexisting standards for finished composts
- inadequate design data for composting facilities
- lack of experienced designers, vendors, and technical staff available to many municipalities
- potential problems with odors
- problems controlling contaminants
- inadequate understanding of the biology and mathematics of composting
- inadequate financial planning.

The failure to control the quality of the compost directly impacts its marketability.

Many existing mixed MSW composting facilities have an over-simplified design that focuses primarily on the production aspects of composting and inadequately addresses factors crucial to producing a high-quality, marketable product. For example, many facilities have limited capabilities to separate compostable materials from the non-compostable fraction before the composting process is begun. Because the quality of the end product is determined by the type of materials that are being composted, inadequate separation of materials can adversely affect compost quality. Similarly, processing to remove physical contaminants is sometimes ignored or done inadequately. The failure to control the quality of the compost directly impacts its marketability. As a result, market development has not kept pace with compost production, which in turn has led to under-capitalized projects.

Inadequate storage space for curing compost to maturity has also been a problem at some facilities. Designing adequate storage space should be an important part of planning and developing facilities. Odors associated with storing organics before composting and odors produced during composting pose a significant challenge for many facilities. The inability to adequately deal with potential or existing odor problems can and has contributed to the closure of some facilities.

THE BIOLOGICAL, CHEMICAL, AND PHYSICAL COMPOSTING PROCESSES

Many factors contribute to the success of the composting process. This section provides a technical discussion of these factors and gives readers who lack a technical background a more in-depth understanding of the basic composting processes. Understanding these processes is necessary for making informed decisions when developing and operating a composting program.

Biological Processes

Peak performance by microorganisms requires that their biological, chemical, and physical needs be maintained at ideal levels throughout all stages of composting.

Peak performance by microorganisms requires that their biological, chemical, and physical needs be maintained at ideal levels throughout all stages of composting. Microorganisms such as bacteria, fungi, and actinomycetes play an active role in decomposing the organic materials. Larger organisms such as insects and earthworms are also involved in the composting process, but they play a less significant role compared to the microorganisms.

As microorganisms begin to decompose the organic material, the carbon in it is converted to by-products like carbon dioxide and water, and a humic end product—compost. Some of the carbon is consumed by the microorganisms to form new microbial cells as they increase their population. Heat is released during the decomposition process.

Microorganisms have preferences for the type of organic material they consume. When the organic molecules they require are not available, they may become dormant or die. In this process, the humic end products resulting from the metabolic activity of one generation or type of microorganism may be used as a food or energy source by another generation or type of microorganism. This chain of succession of different types of microbes continues until there is little decomposable organic material remaining. At this point, the organic material remaining is termed compost. It is made up largely of microbial cells, microbial skeletons and by-products of microbial decomposition and undecomposed particles of organic and inorganic origin. Decomposition may proceed slowly at first because of smaller microbial populations, but as populations grow in the first few hours or days, they rapidly consume the organic materials present in the feedstock.

The number and kind of microorganisms are generally not a limiting environmental factor in composting nontoxic agricultural materials, yard trimmings, or municipal solid wastes, all of which usually contain an adequate diversity of microorganisms. However, a lack of microbial populations could be a limiting factor if the feedstock is generated in a sterile environment or is unique in chemical composition and lacks a diversity of microorganisms. In such situations it may be necessary to add an inoculum of specially selected microbes. While inocula speed the composting process by bringing in a large population of active microbes, adding inocula is generally not needed for composting yard trimmings or municipal solid wastes. Sometimes, partially or totally composted materials (composts) may be added as an inoculum to get the process off to a good start. It is not necessary to buy "inoculum" from outside sources. A more important consideration is the carbon:nitrogen ratio, which is described in a later section.

The composting process should cater to the needs of the microorganisms and promote conditions that will lead to rapid stabilization of the organic materials.

Microorganisms are the key in the composting process. If all conditions are ideal for a given microbial population to perform at its maximum potential, composting will occur rapidly. The composting process, therefore, should cater to the needs of the microorganisms and promote conditions that will lead to rapid stabilization of the organic materials.

While several of the microorganisms are beneficial to the composting process and may be present in the final product, there are some microbes that are potential pathogens to animals, plants, or humans. These pathogenic organisms must be destroyed in the composting process and before the compost is distributed in the market place. Most of this destruction takes place by controlling the composting operation's temperature, a physical process that is described below.

Chemical Processes

The chemical environment is largely determined by the composition of material to be composted. In addition, several modifications can be made during the composting process to create an ideal chemical environment for rapid decomposition of organic materials. Several factors determine the chemical environment for composting, especially: (a) the presence of an adequate carbon (food) / energy source, (b) a balanced amount of nutrients, (c) the correct amount of water, (d) adequate oxygen, (e) appropriate pH, and (f) the absence of toxic constituents that could inhibit microbial activity.

Carbon/Energy Source

Microorganisms in the compost process are like microscopic plants: they have more or less the same nutritional needs (nitrogen, phosphorus, potassium, and other trace elements) as the larger plants. There is one important exception, however: compost microorganisms rely on the carbon in organic material as their carbon / energy source instead of carbon dioxide and sunlight, which is used by higher plants.

How easily biodegradable a material is depends on the genetic makeup of the microorganism present and the makeup of the organic molecules that the organism decomposes.

The carbon contained in natural or human-made organic materials may or may not be biodegradable. The relative ease with which a material is biodegraded depends on the genetic makeup of the microorganism present and the makeup of the organic molecules that the organism decomposes. For example, many types of microorganisms can decompose the carbon in sugars, but far fewer types can decompose the carbon in lignins (present wood fibers), and the carbon in plastics may not be biodegradable by any microorganisms. Because most municipal and agricultural organics and yard trimmings contain adequate amounts of biodegradable forms of carbon, carbon is typically not a limiting factor in the composting process.

As the more easily degradable forms of carbon are decomposed, a small portion of the carbon is converted to microbial cells, and a significant portion of this carbon is converted to carbon dioxide and lost to the atmosphere. As the composting process progresses, the loss of carbon results in a decrease in weight and volume of the feedstock. The less-easily decomposed forms of carbon will form the matrix for the physical structure of the final product—compost.

Nutrients

Among the plant nutrients (nitrogen, phosphorus, and potassium), nitrogen is of greatest concern because it is lacking in some materials. The other nutrients are usually not a limiting factor in municipal solid waste or yard trimmings feedstocks. The ratio of carbon to nitrogen is considered critical in determining the rate of decomposition. Carbon to nitrogen ratios, however, can often be misleading. The ratio must be established on the basis of *available* carbon rather than *total* carbon. In general, an initial ratio of 30:1 carbon:nitrogen is considered ideal. Higher ratios tend to retard the process of decomposition, while ratios below 25:1 may result in odor problems. Typically, carbon to nitrogen ratios for yard trimmings range from 20 to 80:1, wood chips 400 to 700:1, manure 15 to 20:1, and municipal solid wastes 40 to 100:1. As the composting process proceeds and carbon is lost to the atmosphere, this ratio narrows. Finished compost should have ratios of 15 to 20:1.

An initial ratio of 30:1 carbon:nitrogen is considered ideal.

To lower the carbon:nitrogen ratios, nitrogen-rich materials such as yard trimmings, animal manures, or biosolids are often added. Adding partially decomposed or composted materials (with a lower carbon:nitrogen ratio) as inoculum may also lower the ratio. Attempts to supplement the nitrogen by using commercial fertilizers often create additional problems by modifying salt concentrations in the compost pile, which in turn impedes microbial activity. As temperatures in the compost pile rise and the carbon:nitrogen ratio falls below 25:1, the nitrogen in the fertilizer is lost in a gas form (ammonia) to the atmosphere. This ammonia is also a source of odors.

Moisture

Water is an essential part of all forms of life and the microorganisms living in a compost pile are no exception. Because most compostable materials have a

A moisture content of 50 to 60 percent of total weight is considered ideal.

lower-than-ideal water content, the composting process may be slower than desired if water is not added. However, moisture-rich solids have also been used. A moisture content of 50 to 60 percent of total weight is considered ideal. The moisture content should not be great enough, however, to create excessive free flow of water and movement caused by gravity. Excessive moisture and flowing water form leachate, which creates a potential liquid management problem and potential water pollution and odor problems. Excess moisture also impedes oxygen transfer to the microbial cells. Excessive moisture can increase the possibility of anaerobic conditions developing and may lead to rotting and obnoxious odors.

Microbial processes contribute moisture to the compost pile during decomposition. While moisture is being added, however, it is also being lost through evaporation. Since the amount of water evaporated usually exceeds the input of moisture from the decomposition processes, there is generally a net loss of moisture from the compost pile. In such cases, adding moisture may be necessary to keep the composting process performing at its peak. Evaporation from compost piles can be minimized by controlling the size of piles. Piles with larger volumes have less evaporating surface / unit volume than smaller piles. The water added must be thoroughly mixed so all portions of the organic fraction in the bulk of the material are uniformly wetted and composted under ideal conditions. A properly wetted compost has the consistency of a wet sponge. Systems that facilitate the uniform addition of water at any point in the composting process are preferable.

Oxygen

The compost pile should have enough void space to allow free air movement so that oxygen from the atmosphere can enter the pile.

Composting is considered an *aerobic* process, that is, one requiring oxygen. *Anaerobic* conditions, those lacking oxygen, can produce offensive odors. While decomposition will occur under both aerobic and anaerobic conditions, aerobic decomposition occurs at a much faster rate. The compost pile should have enough void space to allow free air movement so that oxygen from the atmosphere can enter the pile and the carbon dioxide and other gases emitted can be exhausted to the atmosphere. In some composting operations, air may be mechanically forced into or pulled from the piles to maintain adequate oxygen levels. In other situations, the pile is turned frequently to expose the microbes to the atmosphere and also to create more air spaces by fluffing up the pile.

A 10 to 15 percent oxygen concentration is considered adequate, although a concentration as low as 5 percent may be sufficient for leaves. While higher concentrations of oxygen will not negatively affect the composting process, they may indicate that an excessive amount of air is circulating, which can cause problems. For example, excess air removes heat, which cools the pile. Too much air can also promote excess evaporation, which slows the rate of composting. Excess aeration is also an added expense that increases production costs.

pH

A pH between 6 and 8 is considered optimum. pH affects the amount of nutrients available to the microorganisms, the solubility of heavy metals, and the overall metabolic activity of the microorganisms. While the pH can be adjusted upward by addition of lime or downward with sulfur, such additions are normally not necessary. The composting process itself produces carbon dioxide, which, when combined with water, produces carbonic acid. The carbonic acid could lower the pH of the compost. As the composting process progresses, the final pH varies depending on the specific type of feedstocks used and operating conditions. Wide swings in pH are unusual. Because organic materials are naturally well-buffered with respect to pH changes, down swings in pH during composting usually do not occur.

Physical Processes

The physical environment in the compost process includes such factors as temperature, particle size, mixing, and pile size. Each of these is essential for the composting process to proceed in an efficient manner.

Particle Size

The optimum particle size has enough surface area for rapid microbial activity, but also enough void space to allow air to circulate for microbial respiration.

The particle size of the material being composted is critical. As composting progresses, there is a natural process of size reduction. Because smaller particles usually have more surface per unit of weight, they facilitate more microbial activity on their surfaces, which leads to rapid decomposition. However, if all of the particles are ground up, they pack closely together and allow few open spaces for air to circulate. This is especially important when the material being composted has a high moisture content. The optimum particle size has enough surface area for rapid microbial activity, but also enough void space to allow air to circulate for microbial respiration. The feedstock composition can be manipulated to create the desired mix of particle size and void space. For yard trimmings or municipal solid wastes, the desired combination of void space and surface area can be achieved by particle size reduction. Particle size reduction is sometimes done after the composting process is completed to improve the aesthetic appeal of finished composts destined for specific markets.

Temperature

The optimum temperature range is 32°-60°C.

All microorganisms have an optimum temperature range. For composting this range is between 32° and 60° C. For each group of organisms, as the temperature increases above the ideal maximum, thermal destruction of cell proteins kills the organisms. Likewise, temperatures below the minimum required for a group of organisms affects the metabolic regulatory machinery of the cells. Although composting can occur at a range of temperatures, the optimum temperature range for thermophilic microorganisms is preferred, for two reasons: to promote rapid composting and to destroy pathogens and weed seeds. Larger piles build up and conserve heat better than smaller piles. Temperatures above 65° C are not ideal for composting. Temperatures can be lowered if needed by increasing the frequency of mechanical agitation, or using blowers controlled with timers, temperature feedback control, or air flow throttling. Mixing or mechanical aeration also provides air for the microbes.

Ambient air temperatures have little effect on the composting process, provided the mass of the material being composted can retain the heat generated by the microorganisms. Adding feedstock in cold weather can be a problem especially if the feedstock is allowed to freeze. If the feedstock is less than 5° C, and the temperature is below freezing, it may be very difficult to start a new pile. A better approach is to mix cold feedstock into warm piles. Once adequate heat has built up, which may be delayed until warmer weather, the processes should proceed at a normal rate.

Pathogen destruction is achieved when compost is at a temperature of greater than 55° C for at least three days. It is important that all portions of the compost material be exposed to such temperatures to ensure pathogen destruction throughout the compost. At these temperatures, weed seeds are also destroyed. After the pathogen destruction is complete, temperatures may be lowered and maintained at slightly lower levels (51° to 55° C).

Attaining and maintaining 55° C temperatures for three days is not difficult for in-vessel composting systems. However, to achieve pathogen destruction with windrow composting systems, the 55° C temperature must be maintained for a minimum of 15 days, during which time the windrows must be turned at least five times. The longer duration and increased turning are necessary to achieve uniform pathogen destruction throughout the entire pile.

Care should be taken to avoid contact between materials that have achieved these minimum temperatures and materials that have not. Such contact could recontaminate the compost.

Compost containing municipal wastewater treatment plant biosolids must meet USEPA standards applicable to biosolids pathogen destruction. This process of pathogen destruction is termed "process to further reduce pathogens" (PFRP). States may have their own minimum criteria regulated through permits issued to composting facilities. A state's pathogen destruction requirement may be limited to compost containing biosolids or it may apply to all MSW compost.

Mixing and agitation distribute moisture and air evenly.

Mixing

Mixing feedstocks, water, and inoculants (if used) is important. Piles can be turned or mixed after composting has begun. Mixing and agitation distribute moisture and air evenly and promote the breakdown of compost clumps. Excessive agitation of open vessels or piles, however, can cool the piles and retard microbial activity.

AN OVERVIEW OF COMPOSTING APPROACHES

USEPA emphasizes the following hierarchy of composting methods in order of preference. A detailed discussion of each approach can be found in the "Composting Approaches in Detail" section later in this chapter.

1. Grasscycling (source reduction)
2. Backyard Composting (source reduction)
3. Yard Trimmings Programs (recycling)
4. Source-Separated Organics Composting (recycling)
5. MSW Composting Programs (recycling)

Grasscycling and Backyard Composting

In 1990, yard trimmings constituted nearly 18 percent of the total MSW waste stream in the United States (USEPA, 1992). Because grasscycling and home backyard composting programs are source reduction methods, that is they completely divert the materials from entering the municipal solid waste stream, USEPA encourages communities to promote these composting approaches whenever possible.

Grasscycling

Labor and the amount of fertilizer required decrease with grasscycling.

Grasscycling is a form of source reduction that involves the natural recycling of grass clippings by leaving the clippings on the lawn after mowing. In one study, researchers found that grasscycling reduced lawn maintenance time by 38 percent. In addition, leaving grass clippings on the lawn reduces the need to fertilize by 25 to 33 percent, because nutrients in the grass clippings are simply being recycled. A 25 to 33 percent fertilizer savings can normally be achieved. Grasscycling also reduces or eliminates the need for disposal bags and for pick-up service charges, as well.

Backyard Composting

Many communities have established programs to encourage residents to compost yard trimmings and possibly other organic materials in compost piles or containers located on their property. Because the materials are used by resi-

Backyard recycling is increasing in popularity.

dents and never enter the waste stream, this method is also considered source reduction. Backyard composting is increasing as more communities recognize its potential for reducing waste volumes which may be as much as 850 pounds of organic materials per household per year, according to one estimate (Roulac, J. and M. Pedersen, 1993).

Source-Separated Organics Composting Programs

Source separation minimizes the amount of handling time, tipping space and pre-processing equipment required in mixed MSW composting.

