Yard Waste Composting

Operator Training Manual

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October 2004

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CHAPTER 1—WHAT IS COMPOSTING

The history of composting is both ancient and modern. As early as roman times, and possibly before, composting was recognized as a transitional force in the "life-cycle". Thus, for 2000 years, compost has been used for the maintenance of croplands and gardens. In this country, the 1940's saw the continued development and refinement of processes which composted organic wastes, such as: leaves, grass, vegetable, etc. Today, residents and municipalities from across the United States use various procedures to convert leaves and yard waste, once considered a waste, into a valuable resource (Minninch, et al).

"Composting is a method of solid waste management; whereby, the organic component of the waste stream is biologically decomposed under controlled conditions to a state in which the compost can be safely handled, stored, and/or applied to the land without adversely affecting the environment."

Composting is often used synonymously with "biological decomposition". However, for purposes here, it may be more appropriate to define composting as: a method of solid waste management; whereby, the organic component of the waste stream is biologically decomposed under controlled conditions to a state in which the compost can be safely handled, stored, and/or applied to the land without adversely affecting the environment. (Simpson and Engel)

Biological decomposition distinguishes composting from other waste management options as: recycling, pyrolysis, incineration, landfilling, etc. Composting implies that the organic fraction of the waste stream can be managed through internal process producing a useful end product. However, because composting of organic wastes are under *controlled conditions,* composting is distinguished from the decomposition processes which occur naturally. Controlled decomposition implies an efficient decomposition process, which is managed to avoid both environmental and nuisance problems. Controlled decomposition also allows the greatest amount of material to be located on a dedicated composting site.

A controlled decomposition of the organic wastes means production of compost that *does not adversely affect* the soil or plants to which it is applied. The end product of the composting process must be "stable". If the decomposition process is incomplete, then the material, when applied to the land, will rob nutrients from the soils and plants (Golueke).

Finally, one often hears many terms attributed to the composting process: degradation, fermentation, decomposition, etc. For our purposes, composting is an *aerobic* (takes place in an oxygen environment) biological process. This essential biological nature of composting means that all environmental factors that affect any biological system also affect the composting

process. Thus, the major focus in controlling the compost process is to maintain conditions for optimum biological activity.

CHAPTER 2—WHY COMPOST?

From a solid waste management perspective, yard waste composting can reduce the amount of solid waste which has to be sent to a landfill. Less waste going to this traditional disposal option results in a decrease in a municipality's cost for transport and disposal.

Burying leaves in the ground at landfills usually occurs over a relatively short time period during specific times of the year. Although leaves and yard waste may make up as much as 12-17 percent (by weight) of a municipality's annual waste stream., during the fall season 35 to 45 percent of a community's waste stream may be composed of leaves and yard waste. A second peak for the material is in the spring and early summer. As a result, such material will end up concentrated in one area of a landfill. Once buried, it will begin to decompose anaerobically (without oxygen). Such degradation leads to methane gas and leachate generation and possible "slumping" or subsidence of the landfill surface. Each of these outcomes can have associated environmental problems and result in increased landfill operation costs. As a result, more and more landfill operators would rather compost this material and produce a soil-like substance, which then can be used as a beneficial product for covering the landfill, either on a daily basis or as a final vegetation stabilization layer.

Similarly, resource recovery facilities (burn technology) are showing signs of promoting composting of leaves and yard waste rather than burning. As one burn facility operator stated, "I put cold wet leaves in the front-end and hot wet leaves come out the back." This may be overstating the case, but facility operators are finding that during the fall season the influx of larger volumes of leaves results in straining the facility capacity, reducing burn efficiency, and increasing both emissions and ash. All of these effects can be translated into an increase in the operating expenses.

More to the point is that many areas of the country are experiencing a disposal capacity short fall. Landfills are being closed because either they have reached design capacity or an associated pollution problem has been discovered. Siting new disposal facilities is becoming increasingly difficult because no one wants landfills or burn facilities in their back yard (often termed NIMBY). If such a facility is being proposed, it may take up to ten years before it could open its doors to waste.

Any solid waste management option which can conserve disposal capacity and do it in an environmentally sound and economically wise manner should be implemented. Yard waste composting is one such solution.

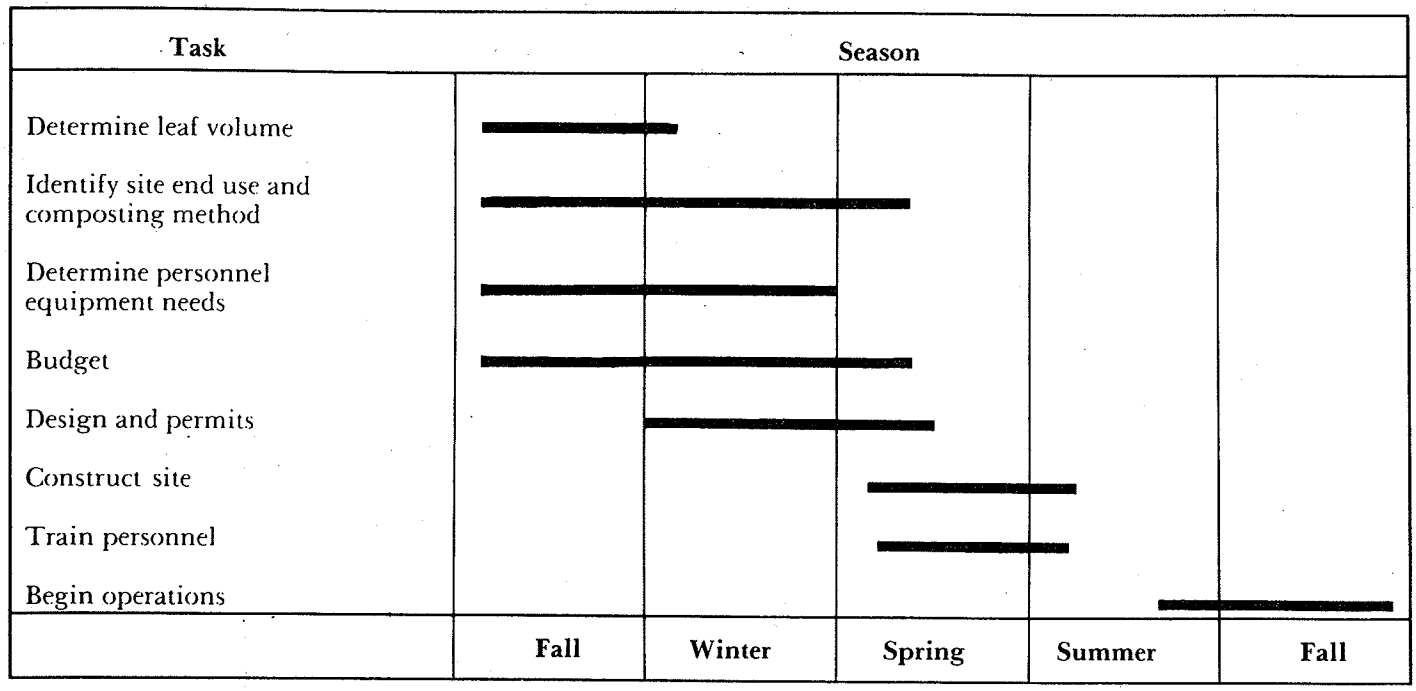
Composting has become more prominent in the role it can play in solid waste management. However, it should also be remembered that composting is a method for renewing a dwindling resource: soil. Where the solid waste disposal crisis has been considered by many as the crisis of today, soil loss in this country has been termed the "quiet crisis". In the United States 1.7 billion tons per year of soil is lost to erosion; this loss has direct financial impact on food production and economy (Brown). Composting is one of the few methods for quickly creating a soil-like material which can help mitigate this loss of the organic fraction from the soil matrix. As development expands and food consumption increases, the need to replace our soil losses will also increase. As such, composting will become more and more essential.

CHAPTER 3—THE NEED FOR PLANNING

3.0 INTRODUCTION

Composting can be a low-effort, cost-effective, and environmentally sound way to dispose of your community's leaves. It conserves scarce landfill space, reduces overall trash disposal costs, and produces a useful product. But composting is not simply piling up leaves and letting them decompose. It is a complex, controlled process requiring advanced planning. Several key decisions must be made regarding leaf collection, processing, and end use. Figure 3-1 summarizes the projected time schedule needed for implementing a new yard waste composting project. This schedule assumes there will be leaves at the composting site prior to receiving the initial delivery of leaves.

FIGURE 3-1
PROJECTED TIME LINE FOR IMPLEMENTING YARD WASTE COMPOST



Source (Connecticut DEP, 1989)

3.1 DETERMINE THE VOLUME OF LEAVES YOU WANT TO COMPOST

An estimate of the volume of leaves is needed to determine what size and type of operation is required and also to estimate how much compost can be made available to an interested end user. One way to gauge leaf volume is to monitor your landfill or transfer station, continuously or by spot-checks during leaf season. If leaves are collected separately from the rest of the trash, this task will be easier. In a recent report released to the U.S. EPA by the Franklin Associates, leaves and yard wastes comprise 12% of the annual municipal solid waste stream (US EPA, 2003).

However, since yard wastes are influenced by the season, this percentage may increase to 35 to 45 percent in the fall. Another peak in yard waste, specifically grass, will also appear in the spring and early summer.

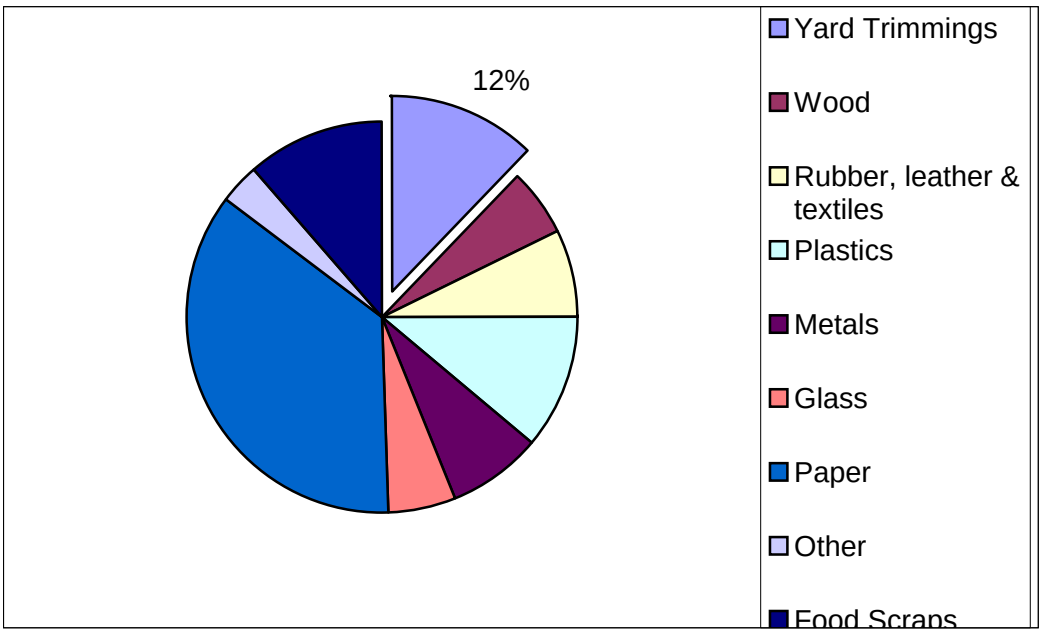
3.2 FIGURE OUT HOW YOU WILL COLLECT THE LEAVES

There are three basic methods of collecting yard waste for composting: a drop-off system at the local landfill or transfer station; curbside collection in bags or barrels; or bulk collection in which leaves are scooped, raked, swept, or vacuumed directly off the street.

Curbside collection of bagged yard waste is more efficient than bulk collection. Studies have shown that, in leaf-only composting programs, bag collection costs can be 45 to 65 percent less than total bulk collection costs (E& A Environmental Consultants and MA DEP).

If biodegradable paper bags are to be used, enough lead-time for ordering is required so they can be distributed to residents at the appropriate time.

FIGURE 3-2
MATERIALS DISCARDED INTO THE MUNICIPAL WASTE STREAM, 2003
(in percent of total discards by weight)



Source: USEPA

3.3 DETERMINE ONE OR MORE END USERS FOR THE COMPOST

As a general rule, the higher the quality of the compost, the easier it will be to find end users. In-town applications, such as municipal parks, recreation areas and roadsides, landfills, or residents' lawns and flower gardens, will minimize the need for "marketing". Other bulk users might include landscapers, cemeteries, golf courses, and nurseries. With the addition of animal manures or other nitrogen sources to the leaves, the compost may be a better grade soil amendment having some fertilizer value. A detailed discussion of compost end use and marketing can be found in Chapter 8.

3.4 CHOOSING AN APPROPRIATE SITE

Concurrently, the municipality must locate a site large enough to receive projected annual deposition of yard wastes. Windrow composting generally requires approximately one acre of land for every 4,000 to 6,000 cubic yards of delivered leaves. As grass comes in during the spring, it is blended with the previous autumn's leaves, which have reduced in volume by as much as 50%. A chosen site should have space for pre-processing yard waste; such as when a tub grinder is used to size-reduce biodegradable bags and yard waste material. Possible composting sites might be farms, forests, municipally owned land, parks, or other land not being used for other activities. Criteria for a site could include:

- A central, accessible location with good traffic flow
- Easy entry and exit for leaf deliveries
- A water source for wetting compost piles
- Adequate buffer area to protect neighbors from the impact of site activities
- A location where prevailing winds blow away from sensitive neighbors
- A low water table (to prevent flooding of the site)
- A location which is an adequate distance from wetlands and floodplains
- A high soil percolation rate, but not excessively permeable soils, so to avoid standing water
- A nearly level surface (two to three percent grade)
- A means of securing the site from illegal dumping

Once a site is located, site alterations may be required in order to allow both proper drainage and support of machinery during the four seasons of the year. Alterations might include regrading the surface (a very slight grade, approximately two to three percent, is required), building access road, laying gravel, landscaping to make the site more aesthetically appealing, and, in special cases, installing an impermeable base with surface run-off collections. Other alterations to consider include security measures so that unwanted materials will not be dumped at the site. Site alterations should be done no later than September, as the site needs to be ready for receiving material by early October.

Additional information regarding siting and site plans can be found in Chapter 6.

3.5 DETERMINING THE TECHNICAL LEVEL REQUIRED FOR COMPOSTING

Choose a composting method appropriate to a municipality's needs. Factors to be considered may include: site constraints and distance to neighbors, material(s) being composted, and costs associated with the composting operation. The following paragraphs describe increasing levels of technology. Additional information concerning compost methodologies is discussed in Chapter 5.

3.5.1 PASSIVE LEAF PILES

In operations that are only composting leaves, this would involve placing the leaves in large piles and letting them remain until a usable product is developed, which could take three to five years. Turning of the piles may take place once or twice per year. A larger buffer will be required because such a composting method is in the absence of oxygen (anaerobic) which tends to result in odors. Also a site would need to be large enough to allow for storage of the leaves that would accumulate over the projected turn around time of three to five years. Although it is a minimal management method, such piling should not be considered a permanent disposal technique.

3.5.2 WINDROW AND TURNING

Windrowing requires leaves to be placed in rows and turned frequently. Special windrow turning equipment may limit the height of the piles; thus, less material may be able to be put in each pile on the composting pad. If a tub grinder is used to pre-process and size-reduce the leaves and yard wastes within biodegradable bags, more material will be able to be put on the composting pad.

> *"Turning is not driven by a fixed schedule. Turnings respond to the conditions within the compost piles."*

Such size-reduction may also result in reduced composting time. This method generally takes eight to twelve months to obtain a final stable compost.

3.5.3 AERATED STATIC PILE

Static pile composting requires that yard waste be placed in large piles through which air is pumped or pulled. Information regarding the use of this technique just with leaves is rare, but it appears that in order to achieve a final product, leaves composted by themselves require four to six months. A static pile composting operation is being successfully employed in Greenwich, Connecticut where leaves are being mixed with the municipality's wastewater treatment sludge and chipped brush.

3.5.4 IN-VESSEL COMPOSTING

The in-vessel technology is a fully enclosed, often fully automated, operation involving

mechanical devices with feedback controls and/or forced aeration. However, due to the high capital costs, such options are not viable unless more than leaves and yard waste are being composted and the volumes are such that a quick throughput process is required.

3.6 STAFFING THE OPERATION

A community should determine what personnel will be needed for the compost operation. A minimum of two workers are required to monitor yard waste deliveries, supervise the compost operation, run the composting operation, and maintain records. Additional personnel may be required to collect and transport yard waste to the site. There should also be trained back-up personnel for each job. The majority of man-hours required will be in the autumn as leaves are being deposited into the windrows. Subsequently, the piles will have to be turned once every 30 to 45 days, depending on ambient weather conditions and temperature trends within the windrows.

3.7 ASSESS AVAILABLE EQUIPMENT OWNED BY A COMMUNITY

The equipment needed for the compost operation can be as simple as a front-end loader. Primarily, this piece of equipment is used both to move material and to turn the windrows. This turning provides the needed oxygen and releases carbon dioxide and water vapor from those microorganisms which decompose the yard waste.

A more substantial piece of equipment could be a specially designed windrow turner which provides good mixing and some size-reducing capability. Such a piece of machinery is more capital intensive but may be ideal if a municipality is mixing waste streams, e.g. sludge and yard wastes, or when excessive amounts of grass are to be composted. Such a turning machine may also be used to enhance degradation by continually size-reducing and mixing materials brought to the site within biodegradable bags.

A tub grinder is another piece of equipment which should be considered. It can be used to size-reduce and shred yard waste, especially when biodegradable bags are used. Such initial size-reduction of the yard wastes and bags will increase the surface area of the particles. Increased surface area will allow more biological activity by decomposing organisms; thus, degradation time is decreased.