Source-separated composting programs rely on residents, businesses, and public and private institutions to separate one or more types of organic materials and set them out separately from other recyclables and trash for collection. Source separation of organics can offer several advantages over mixed MSW composting. For example, source separation minimizes the amount of handling time, tipping space and pre-processing equipment that is usually required in mixed MSW composting. In addition, source-separated composting produces a consistently higher-quality compost because the feedstock is relatively free of noncompostable materials and potential chemical and heavy metal contaminants (Gould, et al., 1992). Table 7-1 shows the comparative benefits and disadvantages of source-separated organics composting programs and mixed MSW composting.

Several approaches to source-separated composting exist. In general, some mix of the following materials are included, depending on the design of the specific program (Gould, et al., 1992):

- yard trimmings (which can include grass, leaves, and brush)
- food scraps (from residential, industrial or institutional sources)
- mixed paper (which may or may not be included because it requires shredding and must be mixed with other materials)
- disposable diapers (like paper, require special treatment, and may or may not be included)
- wood scraps

The number of source-separated composting programs and facilities in the United States is steadily increasing. For example, in early 1994, New York state alone had more than 20 institutional food and yard trimmings facilities located at prisons, colleges, campuses and resorts; two pilot residential source-separated facilities; and one full-scale facility.

Table 7-1

Advantages and Disadvantages of Source Separation versus Commingling MSW

Source-Separated Materials	Commingled Materials
Advantages: • Less chance of contamination. This can result in a higher-quality compost product. • Less money and time spent on handling and separating materials at the composting facility. • Provides an educational benefit to residents and might encourage waste reduction.	*Advantages* • Usually collected with existing equipment and labor resources. • Convenient for residents because no separation is required.
Disadvantages: • Can be less convenient to residents. • Might require the purchase of new equipment and/or containers. • Might require additional labor for collection.	*Disadvantages:* • Higher potential for contamination, which can result in a lower-quality compost product. • Higher processing and facility costs.

Source: USEPA, 1994

Nationwide, in 1994 there were approximately 3,000 yard trimmings composting programs in the United States. State and local bans on landfilling and combusting yard trimmings have contributed to the growing number of such programs. In 1994, 27 states and Washington DC banned all or some components of yard trimmings from land disposal.

Mixed Municipal Solid Waste Composting

USEPA places mixed MSW composting at the bottom of the composting hierarchy.

Some MSW composting programs in the U.S. use a commingled stream of organic materials. In such programs, mixed MSW is first sorted to remove recyclable, hazardous, and noncompostable materials, and the remaining organic materials are then composted. As mentioned above, USEPA places mixed MSW composting at the bottom of its hierarchy of composting approaches. Although mixed MSW composting programs may offer some advantages (see Table 7-1)—for example, materials can usually be collected with existing equipment, residents do not have to separate materials themselves and only need one container—home recycling, yard trimmings, and source-separated composting are increasingly being seen as offering more advantages, especially over the long-term.

DEVELOPING A COMPOSTING PROGRAM

Evaluating Waste Management Alternatives

Communities faced with the task of selecting any solid waste management alternative should consider both monetary and intangible environmental factors in evaluating the various solid waste management alternatives available to them.

No single solid waste management option can solve all of a community's waste problems.

Often there is disagreement among citizens, planners, and decision makers about the best alternative for the community. According to the principles of integrated waste management, no single solid waste management option can solve all of a community's waste problems. To achieve their specific solid waste management goals, communities often combine approaches and alternatives. The options a community selects should complement each other, and the justifications used to select alternatives should be defensible not only during planning, but also during the implementation and operational periods for each alternative chosen.

Selecting the best solid waste management option must be based on goals and evaluation criteria that the community adopts early in the planning process. Any and all options should be given equal consideration initially. Frequently, when communities choose alternatives without considering all of the available options, extensive modifications to the hastily chosen alternative are eventually needed. The result is soaring costs and sometimes total abandonment of the facility and the equipment acquired for the failed project.

Planning the Program

If a community decides that composting is a viable and desirable alternative, there are several steps involved in planning a composting program. A well-planned program and facility will pose few operational difficulties, keep costs within projected budgets, consistently produce a good-quality compost, identify and keep adequate markets for the amount of compost produced, and have continuing support from the community. Below is an outline presenting 14 steps for developing and implementing a successful composting program.

Well-planned programs pose few operational difficulties, follow budgets, produce a good-quality compost and market all of it, and maintain community support.

1. Identify goals of the composting project.
2. Identify the scope of the project (backyard, yard trimmings, source-separated, mixed MSW, or a combination).
3. Gather political support for changing the community's waste management approach.
4. Identify potential sites and environmental factors.
5. Identify potential compost uses and markets.
6. Initiate public information programs.
7. Inventory materials available for composting.
8. Visit successful compost programs.
9. Evaluate alternative composting and associated collection techniques.
10. Finalize arrangements for compost use.
11. Obtain necessary governmental approvals.
12. Prepare final budget and arrange financing, including a contingency fund.
13. Construct composting facilities and purchase collection equipment, if needed.
14. Initiate composting operation and monitor results.

Identifying Composting Project Goals

The goals of any composting project must be clearly identified during the earliest planning stages of the project. Some goals may be further evaluated and redefined during the course of the project, but the project's core goals (for example, reducing the volume of material landfilled, reducing collection costs, or augmenting other reduction efforts) should remain intact because such goals determine how subsequent decisions are made throughout much of the program's development and implementation.

Base goals on the community's short- and long-term solid waste management needs.

Goals must be determined based on the community's short- and long-term solid waste management needs. The project may have multiple goals:

- achieving mandated waste reduction goals by increasing the amount of material recycled.
- diverting specific materials, such as yard trimmings, biosolids, or any high-moisture organic waste, from landfills and incinerators.
- using compost as a replacement for daily cover (soil) in a landfill. In this case only a portion of the material may be composted to meet the daily cover needs, and the quality of compost generated is not critical.
- using compost for erosion control on highways, reservoirs and other applications. (U.S. Department of Transportation regulations provide for use of compost under certain conditions.)

Producing a marketable product (compost) and recovering revenues by selling the compost is another possible goal. In this case, the composting project should be viewed as a commercial production process. Selling compost on the open market requires that the compost meet high standards and be of a consistent quality. A detailed market evaluation should be made when considering this goal (see the "Marketing" section below). No matter what the program's goals are, they should be clearly defined to garner political support for the project. Such goals should be compatible with the community's overall solid waste management plan, including collection and landfilling.

Goals should be clearly defined.

Finally, clearly defining the project's goals saves time during the planning and implementation process. Clearly defined goals help focus activities and resources and prevent wasting efforts on activities that do not contribute to reaching those goals.

Obtaining Political Support for a New Waste Management Approach

Political consensus and support is critical.

Most composting projects, whether municipally or privately operated, will require some governmental support or approval. This may be as simple as local government financing of advertising and education materials. Larger government expenditures may be needed, depending on the composting technique selected. Private programs require siting and perhaps other permits.

To gain political support, it is crucial to inform elected officials and government agencies of the project's goals and the developer's plans for implementing the project. It is also important to solicit input during the early stages of project development from government officials and agencies, especially those responsible for solid waste management.

To elicit support, it may be helpful to arrange for decision makers to visit successful composting facilities. Seeing a successful project in operation provides decision makers with first-hand information that may be useful in evaluating and planning a similar program in their own community.

Engage the officials and concerned members of the public in an open dialogue and do not be surprised if objections are raised. Such objections should be answered without deviating from the project's goals.

Positive media coverage of such projects helps put them on the public agenda, which is usually required to gain widespread community support. Winning approval from an informed public can also be important for obtaining public funding.

If political support is not forthcoming, get a clear picture of the concerns that decision makers have about the proposed project and work to address those concerns. Visits to well-managed facilities in the region may help to assure decision makers that some of their concerns can be successfully addressed. It may also be helpful to consider modifying the project's goals to address some concerns. If support is still lacking or if there is strong opposition to the project, planners should consider abandoning the project.

Identifying Potential Compost Uses and Markets

A useful purpose must be found for the materials recovered from the composting process. In general, the uses for compost include agricultural applications, nurseries and greenhouses, surface mine reclamation, forestry applications, as a topsoil, landscaping, soil remediation, roadside landscaping management, and as final cover in landfill operations. Marketing compost products is crucial to the success of any program and is discussed in detail in the "Marketing" section of this chapter.

Inventorying Potential Sources of Compostable Materials

Conduct a waste quantity characterization study to get an accurate assessment.

The planning process should include an accurate assessment of the quantities of materials available for processing and their composition and sources. Chapter 3 provides a detailed discussion of methods for estimating feedstock quantities and composition. Such data can help determine the size and type of equipment the planned facility will need and also the facility's space requirements. The quantity of feedstock processed and the equipment selected will in turn help determine the program's labor needs and the economics of operation.

Although quantity and composition data may be available from waste haulers, landfills, or other sources, data from such sources may not be reliable for several reasons. The sources from which such data were compiled may not be known or may be incomplete; furthermore, recent increases in recycling and changes in technology make anything but the most recent information irrelevant. Published data should, therefore, be used cautiously. It is far better to obtain as much original data as possible (see Chapter 3 for a discussion of data collection methods).

Composition data should be obtained for each source separately. Data should be collected for at least one year, so as to represent seasonal fluctuations in composition. Although projecting waste stream composition for future years is especially difficult, it is essential to know the compostable proportion of the current waste stream and how much of this material can be realistically separated from the non-compostable fraction before composting. This will help identify the need for any modifications of the collection system.

Program developers must also decide whether to include industrial or commercial materials in the composting program. If such materials are included, they must be carefully evaluated for their compostable fraction, and methods for segregating and collecting them should be developed.

If the community does not already have a household hazardous waste collection program, then planners should consider whether to institute one. In addition to diverting hazardous materials from landfills and combustion facilities, household hazardous waste programs help eliminate contaminants from composting feedstock, which in turn can contribute to producing a consistently higher quality compost product.

Consider the major long-term trends and changes in management strategies already underway.

When planning a program or facility, it is also crucial to consider the major long-term trends and changes in management strategies already underway. For example, the USEPA and many state governments have made source reduction their highest priority waste management strategy. As mentioned earlier in this chapter, source reduction programs and strategies aim at reducing the volume of discarded materials generated by sources (including residents, industries, and institutions) and changing production and consumption patterns, all of which may have long-term impacts on waste volumes and composition. It is essential that such measures be considered when determining long-term estimates of a community's waste stream volume and composition. It is also crucial to consider the community's own long-term waste management plans, given current, and possibly future, local, state, and federal regulations and programs.

Initiating Education and Information Programs

Establishing an effective two-way communication process between project developers and the public is crucial, and public involvement in the project must begin during the planning stages. Concerns voiced by public representatives should be addressed as early in the project's development as possible.

Any new approach to waste management will be questioned by some sectors of the community before it is fully embraced, and an effective education program is crucial to winning full public support. In addition, new waste management practices require substantial public education efforts because they usually require some changes in the public's waste management behavior. For example, new source-separated programs require residents to change the way they sort discarded materials. In some composting programs, residents are also required to separate out household hazardous wastes. As requirements for input from generators increase, so does the importance of public education for ensuring a high rate of compliance.

Education programs should provide factual information about the composting process and potential problems.

The education program should provide objective, factual information about the composting process and potential problems that may be associated with composting facilities. Often, residents equate a composting facility with a waste disposal facility and oppose siting such a facility in their area for that reason. Similarly, some residents may view drop-off sites (for yard trimmings) as disposal sites and oppose them. Providing information about the nature of composting may help dispel such opposition. At the same time, potential problems such as odor should be openly and honestly discussed and strategies for addressing such problems developed. Public education programs and the importance of public involvement in any waste management, recycling, or composting program are discussed in Chapter 1.

Choosing a Composting Approach

Compatibility with Existing Programs

Whichever approach is chosen, it should be compatible with existing collection, processing, and disposal systems. All composting facilities require some degree of material separation, which can take place at the source (as with source-separated programs) or at the processing facility (as with mixed MSW composting programs). Some communities already require generators to separate recyclable from nonrecyclable materials (two-stream collection programs). Others require a three-stream separation into a compostable fraction, a recyclable but noncompostable fraction, and nonrecyclable fraction. Yet other communities choose to collect mixed waste and attempt to separate compostable, recyclable and nonrecyclable materials at the composting facility.

Examine the costs of various options and the level of generator involvement required for each.

The costs of the various collection options should be carefully examined, as should the level of generator involvement required for each. For example, mixed MSW composting may have economic advantages during collection compared to source-separated programs, which may require more intensive education (because of higher generator involvement) and, possibly, separate collection. Mixed MSW composting has increased capital and labor costs, however, which may offset the savings in collection costs. In addition, source-separated programs may offer other benefits, such as a consistently higher-quality compost product and lower daily operating expenses because less complicated machinery is required (Hammer, S., 1992).

The option chosen must also be compatible with existing processing systems.

The option chosen must also be compatible with existing processing systems, for example, waste combustion systems. When “wet” organics (food, grass, leaves, wet paper), in addition to recyclables, are separated from the waste stream, the remaining noncompostable, nonrecyclable fraction (sometimes referred to as “dry” waste) usually has a high Btu value and burns well in waste-to-energy (WTE) systems. Because yard trimmings have a high water content and should be separated from WTE feedstock, operating a yard trimmings composting program in conjunction with a WTE facility works well. Composting programs and incineration programs can also be mutually beneficial, as is the case in Dayton, Ohio, where a composting facility is located next door to an incinerator. If the incinerator is not operating, it may be possible to divert some of the organic matter to the composting facility. Likewise, if the composting facility receives a surplus of organic material that is also suitable for combustion, it may be diverted to the incinerator facility as a last resort.

Finally, if composting is chosen, some of the residual materials must be disposed of in a landfill. It is critical, therefore, that a landfill be considered as part of an overall plan in any composting program.

Communities should consider the following factors when deciding which composting method is most appropriate to meet their needs and goals (taken in part from Gould, et al., 1992):

- preferences of the community
- collection and processing costs
- residual waste disposal costs
- markets for the quality of compost produced
- markets for recyclables
- existing collection, processing and disposal systems.

Selecting Appropriate Technologies and Systems

Once a specific approach has been selected, program developers must choose technologies and equipment specific to that approach. The composting systems available may either be proprietary or generic, labor intensive or capital intensive. Several vendors have proven technologies to offer. In all cases, additional equipment and buildings may be needed that are not supplied by a single system supplier.

Experienced staff should be on the selection team.

Selecting a vendor and a technology for composting early in the planning process is critical. Vendors interested in offering their technology should be asked to provide their qualifications, process technology, appropriate costs and references for consideration. Selection of a single system requires considerable engineering time to evaluate each vendors' qualifications; product design, ease of operation, and maintenance requirements; and the economics of each vendor's system as it relates to local conditions. Consultants should be part of the evaluation team if the community does not have in-house specialists to do the technical evaluation of the technologies under consideration. Hiring an outside professional may make the selection process more objective.

Preliminary assessment of alternative technologies should be made to narrow the choice to a short list of vendors. A customized non-proprietary system may also be compared to the proprietary information provided by vendors. Engineers should work with equipment vendors to evaluate each technology. In addition, the collection system in use should be evaluated for its compatibility and cost, relative to the composting technology to be selected. At the same time, compost markets should be evaluated to determine the cost of developing a market.

A detailed technical discussion is provided for each of the composting approaches in the "Composting Approaches in Detail" section.

COMPOSTING TECHNOLOGIES

Technologies for composting can be classified into four general categories: windrow, aerated static pile, in-vessel composting, and anaerobic processing. Supporting technologies include sorting, screening, and curing. Several composting technologies are proprietary. Proprietary technologies may offer preprocessing and post-processing as a complete composting package. The technologies vary in the method of air supply, temperature control, mixing/turning of the material, and the time required for composting. Their capital and operating costs may vary as well.

Windrow Composting

A windrow is a pile, triangular in cross section, whose length exceeds its width and height. The width is usually about twice the height. The ideal pile height allows for a pile large enough to generate sufficient heat and maintain temperatures, yet small enough to allow oxygen to diffuse to the center of the pile. For most materials the ideal height is between 4 and 8 feet with a width from 14 to 16 feet.

Turning the pile re-introduces air into the pile and increases porosity so that efficient passive aeration from atmospheric air continues at all times. An example of a windrow composting operation is shown in Figure 7-2. As noted above, the windrow dimensions should allow conservation of the heat generated during the composting process and also allow air to diffuse to the deeper portions of the pile. The windrows must be placed on a firm surface so the piles can be easily turned. Piles may be turned as frequently as once per week, but more frequent turning may be necessary if high proportions of biosolids are present in the feedstock. Turning the piles also moves material from the pile's surface to the core of the windrow, where it can undergo composting.

Machines equipped with augers, paddles, or tines are used for turning the compost windrows.

Machines equipped with augers, paddles, or tines are used for turning the piles. Some windrow turners can supplement piles with water, if necessary. When piles are turned, heat is released as steam to the atmosphere. If inner portions of the pile have low levels of oxygen, odors may result when this portion of the pile is exposed to the atmosphere.

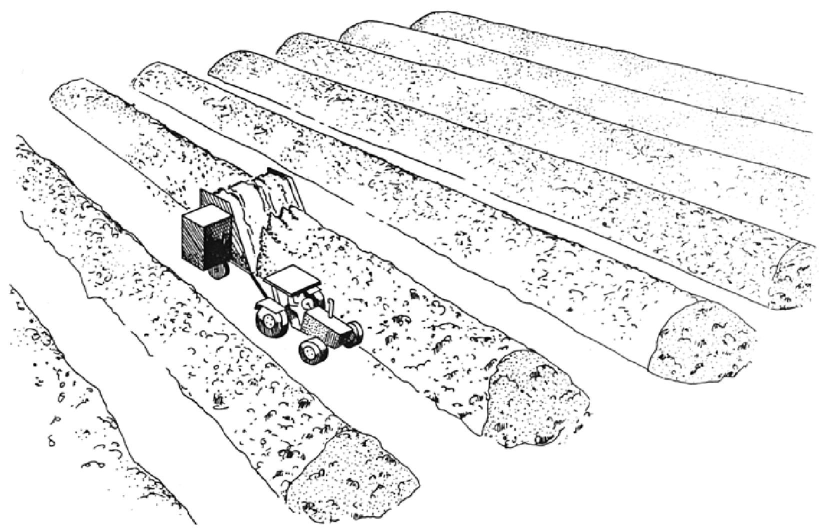
Equipment capacities and sizes must be coordinated with feedstock volume and the range of pile dimensions. Operations processing 2,000 to 3,000 cubic yards per year may find using front-end loaders to be more cost effective than procuring specialized turning equipment (Rynk et al., 1992).

Any leachate or runoff created must be collected and treated or added to a batch of incoming feedstock.

Piles may be placed under a roof or out-of-doors. Placing the piles out-of-doors, however, exposes them to precipitation, which can result in runoff or leachate. Piles with an initial moisture content within the optimum range have a reduced potential for producing leachate. The addition of moisture from precipitation, however, increases this potential. Any leachate or runoff created must be collected and treated or added to a batch of incoming feedstock to increase its moisture content. To avoid problems with leachate or runoff, piles can be placed under a roof, but doing so adds to the initial costs of the operation.

Figure 7-2

Windrow Composting with an Elevating Face Windrow Turner



Source: Reprinted with permission from Rynk, et al., *On Farm Composting Handbook, 1992* (NRAES-54)

Aerated Static Pile Composting

The piles are placed over a network of pipes connected to a blower, which supplies the air for composting.

Aerated static pile composting is a nonproprietary technology that requires the composting mixture (of preprocessed materials mixed with liquids) to be placed in piles that are mechanically aerated (see Figure 7-3). The piles are placed over a network of pipes connected to a blower, which supplies the air for composting. Air can be supplied under positive or negative pressure. When the composting process is nearly complete, the piles are broken up for the first time since their construction. The compost is then taken through a series of post-processing steps.

The air supply blower either forces air into the pile or draws air out of it. Forcing air into the pile generates a positive pressure system, while drawing air out of the pile creates negative pressure. The blowers are controlled by a timer or a temperature feedback system similar to a home thermostat. Air circulation in the compost piles provides the needed oxygen for the composting microbes and also prevents excessive heat buildup in the pile. Removing excess heat and water vapor cools the pile to maintain optimum temperatures for microbial activity. A controlled air supply enables construction of large piles, which decreases the need for land. Odors from the exhaust air could be substantial, but traps or filters can be used to control them.

The temperatures in the inner portions of a pile are usually adequate to destroy a significant number of the pathogens and weed seeds present. The surface of piles, however, may not reach the desired temperatures for destruction of pathogens because piles are not turned in the aerated static pile technology. This problem can be overcome by placing a layer of finished compost 6 to 12 inches thick over the compost pile. The outer layer of finished compost acts as an insulating blanket and helps maintain the desired temperatures for destruction of pathogens and weed seeds throughout the entire pile.

Aerated static pile composting requires less land than windrow composting.

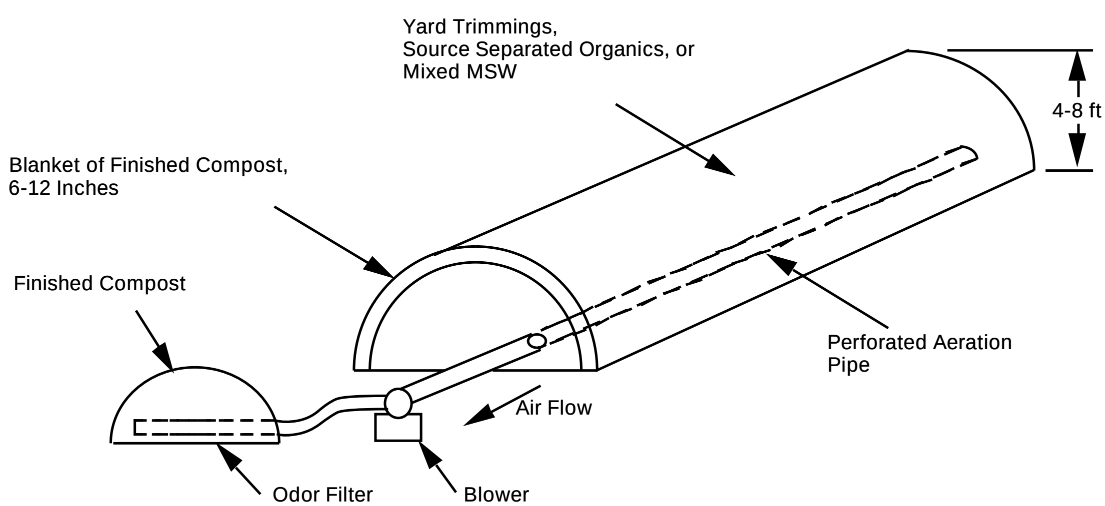
Aerated static pile composting systems have been used successfully for MSW, yard trimmings, biosolids, and industrial composting. It requires less land than windrow composting. Aerated static pile composting can also be done under a roof or in the open, but composting in the open has the same disadvantages as windrows placed in the open (see previous section on windrows). Producing compost using this technology usually takes 6 to 12 weeks. The land requirements for this method are lower than that of windrow composting.

In-Vessel Composting Systems

In-vessel composting systems enclose the feedstock in a chamber or vessel that provides adequate mixing, aeration, and moisture. There are several types of in-vessel systems available; most are proprietary. In-vessel systems vary in their requirements for preprocessing materials: some require minimal preprocessing, while others require extensive MSW preprocessing.

Drums, silos, digester bins, and tunnels are some of the common in-vessel type systems. These vessels can be single- or multi-compartment units. In some cases the vessel rotates, in others the vessel is stationary and a mixing/agitating mechanism moves the material around. Most in-vessel systems are continuous-feed systems, although some operate in a batch mode. All in-vessel systems require further composting (curing) after the material has been discharged from the vessel.

Figure 7-3
Aerated Static Pile for Composting MSW



Source: P. O'Leary, P. Walsh and A. Razvi, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1989-1990

All environmental conditions can be carefully controlled in an in-vessel system.

A major advantage of in-vessel systems is that all environmental conditions can be carefully controlled to allow rapid composting. The material to be composted is frequently turned and mixed to homogenize the compost and promote rapid oxygen transfer. Retention times range from less than one week to as long as four weeks. The vessels are usually placed in a building. These systems, if properly operated, produce minimal odors and little or no leachate.

In addition the air supply can be precisely controlled. Some units are equipped with oxygen sensors, and air is preferentially supplied to the oxygen-deficient portion of the vessel. In-vessel systems enable exhaust gases from the vessel to be captured and subjected to odor control and treatment.

Anaerobic Processing

Anaerobic processes have been used extensively for biologically stabilizing biosolids from municipal sewage treatment plants for many years. Research projects by Pfeffer and Liebman (1976), Wujcik and Jewell (1980), and more recently Kayhanian and Tchobanoglous (1992), and Richards et al. (1991) have demonstrated that similar biological processes can be used to stabilize municipal solid wastes. Several commercial systems have been developed and implemented to a limited extent.

Anaerobic systems generate sufficient energy to operate the process and have excess energy to sell.

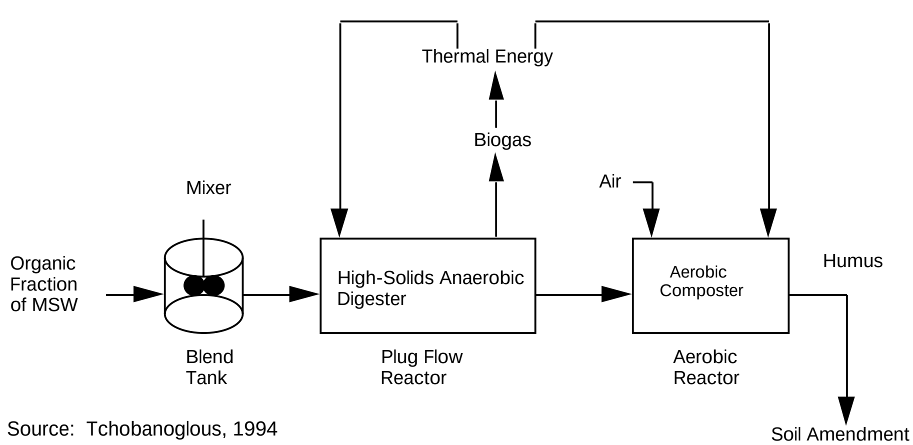
In anaerobic processes, facultative bacteria break down organic materials in the absence of oxygen and produce methane and carbon dioxide. Anaerobic systems, if configured efficiently, will generate sufficient energy in the form of methane to operate the process and have enough surplus to either market as gas or convert to electricity. Conventional composting systems, on the other hand, need significant electrical or mechanical energy inputs to aerate or turn piles.

Several approaches are available for anaerobic digestion of feedstocks. Single-stage digesters contain the entire process in one air-tight container. The feedstock is first shredded, and before being placed in the container, water and possibly nutrients are added to the previously shredded material. The single-stage digester may contain agitation equipment, which continuously stirs the liquified material. The amount of water added and the presence or absence of agitation equipment depends on the particular research demonstration or proprietary process employed.

Two-stage digestion involves circulating a liquid supernatant from a first-stage digester containing the materials to a second-stage digester (see Figure 7-4). This circulation eliminates the need for agitation equipment and also provides the system operator with more opportunity to carefully control the biological process.

Figure 7-4

Anaerobic Digester with Aerobic Compost Curing



Source: Tchobanoglous, 1994

As digestion progresses, a mixture of methane and carbon dioxide is produced. These gases are continuously removed from both first- and second-stage digesters and are either combusted on-site or directed to off-site gas consumers. A portion of the recovered gas may be converted to thermal energy by combustion which is then used to heat the digester.

A stabilized residue remains when the digestion process is completed. The residue is either removed from the digester with the mechanical equipment, or pumped out as a liquid. The residue is chemically similar to compost but contains much more moisture. Conventional dewatering equipment can reduce the moisture content enough to handle the residue as a solid. The digested residue may require further curing by windrow or static pile composting.

Screening

Compost is screened to meet market specifications.

Compost is screened to meet market specifications. Sometimes this processing is done before the compost is cured. One or two screening steps and possibly additional grinding are used to prepare the compost for markets. Screens are used to separate out the compost from the noncompostable fraction. During the composting operation, the compostable fraction undergoes a significant size reduction. The noncompostable fraction undergoes little or no size reduction while being composted. This helps to screen the noncompostable fraction from the compost. Depending on the initial shredding process and the size of screen used, some larger compostable particles may enter the noncompostable stream during screening. One or more screens may be used with the usual configuration being a coarse screening followed by a fine screening step. Screening can be done before or after the curing process. The noncompostable fraction retained on the coarse screen is sent to the landfill. Compostable materials retained on finer screens may be returned to the beginning of the composting process to allow further composting.

The moisture content of the compost being screened should be below 40 percent.

For screening to successfully remove foreign matter and recover as much of the compost as possible, the moisture content of the compost being screened should be below 50 percent. Drying should be allowed only after the compost has sufficiently cured. If screening takes place before curing is complete, moisture addition may be necessary to cure the compost. The screen size used is determined by market specifications of particle size.

The screened compost may contain inert particles such as glass or plastics that may have passed through the screen. The amount of such inert materials depends on feedstock processing before composting and the composting technology used. Sometimes, screening alone is not adequate to remove all foreign matter. This may result in diminished market acceptance of the product.

Curing

By the end of the rapid phase of composting, whether in windrows, aerated static pile, in-vessel, or anaerobic digestion, a significant proportion of the easily degradable organic material has been decomposed and a significant amount of weight has been lost. Organic materials remaining after the first phase decompose slowly. Microbial activity, therefore, continues at a much slower rate, despite ideal environmental conditions. The second phase, which is usually carried out in windrows, usually takes several weeks to six months, depending on outdoor temperatures, the intensity of management, and market specifications for maturity. With some system configurations, a screening step may precede the curing operation.

Cooling indicates reduced microbial activity and may occur before curing is complete.

During curing the compost becomes biologically stable, with microbial activity occurring at a slower rate than during actual composting. Curing piles may either be force-aerated or use passive aeration with occasional turning. As the pile cures, less heat is generated by the microorganisms and the pile begins to cool. When the piles cool, it does not always mean that the curing is complete. Cooling is a sign of reduced microbial activity, which can result from a lack of moisture, inadequate oxygen within the pile, a nutrient imbalance, or the desired result—completing the compositng process. Curing may take from a few days to several months. The cured compost is then prepared for markets.

MARKETING COMPOSTS

A well-planned marketing approach ensures that all the compost will be distributed.

The final use of the compost product and its potential markets are crucial issues that must be addressed early in the planning stages of the compost program and facility. A well-planned approach ensures that all the compost will be distributed; accomplishing this goal, however, requires producing a consistently high-quality compost in order to satisfy the needs of most markets.

A number of state regulatory agencies are considering regulating compost. They usually consider a variety of approaches for regulating the land application of municipal solid waste compost. One possible approach is to rely on the federal standards for land application of biosolids to establish a framework within which to derive the state MSW compost spreading standards. An important consideration is the metals content of the applied material. Table 7-2 shows the maximum metals content for land application of biosolids. A protocol is provided to limit the maximum cumulative amount of metals in biosolids that may be spread on a particular site. If a biosolid has metal content that is less than shown in Table 7-2, the sludge may be sold or given away provided that specified annual cumulative rates for the same list of metals is not exceeded. The federal standards for the use and disposal of biosolids are contained in 40 CFR Part 503.

Table 7-2
Ceiling Concentrations for Biosolids

Pollutant	Concentrations (mg/kg)*
Arsenic	75
Cadmium	85
Chromium	3000
Copper	4300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7500

*Dry weight basis

Source: USEPA, 1994

There is limited regulation of properly processed yard trimmings compost. Where state guidelines do exist, the parameters of interest are often associated with measuring the completeness of the composting process. The land spreading operations are monitored to insure that the yard trimmings compost is being spread, not dumped into piles.

The available nitrogen content of the compost and the soil may be a determining factor for deciding the allowable amount of compost that may be spread onto agricultural land. With biosolids applications, the allowable amount is determined by crop uptake. Similar approaches have been used to establish compost application levels.

Marketing Strategies

Quality and composition factors specific to the targeted markets must be carefully assessed.