An essential item is a three-foot stem, 0 to 200°F thermometer. With proper training, use of this relatively inexpensive piece of equipment will allow the site operators to monitor the windrows' temperatures and determine the most appropriate time to turn the material. By tracking temperature trends, factors which contribute to anaerobic (without oxygen) conditions and subsequent malodors can be avoided. In addition, using the temperature feedback as an indicator, the most efficient compost operation can be attained, thus ensuring that the material is composted and off-site before the next seasonal collection and deposition.

Screening or shredding of the finished compost is an optional step. Although it is time-consuming, it can improve the quality of the end product. Screens and shredders are available in a number of sizes and variations and may be stationary or trailer-mounted.

Since composting is a seasonal operation, it is often possible to save money by using existing DPW, highway, or sanitation department equipment, such as trucks, front-end loaders, shredders, chippers, and some farm equipment. If the community is small, it may want to consider teaming up with a neighboring community and sharing equipment and sites.

Since it may take two to three months to arrive, any processing and monitoring equipment needed should be ordered well in advance. A list of processing equipment costs and operations specifications can be found in Appendix F.

3.8 PROGRAM MANAGEMENT

A town may not have the manpower or equipment to conduct their own operation, but they may still need to divert their yard wastes from disposal. A municipality has a number of options for having a compost operation managed. These management options can also be applied on a

regional basis either with one town supplying a site, and others providing equipment and manpower, continuously or on a rotating schedule.

3.8.1 MUNICIPALLY OPERATED AND MANAGED

A municipally operated and managed facility involves the assignment of municipal employees and equipment to the site, with a designated site manager.

3.8.2 MUNICIPALLY OPERATED, PRIVATELY MANAGED

A municipally operated, but privately managed facility involves the assignment of municipal employees and equipment to the site, but overall management of the pile of windrow construction, turning, watering, etc. is conducted by a private contractor or manager who is paid a flat fee or percentage of the tipping fee, usually calculated on a cubic yardage basis. Normally, the private firm is also responsible for marketing the final product.

3.8.3 PRIVATELY OPERATED AND PRIVATELY MANAGED

A privately operated and managed facility involves total system operation by the private sector under contract with a community. Ideally, such contracts should be long term (five years or more) and may or may not involve the availability of municipality owned or controlled sites for composting. As with the municipally operated/privately managed approach, the firm receives a fee for yard waste delivery and markets the final product.

One alternative to this last scenario is if a local farmer, nursery, or garden center would take the material, this private concern would oversee the composting and utilize the end product for their own agricultural or horticultural uses.

3.9 THE NEED FOR EDUCATING THE PUBLIC

Residents should be alerted and educated early in the planning process. An on-going public education program will help to maintain long-term interest and participation. While composting is still in the planning stages, considerations should be given to holding public meeting and distributing materials to the public to explain its economic and environmental benefits and to alleviate any concerns about its effects on the neighboring community. Consideration may be given to establishing a citizen's advisory committee which could contribute ideas during planning and monitor on-going operations. If possible, designate a staff member to answer inquiries regarding the program.

If a town vote is needed to approve the program, be sure that written information is available to the community. Make sure a system is also in place to keep local boards of health, planning agents, an advisory committee, and/or others informed about the project's status.

Approximately two weeks before actual composting begins, the community should consider distributing flyers or sending a mailing to residents to alert them of the upcoming program and their responsibilities. Regular follow-up publicity campaigns after a year or a season of operation are important for on-going participation because it will advise residents that their

efforts have helped the community (through reduced leaf disposal costs, avoided purchases of soils amendments, etc.).

3.10 SECURE REGULATORY APPROVAL AND PERMITS

To obtain local or state approval, or to be used to inform the citizenry, a document outlining the plan for composting yard waste within a municipality's boundary should be created.

At a minimum, a plan should include: a schematic layout of the site; a listing of equipment and personnel with their qualifications (and/or what training they will receive); an explanation of the composting process; the monitoring techniques for both the process and the end product; provisions for control of odors, leachate, *and run off* from compost piles; and a contingency plan if compost operation ceases.

3.11 DEVELOP A PROTOCOL FOR MONITORING THE COMPOSTING OPERATION

In order to maintain an efficient operation and develop a safe, attractive product, you should regularly track the volume of incoming leaves, the temperature and, possibly, oxygen content of the piles, as well as evaluation of any odor generation. Perform an initial and regular follow-up analysis of the compost produced, including tests for contaminants and the compost's nutrient value. The data will help you evaluate the success of your operation and decide whether to alter your process. Also, it will provide information that would be requested from potential end users. See Chapters 6 and 7 for further discussion about monitoring and quality control.

3.12 DEVISE A SYSTEM FOR TRACKING COSTS AND BENEFITS

Records showing the economic benefits that composting provides a community will help justify the renewed costs on next year's budget. Benefits may be expressed in the form of avoided "tipping fees", the volume of landfill space conserved, avoided transportation costs, money saved through not having to buy soil, or any actual revenues received from sale of the compost.

Benefits include not only monetary factors, but also environmental benefits, such as land conservation and revitalization of soils, which may not be quantifiable. Further discussion about the economics of yard waste compost can be found in Chapter 9.

CHAPTER 4—COMPOSTING BASICS

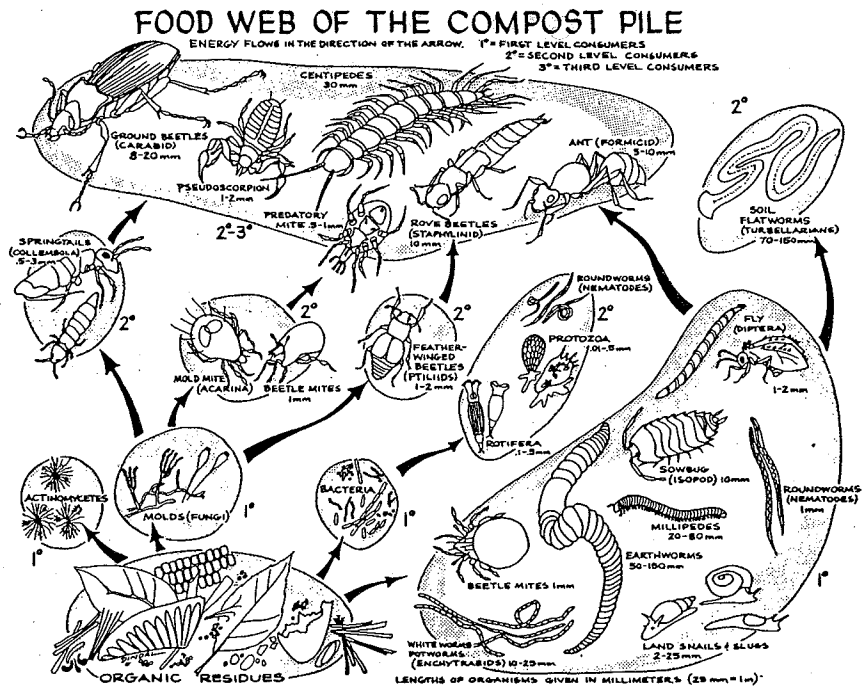
4.0 INTRODUCTION

This section briefly describes principles that one should be familiar with before developing a composting facility. Application of these principles is explained in subsequent sections.

4.1 COMPOSTING

Composting is a waste management option which utilizes the natural process of biological decomposition to stabilize and reduce the volume of organic waste material. The end product, compost, is a valuable soil conditioner and erosion control material. The process is dependent upon biological and environmental factor, including the population of microorganisms, the carbon-nitrogen content of the substrate material, temperature, oxygen concentration, moisture, and pH. These factors are dependent upon one another for successful composting.

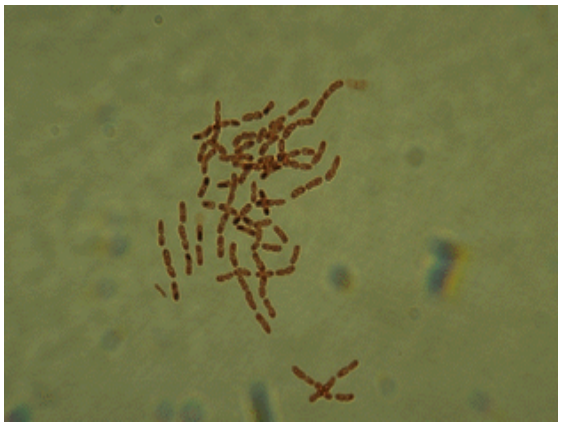
FIGURE 4-1
MICROBIAL COMMUNITY WHICH AID IN DECOMPOSTING OF YARD WASTE



Source (Dr. Daniel Dindal as cited in: Michigan DNR, 1989)

4.1.1 MICROORGANISMS

Decomposition is conducted primarily by a colony of microscopic organisms naturally present in yard waste, including bacteria, actinomycetes, and fungi. These microorganisms reproduce rapidly on the organic material, using it as a source of food. It is the growth of these microorganism populations which result in the rapid degradation of yard waste in the compost piles. Heat, carbon dioxide, water vapor, and compost are produced in the process.



Two categories of microorganisms are active in aerobic composting. At temperatures above freezing, *mesophilic* organisms become active. As a result of their activity, the temperature within the compost pile increases. At temperatures in excess of 110°F, *thermophilic* organisms become active, increasing the rate of decomposition. As the temperature approaches 140°F, the rate of decomposition begins to decline rapidly as organisms begin to die off or assume dormant forms.

4.1.2 TEMPERATURE

Temperature is a key environmental factor affecting biological activity. The metabolism of the microorganisms present in the substrate material results in a natural temperature increase. Due to the insulating effect of the compost pile, the temperature achieved in the pile affects the makeup of the microbial population. The optimum temperature range is between 100°F to 140°F.

Effective composting procedures require that all materials be exposed to high temperatures in the interior of the pile long enough to kill pathogens, neutralize vectors (such as flies), and render weed seeds unviable. At least three days at 131°F should be attained before turning (Michigan DNR).

FIGURE 4-2
GENERIC GRAPHIC REPRESENTATION OF TEMPERATURE CHANGE WITHIN WINDROWS

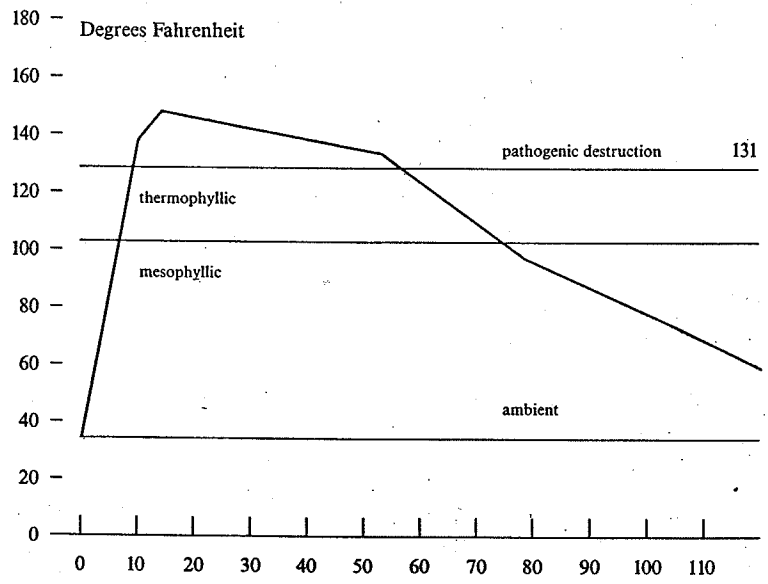


Figure 4-2 demonstrates a typical change in compost temperatures over time. Once the thermophilic phase has passed, the temperature goes down and the mesophilic bacteria again take over the process of degradation. Because a greater number of microorganisms exist within the mesophilic range, composting proceeds fastest at the boundary between mesophilic and thermophilic temperatures. The thermophilic phase needs to be held long enough to control pathogens and weed seeds.

Compost pile temperature is a balance between the heat produced by microorganisms and the heat lost through aeration or surface cooling. During periods of extreme cold, piles need to be combined so as to provide added insulation and avoid excessive surface cooling. When composting high-nitrogen green wastes such as grass, smaller piles may be required so that high extremes in temperature are avoided.

4.1.3 OXYGEN

Yard waste composting is an aerobic process, which means it occurs in the presence of oxygen. The air we breathe is approximately 21 percent oxygen; *aerobic* bacteria in a compost pile can exist if the oxygen content is greater than five percent. When oxygen is present the organisms release carbon dioxide and water vapor. If the oxygen content falls below the optimum level of five percent, these organisms begin to die off and the composting process is taken over by anaerobes, organisms which do not require oxygen.

Anaerobes operate much less efficiently and create malodorous conditions as the result of the release of hydrogen sulfide and ammonia-like substances. Odorless methane is also produced in the absence of oxygen. Since anaerobic degradation is less efficient, it takes longer to achieve a stable product (Dickson).

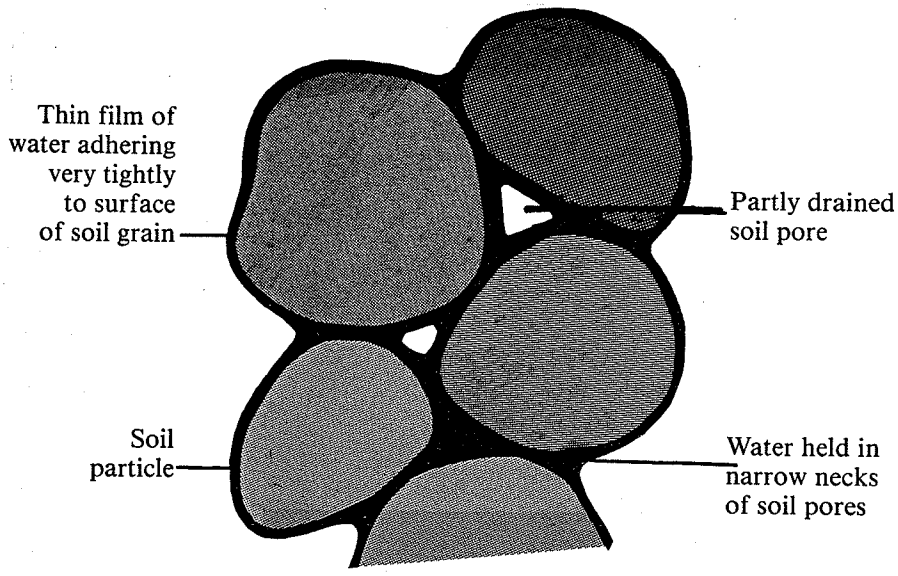
"Conditions leading to foul-smelling, anaerobic decomposition are:

- *Piles that are too large or tightly packed*
- *Piles that are too wet"*

In both cases, the pore space or voids within the pile are not adequate to provide the needed oxygen. Large quantities of dense, nitrogen-rich material, such as grass, can develop anaerobic conditions quickly; thus, this material should be mixed with a drier, fluffier component, such as leaves and aerated frequently.

Aeration, or addition of oxygen, is primarily achieved by turning material or forcing air through the material using blowers. Turning for aeration is dependent on monitoring temperature and/or oxygen within the active compost piles.

FIGURE 4-3
SOIL PORE SPACE WITH WATER FILM



Source (Dern & Leopold, 1978)

4.1.4 MOISTURE

Active microorganisms need a most environment. The amounts of air and water in a pile are related, so rapid decomposition requires a proper balance.

"In yard waste composting, the optimal moisture content is 40 to 60 percent, by weight"

Moisture is required to dissolve the nutrients utilized by microorganisms as well as provide a suitable environment for bacterial population growth. A moisture content below 40 percent limits the availability of nutrients and limits bacterial population expansion. When the moisture content exceeds 60 percent, the flow of oxygen is inhibited and anaerobic conditions begin to develop.

Moisture should be added to piles during initial formation. Throughout aerobic decomposition carbon dioxide and water vapor is released. Further addition of water may be required as piles mature. Forming windrows with a slight depression at the top may be one way to enhance moisture content in the pile. Turning leaves during precipitation events will also allow addition of needed water.

4.1.5 NUTRIENTS: CARBON TO NITROGEN RATIO

Some understanding of the concept of the carbon to nitrogen (C:N) ratio is necessary to manage a compost operation. Carbon and nitrogen are the primary elements that organisms need for food. Bacteria and fungi get their energy from carbon found in carbohydrates, such as the cellulose in grass or leaves. Nitrogen, a component of protein, is necessary for the population growth of decomposing microorganisms.

The availability of nutrients in the organic material is a limiting factor in the composting process. Accelerated decomposition requires a proper balance of these macronutrients. If the carbon to nitrogen ratio is too far out of balance, the microbial system will suffer.

"The optimum range of the carbon-nitrogen ratio is from 20:1 to 30:1."

The more the carbon-nitrogen ratio deviates from this range, the slower the decomposition process becomes. With a ratio of greater than 40:1, nitrogen represents a limiting factor and the reaction rate slows. With a carbon-nitrogen ratio lower than 15:1, excess nitrogen is driven off as ammonia. While this loss of nitrogen is not detrimental to the process of decomposition, it lowers the nutrient value of the end product and can contribute to odors generating from a compost site.

The carbon to nitrogen ratio in leaves tends to range between 60:1 and 80:1. Thus, composting of this material can range from six months to three years, depending on the composting method used. With the proper addition of grass and other nitrogen-rich materials, the carbon-nitrogen ratio will approach the optimum range of 25:1, and the composting process is accelerated.

TABLE 4-1
SOME REPRESENTATIVE CARBON TO NITROGEN RATIOS

Material	C:N
Sewage Sludge: Activated	6:1
Digested	16:1
Humus	10:1
Food Wastes	15:1
Grass Clippings	19:1
Cow Manure	20:1
Horse Manure	25:1
Fruit Wastes	35:1
Foliage	40-80:1
Corn Stalks	60:1
Straw	80:1
Bark	100-130:1
Paper	170:1
Sawdust	500:1
Wood	700:1

Source (Dickson, 1989)

4.1.6 pH

An expression of acidity and alkalinity is pH, based upon the hydrogen ion concentration. The pH scale ranges from zero (0) to fourteen (14) with a pH of seven (7) being neutral; less than seven, acidic; greater than seven, alkaline. Fresh yard wastes are neither acidic nor alkaline, having a pH near seven. Most agricultural and lawn soils are maintained near neutral.