In marketing composts, there are no set guidelines that apply to all composting facilities—every facility and the markets it seeks to serve are somewhat different. Factors specific to the targeted markets must be carefully assessed. The quality and composition required for a compost product to meet the needs of a specific market depend on a mix of factors, including the intended use of the product, local climatic conditions, and even social and cultural factors. The criteria that best fit the specific market should be incorporated in the marketing plan. For example, meeting the needs of agricultural applications requires minimizing the potential uptake of metal contaminants and the presence of glass and plastic, and satisfying other feed / food safety concerns. Satisfying the needs of horticultural nurseries requires ensuring the maturity of the compost, pH, nutrient content, soluble salts, particle size, shrinkage, and moisture-holding potential (Buhr, et. al. 1993).

Marketing efforts should be continuous—before, during, and after the compost production. Two major objectives should guide marketing plans: One is selling or otherwise distributing all of the compost that is produced. The second is optimizing revenues and minimizing costs.

Market developers should also be aware of potential large-scale users of composts and consider targeting such users in their areas or regions. Potential large-scale users include the following (LaGasse, 1992):

Consider targeting large-scale users.

- farms
- landscape contractors
- highway departments
- sports facilities
- parks
- golf courses
- office parks
- home builders
- cemeteries
- nurseries
- growers of greenhouse crops
- manufacturers of topsoil
- land reclamation contractors.

Adopting the right marketing attitude is also critical. Compost should be viewed as a usable product—not a waste requiring disposal. Composting should be portrayed as an environmentally sound and beneficial means of recycling organic materials rather than a disposal method for solid wastes.

Education, Research, and Public Relations

Marketers must thoroughly understand the advantages and limitations of a given compost.

Marketers must thoroughly understand the advantages and limitations of a given compost for a given use. Based on its advantages and limitations, the compost's value to the user should be a focus of the marketing strategy. To attract potential customers who have successfully used other soil amendments, marketers should design an education program focusing on the qualities of the specific compost products and how they can meet customer needs. The challenge is to convince potential customers that there is a compost product to meet specific needs.

A successful marketing program should focus on what the compost can and cannot do. Marketers should emphasize any testing programs that are applicable and uses that are compatible with the compost. Give users specific instructions; they may not have used your compost or a similar product before. If the compost is sold in bags, their labels should describe the contents, its potential uses, any precautions / warnings, and how to use the material. Provide bulk users with written instructions for using and storing the compost.

Potential Compost Uses

A study conducted by the Composting Council (Buhr, et. al.) identified nine major potential markets for compost in the U.S.; these include the following:

- landscaping
- topsoil
- bagged for retail consumer use (residential)
- surface mine reclamation (active and abandoned mines)
- nurseries (both container and field)
- sod
- silviculture (Christmas trees, reforested areas, timber stand improvement)
- agriculture (harvested cropland, pasture/grazing land, cover crops).

The leading markets are agriculture, silviculture (trees grown for harvest), and sod production (Buhr, et al.). Some of these major markets have several different potential compost applications. In agriculture, for example, compost can be used as a soil conditioner, fertilizer, and for erosion control and plant disease suppression. In the residential retail market, compost can be used as potting soil, topsoil, mulch and in soil amendments (Buhr, et al. or Slivka, et al.). Compost is also used as a soil amendment to establish vegetation on disturbed lands (for example at mining sites).

Knowing the many potential uses of a compost is required for targeting appropriate markets.

Knowing the many potential uses of compost is an important prerequisite for targeting appropriate markets. Table 7-3 lists compost markets and specific uses for different types of compost. In evaluating potential uses, however, marketers should also recognize the practical limitations of some applications.

Traditionally, the role of compost as a soil additive/soil conditioner has been widely recognized. As a conditioner composts can do the following:

- improve water drainage
- increase water-holding capacity
- improve nutrient-holding capacity
- act as pH buffering agent
- help regulate temperature
- aid in erosion control
- aid air circulation by increasing the void space
- improve the soil's organic matter content
- aid in disease suppression
- slowly release nutrients into the soil
- correct deficiencies in minor elements
- reduce bulk density
- increase cation exchange capacity of sandy soils.

Composts are a good source of plant nutrients and in some applications may have advantages over fertilizers.

Composts are also a good source of plant nutrients and in some applications may have advantages over fertilizers. For example, the plant nutrients in composts, unlike fertilizers, are released over an extended period of time. In addition, composts supply important micronutrients that fertilizers lack. On the other hand, composts supply fewer amounts of macronutrients than fertilizers.

Certain types of composts can successfully control soil-borne diseases, particularly for container crops. A number of research studies have demonstrated that stable composts made from bark and other materials can be effective in suppressing diseases such as *Pythium* and *Phytophthora* (Hoitink, Boehm and Hadar, 1993; Logsdon, 1989). The disease-controlling qualities of the compost result mainly from the presence of beneficial microorganisms that are antagonists of plant pathogens. Composts from tree barks have been used successfully, and tests are being done with composts made from other materials. The use of composts specifically for suppressing disease have been limited primarily to nursery operators. Technology needs to be developed to manufacture products with defined and consistent properties for use with vegetable and agronomic crops.

Table 7-3
Potential Users of and Uses for Compost

User Group	Primary Uses for Compost Products	Compost Products	Packaging
Agricultural and Residential Users			
Forage and field crop growers	Soil amendment, fertilizer supplement, top dressing for pasture and hay crop maintenance	Unscreened and screened compost	Bulk
Fruit and vegetable farmers	Soil amendment, fertilizer supplement, mulch for fruit trees	Unscreened and screened compost	Bulk
Homeowners	Soil amendment, mulch, fertilizer supplement, and fertilizer replacement for home gardens and lawns	Screened compost, high-nutrient compost, mulch	Primarily bags, small-volume bulk
Organic farmers	Fertilizer substitute, soil amendment	Unscreened and screened compost, high-nutrient compost	Primarily bulk
Turf growers	Soil amendment for establishing turf, top dressing	Screened compost, topsoil blend	Bulk
Commercial Users			
Cemeteries	Top dressing for turf, soil amendment for establishing turf and landscape plantings	Screened compost	Bulk
Discount stores, supermarkets	Resale to homeowners	General screened compost product	Bags
Garden centers, hardware/lumber outlets	Resale to homeowners and small-volume users	Screened compost, mulch	Primarily bags, small-volume bulk
Golf courses	Top dressing for turf, soil amendment for greens and tee construction, landscape plantings	Screened compost, topsoil blend	Bulk
Greenhouses	Potting mix component, peat substitute, soil amendment for beds	High-quality, dry, screened compost	Bulk and bag
Land-reclamation contractors	Topsoil and soil amendment for disturbed landscapes (mines, urban renovation)	Unscreened compost, topsoil blend	Bulk
Landscapers and land developers	Topsoil substitute, mulch, soil amendment, fertilizer supplement	Screened compost, topsoil blend, mulch	Bulk
Nurseries	Soil amendment and soil replacement for field-grown stock, mulch, container mix component, resale to retail and landscape clients	Unscreened and screened compost, composted bark, mulch	Primarily bulk, some bags
Municipal Users			
Landfills	Landfill cover material, primarily final cover	Unscreened low-quality compost	Bulk
Public works departments	Topsoil for road and construction work, soil amendment and mulch for landscape plantings	Unscreened and screened compost, topsoil blend	Bulk
Schools, park and recreation departments	Topsoil, top dressing for turf and ball fields, soil amendment and mulch for landscape plantings	Screened compost, topsoil blend, mulch	Bulk

Source: Reprinted with permission from Rynk, et al., *On-Farm Composting Handbook, 1992* (NRAES-54)

Compost Quality—Impacts on Uses and Markets

The quality of a particular compost product and the consistency with which that quality is maintained directly impact the product's marketability. Table 7-4 summarizes compost quality guidelines based on end use of the compost. Quality is judged primarily on particle size, pH; soluble salts, stability, and the

Table 7-4
Examples of Compost Quality Guidelines Based on End Use*

	End Use of Compost			
	Potting Grade	Potting Media Amendment Grade (a)	Top Dressing Grade	Soil Amendment Grade (a)
Recommended Uses:	As a growing medium without additional blending	For formulating growing media for potted crops with a pH below 7.2	Primarily for top-dressing turf	Improving agricultural soils, restoring disturbed soils, establishing and maintaining landscape plantings with pH requirements below 7.2
Characteristic				
Color:	Dark brown to black	Dark brown to black	Dark brown to black	Dark brown to black
Odor:	Should have good, earthy odor	Should have no objectionable odor	Should have no objectionable odor	Should have no objectionable odor
Particle Size:	Less than 1/2 inch (13 mm)	Less than 1/2 inch (13 mm)	Less than 1/4 inch (7 mm)	Less than 1/2 inch (13 mm)
pH:	5.0–7.6	Range should be identified	Range should be identified	Range should be identified
Soluble Salt Concentration: (mmhos per cm)	Less than 2.5	Less than 6	Less than 5	Less than 20
Foreign Materials:	Should not contain more than 1% by dry weight of combined glass, plastic, and other foreign particles 1/8–1/2 inch (3–13 cm)	Should not contain more than 1% by dry weight of combined glass, plastic, and other foreign particles 1/8–1/2 inch (3–13 cm)	Should not contain more than 1% by dry weight of combined glass, plastic, and other foreign particles 1/8–1/2 inch (3–13 cm)	Should not contain more than 5% by dry weight of combined glass, plastic, and other foreign particles
Heavy Metals:	Should not exceed EPA standards for unrestricted use (c)	Should not exceed EPA standards for unrestricted use (c)	Should not exceed EPA standards for unrestricted use (c)	Should not exceed EPA standards for unrestricted use (c)
Respiration Rate: (mg per kg per hour) (b)	Less than 200	Less than 200	Less than 200	Less than 400

* These suggested guidelines have received support from producers of horticultural crops.

(a) For crops requiring a pH of 6.5 or greater, use lime-fortified product. Lime-fortified soil amendment grade should have a soluble salt concentration less than 30 mmhos per centimeter.

(b) Respiration rate is measured by the rate of oxygen consumed. It is an indication of compost stability.

(c) These are EPA 40 CFR Part 503 standards for sewage biosolids compost. Although they are not applicable to MSW compost, they can be used as a benchmark.

Sources: Reprinted with permission from Rynk, et al., *On Farm Composting Handbook, 1992* (NRAES-54); and USEPA, 1994 presence of undesirable components such as weed seeds, heavy metals, phytotoxic compounds, and undesirable materials, such as plastic and glass. Many markets will also look at the uniformity of the product from batch to batch and sources of the raw materials used to make it. Quality and consistency become more important when compost is used for high-value crops such as potted plants and food, when it is applied to sensitive young seedlings, and when it is used alone, without soil or other additives. Tolerance levels for factors such as particle size, soluble salt concentrations, foreign inert materials, and stability are usually higher when compost is used as a soil amendment for agricultural land, restoration of disturbed soils, or other similar uses.

Many markets will also look at the uniformity of the product for assessing quality.

Concentrations of heavy metals and PCBs that exceed USEPA or state standards for unrestricted use will make compost marketing considerably more difficult or even impossible to undertake. Although regulations differ among states, composts are generally classified according to concentrations of certain pollutants such as heavy metals and PCBs. Markets buying or accepting composts that exceed government standards for unrestricted use often have to limit the application rates or cumulative amount applied. Because heavy metals and PCBs pose dangers to human and animal health, these markets may also have to keep written records, apply for special land-spreading permits, and follow specific management practices such as soil incorporation or observe a waiting period before grazing is allowed.

Concentrations of heavy metals and PCBs will make marketing a compost difficult.

Composting facility operators can increase the marketability of their composts by selectively accepting feedstock materials. Raw materials used in the composting process influence the physical and chemical properties of the compost. Clean, source-separated materials are sometimes preferred as feedstocks over mixed solid waste, particularly when used for high-value crops or retail sale. Facilities designed to accept MSW as a feedstock often have less control over the materials they receive. Table 7-5 lists common sources of chemical contaminants in MSW. A front-end processing system that effectively removes contaminants and a permanent household hazardous waste disposal program serving generators may help improve the quality of MSW compost.

Table 7-5
Common Sources of Contaminants in MSW

Batteries
Consumer electronics
Motor oil
Solvents
Cleaning products
Automotive products
Paints and varnishes
Cosmetics

Source: USEPA, 1994

Compost quality is also affected by the aging process and storage conditions. Compost that has cured for 3 to 4 months will typically have a finer texture and a lower pH. In addition, most of the nitrogen available in compost converts from ammonium-nitrogen to nitrate-nitrogen during that time period. High concentrations of ammonium-nitrogen can cause temporary stunting and burning of the foliage of sensitive species. Storage methods can impact quality because finished compost continues to slowly biodegrade until all sources of available carbon are depleted. Compost should be stored in a dry location and in sufficiently small piles to allow aerobic respiration to continue. Without enough air, compost will become anaerobic and develop odors, alcohols, and organic acids that are damaging to plants.

Compost quality is also affected by the aging process and storage conditions.

The quality of a compost can be measured through periodic testing. Compost markets and end uses usually dictate what types of tests are necessary and the frequency for conducting them. Federal and state environmental regulations require specific tests for composts made from mixed solid waste, biosolids, and certain source-separated commercial and industrial wastes. Regular testing is essential for producing a quality product on a consistent basis. Some of routine tests for composts include moisture content, density, pH, soluble salts, particle size, organic matter content, carbon:nitrogen ratio and level of foreign inerts e.g., glass, plastics. Many independent and state-operated labs also conduct tests for micro-nutrients, respiration rate, heavy metals, pathogen levels, and chemical

Compost markets and end uses dictate what types of tests are necessary and how frequent they should be made.

contaminants. A few labs can perform tests specifically for compost maturity or phytotoxicity. Compost maturity can be defined as the degree of decomposition of organic matter during composting. Definitions of maturity are based on the potential uses of the compost (Chen and Inbar, 1993). A number of analytical methods are used to determine compost maturity, but no single method has yet been identified as consistently reliable. Many researchers and compost facility operators are using a combination of tests to determine maturity. Some of the methods being used include bioassays, starch content, cation exchange capacity, concentration of humic substances, cellulose content, carbon:nitrogen ratio, carbon:nitrogen ratio in water extracts of composts, respiration rate, and spectroscopic analyses (Chen and Inbar, 1993; Inbar et al., 1990).

Compost maturity is an important quality measure.

Quality Control

The compost feedstock affects product quality.

Whatever goes in as compost feedstock will be reflected in the compost produced. Because changes in the compost feedstock also change the compost quality, feedstock material should be carefully controlled to ensure consistent compost quality. This may mean that some noncompostable materials should be rejected at the compost site if the product from these materials will be difficult or impossible to market. If accepted, attempts should be made to segregate these feedstocks and market the resulting compost separately.

The compost should be of a consistent quality. This is important to all sectors of the market, but especially to repeat customers who expect a certain quality product. This may not be as important to the one-time buyer. However, if the quality of the compost is good, the one-time buyer could become a repeat customer. The marketer must understand the risk that some users (businesses) may be taking if product quality is unreliable. In addition, if some composts are extremely poor in quality, customers' confidence in all composts may be reduced. Quality control assurances for consistently producing a high-quality compost are a necessity for compost marketing.

Facility managers should establish a testing program backed by minimum quality standards. Tolerances for quality variations should be set and adhered to. Managers should stand behind their products and address customer complaints by promptly taking corrective action. Maintaining a high degree of credibility and integrity is essential.

Manufacturing Multiple Products

Being able to make different products is a good marketing strategy.

A successful marketing strategy should include the ability to offer more than one grade of product. Such a strategy could increase the revenues earned and the amount of compost sold. This could also alleviate some of the peak demand periods, improve distribution, and require less storage space.

Most composting facilities attempt to make one compost from a mixture of a variety of feedstock types. To meet the needs of specific customers, consider segregating a portion or portions of the feedstocks to produce composts that are significantly different in chemical, physical, or biological properties. Different grades of compost can also be made from a single feedstock. For example, the compost could be supplemented with plant nutrients to enhance the nutrient properties. The pH of the compost can be adjusted to suit different plant needs. Composts can be mixed with different mineral or organic materials to produce potting soil mixes. Varying the particle size by using coarser or finer screens produces a rough-grade and a fine-grade compost respectively.

Inventorying Potential Markets

Who are the potential users of the compost? What are they currently using? Can the compost be a satisfactory substitute for products currently being

Marketers should determine if there are potential users who could benefit from their product.

used? Marketers should determine if there are users who could benefit from using the compost, especially those who have not considered using compost in the past. The marketing plan should include an inventory of those users and marketers should focus on the innovators, those entrepreneurs who are looking for alternatives that can lower their costs. The goal is to develop target markets and focus on them.

Municipalities that manufacture composts should look at in-house markets. Determine the annual dollars spent on fertilizers, topsoil and other soil amendments used by governmental units in the region. Can the compost serve as a substitute for these products? A fair amount of demand can often be created within the municipality.

Marketers should try to project the total demand for compost in a given market and relate this to the production capacity of the composting facility. They should determine the demand pattern through the year. Is the peak demand seasonal? If the demand is seasonal, plans for storing the compost at the site or at the buyer's location should be made. Compromises in price may have to be made if the compost has to be purchased and stored by the user. Who provides the transportation? Unless properly planned, transportation could be a bottleneck in meeting buyer's needs on time. This could jeopardize credibility of the marketing program.

What products, if any, are competing with the compost? Marketers should answer this question and stress the positive characteristics of the compost as a substitute for peat in potting soil mixes, for fertilizer, and for pine bark or peat in landscaping.

Distributing Compost

While many municipalities choose to market their own products, others rely on private marketing firms that specialize in marketing composts and related products. It may be appropriate to take the former approach if a small quantity of compost is produced, although some large facilities market their own compost. The self-marketing approach adds administrative costs and may require personnel with special expertise in marketing.

Compost distribution is an important consideration.

Marketing firms offer many advantages. They may be able to do more if they are serving more than one community by using the resources available to them in a more efficient manner. Private marketers can also expand the range of publicity and advertising by attending trade shows, field demonstration days, etc. They can also develop professional public relations campaigns, suggest appropriate equipment for handling the compost, and competitively price the compost. While all of these functions can be performed by a municipality as well, doing so puts a significant burden on the resources available.

One method of distribution adopted by some facilities that compost yard trimmings is to rely on home owners to remove the compost from the compost site by bagging their own. This approach has been successful for some communities. Most home owners want good-quality compost in small quantities, and many prefer to purchase it already bagged because they lack containers or the means to transport loose compost. Bagging composts, however, requires additional investment in capital and manufacturing costs. If the compost is bagged, it should be sold through local retail outlets. A successful marketing program for bagged compost requires intensive advertising and a good-quality product. This marketing approach is likely to return a greater amount of revenues as well.

Pricing

Pricing any product depends on supply and demand, the price structure of competing products, the quality of the product, transportation costs, production costs, research and development costs, marketing costs, the volume of material purchased by a single customer. The pricing structure should be individually established for each composting operation.

Decide early on a pricing strategy.

The goal of marketing should be to sell all the compost that has been produced. The price of the compost should facilitate this goal. Revenues alone should not be expected to offset the cost of producing the compost, but prices should be set to offset as much of the production costs as possible.

Price the product modestly at first, then increase the price based on demand. If the compost is given away for free, the user attaches very little value to it. Pricing should be adjusted based on quantity purchased, and large volume buyers should get a significant discount.

One of the most sensitive factors in pricing and marketing compost is the cost of transportation. Compost is bulky and bulky products can be very expensive to transport. Transportation costs must be carefully evaluated while the facility is being planned, and the distance between potential markets and the manufacturing facility should be minimized.

First-time users of the compost should be charged for the compost or its transportation. This helps customers see compost as a valuable product. Moreover, if customers like the compost, they will be willing to pay for the next shipment.

Compost can be sold at lower prices during low-demand periods. Doing so means the manufacturer does not have to use up valuable storage space. It also helps the users because they will have the compost when they are ready to use it.

Finalizing Market Arrangements

Both formal and informal contracts have advantages.

A composting program's ultimate success depends on the marketing arrangements for the processed products. A technical evaluation conducted during the planning stages should provide quantity and quality data, which can be used to finalize marketing agreements.

Contracts between compost facility operators and product buyers will state the quality specifications, price, quantity, delivery arrangements, use restrictions, and payment procedures. All legal contracts should be reviewed by an attorney.

Most contracts are made with large-quantity buyers. If compost is to be supplied to a large number of small users, contract agreements may be less formal. The agreement must at least specify the minimum quantity and how the compost will be used.

Informal contracts are probably more appropriate when the compost is being given away. Nevertheless, the informal contract is an important communication vehicle.

COMPOSTING APPROACHES IN DETAIL

Composting options available to communities range from the low-capital-investment methods of backyard residential composting to the more capital-intensive mixed municipal solid waste composting, requiring advanced-teaching high-technology processing plants. Each approach has specific benefits and limitations. The approach or mix of approaches that a community chooses depends on that community's characteristics and particular needs.

Grasscycling

Grasscycling can significantly reduce the amount of yard trimmings in the waste stream.

During the growing season, 30 or more percent of the MSW generated in some communities is yard trimmings. An aggressive program of "grasscycling" can significantly reduce the amount of yard trimmings and, hence, the need for processing and disposing of those materials.

Grasscycling is the natural recycling of grass clippings by leaving the clippings on the lawn after mowing (see Figure 7-5). Contrary to widely accepted misconceptions, leaving grass clippings on a lawn after mowing is not

Most residents need to be told of the benefits of grasscycling.

detrimental to maintaining a good lawn if several simple guidelines are followed. Studies have shown that total lawn maintenance time is reduced when clippings are mulched and left on the lawn, despite the fact that the lawn may need to be mowed slightly more often. For example, a Texas study (Knoop and Whitney, 1993) found that grasscycling reduced lawn maintenance time by 38 percent. In addition, leaving grass clippings on the lawn reduces the need to fertilize by 25 to 33 percent, because nutrients in the grass clippings are simply being recycled. A 25 to 33 percent fertilizer savings can normally be achieved. In addition, grasscycling reduces or eliminates costs for disposal bags and possibly pick-up service charges are eliminated.

When establishing a grasscycling program, residents should be told about the benefits described above and how to best maintain grass so that clippings can be left on the lawn. Turf management experts recommend cutting when the grass is dry. A maximum of one inch should be removed during each mowing and no more than one-third of the length should be removed. U.S. Department of Agriculture studies have shown that when these cutting guidelines are followed thatch does not build up in the lawn. If grass is not wet most lawn mowers can cut it into small enough pieces so that the clippings will simply be recycled into the lawn. Simple attachments are also available for converting standard mowers into mulching mowers.

The key to a successful grasscycling program is public education. To build awareness, support, and participation, the cooperation of lawn and garden supply stores and other businesses that provide lawn maintenance equipment and supplies should be sought. Such businesses can post announcements and distribute informational materials to their customers. Government agencies, such as the local parks department, can serve as a good example. To help residents overcome skepticism, demonstration plots can be established in high-visibility locations. All recommendations should accurately reflect local growing conditions and address any concerns that residents may have.

More information is rapidly becoming available about successful grasscycling programs. Detailed information is available from the American Horticultural Society in Alexandria, Virginia.

Figure 7-5

Grass Being Mowed and Returned to the Lawn for Grasscycling

Source: University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 1994

Backyard Residential Composting

Many communities have established programs to encourage residents to compost yard trimmings and possibly other organic materials in compost piles or containers located on their property.

Process Description

Simply constructed boxes make a residential compost pile easy to set up and maintain.

Yard trimmings, which include grass clippings, leaves, garden materials, and small twigs, are ideally suited for composting. Although materials can be composted in a small heap, simply constructed boxes can make a residential compost pile easier to set up and maintain. Figure 7-6 shows several yard trimmings composting containers. Waste is placed in the containers to a depth of about four feet and turned every few weeks or months. Depending on weather conditions, the addition of water may be necessary. Aerobic conditions are generally sustained, and decomposition is faster than would naturally occur if the yard trimmings were left on the ground. As decomposition takes place, the frequency of turning can be reduced to every few months. Significant settling will occur as compost is formed. Complete stabilization and production of finished compost can take from four months to two years with longer times being associated with colder climates and little or no turning. Residents can produce compost at a higher rate by more frequently stirring the contents and moving the material through a series of containers. More detailed information about grasscycling is available in "Composting to Reduce the Waste Stream" (1991).

Implementation

An effective educational program and appropriate incentives must be provided to successfully implement on a community-wide basis. Chapter 1, "Public Education and Involvement," deals in depth with public education programs and readers are encouraged to review it along with the information provided below.

Public Education

The education program must describe how to do backyard composting and its benefits.

Developing a backyard composting program begins with an awareness program explaining why backyard composting is needed and providing information about various options and methods. More detailed information is then presented to encourage participation. Once backyard composting has been adopted, a continuing community relations program must report benefits, answer questions or concerns, inform new or nonparticipating residents, and encourage ongoing composting activities.

Some communities have found that working through schools or community groups can facilitate implementation of backyard composting. These groups provide a forum establishing communication channels. Some of these groups are already committed to environmental improvement as part of their mission. A variety of manuals have been prepared for backyard composting education programs. Contact your state's environmental agency or your local solid waste program for such publications.

Financial Support

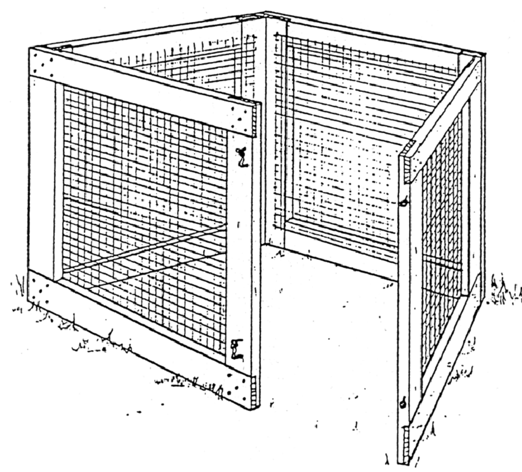
A community that is serious about implementing backyard composting as part of an integrated solid waste management program must appropriately support the program. Backyard composting can divert significant quantities of organic material and save money that otherwise would be spent on waste collection, processing, or disposal. Consequently, allocating funds to support a backyard composting program can prove cost-effective. In addition, diverting yard trimmings from the MSW stream can save landfill space.

Figure 7-6
Yard Trimmings Composting Units

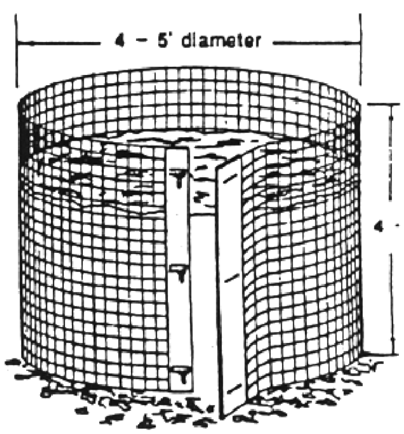
Residential Yard Trimmings Composting

- Holding units like these are used for composting yard trimmings and are the least labor- and time-consuming ways for residents to compost. Some units are portable and can be moved to the most convenient location. Non-woody yard materials are best to use. As you collect weeds, grass clippings, flowers, leaves and harvest remains throughout the year, place them in the bins.
- It can take four to six months or as long as two years to produce a good-quality compost using such units. Chopping or shredding the materials, mixing in high-carbon and high-nitrogen materials, and providing adequate moisture and aeration speeds the process.
- Sod can also be composted, with or without a composting structure, by piling it upside down (roots up, grass down), providing adequate moisture, and covering it with black plastic to eliminate light.
- Leaf mold can be made by placing autumn leaves in a holding unit for a year or more.
- Holding units can be constructed from circles of wire fencing, from old wooden pallets, or from wood and wire.
- Backyard composting of food scraps is regulated or prohibited in some communities. Residents should check with their local and state environmental agencies before attempting to compost food scraps.

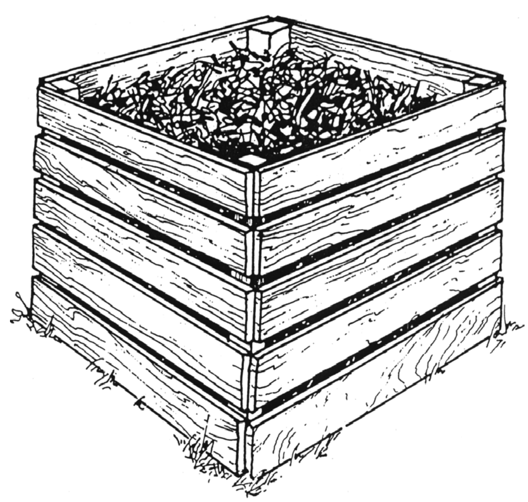
A. Portable Wood and Wire Unit



B. Wire Bin



C. Wooden-Pallet Unit
(Made from wooden pallets or pressure-treated lumber)



Sources: *Home Composting Handbook* 1992. A and B Reproduced by permission of the Seattle Engineering Department's Solid Waste Utility and the Seattle Tilth Association, Seattle, WA; C reprinted with permission from *Composting to Reduce the Waste Stream* (NRAES-43), N.E. Regional Agricultural Engineering Service, Cooperative Extension, Ithaca, NY 14853, 1991

Financial incentives may be needed.

Communities will need to provide financial support for public education programs. In addition, to further encourage participation, some communities have provided containers for composting. This represents a nominal per-household cost.

Some communities also provide incentives to encourage backyard composting or reduction in the generation of yard trimmings. For example, the City of Seattle allows home owners who do not generate yard trimmings to avoid paying a $2-per-month fee for yard trimmings pickup. Likewise, some communities charge for yard trimmings pickup separately, often by the bag, in an effort to induce home owners to reduce the quantity of yard trimmings produced.

Yard Trimmings Composting Programs

Off-site composting of yard trimmings is another alternative.

Composting yard trimmings is another very effective means of diverting significant quantities of materials from land disposal facilities. The challenge lies in managing the yard trimmings stream and the composting process in the most economic, nuisance-free manner. This challenge is formidable, since new material management techniques often require individual residents to do more than simply put bags of waste at the curb and may require communities to devise methods of handling materials that have already begun to decompose by the time they are picked up or delivered to a composting facility. Unless the benefits of composting are carefully explained to a community's residents, intense opposition to even the best-designed program can occur.

Grass and leaves make up the bulk of yard trimmings produced. Other materials include tree limbs, trunks and brush; garden materials such as weeds and pine needles; and Christmas trees.

Different types of yard trimmings decompose at a different rates and mixing them can affect the quality, marketability, and composting time of the finished product. To maximize system efficiency, it may be better to determine separately the proper handling method for each type of material. For example, rather than composting woody materials such as trees and brush, these materials may be better handled by chipping for the purpose of producing mulch. Wood chips are often in demand for use in community parks or highway projects. Likewise, tree trunks or large limbs can be cut and used as firewood.

Collection

Obviously, the most expedient and cost-effective option is *not* to collect yard trimmings in the first place. And for an increasing number of communities and states, barring or restricting the collection and disposal of yard trimmings is the option of choice. For many rural communities, a prohibition on disposing of yard trimmings at the local landfill can significantly reduce land disposal quantities. Refusing to accept yard trimmings may be enough of an incentive for local residents to change their habit of collecting and bagging leaves and grass.

Drop-Off Sites

For more urbanized communities, however, the "no collection" approach may create problems. For example, piles of leaves and grass may begin to show up in ditches and in open areas, where they pose local eyesores or nuisances. People may rake yard trimmings into roadways, creating transportation hazards, blocking sewer systems, or polluting local lakes and streams. For small or medium-sized communities, establishing a drop-off site may be the preferred method of collecting yard trimmings. Establishing a drop-off site allows a community to avoid yard trimmings collection costs by requiring that residents deliver the waste to a designated site. The site can be the compost facility or, for a larger community, a drop-off point where yard trimmings are collected and transported to a central composting location.

The drop-off approach gives people the option of removing the material from their yards, but requiring them to move it, still providing an incentive for

The method of collection depends on many factors unique to the community.

them to handle the material at home. A community can provide the composting service without having to worry about collection. Some small communities operating drop-off sites find that no additional personnel, equipment, or administrative costs are needed to run a successful site. If supervision is necessary, one person can usually oversee drop-off site operations.

The key to the success of a drop-off site is convenience. If drop-off sites are easy for most residents to get to (within a few miles of their homes), most will support the program. The proximity of the composting site always needs to be balanced against the chance of causing an odor nuisance in the community. Support for a drop-off program can often be increased by allowing local residents to take the finished compost for their own use. People can drop off a load of fresh yard trimmings and pick up a load of finished compost during one visit to the site.

Drop-off programs can present some problems for some residents. Often, elderly residents or those with physical problems are unable to carry the yard trimmings to the site without assistance. Others may also feel that transporting wet yard trimmings in plastic bags in a passenger vehicle is risky, because bags break. To avoid the costs and headaches involved in establishing a curbside collection program, it is worthwhile for a small or medium-sized community to work through these problems in order to make a drop-off site workable.