One should not expect variations in pH during the composting process. During the initial decomposition stages, the material will become slightly acidic and then return to near neutral conditions as stability is approached. If extensive anaerobic conditions develop, the pH may go as low as 4.2 due to the production of excessive organic acids. In later phases these organic acids will be decomposed resulting in a pH rise towards seven (Michigan DNR, 1989).

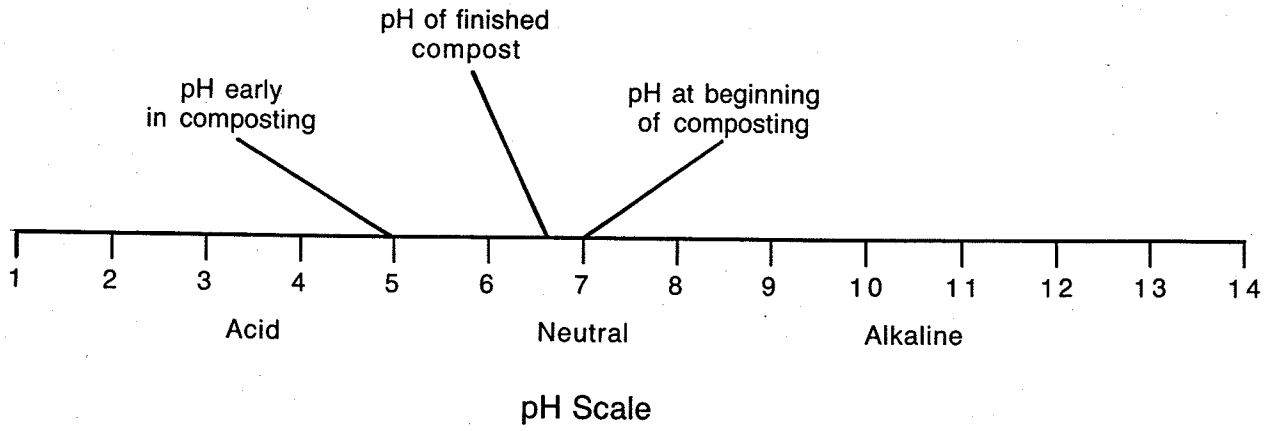
"Decomposition is most efficient between a pH of 6 and 8."

If the pH is too high, nitrogen is driven-off as ammonia. As the pH drops below six, the microorganisms begin to die off and the decomposition process slows."

4.1.7 SURFACE AREA

Exposed surface areas of the material within the composting pile will have a direct effect on the rate of degradation. Shredding or size-reducing leaves and yard waste increases the total surface area exposed to microbial activity, thus accelerating decomposition. Size-reduction of particles will also reduce available porosity and at the same time will increase oxygen demand. As a result, finely shredded material needs to be aerated more frequently to prevent anaerobic conditions.

FIGURE 4-4
THE pH SCALE



Source (Michigan DNR, 1989)

CHAPTER 5—COMPOSTING METHODS

5.0 INTRODUCTION

There are many different composting methodologies which can be utilized for the stabilization of organic yard waste. It could be said that these methods differ in the amount of management required. More specifically, the methodologies vary in:

- Degree of technology used
- Attention paid to monitoring the operation
- Required space needed for the active composting site
- The length of time available to obtain a finished product
- The ability to combine other organic materials with the leaves and yard waste

As a result of all the above, costs also vary. In essence, the lower the level of technology, the greater the requirements for available space, size of buffer, and composting time—and the lower the cost.

5.1 DIRECT LAND APPLICATION

Direct land application of leaves and yard wastes is not composting as has been defined here. Composting is a technology initiated by man. However, natural decomposition is a process which can be utilized by a community if it manages the operation properly and has enough space.

Decomposition of land-applied yard waste is carried out by macro organisms such as earthworms, soil insects, micro-flora, and micro-fauna. This degradation process occurs near the soil surface. Once these larger organisms size-reduce and consume some of the yard waste material, mesophilic organisms take over and decompose the material at a relatively slow rate.

Care should be taken when material is applied to the land. Uncomposted material is not a stable product. Therefore, as decomposition proceeds, nitrogen within the soil will be utilized during the process of degradation. This nitrogen will eventually be returned to the soil at the end of the decomposition process. However, if raw leaves and yard wastes are applied to soils which support plants, nitrogen utilization during the composting process can affect plant health and growth. Thus, direct land application of yard waste is viable only if the material is incorporated into the soil long before a crop is planted.

The main advantage to direct land application is that is costs a municipality less for equipment and operations than a composting operation. A general rule of thumb is to apply the material at a rate of 400 cubic yards per acre. Application should result in a layer not thicker than three inches. To speed up the breakdown, the material could be harrowed into the upper layer of the soil. Size-reduction before application will also shorten the degradation time. Obviously, with such a small per-acre application rate, large areas will be required to handle a municipality's leaves.

A variation on the land application method is termed “sheet” composting. In this process, leaves and yard waste material is size-reduced, mixed, and spread over the ground in a layer up to two feet thick. Moisture is added. By spring, the material has substantially reduced in volume, at which time a rototiller is used to aerate, mix, and further size-reduce it. Eventual incorporation of material into the upper layer will produce a rich topsoil which later can be removed for various municipal projects (Michigan DNR, 1989).

5.2 LEAF PILES

A traditional method for handling yard waste was the leaf dump. Typically, these leaf piles were as large as machinery could maintain. Today this methodology has been termed “minimal technology” composting, since the piles may only be turned once a year. With this “minimal” technology the necessary conditions for rapid composting are not achieved. Much of the pile remains anaerobic for a full year at time between turnings. The center of the pile will probably also reach inhibitively high temperatures, especially during the first year. However, the greatly reduced rate of activity is compensated for by providing a prolonged composting time.

Using this approach, some odor can be expected during the first year, and serious odors may be released during the first turning. Usually by the second turning, odors have diminished. Because of these odors, an extensive buffer zone is required. In fact, up to a quarter mile distance or more to sensitive neighboring land uses may be required.

Because a “minimal technology” leaf composting operation is difficult to distinguish from a leaf “dump”, this method may meet with resistance from community residents and regulatory

agencies. Controlled access to the site will help guard against illegal dumping or vandalism (Dickson, 1989).

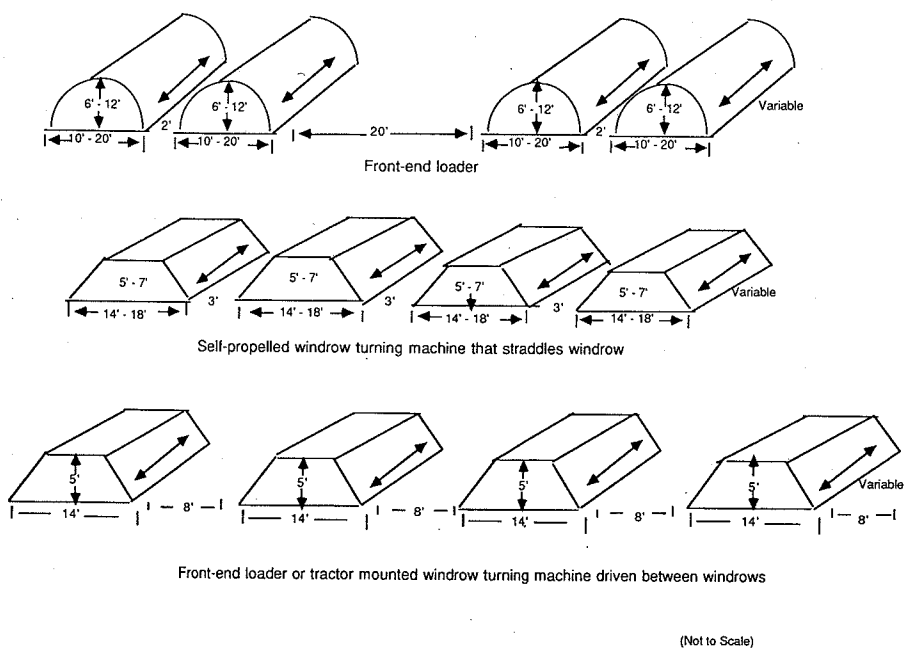
The obvious advantage of this approach is that it is extremely inexpensive. Relatively few days per year of front-end loader operation is required. Even wetting of the incoming leaves may not be necessary except in very dry years since the large piles will conserve moisture, and the long time period insures the cumulative exposure to considerable precipitation.

A second advantage is that relatively little space is required for the composting itself because the piles are so large and little aisle space is needed.

5.3 WINDROW COMPOSTING

In densely populated areas, siting of large leaf piles and using a "minimal technology" methodology is rarely feasible. Most communities have site constraints and thus must be able to remove a stable compost product from the site by the time the next year's deposition occurs.

FIGURE 5-1
PROFILES OF WINDROWS



Source (Dickson, 1989)

Therefore, conditions within the compost pile need to be optimized to insure rapid decomposition. In particular, this means greater attention to moisture content, oxygenation, and temperature control. With proper management, it is possible to produce a thoroughly decomposed (stable) product within twelve months.

In a turned windrow method—also termed "low-technology" composting—the mixing, aeration, control of excess heat, and release of metabolic wastes (CO_2 and H_20) are accomplished by mechanical turning by a piece of equipment with the versatility of a front-end loader. This is the most common municipal scale methodology used today, since most municipalities already own such equipment and the equipment is usually available enough of the time to successfully operate a composting project.

Slight odors may be produced early in the composting cycle, but these are usually not detectable more than a few yards away from the windrows.

After ten to eleven months, large curing piles are formed around the perimeter of the site, freeing the original area to accept the new leaf collection. Costs are still quite low, as only three to seven turning operations with a front-end loader are required after initial windrow formation. Compared to "sheet" composting and leaf piles, windrowing requires more space for the actual composting (roughly one acre per 4,000 to 6,000 cubic yards of leaves). However, since this is a more closely managed and monitored process, negative impact or nuisance conditions are less likely. As a result, large buffer areas will not be essential.

A variation on this method is turning material with specialized equipment. These machines have the advantage of being able to completely turn a pile by shredding the windrows and totally agitating the mass of material. These machines can be pulled with a tractor or other piece of equipment that has a "creeper" gear (moves at a rate of less than one mph). Some models are self-propelled. Besides being able to efficiently aerate the windrows, as the material is being turned, it is also being well mixed and size-reduced. The limitation of a specialized windrow-turning machine is that the pile height cannot exceed seven feet, which may be a concern during excessively cold winters or if there are site constraints. In addition, such specialized equipment can be found in Appendix F.

5.4 STATIC PILE COMPOSTING

This "high-level" technology is appropriate if less space is available and completion of composting within one year is desired, or if high amounts of grass, manure, or sludges are mixed with leaves to better manage generation of potential odors. Simply turning the windrows more frequently (for example, once per month) with a front-end loader might produce a finished product in under a year. However, if odor problems are to be avoided, the original windrows can still be no larger than those of the low-level technology; hence, little space is saved. While costly specialized windrow turning machines may be used to increase turning efficiency, this method actually requires more space, since the starting windrow size is usually even more limited by the machine working height and width.

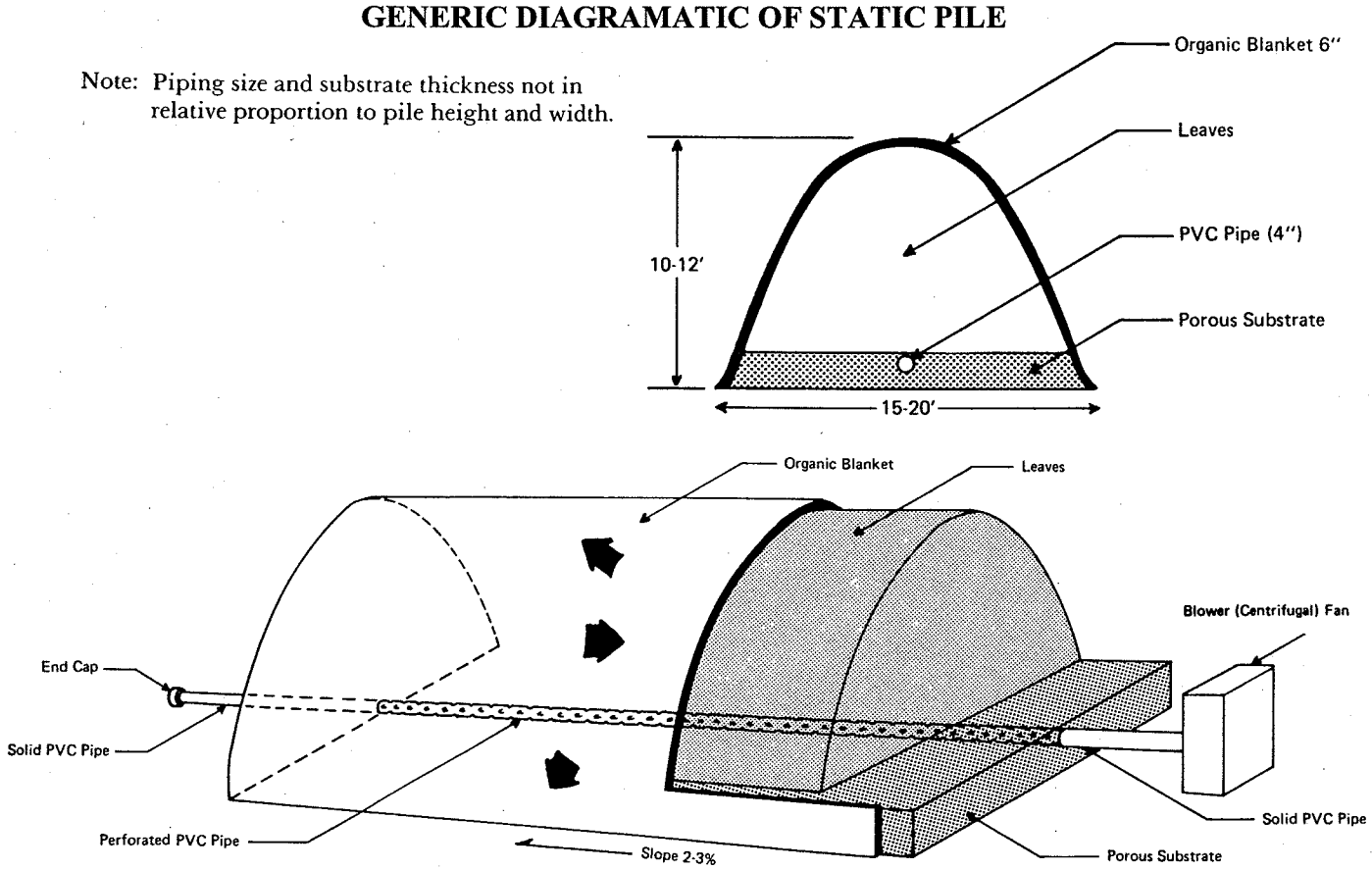
In order to approach a maximal rate of decomposition, near optimal levels of temperature and oxygenation must be maintained. These required conditions will be needed to minimize odors as the putrescible (odor-causing) materials are quickly decomposed. These desired conditions can best be achieved by using an approach originally developed for sewage sludge composting.

Briefly, this approach consists of using forced pressure aeration of the composting pile, with the blower controlled by timers or by a temperature feedback system. When the temperature at a specific monitoring location within a pile exceeds a preset value, usually around 113°F (45°C),

the blower automatically comes on to remove heat and water vapor and cool the pile. This control strategy insures near optimum temperatures in the bulk of the material, and at the same time maintains a well-oxygenated condition. During the start-up period (and at other times, if needed), the blowers also come on under control of a timer (perhaps for 30 seconds every 15 minutes) to provide a minimal level of oxygen. After two to ten weeks of composting, the aeration system would be removed, and the windrows turned periodically.

Such a system has been successfully utilized by Greenwich, Connecticut, which composts their leaves, water, and wastewater treatment sludges. Thus, that community is handling two waste disposal problems with one solution (E&A Environmental Consultants).

FIGURE 5-2
GENERIC DIAGRAMATIC OF STATIC PILE



Source (Connecticut DEP, 1989)

5.5 IN-VESSEL COMPOSTING

In-vessel composting encompasses a variety of systems involving mechanical agitation, forced aeration, and enclosure within a building. These systems are designed and supplied by consultants or commercial suppliers. They are generally not economically feasible for composting leaves alone, but may be appropriate if sludge disposal is an issue.

The advantages include fast processing, avoidance of weather problems, and better process and odor control.

5.6 COMPOSTING LEAVES WITH SEWAGE SLUDGE

This option should be considered if sludge disposal is an issue. But since it requires higher capital cost technology, yard waste composting by itself should not be the motivating force. In addition, composting of sludges will require a more detailed permitting step and comprehensive on-going monitoring of the process and the quality of the final compost product.

Leaves can be added to sewage sludge to provide a bulking agent for the sludge. The leaves provide a carbon nutrient source and increase the number of voids (air spaces) to improve air passage for process temperature control, addition of oxygen, and removal of excess moisture. . Composting leaves with sewage sludge would normally be an option with the forced aeration and in-vessel methods. There may be other materials currently being composted by private companies or agricultural operations for which leaves can serve as a bulking agent.

5.7 BACKYARD COMPOSTING & MULCHING MOWERS

When siting a municipal scale yard waste project, a community should expend the effort to educate people in backyard composting and the use of mulching mowers. Backyard composting should be encouraged because residents can benefit from readily available leaf compost. From a solid waste management perspective, backyard composting and mulching mowers are a “waste reduction” strategy, rather than a form or recycling. Every ton of leaves handled in backyards is a ton of material which will not have to be picked up, transported and deposited at a municipal scale project site. In the long run, this can translate into substantial savings for a community.

A recent survey of Delaware's landscaping companies (DSM Environmental) found that the majority have switched to mulching mowers to service homeowners. Their costs have been significantly reduced due to the avoided time of raking and collecting grass for disposal. Residents can realize a similar savings in time and costs by utilizing such mowers.

A successful "master composter" project first developed in the Seattle, Washington area has resulted in a workable strategy of disseminating technical assistance and information to residents. After jus a few years, significant reduction has occurred in the amount of yard waste ending up on the curb for municipal collection and deposition.

Backyard composting involves the composting of leaves and other yard wastes on a small scale within the confines of one's own property. This method is particularly appropriate for areas where the residences are located on one-half acre plots or larger (CT DEP).

Also, municipalities with community gardens should site a neighborhood scale composting project adjacent to the gardens. The end product would then be utilized on-site.

CHAPTER 6—COMPOST OPERATION

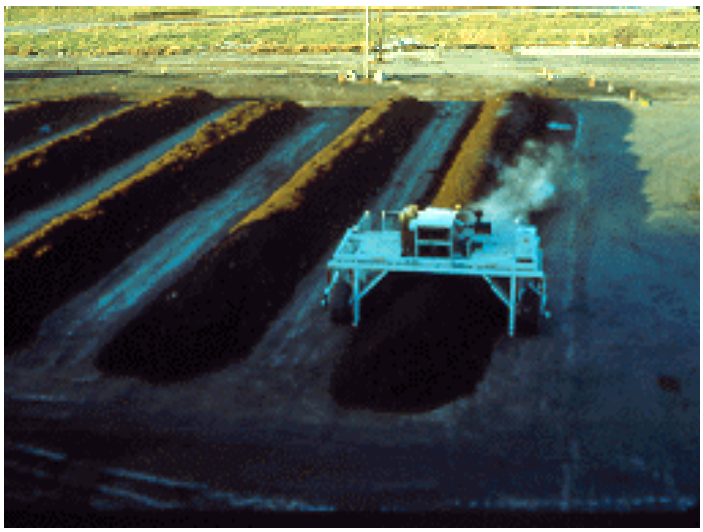
6.0 INTRODUCTION

This chapter is divided into three sections. The first applies to those factors which need to be taken into account when attempting to locate a potential compost site. Part Two reviews some guidelines for site alteration and design. The final section discusses the composting operational process steps.

"Choosing the appropriate site for a composting operation is the basis for avoiding future problems during operation."

6.1 SITING GUIDANCE

Proper siting is a prerequisite to the establishment of safe and effective yard waste composting facilities. Design requirements, and to some extent operation, are influenced by site conditions. Communities should take care in selecting a suitable site as a means of controlling design/construction costs and operational problems over the life of the facility.



Three primary considerations should drive the site selection process:

- Area—Site must be large enough to contain a composting facility with the capacity to easily process projected volumes of yard waste, and to provide room for storage of finished compost.

- Protection of surface and groundwater—Site should be evaluated for its potential impact on waters of the state. Of primary concern are proximity to wetlands, floodplains, and surface waters and the depth of groundwater.
- Relationship between site and surrounding land uses—Site should be adequately buffered from sensitive adjacent land uses such as residences, schools, and parks.

The following sections (6.1.1 to 6.1.12) describe factors which should be considered when attempting to locate a yard waste composting site. This list may not be inclusive. Local and state guidance should be reviewed for site requirements and mandated set backs. Also, those factors which can *by themselves* disqualify a site may include: operation non-compatible with zoning, siting within a jurisdictional wetland or floodplain, shallow depth to groundwater, impermeable or excessively well draining shallow soils.

6.1.1 LOCATION

The community should assess the general location of site with particular attention to the impact of traffic delivering leaves and yard waste on neighborhoods along the major delivery routes. A second concern is how centrally located the proposed site may be. Distance traveled to site by residents and/or collection vehicles may affect cost or participation rate. A site which requires delivery routes through densely populated areas would receive the lowest rating. A site which is centrally located in a sparsely populated area would rate high.

6.1.2 TOPOGRAPHY

Two factors need to be assessed when reviewing site topography. The first is general slope of the land. Ideally, the slope should be of a grade to enhance the movement of precipitation run-off away from piles—slopes less than two percent should be avoided. Also, the slope should not be too great so as to diminish the operation efficiency of deposition and turning equipment—slopes greater than six percent should be avoided. A second topographical consideration in choosing a potential site is the amount of clearing and general grading which would need to be done to alter the site to the point that it is usable for a composting operation.

Thus, a site with slopes ranging between two and five percent with minimal need of clearing would be the most desirable. If no such site exists within a municipality, site alterations would need to be employed to bring a site up to proper grade.

6.1.3 ZONING/LAND USE

If local zoning is such that a composting operation cannot be sited on a proposed location, in most cases, the only alternative is to ask for a variance. Experience has shown that if a compost site is being proposed at a location which runs counter to the zoning designation, the chances are that the operation will not be allowed or, at the very least, will be substantially delayed. Ideally, the compost operation is not only in compliance with local zoning but also should be compatible with existing adjacent land use. Some possible compatible land uses could include various activities in the commercial, industrial, or agricultural sectors.

6.1.4 BUFFERS

In the event the proposed composting site is not ideally situated in regards to adjacent land uses, the existence of natural or man-made buffers would enhance the acceptability of the site. Coupled with these visual buffers is the distance between the actual compost operation and the adjacent sensitive land uses. Obviously, the greater the distance, the less the impact.

If a community opts for a minimal technology method of large leaf composting piles, then a more extensive buffer would be required to mitigate the potential impact of odor generation. The higher the technology, resulting in increased management and monitoring, the less the need for a large buffer. Buffer areas and setbacks are often specified by state environmental regulations.

6.1.5 WETLAND/FLOODPLAIN

Compost operations should be located outside the 100-year floodplain and should be of significant distance from wetlands and/or open water to avoid adverse effects on these surface waters. In addition, close proximity to wetlands or floodplains increases the chances of compost piles becoming saturated from the existence of standing water during periods of excessive precipitation. Water is soaked up into the bottom of the pile through capillary action. The water displaces oxygen, creating an anaerobic environment. The result is slow down in degradation and creation of malodors. Also, standing water makes operations difficult; ruts form if the site is muddy and results in equipment getting bogged down. In addition, having compost windrows wash away in a flood is not a desirable scenario. Flood hazard maps can be obtained from local Soil Conservation Service offices.

6.1.6 GROUNDWATER/BEDROCK

Distance to groundwater and/or bedrock is of critical concern. Enough soil should exist between the surface and subsurface waters or bedrock to insure that during heavy precipitation, run-off is adequately diverted and mitigated, rather than becoming an environmental concern. Conversely, a high water table or shallow depth to bedrock can increase the likelihood of standing surface water during heavy precipitation events. Such a situation should be avoided to prevent soaking the compost piles.

General drainage information can be obtained from U.S. Geological Survey topographical maps. Descriptions of soils and indication of high water is available from the US Natural Resource Conservation Service's County Soil Survey.

6.1.7 SOILS

Soil type at the proposed compost location must meet two basic needs: to avoid standing water and to support machinery through four seasons of the year. The soil should be permeable enough to allow precipitation to move down, away from the yard waste, thereby not soaking the compost piles. Conversely, soil permeability should not be excessive to the point that the soil complex mechanisms do not have a chance to attenuate the precipitation percolating down from the compost pad. In the event that a pad is sited on impermeable material, a mechanism should be in place to move run-off away from compost piles. Subsequently, this run-off should be treated appropriately to avoid environmental and/or nuisance conditions.

The compost pad should be composed of a material that can support deposition, turning, and emergency (fire) equipment during all four seasons of the year, thus, it should consist of a soil material that allows slope and grading with minimal amount of maintenance.

6.1.8 SIZE

A compost site can be any size; however, an ideal size reflects the potential volume of leaves which could be delivered to the compost location during one complete annual cycle. In addition, certain operational (pre-processing) procedures can increase the throughput volume at a composting location.

For low technology operations using a front-end loader to turn the windrows, a 15 to 20 foot aisle needs to exist between piles so the equipment can maneuver adequately. In addition, at least a 20-foot zone should be allowed around the compost area for this purpose. Additional space should be provided for the turn-around of any delivery trucks, and for the drop-off of bagged leaves.

Adequate space must also be allocated for the on-site storage of finished compost, which is approximately 25 percent of the original volume of the leaves.

At minimal technology facilities 8,000 to 12,000 cubic yards of organic waste can be composted per acre. (For leaves, a cubic yard is roughly equivalent to 500 pounds or ¼ ton). This includes 20 feet between windrows for equipment maneuvering. Operators must plan for three to five years on-site residence of yard waste until the compost process is complete.

At low-level technology facilities 4,000 to 6,000 cubic yards of organic waste can be composted per acre, or about one-half that of the minimal technology facility. This also includes 20 feet between windrows for equipment maneuvering. On-site residence of 10 to 12 months, from deposit of the leaves to curing, should be expected for complete composting. The curing process takes place from six to eight months after the leaves have been deposited at the site. The composted leaves are moved to the curing area, allowing adequate room for composting a new year's supply of leaves.

High-level technology operations require somewhat less area per cubic yard than low-level technology facilities with an on-site residence time of less than 10 months.

6.1.9 OWNERSHIP

A site which is owned outright by those proposing a compost project obviously will avoid unnecessary delays or added costs to the project. However, arrangements with a landowner may be necessary in municipalities that lack viable sites. Innovative agreements which share the end use of the compost product and/or allow some sharing of user fees can overcome these ownership hurdles.

6.1.10 INGRESS/EGRESS

A proposed composting site needs to have orderly ingress and egress, to the point that traffic problems do not arise from vehicles delivering yard waste material. An associated concern is that on-site roads are of such design that they can support both operational and emergency (fire) vehicles during all seasons of the year.

6.1.11 SITE SECURITY

A proposed site must have sufficient barriers to control access so that illegal dumping is not possible and potential for vandalism (arson) is discouraged. Site security is of particular concern to state solid waste regulatory agencies since their experience has shown that leaf piles tend to attract illegal dumping of non-compostable material.

Barriers such as water bodies, natural topography, or vegetation can all be viable deterrences to entry. In addition, access from entry roads need to be curtailed by some form of a man-made barrier.

6.1.12 WATER SOURCE

Availability of water at a proposed composting site is essential. Water is needed at times when moisture content within the pile falls below 40 percent (by weight). Such water can be applied manually through a hose or a water truck, or this water can be connected to a sprinkler or seep watering system which could operate without the need of an attendant on-site.

For very dry leaves approximately 20 gallons of water are required for each cubic yard of leaves (Strom, et al., 1985). As such, for large operations on-site water is a necessity. In addition, experience has shown that watering leaves and yard waste before windrow formation or during a

turning event will be more efficient, hence, requiring less water. This is because recently windrowed leaves tend to shed water which is applied from above.

6.2 DESIGN GUIDANCE

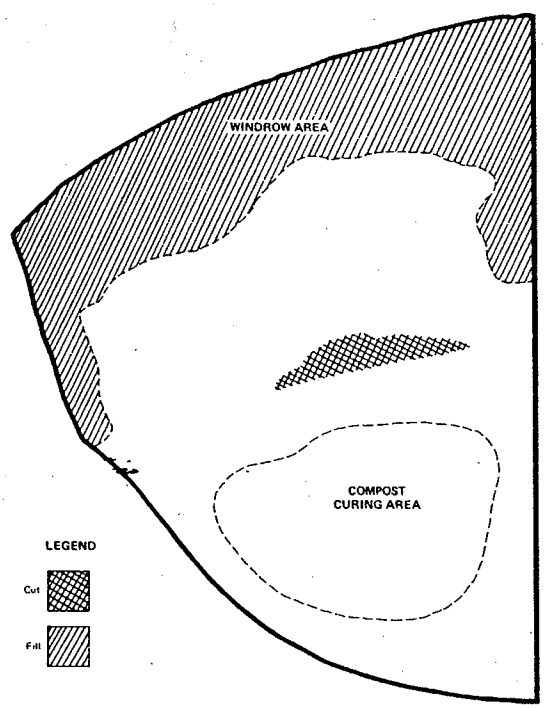
Design requirements vary with the level of technology employed at the facility, and the physical characteristics of the site. Facilities must be designed to promote operational efficiency and to minimize adverse environmental and health impacts.

6.2.1 SITE PREPARATION

6.2.1.1 Clearing and Grading

Once selected, the site must be cleared to provide adequate space for the composting process, on-site roads, and storage of the finished product. Existing perimeter vegetation, particularly trees and shrubbery, should be retained for noise reduction, aesthetic and environmental screening, and access control purposes. Care taken at this stage may prove a key factory in the establishment of good relations with neighbors.

FIGURE 6-1
GENERIC CUT AND GRADE PLAN



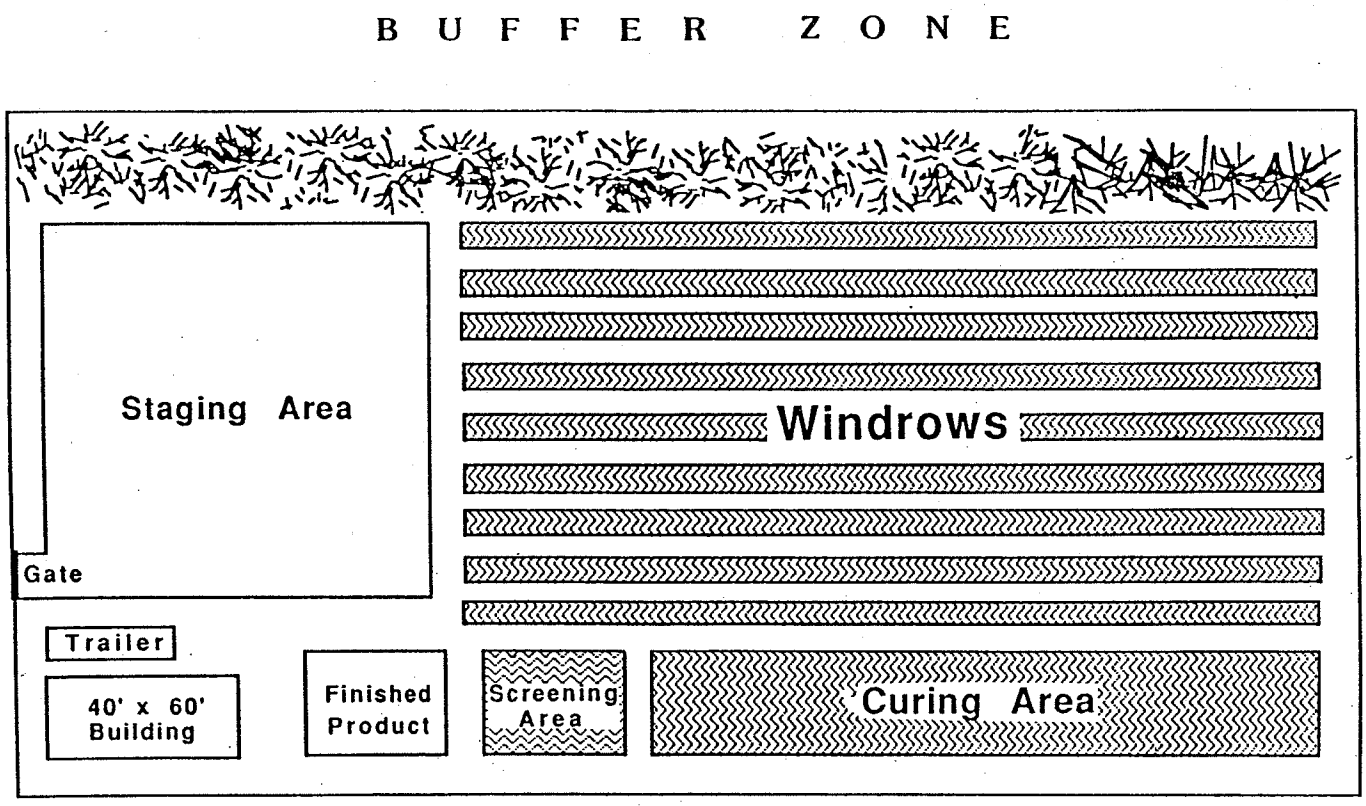
Source (Worcester, MA Compost Project as cited in: Connecticut DEP, 1989)

Depending on existing conditions, site preparation may involve grading. Grades of two to five percent are acceptable and a three percent grade is optimal. The grade should be steep enough to prevent ponding, yet gentle enough to minimize run-off and operational concerns.

6.2.1.2 Compost Pad

The surface on which the composting will take place, otherwise known as the pad, should be designed to support heavy equipment during all seasons, and to prevent ruts from forming. In most cases, the pad should be permeable enough to allow water to percolate through the soil and avoid ponding. If the compost pad is sited on an impermeable surface, run-off should be diverted to a drainage system or swale for appropriate treatment. Impermeable pads are suggested where soils are highly permeable or where groundwater rises close to the surface.

FIGURE 6-2
GENERIC COMPOST SITE LAYOUT



6.2.1.3 Pre-Processing Area

Additional space is needed at several stages of the composting process. Space is required to unload incoming yard waste, mix and blend materials, chip brush, shred compost, and load trucks for distribution.

In the event that biodegradable bags are used, a pre-processing or staging area may be required so that the bags and leaves can be size-reduced by a piece of equipment, such as a tub-grinder.

Such size reduction will enhance optimum composting conditions, resulting in more rapid degradation of material. Depending on the amount of processing anticipated at the site, this area may need to be the same size as the curing area, or about 25 percent of the compost pad size.

Pre-processing is highly recommended for material collected in biodegradable plastic bags. Pre-processing is optional for Kraft paper bags. Field trials have demonstrated that whole bags compost slowly than bulk or shredded material during initial phases. However, subsequent bag degradation and composting will produce a stable compost within a comparable time frame.