Curbside Collection

Some communities find that the drop-off approach does not satisfy their needs and decide to operate separate curbside collection programs. Collecting yard trimmings presents a variety of challenges. Because yard trimmings make up a significant portion of most municipal waste streams, handling it separately requires that decisions be made concerning pickup schedules and handling equipment. Revising pickup schedules to handle yard trimmings may require changing an existing route pattern and negotiating with unions or other labor representatives for increased staffing or overtime. If the community is served by a number of private haulers, the scheduling problems can become complex. In either case new equipment may be needed.

A major decision when establishing a curbside yard trimmings collection program is how residents should place the materials at the curb for pickup. The method of setting out yard trimmings will determine what equipment the community will need to efficiently pick it up. Different materials may need to be set out differently. A uniform policy should be made and enforced so residents know what is expected of them.

Different materials may need to be set out differently.

One method for setting out yard trimmings is to require that residents rake leaves, grass, or brush into piles to be collected at the curb. The material should either be placed between the sidewalk and the curb or in the street close to the curb. Different pieces of equipment are designed to collect the material in different locations. For example, a vacuum truck to collect leaves usually requires only that leaves be placed between the curb and the sidewalk. Other collection equipment, such as sweepers, may require that the material be in the street.

Yard trimmings piled in the street can cause other problems. Cars may run into and scatter the piles or children may play in them, creating a safety hazard. Precipitation can wash some of the piles into sewers, creating a flooding hazard or adding to the pollution load in the wastewater system.

Noncontainerized piling may work best for leaves and brush. Leaves tend to be light and dry and easily collected. Piled brush is fairly easily chipped and transported. Grass, on the other hand, is often dense and wet, and can create objectionable odors if left piled for more than a few hours.

For ease in handling yard trimmings, bags are often used. Frequently the bags used are made of materials that must be segregated from the yard trimmings. Removal steps can be costly, requiring either extra labor time or special processing equipment. Odors may also be a problem when emptying bags containing highly decomposable grass clippings.

Significant efforts have been made to eliminate the need to debag yard trimmings by developing biodegradable bags or by using paper bags. Each have shown promise, but reliability and cost constraints have limited their implementation. Ideal bags have the following features: they securely hold the yard trimmings until the bag has reached the composting site, are easily punctured or broken open so air can enter the materials, and they biodegrade in the compost as the materials are stabilized.

Rather than using bags, some communities use permanent bins for storing yard trimmings. For example, in a pilot program, the city of Omaha, Nebraska, has provided a group of residents with a 90-gallon, plastic, wheeled cart for storing yard trimmings. The carts are wheeled to the curb where they are lifted by special hoists and the contents dumped into a packer truck. Using these covered carts has reduced problems with odors and has generally been well accepted by Omaha's residents. Conventional garbage cans should not be used for yard trimmings because they are very heavy when full and can cause injury to workers when the cans are lifted into packer trucks.

Whether yard trimmings are collected loose, in bags, or in bins determines the type of collection equipment needed.

The decision to collect yard trimmings loose, in bags, or in bins will help determine the equipment that will be needed to efficiently collect the yard trimmings. Yard trimmings collection equipment can be divided into two categories: gathering devices and transport vehicles. Gathering devices move the yard trimmings from the street to the transport vehicle, which takes the trimmings to the compost site. Some equipment performs both functions. Still others are general purpose vehicles that handle yard trimmings using special attachments.

The types of gathering devices needed will depend on material types to be collected and how residents store the material at the curb. For leaves stored between the sidewalk and the curb, vacuum leaf collectors are popular. These collectors suck the leaves into a shredder, which blows the leaves into a collection vehicle. For some units the leaves are compacted as well. These units can be damaged if snow and ice are present in the leaf pile. Vacuum collectors may be used to collect grass, but materials with a higher moisture content are more difficult to handle with a vacuum truck.

A number of collection options are available for yard trimmings piles placed in the street near the curb. Front-end loaders are the most popular, since most communities already have one. Front-end loaders can pick up the yard trimmings and place them in a dump truck. For tight spaces or small piles, a dust or leaf pan can be attached to a jeep for similar collection. Street sweeper-type broom collectors are also becoming popular. These gathering vehicles sweep the yard trimmings into a processor where they are shredded and transported to a collection vehicle. The problem with this type of collection is that the curb must normally be free of vehicles for the broom system, which is normally quite long, to have free access to the curb.

Most communities use tree chippers to collect brush and wood. The chipper processes the material at the curb, and trucks transport the chips to a re-use site or disposal site. Some communities also run larger, high-volume chippers at the compost site, and transport unprocessed wood there to be chipped.

Combined Approaches

A combination of collection approaches may be best.

Many communities use a combined approach to manage yard trimmings. For example, Madison, Wisconsin, offers curbside pickup of leaves for limited periods in the spring and fall. Grass is not picked up, to encourage grasscycling and home management, but a number of drop-off sites have been established for those residents still desiring to remove grass or other greenery such as weeds from their property. Brush is picked up and chipped on a monthly schedule. Local private haulers offer pickup service as well. By looking at each type of yard trimming material separately, the most economic, efficient, and politically acceptable management approach can be chosen for each.

Preparing Yard Trimmings for Composting

If the drop-off or curbside collection program is managed to limit the inclusion of undesirable materials, a minimum of effort is needed to prepare yard trimmings for composting. Bags must be emptied or somehow punctured to allow air to pass through. When contamination is a problem, special steps must be taken to segregate and separately dispose of the undesirable materials, which can be very time-consuming and costly.

Pre-shredding of yard trimmings can speed up the rate of decomposition. However, besides increasing operational and equipment costs, pre-shredding will also increase the oxygen demand of the windrow, and require more pile turning or the use of forced aeration to avoid odor problems. For most yard trimmings composting programs, pre-shredding is probably not necessary.

Applicable Composting Technologies

There are a variety of methods for processing yard trimmings. In deciding which option or options to employ, the best approach is to try to adopt the simplest method available.

The most common method for yard trimmings composting is the windrow. With this method the material is placed in piles, which are turned periodically. By carefully choosing the pile sizes, the rate of decomposition can be optimized.

The windrow method is the most commonly used technology for composting yard trimmings.

Windrow composting works especially well with leaves, which break down more slowly than grass clippings. This makes management easier and the creation of nuisance conditions less of a problem. Where both leaves and grass are to be composted in the same pile, it is suggested that leaves be composted first and grass added later. Mixing the new grass with the already partially composted leaves reduces the potential for odor problems to develop. Grass decomposes quickly, sometimes even in the bag, and often will begin to emit objectionable odors associated with anaerobic decomposition very quickly unless the leaves are mixed with dryer, more stable materials as soon as possible. A 1:1 weight ratio (3:1 to 5:1 by volume) of leaves to grass clippings is desirable to provide an optimum carbon-to-nitrogen ratio, but a higher ratio of leaves to grass may be necessary to reduce odor potential. When the leaves and grass are collected also influences the ratio. If only leaves are collected, supplemental nutrients may be necessary.

For communities with large areas of sparsely inhabited land available to them, the "low-effort" composting approach may be the most economical.

For communities with large areas of sparsely inhabited land available to them, the "low-effort" composting approach may be the most economical. In the low-effort approach, windrows are formed and usually turned only once a year. Because infrequent or no turning creates anaerobic conditions in the windrow pile, the low-effort approach can be associated with strong odors when the pile is turned. If this approach is used, it is suggested that a large buffer zone be available. The low-effort approach usually takes about three years to make usable compost. Its advantage is that it takes only a few days per year of the community's personnel and equipment to operate the entire program.

Scientists at Rutgers University developed an effective method for composting leaves. In this approach, windrows are made large enough to conserve the heat of decomposition, but not so large as to overheat the piles, which adversely affects the microorganisms. The goal is to maintain an optimal temperature in the pile throughout the composting time period.

The Rutgers process is to receive leaves in a staging area rather than dumping them on the ground and immediately forming windrows. By using a staging area, the materials are better distributed in the windrow pile. Contamination of the feedstock can also be kept to a minimum. The leaves are formed into piles using a front-end loader, which moves the material from the staging area to the composting area. One acre can handle about 3,000 cubic yards of material.

As the front-end loader breaks the masses of leaves apart in preparation for creating the windrow, water is sprayed on the leaves. A rule of thumb is that 20 gallons of water are required per cubic yard of leaves collected. The need to add water can also be reduced by forming a flat or concave top on each windrow to catch rain or other precipitation, which then filters down through the material.

Once each windrow is formed, the piles should be monitored for temperature and moisture content. Any odor inside the windrow should be investigated to determine if an area of anaerobic decomposition is present in the pile (the largest volume of leaves is generated in the fall).

After approximately a month, the windrow piles should be about half their original size.

After approximately a month, the windrow piles should be about half their original size. Two piles should then be combined to form one pile of approximately the original size. Combining the piles will add needed oxygen to the process, as well as help conserve heat during the oncoming colder weather. The combined piles can be allowed to sit during the winter, but should be turned as soon as practical in the spring. Additional turnings throughout the spring and summer will enhance the rate of decomposition and ensure that pathogens and weed seeds present in the compost pile are destroyed. By late summer, the pile can be moved to the outer perimeter of the compost site and allowed to cure until the following spring.

Another approach initiated by Ramsey County, Minnesota can be used to compost both leaves and grass even during the cold winters in northern areas. First, windrows are built from leaves collected in the fall. The windrows are constructed with flat tops to retain water, but no additional water is added. The windrow is left in place during the winter to conserve the carbon. During the following spring and summer, new materials, including about 25 percent by volume grass clippings, are mixed into the existing pile. The windrow is turned by rolling it over into an adjacent area where it remains until the following spring, when it is rolled again and left for final curing. This composting process takes about 18 months to produce a finished compost.

Aerated static pile composting is also a possibility for yard trimmings. The advantage is that piles do not need to be moved, a premium where space is limited. The effectiveness of forced aeration may, however, decline if air channels develop in the pile. A similar approach is used in Maryland (Gouin, 1994). In the fall, the leaves are placed in windrows 6’-8’ high and 10’-15’ wide at the base. The windrows are left undisturbed all winter long. In the spring, as soon as the grass clippings are received, they are applied to the windrows at a 1:1 ratio by volume and mixed. This is accomplished by placing a windrow of grass clippings, of equal size, adjacent to the windrow of leaves and blending them together. This technique makes maximum use of all the available carbon from the leaves and minimizes odor problems from the composting of grass clippings. When there is an insufficient amount of leaves to dilute the grass clippings, ground brush is used at the same 1:1 ratio by volume. However, when using ground brush as a bulking agent, the piles can be recharged at 4 to 5 week intervals at the same 1:1 ratio (Gouin, 1994).

Facilities developed for yard trimmings composting must be carefully planned.

Facilities developed for yard trimmings composting must be carefully planned. The facility should be designed to efficiently receive yard trimmings from both large and small vehicles. Adequate space must be available for composting windrowing, curing, and storage. An example layout for yard trimmings composting is shown in Figure 7-7.

Processing for Markets

It may be necessary to shred and screen finished yard trimmings compost to satisfy market specifications. Sticks, twigs, other woody materials, or stones may make the compost unattractive to potential users. If the compost might be used in parks for a highway project, additional shredding and screening may not be necessary.

Product Characteristics of Yard Trimmings Compost

Yard trimmings compost has fewer plant nutrients than municipal wastewater treatment plant biosolids, livestock manure, or MSW-derived compost.

The compost's characteristics should be monitored.

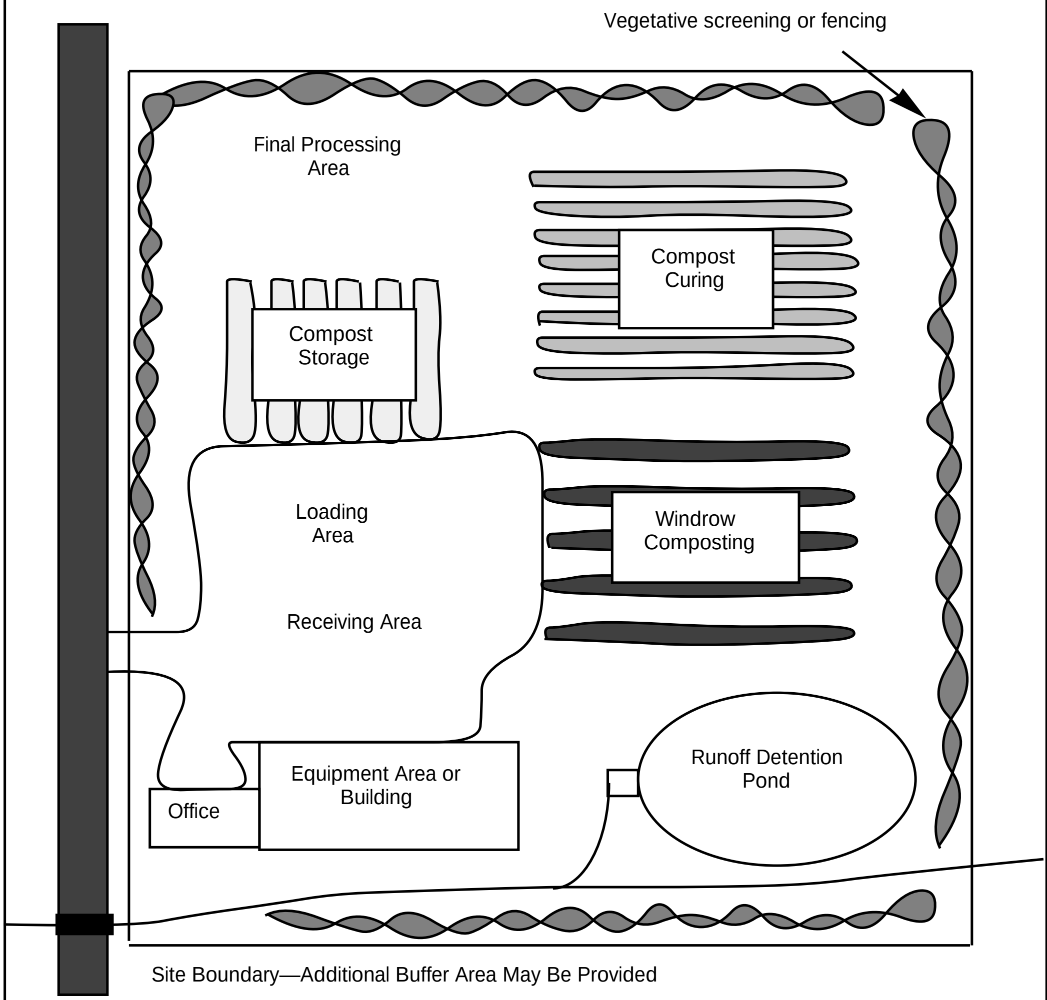
Samples of the finished yard trimmings compost should be analyzed for plant nutrients. On the other hand, heavy metal and pesticide contaminants are detected less often or are at lower concentrations in yard trimmings compost than in compost made from mixed MSW. Table 7-6 shows heavy metal concentrations found in two yard trimmings compost programs. The heavy metal contents varied, but remained below levels of soil concentrations toxic to plants, as well as below maximum levels established in Minnesota and New York for co-composted MSW and municipal sludge biosolids. Pesticide concentrations are shown in Table 7-7. Studies by Roderique and Roderique (1990) and Hegberg et al. (1991) indicate that under normal conditions heavy metals and pesticide residues detected in yard trimmings compost have generally been insignificant. Periodic testing should be done to determine if unanticipated concentrations of metals or pesticides are present in the finished compost.

Direct Land-Spreading of Yard Trimmings

Rather than compost yard trimmings, some communities and private haulers are directly land-spreading yard trimmings with agricultural or specially adapted distribution equipment. This approach bypasses the need to site and

Figure 7-7

Example of Yard Trimmings Composting Facility Site Layout



Source: University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 199

Table 7-6
Heavy Metals in Yard Trimmings Compost

Heavy Metal	Croton Point, New York	Montgomery Co., Maryland[a]	Standard[b]
Cadmium (ppm)	ND[c]	<0.5	10
Nickel	10.1	NA[d]	200
Lead	31.7	102.7	250
Copper	19.1	35.5	1000
Chromium	10.5	33.6	1000
Zinc	81.6	153.3	2500
Cobalt	4.2	NA	NS[e]
Manganese	374.0	1,100.0	NS
Beryllium	15.0	NA	NS
Titanium(%)	0.09	NA	NS
Sodium	1.51	0.02	NS
Ferrous	2.67	0.96	NS
Aluminum	3.38	0.66	NS

(a) Average of 11 samples 1984-1985.