6.2.1.4 Curing/Storage Area

The curing process stabilizes the compost. Compost will need to be kept in the curing area for a minimum of one month. During this time oxygen demand is reduced and the pile is re-colonized by soil-dwelling microorganisms. Once cured, the compost will not generate foul odors. The curing area should be approximately 25 percent of the compost pad size.

If the compost is not used immediately, a site for storage of the material needs to be considered. Easy access for vehicles to remove this stored material is essential. Since the compost is completely stabilized, some of the siting requirements recommended for the active composting area would not be an issue for the storage area.

6.2.1.5 Buffer Area/Set-Backs

A buffer zone is required between the composting facility and the neighboring land used to minimize possible odor, noise, dust, and visual impacts. A generous buffer between the site and non-compatible uses can do much to eliminate potential complaints. Local and/or state regulations may have specifically designated setback distances from such points as:

- Property lines
- Residences or adjacent businesses
- Potable water supply
- Surface water bodies
- Drainage swales

Thus, it is important to consult these regulations before a site is developed.

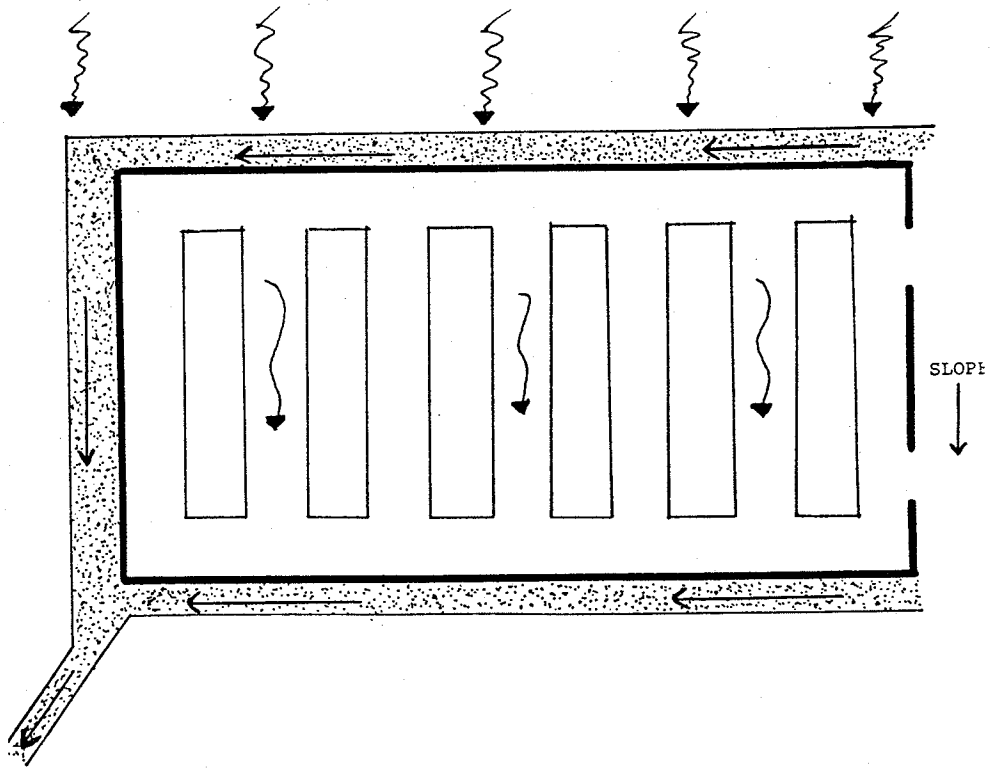
When calculating the total site area requirements. Be sure to realize that the buffer area may need to be several times the size of the active site, particularly for small operations. For example, in a site surrounded by businesses or homes, as much as eight acres of buffer might be required for the first acre of active site. A location where much of that buffer is provided by adjacent undeveloped land has obvious advantages.

6.2.2 DRAINAGE CONTROL

A system should be devised to prevent sediment or infiltration water from running off the site and into nearby surface waters. Diversion ditches or baled hay should provide adequate run-off control at most sites. Run-off from up-slope should be diverted around the compost pad to prevent seepage into compost and curing piles. The run-off drainage system from the compost

pad and up-slope area should be designed to accommodate an unusually long and heavy rainfall statistically shown to occur every 25 years. (Simpson)

FIGURE 6-3
GENERIC PRECIPITATION RUN-OFF DIVERSION DESIGN



RUNOFF SHOULD BE DIVERTED TO APPROPRIATE METHODS OF TREATMENT.

6.2.3 ACCESS ROADS

Roads should be designed to permit orderly entrance and egress, even during episodes of inclement weather. Ideally, vehicles coming to the site with leaves and yard waste should enter at a different point from those exiting the site. If this is not possible, then areas set aside for queuing of vehicles wanting to deposit material might be included in the site plan.

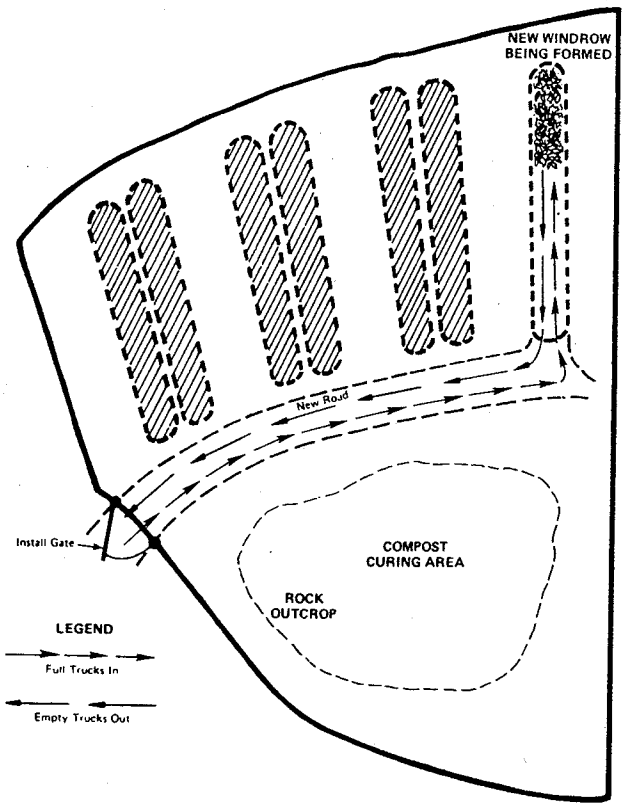
Road surfaces must be capable of supporting delivery and fire equipment. Also, roads should be designed to minimize erosion.

6.2.4 ON-SITE ROADS

Roads should be designed to facilitate quick and easy drop-off of leaves and yard waste. A circular traffic pattern is suggested where feasible. Consideration should be given to the seasonality of these operations, as heavy traffic is likely for a short period on the fall.

Roads must be capable of handling all season operation of heavy equipment and support fire equipment if the need arises. While paving improves all weather mobility, it increases the cost of the facility and may contribute to run-off problems.

FIGURE 6-4
VEHICLE TRAFFIC PATTERN



Source (Worcester, MA Compost Project: Vehicle Traffic Pattern, as cited in Connecticut DEP, 1989)

6.2.5 ACCESS CONTROL

Controlled access is required to prevent illegal dumping at the compost site. The required level of security depends on the potential for illegal dumping or vandalism.

A gate or cable across the road at all access points in a minimum precaution. Where problems of illegal dumping and/or vandalism exist, construction of perimeter fencing may be necessary. Pre-existing features such as bodies of water or geological barriers may suffice as access control measures.

Gates to the site should only be open during times of deposition, monitoring, turning, or removal of compost. At all times composting staff should be on the site to provide the necessary quality control.

6.2.6 VISUAL BARRIERS

Visual screens should be considered at facilities located in urban or suburban settings. Protecting the aesthetic integrity of the neighborhood will go a long way in reducing opposition to yard waste composting facilities located in urban or suburban settings. Berms or landscaping can serve this function where natural relief features or tree stands are lacking. If, from the beginning, site impact is considered, then proper site selection and careful site clearing can eliminate costly landscaping or berm construction.

6.2.7 SIGNS

A sign should be posted at each entrance indicating the:

- Nature of the project
- Facility name
- Operating hours
- Business address and phone number of the operator
- Where or who to contact for the compost

In addition, on-site signs may be required to direct vehicles to unloading areas and indicate traffic circulation patterns.

6.2.8 WATER SOURCE

Facilities need a source of water adequate for wetting piles and fire protection. Possible water sources include water trucks, fire hydrants, and fire ponds.

Water requirements are based both on the moisture content of the incoming material, and on the amount of material delivered during a deposition season. In other words, yard waste may be at the optimal moisture content upon arrival. But this is quite variable and a site operator should not depend on nature to provide needed moisture. As a general rule of thumb, it should not be possible to squeeze water from a fistful of moist decomposing leaves. Also, if a compost site is to receive a larger amount of leaves and yard waste, then less efficient watering mechanisms, such as a water truck, should be superseded with an on-site water source, such as a fire hydrant.

6.3 COMPOST OPERATION

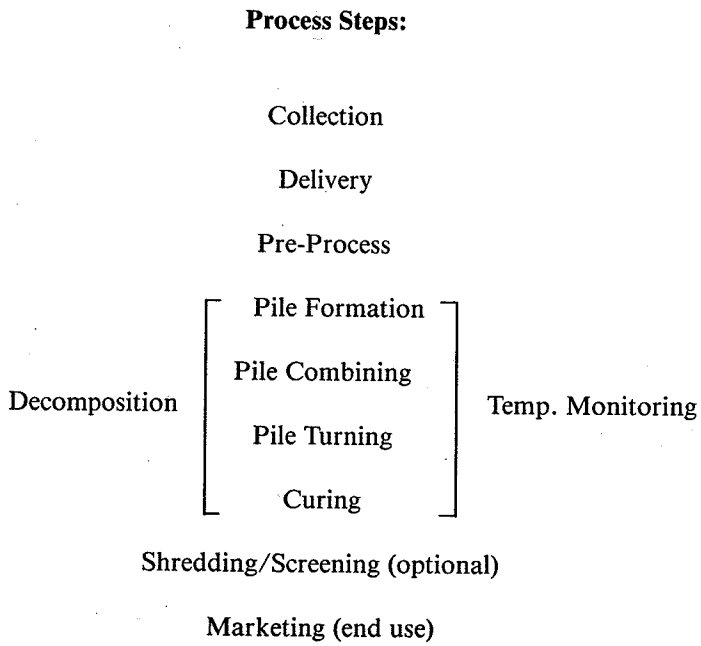
Figure 6-5 generally outlines the operation steps involved with a generic yard waste composting project. Since windrow composting, or the low-technology method, is the most universally used composting procedure, comments here will be most appropriately applied to that scale of compost project.

6.3.1 ANNUAL SITE PREPARATION

Prior to the start of the leaf collection season, re-grade the site as needed to maintain a two to three percent slope and to maximize run-off and minimize ponding of surface water. Bring in fill as needed. Any ruts that have developed between windrows during prior turnings should be filled and back bladed so that water is not captured. Maintain the drainage system components

such as subsurface drains or diversion ditches. In essence, the operator needs to review and prepare the site to insure good vehicle operation conditions.

FIGURE 6-5
PROCESS STEPS FOR A GENERIC COMPOST OPERATION



Also, it may be necessary to check the availability and method for handling water to wet the leaves. If there is no water at the site, a water-hauling tank vehicle and a mechanism for spraying the water on the leaves will need to be scheduled.

6.3.2 DEPOSITION

Staging areas may be used for depositing yard waste prior to windrow formation. This process is more expensive and time-consuming than depositing the material directly into the windrow area. The use of a staging area, however, offers the following advantages:

- Facilitate the formation of more uniformly compacted windrows
- Makes wetting the material easier
- May result in more efficient composting
- Promotes the development of a more attractive and marketable product
- Speeds up the delivery process
- Allows better quality control

If a staging area is used, leaves, especially with yard waste such as grasses, should be formed into windrows with 48 hours of being deposited on-site. Unless the incoming material is dry, vigorous decomposition of grass begins quite rapidly and considerable odor may result.

6.3.3 PRE-PROCESSING

Pre-processing can involve either size-reduction or mixing.

6.3.3.1 Size-Reduction

Size-reduction will enhance the composting process by increasing the surface areas of particles, thus, allowing greater surface microbial activity which results in quicker degradation.

For material arriving at the site in biodegradable bags, size-reduction may be necessary so that decomposition of these materials is within a time frame allowed by the designed throughput rate of the yard waste. Such size-reduction will also facilitate oxygenation of the material within the bags, as well as enhance the operator's ability to maintain optimum moisture conditions.

Size reduction is also required for woody material. Woody material does decompose quite slowly, and the inclusion of this material at a compost site may delay the development of compost end product. Even material put thorough a chopper or grinder will not be decomposed within one year. If site constraints allow it, woody material can be mixed with yard wastes and leaves and then isolated in special windrows which will be left for a longer period due to the slower decomposition rate.

6.3.3.2 Mixing

Water is an essential ingredient to mix with the incoming yard waste. Research at Rutgers University states 20 gallons per cubic yard is the average water needed to insure optimum composting conditions (Strom, et al). Amounts as high as 40 gallons per cubic yard have been stated (Michigan DNR). However, because the moisture content of leaves varies dramatically,

water addition should be gauged by visual inspection. During the early stages of composting, leaves must be mixed during wetting; otherwise the water will run off the pile surface. Over watering is normally not a problem at this early stage as excess water will drain off. Two rules of thumb which have been successfully used by compost site operators are:

- If moist leaves are squeezed and no water drains out, proper moisture has been attained
- If the leaves have the feel or moisture consistency of a sponge that be been wrung out, then optimum conditions for moisture within the piles have been approached

Mixing may also be necessary if different types of yard waste arrive at t he site, or if other organic materials are going to be added to the windrows. Of major concern is to provide an appropriate mix to obtain an optimum carbon to nitrogen ratio. In addition, the porosity of the various materials is a concern. This is especially true with grass. When grass arrives at a site it usually heavy, wet, and matted and may already have odors resulting from anaerobic conditions developing. This material should be mixed in with a high carbon source that has good bulking potential (has the structural integrity to maintain adequate porosity). Research has shown a mixing ratio of one part grass (by volume) to three parts partially decomposed leaves will not only enhance the degradation of the leaves, but also avoid potential odor or leachate problems (Fulford).

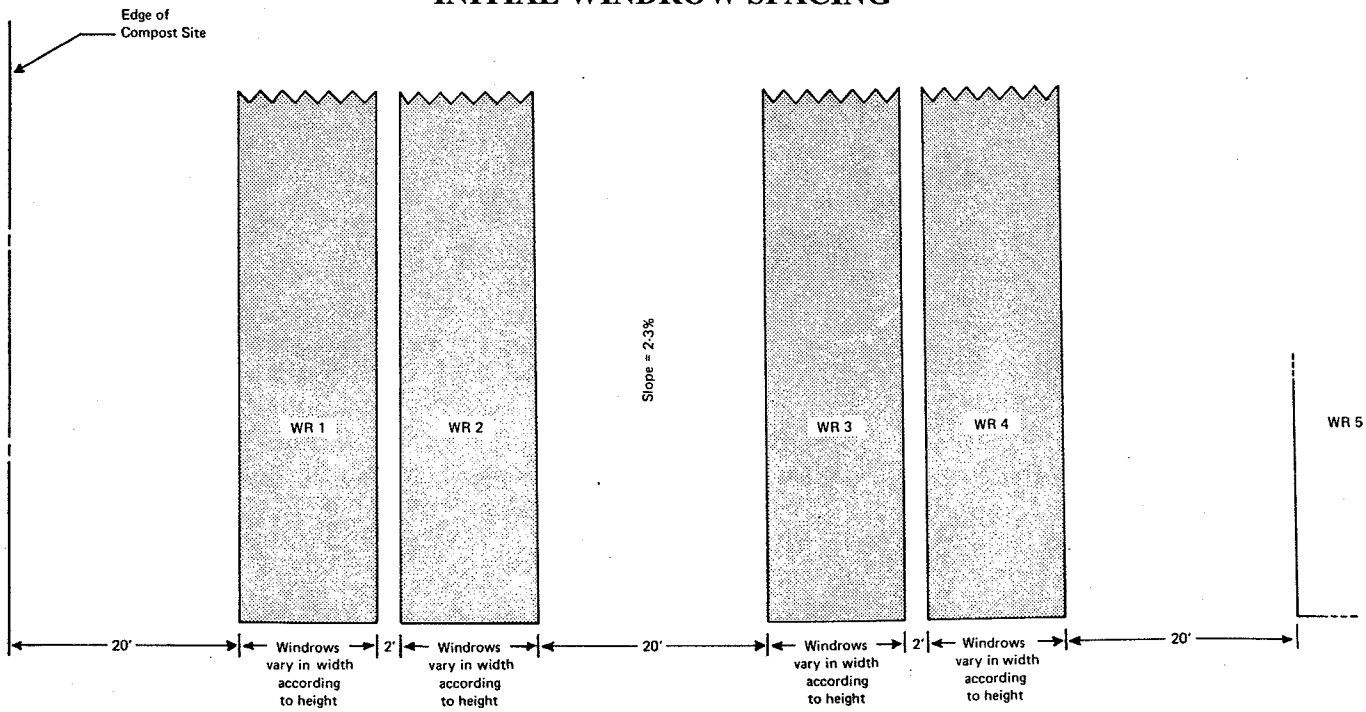
6.3.4 WINDROW FORMATION/COMBINING

Proper windrow heights are a function of climate and geography as well as the compaction potential of the composting material. Oversized piles are cited as the primary cause of odor at composting facilities since they tend to compact, thereby reducing aeration. Undersized piles are susceptible to heat loss. In northern temperate climates, piles lower than six feet may be adversely affected cold temperatures. Thus windrows should initially be piled up to six to eight feet with a bottom width of 12 to 14 feet. The length of the windrow is only constrained by the active composting pad size.