(b) For pesticides, standards are derived from USDA tolerance levels for pesticided in food (40 CFR Chapter 1, Part 180). For metals, standards are Class 1 Compost Criteria for mixed MSW compost, 6 NYCRR Part 60-5-3.

(c) ND = not detectable (d) NA = not available (e) NS = no standards

Source: J. O. Roderique and D. S. Roderique, 1990

operate composting facilities. The yard trimmings may be directly incorporated into the soil or left for later incorporation.

Some communities directly land-spread yard trimmings.

Direct land-spreading programs do have advantages, but they require careful management for several reasons to avoid soil fertility problems if the carbon:nitrogen ratio is too high. First, the available nitrogen in the soil may become tied up in the yard trimmings decomposition process and not be available to the crop. In addition, weed seeds, excessive runoff of organic materials, and odors may pose problems if the spreading site is poorly managed. Some state regulatory authorities may view spreading as a disposal practice and require special permits. Research is underway to better characterize the special challenges associated with higher-rate land-spreading of yard trimmings and the benefits of introducing additional organic matter into the soil profile.

Source-Separated Organics Composting

Source-separated organics composting is a relatively new approach being implemented, in part, to overcome some of the limitations of mixed MSW composting. The definition of source-separated organics is somewhat variable: food scraps are common to all definitions, yard trimmings may be included, and some programs handle small quantities of paper.

Waste Collection

In source-separated composting programs, organics are collected separately from other materials, such as recyclables and noncompostable material. The source-separated material is collected from residences and selected businesses, such as restaurants. Because these materials have a high moisture content, special liquid-tight containers are necessary for transporting them.

In European programs, specially made metal or plastic containers are provided to residents for their organic materials. A demonstration project in

Composting organic materials that have been kept separate from other materials reduces quality and production problems.

Connecticut collected the materials in conventional garbage bags onto which the residents placed brightly colored stickers indicating "Compostable Materials." The stickers helped the collection vehicle operators identify the organics and also helped remind the residents to carefully separate out their organic materials.

Given the innovative nature of this approach, special educational programs should accompany implementation. The primary advantage of source-separated organics composting is the ability to produce compost that is essentially free of contaminants. Accomplishing this depends on the conscientious efforts of generators and an effective collection program.

Preparing Materials for Composting

Depending on the material types collected, shredding may be necessary to reduce particle size for the particular compost technology being used. A bulking agent such as wood chips may also be necessary.

Table 7-7

Pesticide Analysis of Portland, Oregon, Yard Trimmings Compost

Pesticide Classification	Residue	Number of Samples[a]	Samples Above Detection Limit[b]	Mean[c] (mg/kg)	Range[c] (mg/kg)
Chlorophenoxy Herbicides	2,4-D	16	0	ND[d]	–
	2,4-DB	16	0	ND	–
	2,4,5-T	16	0	ND	–
	Silvex	16	0	ND	–
	MCPA	16	0	ND	–
	MCPP	16	0	ND	–
	Dichloroprop	14	0	ND	–
	Dicamba	16	0	ND	–
	Pentachlorphenal	14	9	0.229	0.001-0.53
Chlorinated Hydrocarbons	Chlordane	19	17	0.187	0.063-0.370
	DDE	14	3	0.011	0.005-0.019
	DDT	8	0	ND	–
	opDDT	14	2	0.005	0.004-0.006
	ppDDT	14	4	0.016	0.002-0.035
	Aldrin	16	1	0.007	0.007
	Endrin	16	0	ND	–
	Lindane	16	0	ND	–
Organophosphates	Malathion	14	0	ND	–
	Parathion	14	0	ND	–
	Diazinon	14	0	ND	–
	Dursban	15	1	0.039	0.039
Miscellaneous	Dieldrin	13	1	0.019	0.019
	Trifluralin	10	0[e]	–	–
	Dalapon	4	0	ND	–
	Dinoseb	5	1	0.129	0.129
	Casoron	8	0[e]	–	–
	PCBs	8	0	ND	–

(a) The number of samples is the combined total for 2 sources of compost sampled in June and October 1988; April, July and October 1989. The number of samples taken was not uniform (mostly 2 per period per source in 1988 and 1 per period per source in 1989).

(b) The minimum detection limit is 0.001 ppm for pesticides and 0.01 ppm for PCBs. (c) Dry basis

(d) Not detectable (ND) (e) Residue detected but not measurable

Source: Hegberg et al., 1991

Applicable Composting Technologies

New technologies are becoming available for source-separated organics composting.

Each of the technologies applicable to mixed MSW composting is also appropriate for source-separated organics. Special attention, however, must be given to nutrient balances. In-vessel systems with windrow or aerated static pile for curing are the most commonly used technologies. Methods for applying anaerobic digestion technology to this type of material are currently under study (Tchobanogous, 1993). Researchers have found that using an anaerobic digester followed by an aerobic digester composted almost all the biodegradable fraction of the organic matter in the feedstock.

Processing for Markets

In one Connecticut study, source-separated organics compost was screened twice: first after agitated bay composting and a second time after windrow curing (see Figure 7-8). Approximately 4 percent of the collected material was screened out by the first 2-inch screen and defined as non-compostable. The remaining cured compost was then passed over a 3/8-inch screen. Approximately 12 percent of this material was retained on the second screen and sent to a landfill. The discarded material included wood chips, brush, and some plastic film.

Product Characteristics of Source-Separated Organics Compost

Published studies to date of cured compost have found heavy metals and other chemicals to be in concentrations far below levels of concern. The chemical analysis is summarized in Table 7-8, which also shows heavy metal concentration in a mixed MSW compost for comparison.

Mixed MSW Composting Systems

Mixed MSW composting has been successful in a number of communities but has failed in several others.

Because a significant portion of residential and commercial solid waste is compostable, MSW composting programs can divert a substantial portion of a community's waste stream from land disposal. Composting, which requires sophisticated technology and specially designed facilities, has been successfully implemented in a number of communities but has failed, with rather dire financial repercussions, in several others.

Collection

The source of feedstock for a mixed MSW composter is usually conventionally collected residential and commercial solid waste. The type of collection container does not significantly impact the mixed MSW composting system, but bags must be opened before or during the process. A variety of materials that must be removed by screens later enter the composter.

The quality of the feedstock and consequently the compost product is enhanced when potential contaminants are segregated from the input stream. For example, a recycling program that diverts glass reduces the amount of glass in the compost. A program for source segregating household hazardous wastes has similar benefits. Careful supervision of materials collected from commercial facilities may forestall entry of potential contaminants from those sources.

Preparing Materials for Composting

As a first step a mechanical device may open the garbage bags. After the bags are opened some composting systems have conveyor lines, which move the materials past workers who manually remove recyclables. It is also inspected to detect undesirable materials. The waste is then shredded. This is usually

Waste preparation is a critical step.

accomplished by a low-speed shredder or by the grinding action that occurs in the first stage of an in-vessel composter.

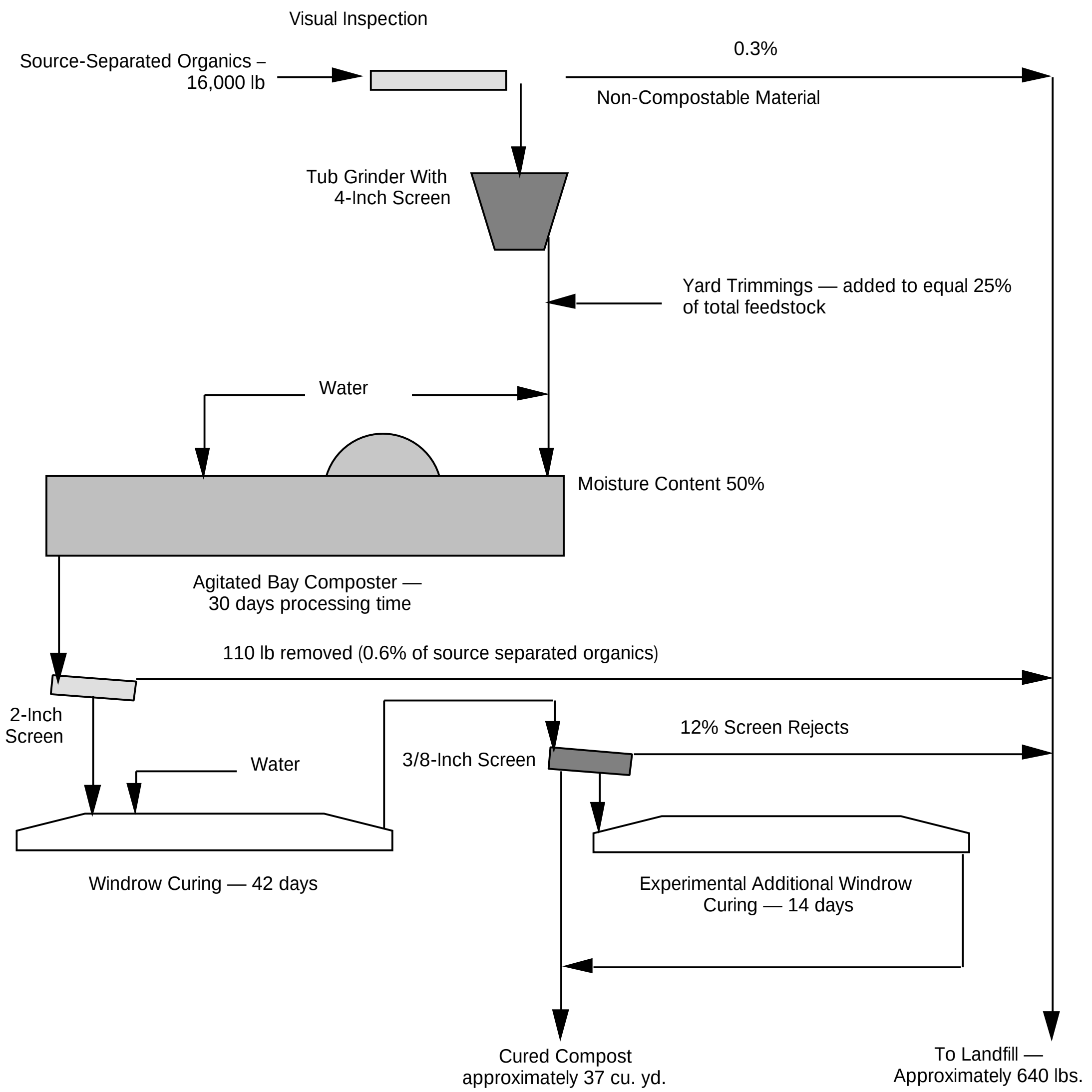
At some mixed MSW composting facilities the feedstock, after shredding, is more extensively processed through screens and trommels to segregate plastics, dirt, and other materials that are not suitable for composting. Magnetic and eddy current separation can be used to recover ferrous and aluminum. The recent trend appears to more aggressively process the waste stream before composting to improve its quality and to capture recyclables.

Applicable Composting Technologies

Typically, a two-stage process is used for composting mixed MSW. The first stage promotes rapid stabilization of the feedstock and the second stage achieves final curing. Aerated static pile, in-vessel, or anaerobic processes are

Figure 7-8

Example of Source-Separated Organics Composter Material Flow and Mass Balance



Source: Wet Bag Compost Demonstration Project, Greenwich and Fairfield, Connecticut, 1993

Compare the various technologies before selecting a mixed MSW composting system.

usually the first stage, and turned windrow or aerated static pile is the second-stage curing technology. The combination of technologies depends on the proprietary process selected, space considerations, and operating preferences.

No single technology has an outright advantage over another but recent experience has shown that a system must be carefully developed and operated to achieve success. Several large mixed MSW composting facilities have closed as result of operational problems, principally odors. Often, inadequate financial support is a contributing factor, as it precludes solving odor and other problems.

Aerated static piles are best suited to sites which have suitable land available for the piles and a buffer area. The shredded MSW is placed in piles that are 5 to 8 feet high and 10 to 16 feet wide. A critical design factor is to achieve uniform distribution of air through the length of the pile. A 6 inch cover of cured compost is initially placed over the pile to control odors. In the negative pressure mode, air is drawn into the pile by blowers that then discharge into a biofilter of cured compost. The cured compost acts as an odor filter. A positive pressure aeration system involves blowing air into the compost pile. This approach is simpler to set up but is more susceptible to odor problems. The pile's internal temperature is monitored to assess process performance. Compost is ready for final curing in 6 to 12 weeks.

Table 7-8

Examples of Inorganic Constituents in Compost

Inorganic Constituents (ppm)	Wet-Bag Compost[a]	Source Separated Organics[b]	Mixed MSW[c]
Regulated Elements			
Arsenic	2.1		
Cadmium	1.2	0.8	7.0
Chromium	20.0	29.0	180.0
Copper	173.0	43.0	600.0
Lead	92.0	76.0	800.0
Mercury	1.7	0.2	
Molybdenum	<22.0		
Nickel	17.0	7.0	110.0
Selenium	<1.0		
Zinc	395.0	235.0	1700.0
Other Elements			
Aluminum	5700.0		
Antimony	<140.0		
Barium	172.0		
Beryllium	0.26		
Boron	<29.0		
Calcium	19000.0		
Chloride	4400.0		
Cyanide	<1.0		
Iron	9600.0		
Magnesium	3600.0		
Manganese	440.0		
Silver	<6.0		
Sodium	1800.0		
Titanium	230.0		

Sources: (a) D. Stilwell, 1993 (b) U. Krogmann, 1988 (c) J. Oosthnoek and J. P. N. Smit, 1987

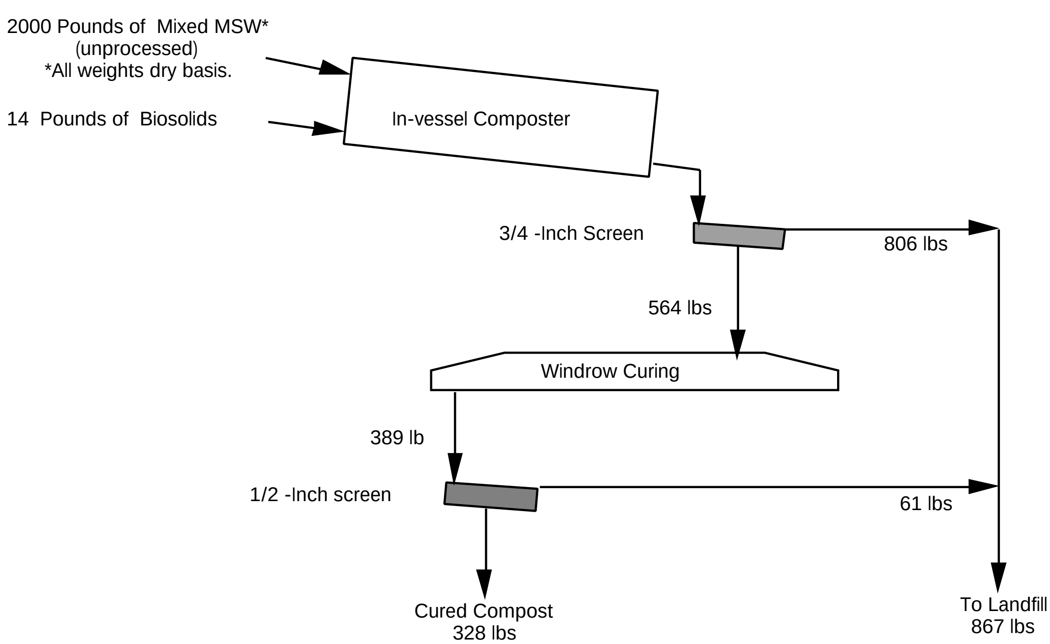
Several alternative configurations are available for the aerated static pile. The pile may be periodically turned to ensure more uniform compost production. Feedstock placed in piles may be located between retaining walls. Air is distributed through the floor and the stabilizing compost is periodically agitated.