Volume reduction during the composting process will necessitate periodic combining of windrows for proper size maintenance. In the colder winter months, piles should be made larger to provide more insulation for heat retention. In the summer, when the yard waste has composted into a heavier, soil-like material, piles may be reduced in overall height to allow appropriate movement of oxygen in to the pile.

Placement of windrows should start with the first windrow 20 feet from the edge of the composting pad. Leave two feet between the first two windrows and a 20-foot space between pairs of windrows. Windrows should run in the direction of the slope. This will allow precipitation run-off to move down between the windrows rather than into them; thus, avoiding the potential for ponding and subsequent anaerobic conditions in the bottom layers of the piles.

FIGURE 6-6
INITIAL WINDROW SPACING



After the windrows have been reduced to almost one-half of the initial size (about one to two months after windrow formation), each pair of windrows is combined into a single windrow.

With the use of a specialized windrow-turning machine, yard waste may fall into the vacant aisle. It will be necessary periodically to gather these leaves and place them in the windrow. Depending on how the windrows are spaced, with turning machines windrows can be combined 15 to 25 days after the start of the composting process.

Windrow layout should address fire protection concerns as needed. Although a leaf windrow fire is an unlikely occurrence, the layout of the windrows and the site conditions should provide access for fire fighting equipment.

6.3.5 MONITORING

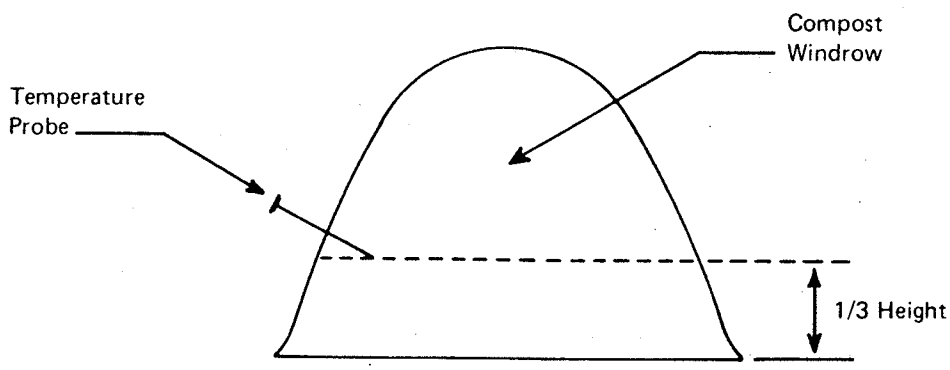
The monitoring of leaves and yard wastes should take into account factors such as temperature, oxygen, moisture, and porosity. Optimum levels for each of these should be maintained. Turning the windrows is the one necessary mechanism that is used for control. The concept of a "feedback" mechanism should be employed. Instead of turning based on some set schedule, a decision to turn should reflect the conditions both within and outside the piles. This is because ambient (outside) conditions, such as temperature, wind, and precipitation, is so variable that at times a set schedule for turning may result in a slowdown in the rate of decomposition. In essence, monitoring piles will insure optimum conditions and avoid unnecessary turning, and as such, keep costs to a minimum.

Temperature is the easiest to monitor, and it reflects how well other factors, such as oxygen and moisture content, are being maintained.

The thermometer most appropriate for a municipal scale yard waste composting operation should have a range of zero to 200°F, a three to five inch diameter dial, and an adjustable calibration screw. The stem of the thermometer should be steel (aluminum tends to bend easily), and the tip of the stem should be pointed. The cost for such thermometers range from $60 to $100. If a lot of woody material is being composted, a stronger, larger thermometer may be required.

Windrow temperature measurements should be made and recorded at least twice a week to monitor the compost process and to determine when the compost is stable. Monitoring points should be at least every 75 feet along a windrow, since material coming onto a site can be quite varied in both its moisture content and mix of yard waste.

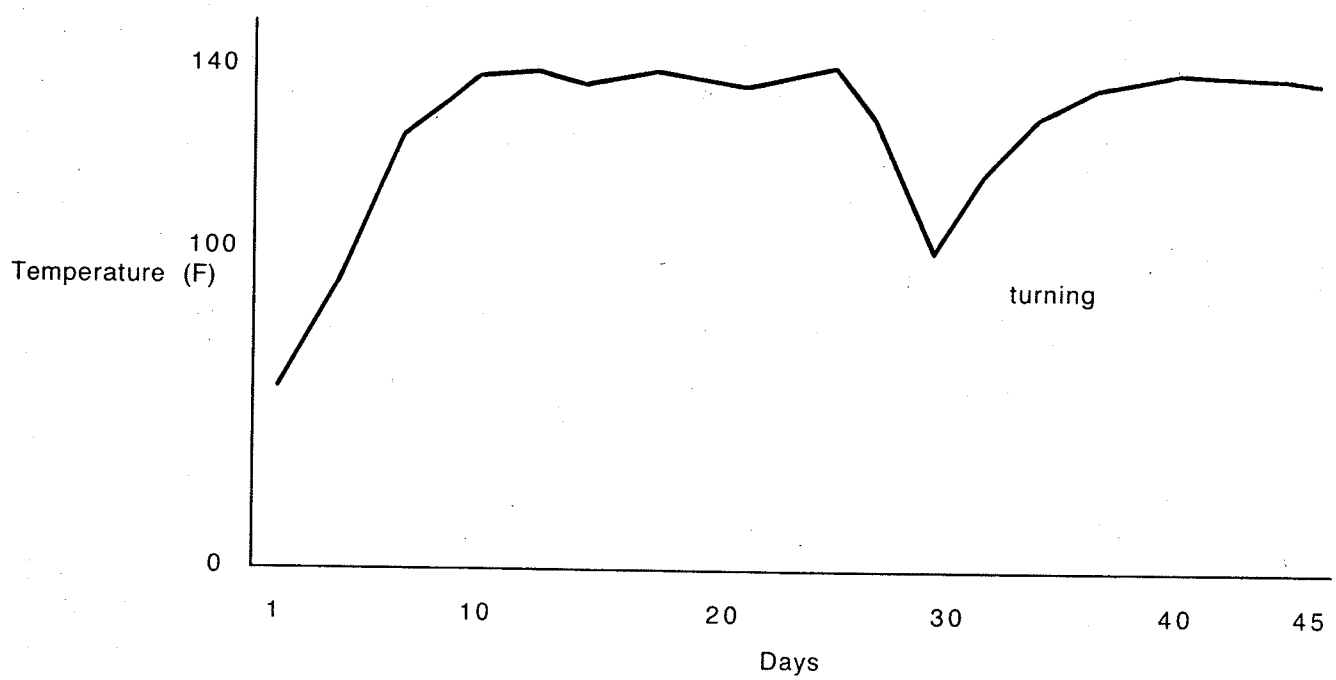
FIGURE 6-7
TEMPERATURE MEASUREMENT TECHNIQUE



Windrow temperature does fluctuate due to changes in outside temperature and precipitation events. So a temporary drop in temperature is not necessarily indicative of a need to turn the pile. However, by keeping records of temperature over time, a downward or upward trend of change can be observed. Temperature should be maintained between 100 and 140°F. Temperatures in excess of 150°F may result in the heat "sanitizing" the pile, where decomposing microorganisms die off and the pile will cool off to mesophilic ranges. The result is a delay in the degradation process resulting in leaves and yard waste remaining on the composting pad longer than expected. Such extremes in temperature result in the inclusion of large amounts of green wastes, either as grass, or as the result of a windrow being too large, resulting in over-insulating the pile interior. Turning the piles can release excess heat and control high temperatures. Also, reducing pile size may be required in extreme cases.

A drop in temperature indicates that microbial activity has reduced. This is most often as a result of loss of oxygen through metabolic respiration of the decomposing organisms. Turning will provide the needed oxygen and release the waste products of metabolic respiration, CO_2 and H_2O. After a turning, a temperature rise into thermophilic ranges should be observed within two or three days.

FIGURE 6-8
TYPICAL WINDROW TEMPERATURE RESPONSE TO OXYGEN AVAILABILITY



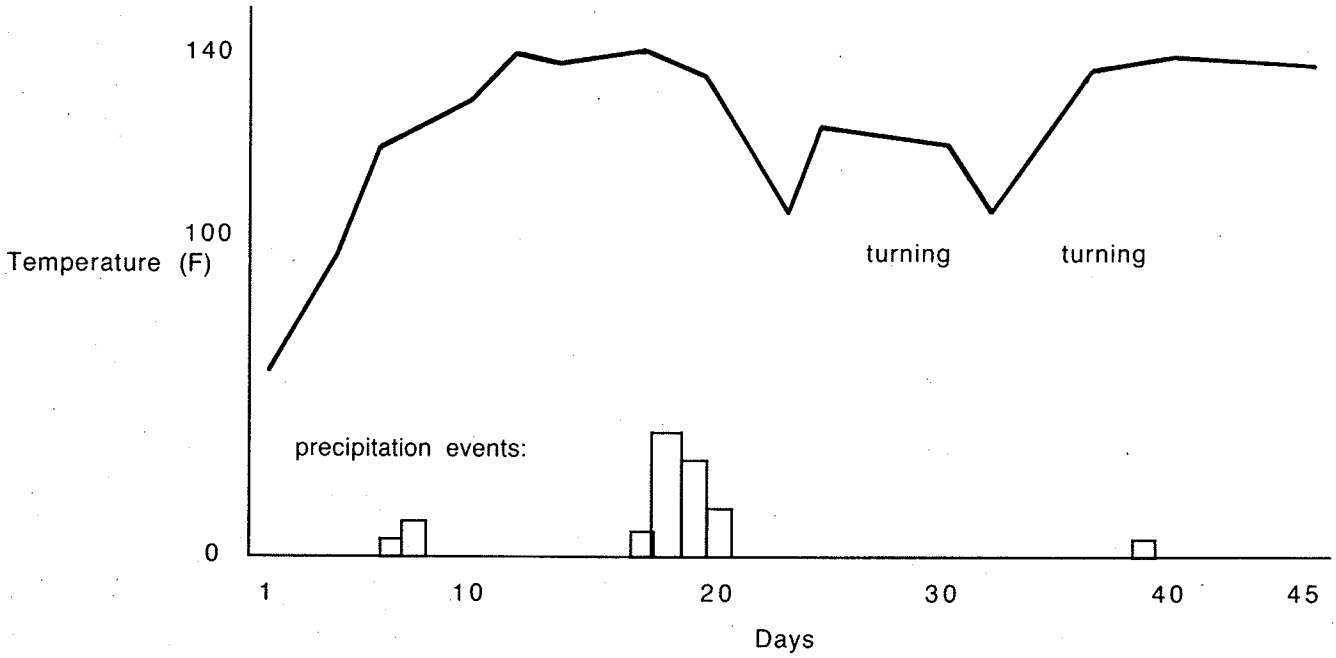
A temperature drop can also indicate that moisture conditions are not at optimal levels. If the pile has been too wet due to excessive precipitation or after spring snowmelt, then water will displace oxygen in the available pore space. The result is microbial activity decreases with a subsequent drop in temperature. Turning the pile will reduce excess moisture and allow re-oxygenation. If temperature does not maintain an upward trend after such a turning, then a second, or possibly third, turning will be needed to dry out the piles to optimum levels.

Conversely, if the leaves and yard waste are too dry, decomposing microbial population will not be able to grow and resulting thermophilic temperatures will not occur. Addition of moisture from an on-site water source is then indicated.

Another method for moisture addition is to mix wetter incoming yard waste with already present dry material in the windrows. Such blending will allow a better all-around operation. In addition, turning piles during precipitation events could add needed water.

If yard waste remains too dry, they will not break down rapidly and may be on-site longer than desired. If yard waste is too wet, the rate of decomposition will also be decreased; in addition, anaerobic conditions could result in malodors.

FIGURE 6-9
WINDROW TEMPERATURE RESPONSE TO HEAVY PRECIPITATION



In this case two turnings were required to remove excess moisture from a heavy precipitation event.

Thus, temperature only indicates a decrease in microbial activity. The operator of the compost site will need to dig into the piles to determine if the reason for this decrease in temperature is related to moisture levels.

6.3.6 TURNING

The schedule for turning should not be driven by a fixed schedule; rather the environmental conditions within the compost pile should be monitored to determine when to turn the piles.

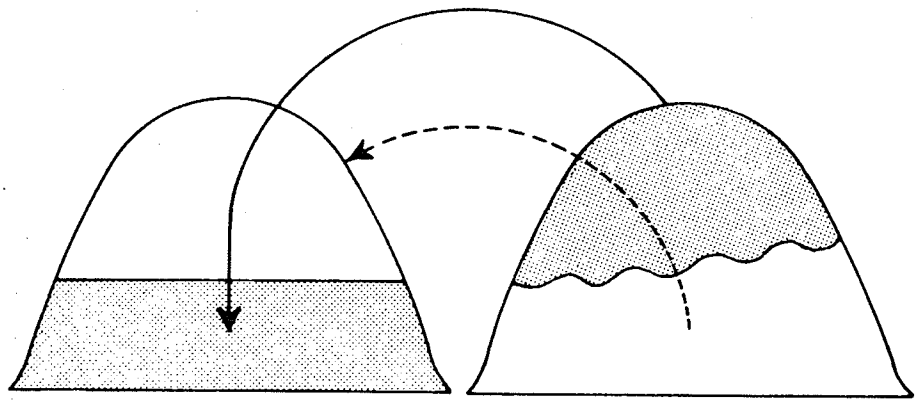
Windrows should be approximately 12 feet to 14 feet wide at the base for convenience in turning and haystack-shaped in cross-section to shed water. Piles can be as long as several hundred feet, depending on the size and shape of the site and operational convenience.

Windrows must be turned to exchange material at the center of the pile with that on the outside, a process which provides the oxygen necessary for the maintenance of aerobic decomposition. Neither a simple overturn nor a vertical expansion of the pile constitutes adequate turning; an

exchange of material from outer to inner sections of the windrow is necessary. The material should be lifted high and dropped to allow it to cascade down for greater aeration and mixing.

FIGURE 6-10
WINDROW TURNING FOR AERATION AND MIXING

Lift leaves high with bucket loader and let leaves fall to new location to create a cascading (mixing) effect.



Note: The principle of the mixing technique is to move the top of the windrow to the bottom of the windrow being formed, mixing the leaves well during this process.

Source (Connecticut DEP, 1989)

If space allows, turning of each windrow should be done twice in the same direction to insure that material on the bottom and center of the pile is to the top and outside of the pile. At locations with site constraints, windrows may need to be turned once in one direction and then turned a second time in the opposite direction. The result will be a new windrow formed in its original spot, but now the pile has been oxygenated and the leaves fluffed up so that exchange of gases in enhanced.

On turning, the front-end loader operator should avoid just "pushing" the leaves. Again, lifting and cascading the leaves is essential for proper aeration. Also, operators should avoid driving up on the windrow or pressing the leaves down with the bucket; both activities will only compress the leaves and reduce the pore space which is essential for aerobic conditions.

The turning schedule should be based on temperature and moisture content monitoring. When the temperature drops below the 100°F threshold or exceeds 150°F, the pile should be turned. If the moisture content exceeds 60 percent, the windrow should be turned. If possible, piles should

be turned when the wind is blowing away from sensitive land uses. Piles can be turned in the rain if additional moisture content is required. Other considerations include the desired rate of decomposition and the availability of a front-end loader.

6.3.7 CURING

As decomposition proceeds, the windrows will reduce in volume and the material will lose visual characteristics of yard waste and begin to resemble soil. The material is moving toward a stable product. The carbon-nitrogen ratio is approaching 20:1 and the volatile nitrogen is being captured in organic compounds.

For low-technology composting methodologies, after about ten months the operator should begin to monitor the level of stabilization of the compost. Two simple procedures can be used for this purpose. The first test involves turning the windrow and monitoring the internal temperature. If the pile reheats, the product is not yet stable enough for curing. In the second test, a sample of the compost can be placed in a plastic bag and sealed for 24 to 48 hours. If significant odor is given off as the bag is opened, the product is not yet stable.

When the material appears to have ceased active composting, it can be moved to a curing pile, off the active compost site, which will free up space for incoming material.

The curing pile can be larger. The compost should remain in such a pile for at least 45 days. This will allow final stabilization within the mesophilic range. Also, this curing period will allow organisms that are compatible with soil environments to re-inoculate the compost.

6.3.8 SCREENING

Screening of compost material in an optional step. Since the throughput time through a screener is slow, it may be the costliest operational step.

The primary decision of whether to screen or not is dependent on the projected end use for the compost product. If the material is going to be distributed to residents, landscapers, garden centers, etc., the screening may be desired to produce a product which is visually pleasing and

looks uniform throughout. However, if the yard waste compost is destined for uses such as landfill cover or bank stabilization material for public works projects, the screening step may not be necessary.

Screening, besides producing a more uniform end product, also removes non-compostables. It is the ultimate quality control step. In addition, if woody waste has been included in the windrow, it may not be as completely decomposed. Screening can separate out this material which can be reintroduced into newly built windrows to allow further degradation.

6.3.9 STORAGE

Once cured, the compost is similar to soil and can be stored indefinitely. Since the compost is now reduced down to 50 to 25 percent of the original volume of material originally arriving on site, adequate space must be allocated for the on-site storage of finished compost.

One concern for storage of compost is growth of unwanted plants. If yard waste is properly composted, weed seeds are destroyed. After curing, weeds can be transported to the storage pile by the wind. If plants are allowed to grow and seed, the compost will be contaminated to the point that special end user markets, such as garden stores, landscapers, nurseries, golf courses, etc. may not want the product.

Depending on projected end use, the storage pile may need to be either covered or sent to end users in a relatively brief time. This would not be a concern for end uses such as landfill cover, public works projects, etc.

6.3.10 COMPOSTING GRASS

Once cured, the compost is similar to soil and can be stored indefinitely. Since the compost is now reduced down to 25 percent of the original volume of material originally arriving on site, adequate space must be allocated for the on-site storage of finished compost.

The addition of grass to leaf windrows accelerates the breakdown time of the leaves, and shortens overall composting time. On the other hand, nitrogen is in higher concentrations in grass than in leaves and is converted into nitrate, a soluble form, by the aerobic composting and curing process. Nitrate is a valuable nutrient, which can also be a pollutant in sufficient quantities. Potential nitrate leaching can be prevented through proper site design and compost management.

Grass collected in plastic or paper bags must be debagged as soon as possible after arrival. If grass is allowed to remain in bags for more than two days, the grass may become anaerobic and generate strong odors when the bags are opened. This creates an unpleasant job for the debaggers and could cause an odor release to the immediate area. Collection in no-biodegradable plastic bags is discouraged given the additional labor requirements involved in debagging. Grass collected in biodegradable bags should be shredded.

Thus, to properly compost grass it is recommended that:

a) Grass left in a large heap will begin to decompose anaerobically very quickly and become difficult to handle and will result in odor generation. Thus, grass needs to be quickly mixed

with leaves or other carbonaceous sources, creating a slimy mass. It will emit strong odors when disturbed and will be difficult to blend with leaves.

b) For safe and practical handling of grass, the most important single factor is the proper mix ratio. In general a maximum of 1 part grass to 3 parts leaves by volume is the recommended mix. The higher the proportion of leaves to grass, the lower the potential for problems. If leaves are not available, another carbonaceous material such as wood chips can be used. If composting on sandy soils, especially where there is a relatively high water table, it is important not to compost a higher ratio of grass to leaves than 1 to 3. (CT DEP)

c) Higher levels of nitrates are formed during the mesophilic (low temperature) and curing stages than during the thermophilic (high temperature) stage of active composting. Thus, monitoring piles to be sure composting is occurring within the thermophilic range will minimize nitrate generation. Proper management of curing piles, which will be described later, mitigates potential leaching of nutrients. (Fulford, et. al.)

d) A possible danger from collecting and composting grass is spontaneous combustion, which requires a moisture level less than 40% and temperatures in excess of 450° F. If the windrow has dry pockets, fire is a possibility. Temperatures approaching 200° F will quickly lower the moisture content of the pile below 40%. If the compost windrow reaches temperatures above160^{o} F, the pile should be turned and aerated. Turning will cool it down.

Mixing Procedures

⇒ When composting grass with leaves, greater care should be taken to monitor temperatures. Grass is high in nitrogen and generates higher temperatures than leaves as it decomposes. This could raise the temperature high enough to kill off the microbial population in the windrow. A loss of composting time will result, because it will take a period of time for the microbes to repopulate the windrow and continue their work.

⇒ Blend grass with leaves as thoroughly as possible in initial mixing. It is important to make sure that grass isn't mixed in with the leaves in large clumps. If grass is not properly blended, there may be pockets of anaerobic grass breaking down which will cause odor and potential nitrate problems.

⇒ If the interior of the windrow is dry, thoroughly mix in grass. The high moisture content of grass will provide needed moisture to the windrow;

⇒ If the interior of the windrow is at the correct moisture content, or is on the wet side, spread the new grass in a 3-4" layer on top of the windrow and let the sun dry it out. Then mix the dry grass in with the leaves. Calculate the approximate volume of leaves, and keep records of the amount of grass added to the windrow. In this way, you may keep adding grass to the windrow on a weekly basis until you reach 1:3 parts grass to leaves by volume. and let it dry. (MA DEP)

CHAPTER 7—QUALITY CONTROL

7.0 INTRODUCTION

Quality control is needed to avoid negative impacts to the environment. Without a quality control set of procedures, environmental problems would develop, resulting in regulatory agencies shutting down a project. Similarly quality control can reduce the likelihood for nuisance conditions which may adversely affect residents of the community. In essence, if the citizens are not pleased with the way a site appears or smells public sentiment could also result in the termination of the composting operation.

7.1 REMOVAL OF NON-COMPOSTABLES

Quality control starts with proper public education. Information should be provided to residents on what wastes will be accepted at the composting site and/or how it would be separated and set-out at the curb for pick up. Newspaper advertisements and articles, public service announcements over local radio and television stations, and inclusion of a flyer with facts on water bills are all effective measures for informing the public on how best to participate in a composting project.

Again, a similar education effort needs to take place at the composting site. This is especially true if residents are dropping-off their own leaves and yard wastes. The type of organic material to be accepted at a facility must be clearly described to residents and haulers. Materials typically considered yard waste are: leaves, lawn clippings, garden waste, weeds, and hedge clippings. Incoming waste should be carefully monitored to control the dumping of inappropriate wastes. While care should be taken to minimize the amount of non-compostable material incorporated into the windrows, quality control monitoring should continue throughout the entire composting process.

If pre-processing, such as size-reduction and/or mixing, is to be required, such as with material arriving in biodegradable bags, it may need to be dropped off in a separate area from material that arrives in bulk. Monitoring and controlling waste material in the compost piles serves to minimize environmental impacts to the site and adjacent area and to protect the final product from contaminants. Experience has shown that a good deal of inorganic material tends to “float” to the top of the pile as the volume of organic material decreases due to the process of decomposition. These non-compostables can also be removed during windrow turning and curing pile formation. Other opportunities for removing this type of material is during pile turning and pile combining. Finally, a screening step can be employed to remove those objects missed during previous procedures. Screening may only be considered if the end use requires a clean, uniform-looking product.

FIGURE 7-1
EXAMPLE OF A FLYER DISTRIBUTED TO RESIDENTS

CITY OF BRISTOL
LEAF COLLECTION AND COMPOSTING PROGRAM

WHAT IS THE BRISTOL LEAF COMPOSTING PROGRAM?

Starting in October, 1988, the City of Bristol will be collecting leaves placed at the curb loose or in special biodegradable bags. The leaves will be composted or converted into leaf humus.

WHAT IS COMPOSTING?

Composting is a process which decomposes vegetative materials, such as leaves and grass clippings, into compost or humus. It is an environmentally safe process which produces a useable end product. The finished compost is an excellent soil conditioner, especially effective for improving soil aeration and drainage characteristics of clayey soils and for improving water and nutrient holding capacity of sandy soils. Compost also supplies micronutrients essential for good plant growth.

WHY COMPOST OUR LEAVES?

The State of Connecticut has set a goal of reducing by 25 percent the volume of solid waste that must be landfilled or incinerated. Composting not only removes significant volumes of solid waste from the waste stream, thus reducing the possibility of harm to our air and water, but produces a useable end product. The City of Bristol is cooperating with the State to achieve this recycling goal and to save your tax dollars.

HOW WILL THE LEAVES BE COLLECTED?

Loose leaves raked to the curb will be collected provided no trash is mixed with the leaves. In addition, the City of Bristol will make available, free of charge, special biodegradable bags for use only in the leaf collection program. No leaves will be collected in regular trash bags.

WHEN WILL THE LEAVES BE COLLECTED?

A collection schedule for leaves raked to the curb will be published in the Bristol Press. Leaves bagged in biodegradable bags, placed at the curb separately from the trash, will be collected on regular trash collection day between Oct. 17 and Dec. 2

7.2 THE QUALITY OF THE END PRODUCT

Depending on the end use, cured compost should be analyzed for stability, nutrient value, and contaminants. Contaminants are not likely to be present, but should be tested for as a safety measure. Tests for stability include volatile solids (which indicate organic content) carbon/nitrogen ration, moisture, and pH.

The nutrient content of the end product should be analyzed to determine the percentage of nitrogen, phosphorous, and potassium (N:P:K) present in the compost. This information indicates the fertilizer value, which is important to consumers of the product and is useful in marketing the compost. While leaves composted by themselves tend to have low N:P:K, the compost is an excellent soil conditioner.

An analysis of the total concentration of heavy metals present in the compost should be conducted. The concentration of lead may be of particular concern with yard waste compost. Studies in Oregon, Minnesota, and Massachusetts shows heavy metal levels well within the range of acceptability (Simpson, E&A Environmental Consultants).

Organic residues from herbicides and pesticides may be present in the compost. While preliminary studies indicate that these materials break down after two or three months of aerobic decomposition (Fulford), an inexpensive generic screen test for volatile organics is suggested. If the tests show positive, more sophisticated follow-up tests may be necessary.

Records of these analyses should be maintained and made available to prospective consumers of the product.

7.3 GREEN WASTES

To avoid odors, green wastes, such as grass and garden wastes, should not be composted alone, nor stored for long periods of time before incorporation into existing windrows. On the other hand, because grass clippings are high in nitrogen and moisture, when added to an existing pile, they can enhance the composting conditions and increase the rate of degradation. Grass clippings arriving in degradable bags may be of concern, since odors can develop within one or two days, while degradable bags may not begin to break down for weeks (Michigan DNR). Thus, if large amounts of green wastes are arriving in bags, other pre-processing steps of size-reduction and mixing is recommended.

7.4 FIRES

Fires are rarely a problem in outdoor composting operations, primarily because when operated correctly, a pile's moisture content is between 40 and 60 percent; as a result, compost normally burns poorly. Without proper quality control of the process, materials could dry out and get too hot, resulting in spontaneous ignition. This may be especially true when green wastes are incorporated into the windrow. This condition requires a moisture level less than 40% and temperatures in excess of 450° F. (Dickson). If proper monitoring procedures are in place, combustion is not likely to happen. Designing the site for access by firefighting equipment and an available water source on site are all contingency measures which should be employed. In addition, the site should have secured access to discourage vandalism.

7.5 WORKER SAFETY

Safety concerns with composting are more related to equipment operation. Especially with specialized compost pre-processing and turning equipment where blades, hammers, and flails rotate at high RPMs resulting in material being thrown out, human contact should be minimized and operators appropriately shielded.

Health concerns related to the compost itself are minimal. While few pathogenic organisms are found in yard waste, normal sanitary measures, such as washing hands before handling food or toweling eyes, should be implemented.

In some cases, certain individuals may be sensitive to organisms in the compost itself, since many of the organisms are mod and fungi and tend to release spores. Once specific fungus has been documented as causing an allergic response in operators and that is the fungus Aspergillus

fumigatus. This fungus in a naturally occurring organism in all decaying matter. The spores of this fungus are universal and can be found any place. Simple precautions such as OSHA approved dust masks and goggles can help limit exposure of individuals to dust and molds. Those individuals with conditions which may predispose them to an allergic response (conditions such as weakened immune systems, history of allergies or asthma, punctured eardrums, or medications such as antibiotics or cortical hormones) may not opt for working at a compost site.

7.6 RECORDKEEPING

The importance of good recordkeeping cannot be over emphasized and it may be required by local and/or state environmental regulatory agencies.

Operators should keep a log to track the volume of weight of incoming yard waste and its origin. This data will be useful for:

- Developing estimates on the amount of compost that will be produced;
- Determining the adequacy of the site for handling projected levels of yard waste;
- Isolating the origin of contamination problems; and
- Developing a cost/benefit analysis.

In addition, records of any problems occurring, such as odors, and what steps were taken to mitigate them may be valuable in resolving negative public relations which can be created by just a few disgruntled residents.

Temperature monitoring and ambient weather conditions should be recorded, so not only a change of temperature can be assessed over time, but also trends can be recognized so as to indicate when a turning will be needed. Graphic representation of internal pile conditions to external conditions will also demonstrate how effective operating procedures maintain optimum biological activity. Appendix B gives examples of generic recordkeeping sheets which could be used by a site operator.

Finally, records of analysis of the quality of the end product should be developed and made available to prospective end use markets.

7.7 CONTINGENCY PLAN

Operators should develop alternate plans for managing yard waste in the event that the compost operation is disrupted by natural disasters, fiscal problems, staffing shortages, or equipment failure.

A permitted solid waste processing or disposal facility should be available as a back-up measure.

If the composting facility is inoperable for a longer period than the site storage capacity will allow, no additional yard waste should be accepted.

CHAPTER 8—COMPOST END USE

8.0 INTRODUCTION

A yard waste composting program is more than a solid waste management strategy. One is also entering the commodity market for soil amendments. Therefore, one of the first things to be done in planning a yard waste composting program is to determine local end uses for the compost. Adequate information on the potential users' requirements for quality and quantity is a mandatory pre-requisite for defining the composting methods, equipment, and operations, necessary to produce a compost meeting the user's demands.

"As long as a high quality, consistent, and stable compost is produced there should never be any difficulty securing more than adequate demand."

8.1 CHARACTERISTICS

Compost is a stable, soil-like material that is an excellent substitute for topsoil, peat moss, and mulches in horticultural and agricultural applications. Yard waste compost is considered to be an excellent soil conditioner or amendment. Typically, it is a very high quality compost with very low to not measurable concentrations of heavy metals and toxic organic compounds. Yard waste compost requires post-processing in order to have the greatest value. Screening and shredding will remove clumps, twigs, branches, and inert contaminants, producing compost which has a very consistent quality and high value.

Composts benefits to soil condition include:

- Improved soil aggregation
- Improved water infiltration
- Improved water retention
- Improved soil porosity
- Improved soil aeration
- Decreased soil crusting

In most cases, this compost has limited fertilizer value due to low nitrogen, phosphorus, and potassium content.

8.2 USER TYPES

Compost users can be grouped into four categories: commercial, residential, public agencies, and land reclamation. The specific user types are summarized as follows:

Commercial
Landscape Contractors
Nurseries
Greenhouses
Turf Farms
Topsoil Suppliers
Soil Blenders
Golf Courses

Residential
Garden, Lawn and Flower

Public Agencies
Park Maintenance
Decorative Planting
Curb Repair
Backfilling
Community Gardens

Land Reclamation
Landfill Cover
Mined and Derelict Land
Re-vegetation

Horticultural operations require large, continual supplies of high quality organic material. For landscapers, compost can be substituted for topsoil and peat moss in landscape construction and maintenance. Greenhouses and nurseries may substitute compost for peat moss in potting and planting soil mixes. Turf farms and golf courses may use compost to help establish new sod or as a fine-textured top dressing. Public agencies can use compost in a wide variety of ways, thereby reducing their purchases of soil and mulches. Compost can be used effectively as a final cover for landfills and for re-vegetation of strip-mined or derelict lands. If adequate amounts of free compost are available, public agencies may even expand their use of compost above previous levels that were constrained by budgetary limits.

If adequate amounts of free compost are available, public agencies may even expand their use of compost above previous levels that were constrained by budgetary limits.

8.3 DEMAND

In order to determine the potential for compost, one must gather the following information from potential users (CT DEP):

- Specifications for organic materials
- Capacity to utilize compost (both seasonal and annual)
- Shipping and handling requirements
- Potential revenue from sales of compost

Another important factor is the price of competing materials such as topsoil, peat moss, or other compost products.

"Most potential users require high quality and consistency."

Therefore, maintaining an adequate, stable demand for compost will be greatly dependent on having adequate supplies of high quality compost at competitive prices. It also should be remembered that compost is in highest demand during the spring and early summer months.

Public education also plays a key role in increasing product demand. All potential markets need to be informed of the values and benefits of compost, stressing the value of adding organic matters well as nutrients. The fact that the compost is a locally produced resource can be a secondary factor contributing to steady demand.

8.4 CONSTRAINTS

8.4.1 USER RESISTANCE TO CHANGE

In general, it is difficult to capture a market share for a new product, such as compost. If potential users are satisfied with certain existing materials, there is little incentive to change, unless there is a significant price difference. On the other hand, offering compost for free can make potential users suspect that there must be something wrong with it since it is being given away. Private sector users will be especially resistant to leaving their current supplier if it cannot be demonstrated that a large and datable supply will exist. It will require several years of works to overcome such resistance to change. Efforts can focus on providing accurate product information, user trials, cooperative extension and university testing programs, extensive public education, demonstration plots in visible areas, etc. (Tyler)

8.4.2 TRANSPORTATION

Because of composts relatively low value, it can only be transported cost-effectively within a certain radius. One must be careful to reconcile potential revenue or avoided soil purchase costs against the cost to transport compost to users. Many programs are able to distribute compost primarily through a pick up programs, and to charge a fee for delivery that covers costs.

8.5 DISTRIBUTION AND MARKETING OPTIONS

There are several bulk compost distribution and marketing options available for yard waste composting programs. Production and distribution of a bagged product, is not recommended for yard waste compost. However, local public agencies and departments can obtain compost free of charge utilizing their own equipment to load and transport compost off-site to various job sites or storage areas. In addition, private operations can be charged on a volume or vehicle basis for bulk material picked up at the compost site or delivered for an additional charge. Also, residents can be encouraged to pick up compost at no charge or at a minimal fee. This third distribution option provides an excellent way not only to publicize the advantages of composting and resource recycling in general, but it also increases and instills a greater sense of community identity and pride.

A fourth distribution and marketing option is wholesale. Compost can be sold at low cost to soil blenders, topsoil suppliers, and other large-scale suppliers of organic materials. Although this option does not provide maximum revenue or publicity, it requires the least effort on the community's part to assure that all the compost is distributed for productive use.

CHAPTER 9—ECONOMICS

9.0 INTRODUCTION

In many areas of the United States the cost of yard waste composting is less than the traditional means of disposal. Program benefits are primarily measured in terms of avoided disposal cost based on the amount of material diverted from landfilling or incineration. In addition, the production of compost results in additional savings by reducing municipal soil purchases. Some programs also generate revenue from compost sales to citizens and private businesses.

Evaluating program economics plays a central role in program planning and development. These activities include:

- Evaluating program capital and operating costs
- Estimating avoided disposal and soil purchase costs
- Determining if and what fee will be charged to end users
- Estimating the potential revenue
- Assessing the overall costs and benefits

Another important function of information on program economics is to facilitate decision-making regarding program modifications to improve efficiency and reduce costs.