Currently the most common type of in-vessel systems are an inclined rotating drum into which MSW is loaded in time periods ranging from every few minutes to hours. The MSW may not have been previously shredded depending on the particular proprietary process being used. The waste moves gradually down the inclined drum towards a discharge hatch. The hatch, when open, allows compost to be discharged. The detention time in the drum ranges from 3 to 15 days. After the mixed MSW compost exits the drum it may be screened to remove large objects that did not biologically decompose or were not mechanically broken down in the drum. The material passing through the screens is ready for further composting or final curing if the drum has a long detention time. The waste retained by the screens is usually landfilled. A material flow and mass balance for an in-vessel composter is shown in Figure 7-9. Other configurations of in-vessel systems are produced by various manufacturers. Each design should be carefully evaluated when selecting equipment.

Odor problems occurring with aerated static pile and in-vessel mixed MSW composting have been the principle operating problem. Operating controls must be carefully managed to insure that aerobic conditions are maintained throughout the entire system. Various types of odor control equipment have been installed to filter or mask odors. An experienced technical specialist should be consulted for incorporating odor control methods in the process.

Figure 7-9

Example of Mixed MSW Composter Material Flow and Mass Balance



Feedstock		Output		
Mixed MSW	2000 lbs	Cured Compost	328 lbs	16 %
Biosolids	14	Landfilled Residue	867	43
Total	2014	Weight Lost to Atmosphere	819	41
		Total	2014	100

Source: Razvi and Gildersleeve, 1992

Anaerobic processes have been studied extensively for mixed MSW but there is only limited full-scale operating experience. Higher capital costs and operating problems during testing appear to be the principle factors that have slowed using anaerobic processes for mixed MSW. These systems are totally enclosed and therefore less subject to odor problems than aerobic systems. Methane is produced as a by-product so that the net energy balance is positive.

Once the feedstock has completed first-stage composting it is ready to be cured. Curing is a continuation of the composting biological process but at a slower rate and is less equipment- and cost-intensive. Windrows that are periodically turned, aerated static piles, or a combination of the two, are the normal curing method. Curing usually takes 3 to 9 months.

Processing for Markets

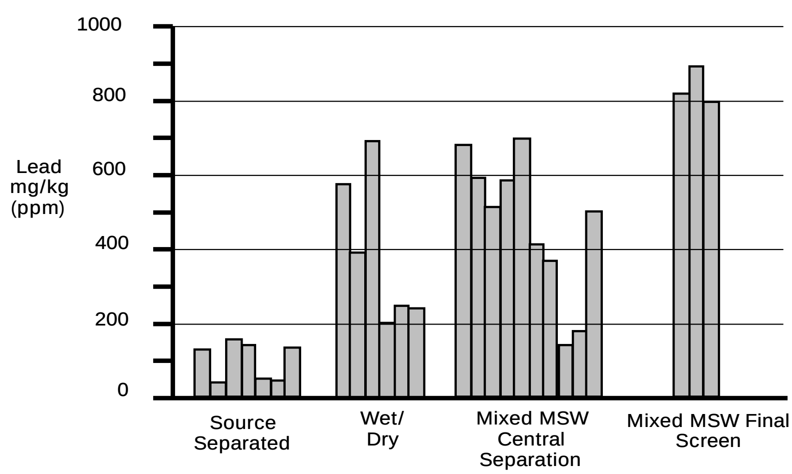
When curing is completed, the mixed MSW compost is ready for final processing. This usually involves a one- or two-stage final screening to remove inert materials and possibly an intermediate grinding step to reduce particle size. The final processing depends greatly on the needs and specifications of the compost users.

Product Characteristics of Mixed MSW Compost

The composition of mixed MSW compost is influenced by feedstock characteristics, collection methods, processing steps, and composter operating procedures.

In order to market mixed MSW compost to many end users, concerns about potential threats to plants, livestock, wildlife, and humans must be addressed. One of the primary concerns is the presence of heavy metal compounds (particularly lead) and toxic organic compounds in the MSW compost product. To date, where problems have occurred with mixed MSW compost, they have resulted from immature composts, not metals and toxic organics (Chaney and Ryan, 1992; Walker and O'Donnell, 1991). Manganese deficiency in soil and boron phytotoxity as a result of mixed MSW compost application can be potential problems. Measures, including further separation by generators or at the facility, can be taken to prevent problems and produce a high quality compost. Figure 7-10 shows the variations in lead concentrations which have been reported in different types of compost. The influence of source separation on lead content is readily apparent. The composition of mixed MSW compost is influenced by feedstock characteristics, collection method, processing steps, and composter operating procedures.

Figure 7-10
Lead Concentrations in Various Types of Compost



Source: T. Richard and P. Woodbury, 1993

Testing compost for chemical constituents must be carefully planned and executed. Wide variations in metal concentrations within the same compost pile have been reported. Woodbury and Breslin (1993) found only small variations in copper concentration at one compost facility. However, ten samples collected at a second facility had copper concentrations ranging from 300 to 1180 parts per million. Sampling and testing programs for mixed MSW compost must be carefully planned and executed. The program must recognize the inherent variations that will influence test results. See Cornell Waste Management Institute MSW Composting Fact Sheet #7, "Key Aspects of Compost Quality Assurance," for more detailed information regarding sampling and testing protocols.

OPERATIONAL CONSIDERATIONS AND CONCERNS

Housekeeping

The appearance of the compost facility should be appealing from the outside. Any wind-blown paper near the site should be picked up routinely. Streets, parking areas, and weighing areas should be free of dust and mud. Use as much compost as needed to provide landscaping for the site.

Indoors, the floors and equipment should be cleaned periodically and maintained in a dust-free manner. Areas where compost or other recovered materials are likely to spill should be cleaned immediately when spills occur. The cause of the spill should be taken care of immediately.

Leachate

Poor water management at a compost site can lead to water pollution and odor problems.

Leachate is the free liquid that has been in contact with compost materials and released during the composting process. Even well-managed composting operations will generate small quantities of leachate. Leachate pools are a result of poor housekeeping and may act as a breeding place for flies, mosquitoes, and odors. Leachate can also contaminate ground- and surface-water with excess nitrogen and sometimes other contaminants. For these reasons, leachate must be contained and treated. It is advisable for the composting facility design to include a paved floor and outdoor paved area equipped with drains leading to a leachate collection tank. Leachate may be transported and treated at a wastewater treatment plant or mixed as a liquid source with the incoming material. Leachate may contain pathogens, and therefore must not be returned to material that has been through the pathogen destruction stage.

Piles left outdoors (without a roof) will be exposed to rain, which will generate leachate. Attempts must be made to minimize leachate production by diverting any surface-water runoff from the up-slope side of the piles. Another method is to shape the peak of the pile concave, so the rain water will soak into the pile rather than shed off the pile.

Odor and Dust Control

Offensive odors may be generated during the active stage of composting. The intensity of odors increases if composting conditions are not controlled within narrow tolerance limits from the ideal. Process air should be routed through filters, deodorizers, or scrubbers before it is exhausted to the atmosphere. If there are odors, the specific source and type of odor should be identified; this may be difficult to do with mixed MSW. Masking agents are specific to certain types of odors and have worked with a limited degree of success. Scrubbers are efficient in removing a significant portion of odors, but they do not remove all odors.

The use of "biofilters" in composting to treat odorous compounds and potential air pollutants is expanding. Biofiltration involves passing odorous gases through a filtration medium such as finished compost, soil, or sand. As the gases pass through the medium, two removal mechanisms occur simultaneously: adsorption / absorption and biooxidation (Naylor et al. 1988, Helmer, 1974). The biofilter medium acts as a nutrient supply for microorganisms that biooxidize the biodegradable constituents of odorous gases.

The degree of odor control needed depends in part on the facility's proximity to residences, businesses, schools, etc. For example, some facilities located in remote areas have operated without any odor control devices.

Odor and dust control require careful attention to a number of operational factors.

Odors can also be generated if unprocessed or processed feedstock containing putrescible materials has been stored for an extended period. Every attempt should be made to process the feedstock as soon as possible after it is received, while it is in optimal condition for composting.

Air from the tipping floor and material processing and separation areas and exhaust air from the actively composting materials should be captured and treated or diluted with large amounts of fresh air before it is dispersed into the atmosphere. Exhaust air from composting materials is generally warm and almost always contains large amounts of moisture. This air may be corrosive and could affect equipment and buildings. During winter months, if ambient temperatures are cool, exhaust gases can fog up the work area, affecting visibility; the resulting condensate can affect the electrical system. This is common in northern climates where piles are placed indoors and turned.

The ventilation system must be able to remove the humidity and dust from the air. Adequate fresh air must also be brought into the buildings where employees are working. In such work areas, the air quality should meet minimum federal standards for indoor air quality.

In addition, operators should be aware of *Aspergillus fumigatus*, a fungus naturally present in decaying organic matter. It will colonize on feedstocks at composting facilities. Spores from the fungus can cause health problems for some workers, particularly if conditions are dry and dusty. Workers susceptible to respiratory problems or with impaired immune systems are not good candidates for working in composting facilities.

Siting a facility at a remote location so as to provide a large buffer zone between the composting facility and any residents should help alleviate odor-related complaints.

Personnel

Composting facility personnel are responsible for operating the plant efficiently and safely. Personnel must be trained so they understand all aspects of the composting process. Employees should appreciate the public relations impact the facility may have, and they should be taught to portray a positive image at all times. Employees should be trained in safety, maintenance, monitoring, and record keeping at the facility. Employees should also understand the environmental impacts of the finished compost and liquid / gas release to the atmosphere.

Monitoring

Routine testing and monitoring is an essential part of any composting operation. Monitoring the composting process provides information necessary to maintain a high-quality operation. At a minimum the following should be monitored:

- compost mass temperatures
- oxygen concentrations in the compost mass
- moisture content
- particle size

- maturity of the compost
- pH
- soluble salts
- ammonia
- organic and volatile materials content.

Record Keeping

Record keeping is an essential part of any operation. Maintaining detailed records provides a historical record of the operation and the improvements made over the years. Good records also provide a basis for building political support. Periodically evaluating records helps identify where improvements are needed and provides information necessary for making the operation more efficient. Records are the basis for quality control, safety, and minimizing down time in any operation. Records should be kept on employee safety training, facility and employee safety procedures, and health monitoring at the facility.

Good record keeping can result in better decision making in the long run.

The importance of keeping good records should be understood by all employees. They should be trained in accurate record-keeping methods and should know that they will be held accountable for keeping accurate records. At a minimum the following records should be maintained:

- incoming materials (solid and liquid) weights and types
- recyclables recovered and shipped
- noncompostable fraction recovered and shipped to landfill
- amount of compost made/shipped in different forms (buyer/client lists)
- amount of residence time required to make the compost (time, material received, placed into windrows, turning frequency, etc.)
- inventory of supplies/equipment
- maintenance record of equipment
- routine monitoring data
- marketing and distribution
- permits and approvals
- monitoring and testing
- accidents
- personnel (training, evaluation, health)
- expenses and revenues
- major problems and how they were corrected
- complaints and how they were resolved
- public information and education activities
- health and safety training, procedures, and precautions.

Public Information

Open, positive, communication with community leaders and neighbors should be ongoing. Good communication is critical if there is a problem at the site. Brochures describing the facility and its operations should be printed and distributed throughout the community. Neighbors, civic organizations, and school groups should be invited to take educational tours of the facility. Well-trained employees who understand the facility and its impact on the community can also contribute to public relations.

Objective, factual information should be continuously distributed to the public.

To ensure good relations, the public should be periodically informed of the types of materials accepted, those that are not accepted, and the collection schedules. If the finished compost is to be made available for public distribution, a distribution policy (costs, potential uses, when and where to pickup, risks, etc.) should be developed and publicized in the community. A well-planned and executed public information program can build significant support for the facility. The community needs to be periodically reminded that composting is an effective management tool and that having such a facility is evidence that the community is progressive and environmentally conscious.

Complaint Response Procedure

A complaint and response procedure must be developed. For all complaints, the names, time, date, nature of complaint, and the response made by facility personnel should be recorded. Any action taken must be communicated to the person complaining and recorded.

Complaints should be promptly responded to.

The most common complaint is about odors. These complaints normally come from those most likely to be exposed—neighbors. Individuals' sensitivity and tolerances to odor varies and some neighbors may call more frequently than others. Take all complaints seriously and attempt to resolve the situation as soon as possible after the complaint.

FACILITY SITING

One of the most important issues in selecting a composting site is its potential to generate odors. Odors from a facility can be strong enough to cause public opposition. When odors become a problem, public pressure may be intense enough to force the facility to close.

Every attempt should be made to minimize the impact of odors to local residents. It is best to avoid sites that may be located close to populated areas of a community. A thorough evaluation of the microclimatology (local weather conditions such as prevailing wind direction) of a potential site is critical to avoid future complaints from neighbors. Odor control devices should be installed, but their installation may add significantly to costs, and alone may not guarantee complete odor removal.

Other nearby odor sources should be evaluated. Locating a composting facility in a comparable land use zone such as at a landfill or wastewater treatment plant site may be one option. The neighboring land use may somewhat influence the sizing of the odor control equipment installed at the composting facility. In addition, zoning requirements may allow the composting facility and landfill wastewater treatment plant to be sited together.

Many factors must be considered when selecting a composting site.

Construction of a composting facility at an existing landfill has its benefits. One of the major advantages is the savings in transportation costs for the noncompostable and nonrecyclable wastes. A second advantage is that the difficulty of acquiring a site is significantly reduced. In addition, the neighbors are accustomed to the traffic patterns of the waste hauling trucks.

If composting biosolids is a project objective, locating the facility at the wastewater treatment plant should be considered. If a composting facility should be sited independent from an existing wastewater treatment facility, an isolated site where odors may not cause problems should be seriously considered. Other considerations for siting a composting facility include the following:

- potential for release of contaminants to surface and ground waters
- potential for airborne dissemination of contaminants (dust, litter, spores, etc.)
- distance from where feedstock materials were generated to the compost facility

- distance to compost markets
- distance to landfill
- traffic patterns / roads to and from the facility
- buffer zones for visual / noise screening and odor dilution
- availability of appropriate utilities
- appropriate soil types and geotechnical conditions
- drainage patterns
- flood hazard
- past ownership and usage
- zoning limitations
- room for future expansion of the facility
- anticipated growth and development near the facility.

The size of the site needed will depend on the composting system selected.

The size of the site needed will depend on the composting system selected. For example, an in-vessel system requires less land space than a static pile or windrow system. Site size will also depend on the amount of storage that will be provided. At a minimum four months of storage space must be available at the site. Sizing should be based on projections of anticipated feedstocks and increase in generation of existing feedstocks. A large buffer zone should be planned around the facility to minimize odor-related complaints from neighbors.

Public participation is crucial in the siting and planning process. Encouraging the public to participate during the planning process is both time-consuming and expensive. In the long run public participation will pay off because it will provide greater political support for the project, help promote interest in the compost product, and help develop local markets, which in turn will reduce transportation costs. In addition, as participants in the program, local residents may tolerate and even overlook some minor problems in the future.

GOVERNMENT APPROVALS, PERMITS, AND ORDINANCES

Make a list of necessary permits and approvals before starting a compost facility development project.

Composting facilities may need approvals / permits from the state before they can begin operating. The requirements for permitting composting facilities may vary among states. Submittal requirements as a prerequisite for permitting may include detailed facility design, operating plans, a description of incoming materials, the amount and types of residue to be generated in the plant, monitoring plans, potential environmental releases, landfills to be used, potential markets for the compost, etc.

State agencies may also issue public notices offering interested citizens an opportunity to have input and comment relative to the request for permit. In addition to a state-level permit, there may be additional local-level permits required, such as building permits, zoning variances, or special land use.

Sometimes new ordinances are required for compost facility siting, operation, and management. These ordinances may focus on centralized community yard trimmings facilities, mixed MSW composting facilities. Flow control agreements may be required for the facility to operate with a minimum amount of waste (see Chapter 3 for a discussion of flow control). Supply agreements should broadly define the types of feedstocks that will be accepted and the service area from which they will be accepted.

PROJECT FINANCING

Obtaining the necessary financing is an integral part of planning a composting project. The most common methods of financing a project are through bond

A variety of financing methods may be available.

sales or bank loans. A financing professional should be consulted for advice and assistance to coordinate necessary transactions and obtain favorable interest rates and payment terms. Some communities have budgeted for and used tax revenues to construct a composting facility. In such cases project construction could be spread over two or more years. Approval of any financing may be contingent on review of a detailed budget for the construction and operation of the facility, all necessary regulatory approvals, and details of marketing arrangements for the compost.

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