This chapter focuses on the major operational components of yard waste composting; discussing major cost variables, common equipment and personnel configurations, efficiency/throughput, and some reported costs for operating programs. The worksheets in Appendix C can provide the basis for estimating costs and subsequent development of a cost accounting system. Site development, education, and start-up costs are *not* reviewed.

Costs vary greatly from program to program due to such factors as the scale of operation, material input, labor costs, available equipment, and technology used, and even the regulatory framework for composting facilities.

Additionally, for many yard waste programs, costs are not a "line item" in budgets, but are blended into overall department costs. When equipment and personnel are utilized for various projects or tasks, it can be difficult to track actual costs directly. ***Consequently, the costs reported in this document should serve as guides only***. Individual program costs will vary based on the degree of detail desired and local conditions.

9.1 BUDGETING AND COST ACCOUNTING

Program operations can be divided into five components: collection, pre-processing, composting, post-processing, and end use. For each component, the key cost variables are:

- The quantity of material
- The amount of labor required
- The efficiency or throughput of the equipment utilized

Generating these numbers allows one to see the relative proportion each component represents of total program costs. In addition, there are specific variables associated with each component.

Labor requirements and equipment efficiency are the major places for identifying options for cost-saving and increased efficiency.

The following sections provide an overview of equipment and personnel requirements, estimated efficiencies, worksheets for calculating costs, and strategies for increasing efficiency and reducing costs.

9.2 COLLECTION

Although not the focus of this particular manual, it is important to remember yard waste collection costs will be the largest single cost component of the total yard waste program. A recent survey (DSM Environmental) of regional haulers was conducted to ascertain the incremental cost to households for the separate collection of yard waste. The survey results, while limited, indicate that subscription service would cost a subscribing household between $4 and $5 per month over the course of the yard waste season. Organized collection would cost between $2 and $3 per month

Table 1 of Appendix C uses an example of biodegradable plastic bags used for the collection of yard waste. If bulk collection of yard waste was the preferred method, utilizing a leaf-vacuum unit and crew, this table would need to be amended.

9.3 PRE-PROCESSING

Because leaves and yard waste is collected in bags, they should be shredded before composting in order to allow for proper oxygenation and moisture addition. Also, such size-reduction is necessary for woody material to increase surface area to accelerate decomposition, and to produce a relatively homogenized mixture of leaves and yard waste. Included in the cost calculation for this component are watering and windrow formation. Table 2 (Appendix C) presents a cost estimating format. A common configuration employed is a tub mill grinder equipped with a grapple and knuckle-boom, a front-end loader, two dump trucks, and a water truck or fire hydrant. Crew requirements for such a system are two heavy equipment operators and two or three drivers/laborers.

Pre-processing efficiency can range from 15 to 20 tons/paid crew hours, dependent primarily on actual throughput of the shredding/grinding equipment. Costs for pre-processing are not usually listed separately from overall composting costs. However, cost data from the Bristol, Connecticut program has estimated pre-processing at approximately $15 per ton, including amortized capital cost for a tub mill grinder, (E&A environmental Consultants). O&M costs for a tub mill grinder are comparatively high because the hammers require frequent maintenance.

9.4 COMPOSTING

Costs associated with composting include windrow turning, monitoring, and curing pile formation.

Temperature data and visual inspection are used to determine when turning/aerating should take place. Once temperature indicates cessation of thermophilic condition, large curing piles are formed to insure that adequate pad area is available for incoming material. Table 3 (Appendix C) presents a method for estimating costs for this phase of a program. Two common configurations for windrow turning/aeration are:

- A front-end loader with one equipment operator
- A windrow turning machine with one equipment operator

Average composting efficiency can range from 30 to 90 tons per paid crew hour for a front-end loader depending on the bulk density of the compost, operator skill, distance between windrows, and weather conditions. A self-propelled, flail-type windrow-turning machine can process 2,000 to 3,000 tons per paid crew hour, dependent on similar variables. Capital and operating cost estimates for this type of machine are $125,000 and $25 per hour, respectively. Such equipment can generally be justified only for larger city or regional programs.

Reported Composting Annualized Capital Costs

Austin, TX	**$ 21**
La Crescent, MN	**$ 17**
Newark, NJ	**$ 6**
Lincoln Park, NJ	**$ 1**

Source USEPA

It should be realized the composting methodologies and the size of these communities may vary, and there may be some economies of scale with utilizing large pieces of equipment that can be shared between communities.

Monitoring requires gathering temperature records at least twice weekly during early phases of decomposition. Less frequent temperature reading may be taken as composting slows to mesophilic condition.

Reported O&M Composting Costs

Austin, TX	**$ 58**
Berkley, CA	**$ 25**
La Crescent, MN	**$ 12**
Newark, NJ	**$ 11**
Lincoln Park, NJ	**$ 3**

Source USEPA

Curing pile formation generally entails use of one front-end loader and two dump trucks with associated labor. This method moves 90 to 100 tons per paid crew hour.

9.5 POST-PROCESSING

Good compost quality is crucial to successful distribution. Post-processing entails shredding and screening to break up clumps and remove contaminants, producing a uniform, high-quality soil amendment. A common configuration for yard waste compost post-processing utilizes a shredder/screener, a front-end loader, and possible a dump truck for moving compost. The labor requirement is one heavy equipment operator.

Table 4 (Appendix C) can be used to calculate costs. Shredder/screener equipment can be either purchased or rented. A number of programs choose to rent because of the relatively infrequent schedule for post-processing. An alternative is for several programs to jointly purchase, maintain, and utilize one machine. Large shredder/screeners are available that process up to 200 tons per hour. However, a more common size for municipal scale programs is 25 to 35 tons per paid crew hour. Capital and operating cost estimates for such a unit are $70,000 and $15 per hour, respectively.

9.6 DISTRIBUTION

Finished compost is an excellent soil amendment and topsoil substitute that can be used in horticultural, landscaping, and grounds maintenance work. Distribution activities are diverse and in some cases very creative. A strategy is developed based on a survey of the needs and capacity of waste potential user types. Yard waste compost is most commonly distributed in bulk. Distribution of a bagged compost product requires much more careful market analysis and persistent marketing efforts; time and money that most communities decide is not needed because demand for bulk compost is more than adequate.

Commonly, compost is distributed in three ways:

- Utilized by parks and public works departments
- Sold or given away to residents and private enterprises
- Sold or given away to soil blenders, compost brokers, or topsoil suppliers

Many programs will depend primarily on the first two options. Public sector use will generate avoided soil purchases costs that should be factored into a cost-benefit analysis. Compost can be sold to residents and the private sector at a fee which can be used to cover some of the program costs. Revenue generated from sales must be part of a cost-benefit analysis. Greenwich, Connecticut sells compost for $6 per yard (Illinois DENR). Woodbury, Minnesota avoids land costs by exchanging compost for use of a nursery's land. East Tawas, Minnesota uses all its compost in parks and public works projects. Seattle, Washington charged $7.50 to $12.50 per yard (Taylor & Kashmanian).

When compost is given away or sold at the compost site, distribution costs will be limited to site monitoring and possible operation of a bucket loader for loading material. If compost is given

away or sold at several distribution points, or delivered to customer, additional costs will be incurred for transportation. Distribution costs can be calculated using Table 5 (Appendix C).

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APPENDICES

APPENDIX A: TROUBLE SHOOTING GUIDE

This appendix outlines potential pollution and nuisance problems which may arise as a consequence of poorly managed leaf and yard waste composting.

ODOR: Odor is generally considered to be the most prevalent problem encountered at leaf and yard waste composting facilities.

SITING:
(1) Provide an adequate buffer between the composting operation and sensitive land uses.
(2) Locate sites downwind of sensitive uses.

DESIGN:
(1) Place windrows at the center of the site and curing piles at the perimeter.
(2) Align windrows perpendicular to the topographical fall line, so that water runs between the piles rather than through them, to minimize ponding.

OPERATION:
(1) Build windrows to proper height and shape.
(2) Form incoming leaf and yard waste into windrows promptly.
(3) Maintain proper temperature, moisture and oxygen content with an effective turning schedule based on temperature and moisture monitoring.
(4) Time pile turnings to coincide with favorable wind conditions.
(5) Monitor incoming waste to limit the amount of putrescrible material incorporated into windrows.

RUN-OFF: Run-off from leaf and yard waste composting operations may contain small quantities of heavy metals, insecticides, herbicides and inorganic nutrients all of which can have a detrimental impact on surface and ground water if not properly managed.

SITING:
(1) Facilities must be sited in compliance with Federal and State Regulations.
(2) Avoid sites adjacent to lakes, rivers, and reservoirs.
(3) Avoid sites where the water table rises closer than 4 feet to the surface.
(4) Avoid steep slopes.
(5) Choose a site with soils capable of attenuating leaf drainage water.
(6) Avoid sites where the bedrock is less than 5 feet from the surface.

DESIGN:
(1) Design a method to divert run-off from compost and curing piles.
(2) Design a method that will contain run-off on-site, and that will handle the run-off with minimal impact to the groundwater.

OPERATION:
(1) The concentration of heavy metal contaminants in leaf and yard waste can be reduced by prohibiting or limiting the volume of leaves collected by street sweepers that are incorporated into the compost pile.
(2) Plan for prompt disposal of non-compostable material.

EROSION AND SEDIMENT CONTROL: The potential exists for erosion to occur on-site and along access roads. The problem of sediment laden run-off entering surface water is a related concern.

SITING:
(1) Avoid sites in close proximity to surface waters.
(2) Avoid steep slopes.
(3) Choose a site with moderately permeable soil.

DESIGN:
(1) Grade the site properly, perferably with a 1–2 percent grade.
(2) Retain as much vegetation as possible when clearing the site.
(3) Design access and on-site roads properly.
(4) Use diversion ditches and baled hay to contain run-off.

DUST: Problems with dust can result from uncontained, dry organic materials and the movement of equipment over unimproved surfaces.

SITING:
(1) Provide adequate buffer between the operation and sensitive land uses.
(2) Locate the site downwind of sensitive uses.

DESIGN:
(1) Construct access roads with improved surfaces.

OPERATION:
(1) Maintain proper moisture content in the windrows.
(2) Periodically wet unimproved surfaces during episodes of extended dry weather.

LITTER: This is a minor problem at leaf and yard waste composting facilities, but one which can create nuisance problems if not properly controlled.

SITING: (1) Provide an adequate buffer zone.
(2) Locate site downwind from sensitive land uses.

DESIGN: (1) Retain perimeter vegetation or design berms to act as wind screen.

OPERATION: (1) Form leaf and yard waste into windrows promptly.
(2) Regularly collect litter from fences or tree line barriers and along roadways.

VECTORS: Leaf and yard waste composting operations do not normally attract vectors, but operators should not disregard the potential.

OPERATION: (1) Maintain an effective composting process.
(2) Properly store and promptly remove and dispose putrescribles that have been mixed with incoming leaf and yard waste.

ASPERGILLUS FUMIGATUS: The spores of this fungus, common at composting operations, can produce an allergic response in susceptible individuals, and can cause infections in individuals with weakened immune systems.

OPERATION: (1) Adequate wetting and minimum disturbance of windrows.
(2) Screen job candidates, at the composting facility, for allergic conditions.

APPENDIX B-1: SAMPLE MATERIAL DELIVERY DATA SHEET

Month_____								Year_____	
DATE	Vehicle No._____ Type_____ Cap. Cu.Yd.		Vehicle No._____ Type_____ Cap. Cu.Yd.		Vehicle No._____ Type_____ Cap. Cu.Yd.		Vehicle No._____ Type_____ Cap. Cu.Yd.		TOTAL
	Loads	CY/Tons	Loads	CY/Tons	Loads	CY/Tons	Loads	CY/Tons	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
total									

Source: New Jersey Office of Recycling (Form OR-3A)

APPENDIX B-2: SAMPLE WINDROW TEMPERATURE

MONITORING DATA SHEET

Data collected by:_____ Year:_____ Month:_____

Weather Information (Sunny, rain, etc.)_____

Wind direction (from Northeast, South, etc.)_____

Air Temperature: ^{0}F_____ **Time of day:**_____

Site Observation Comments (Water ponding, dust, etc.)_____

_____

_____

Windrow Moisture ("Hand squeeze" test observation) *circle item:* Needs moisture Satisfactory Excess

Odor *(circle item):* None Minimal Strong

Windrow temperature measurement location:	**Temperature Observation, ^{0}F**								
	Windrow Observation (See Sketch Below)								

Diagram

Actions Taken (turned windrow, graded, etc.): _____

_____

_____

Source: Connecticut DEP, 1989.

APPENDIX C: ECONOMIC WORKSHEETS

TABLE 1—COLLECTION COSTS

A. **Capital Cost:**

In order to determine how much of capital cost should be charged to collection program, capital cost is multiplied by an annual depreciation factor (ADF), see Table 7, and prorated based on percent of total equipment year dedicated to collection program.

1. Compactor Trucks:

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

B. **Equipment Cost:**

Based on the estimated quantity of material to be collected, and an average crew efficiency, the required hours is multiplied by either hourly O&M costs or rental cost.

1. Compactor Trucks:

(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____

C. **Labor Cost:**

The required hours has been calculated above from quantity of leaves and yard waste times equipment efficiency.

1. Drivers:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

2. Collectors:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

D. **Degradable Plastic Bag Cost:**

Assume that on average each household will require 2 bags per week.

(_____ hsehlds) * (_____ wks) * 2 * (0._____ /bag) = $ _____

E. **Total Collection Cost:**

Sum of above costs. = $ _____

F. Net Collection Cost

By subtracting former or current collection cost from total degradable bag collection cost the impact of separate collection for composting can be measured. A positive number indicates increased collection costs, and a negative number indicates reduced costs.

1. Collection Cost for Composting: $ _____
2. Current or Former Collection Cost: – $ _____

($_____ /ton) * (_____ tons)

3. Change in Collection Cost: = $ _____

APPENDIX C: ECONOMIC WORKSHEETS

TABLE 2—PRE PROCESSING COSTS

A. **Capital Cost:**

In order to determine how much of capital cost should be charged to pre-processing component, capital cost is multiplied by an annual depreciation factor (ADF), see Table 7, and prorated based on percent of total equipment year dedicated to pre-processing component.

1. Tub Mill Grinder:
(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____
2. Front End Loader:
(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____
3. Dump Trucks:
(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____
4. Water Truck:
(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____
5. Fire Hydrant & Hose:
(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

B. **Equipment Cost:**

Based on the estimated quantity of material to be pre-processed, and an average crew efficiency, the required hours is multiplied by either hourly O&M costs or rental cost.

1. Tub Mill Grinder:
(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____
2. Front End Loader:
(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____
3. Dump Trucks:
(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____
4. Water Truck:
(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____

C. **Labor Cost:**

The required hours has been calculated above from quantity of leaves and yard waste times equipment efficiency.

1. Heavy Equipment Operators:
(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____
2. Drivers:
(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____
3. Workers:
(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

D. **Total Pre-Processing Cost:**

Sum of above costs. = $ _____

APPENDIX C: ECONOMIC WORKSHEETS

TABLE 3—COMPOSTING OPERATIONS COST

A. **Capital Cost:**

In order to determine how much of capital cost should be charged to composting component, capital cost is multiplied by an annual depreciation factor (ADF), see Table 7, and prorated based on percent of total equipment year dedicated to composting component.

1. Front End Loader:

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

2. Windrow Turning Machine:

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

3. Thermometers:

(_____ units) * ($_____) = $ _____

4. Dump Trucks (for curing pile formation):

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

B. **Equipment Cost:**

Based on the estimated quantity of material to be composted, and an average crew efficiency per turning/aerating, the required hours is multiplied by number if turnings and either hourly O&M cost or rental cost.

1. Front End Loader:

(_____ tons) . (_____ tons/hr) * (_____ turnings) * ($_____ /hr) = $ _____

2. Windrow Turning Machine:

(_____ tons) . (_____ tons/hr) * (_____ turnings) * ($_____ /hr) = $ _____

3. Dump Trucks (for curing pile formation):

(_____ tons) . (_____ tons/hr) * (_____ turnings) * ($_____ /hr) = $ _____

C. **Labor Cost:**

The required hours has been calculated above from quantity of leaves and yard waste times equipment efficiency.

1. Heavy Equipment Operators:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

2. Drivers:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

D. **Monitoring Cost:**

Based on the linear yardage of compost windrows and an average monitoring rate, the required hours is multiplied by number of monitorings and either hourly O&M cost or rental cost.

1. Monitors:

(_____ persons) . (_____ yards/hr) * (_____ monitorings) * ($_____ /hr) = $ _____

E. **Total Composting Cost:**

Sum of above costs. = $ _____

APPENDIX C: ECONOMIC WORKSHEETS

TABLE 4—POST-PROCESSING COSTS

A. **Capital Cost:**

In order to determine how much of capital cost should be charged to post-processing component, capital cost is multiplied by an annual depreciation factor (ADF), see Table 7, and prorated based on percent of total equipment year dedicated to post-processing component.

1. Front End Loader:

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

2. Shredder/Screener:

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

3. Dump Trucks (for stockpiling compost):

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

B. **Equipment Cost:**

Based on the estimated quantity of material to be post-processed, and an average crew efficiency, the required hours is multiplied by either hourly O&M costs or rental cost.

1. Front End Loader:

(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____

2. Shredder/Screener:

(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____

3. Dump Trucks (for stockpiling compost):

(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____

C. **Labor Cost:**

The required hours has been calculated above from quantity of leaves and yard waste times equipment efficiency.

1. Heavy Equipment Operators:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

2. Drivers:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

D. **Total Post-Processing Cost:**

Sum of above costs. = $ _____

APPENDIX C: ECONOMIC WORKSHEETS

TABLE 5—DISTRIBUTION COSTS

A. **Capital Cost:**

In order to determine how much of capital cost should be charged to distribution component, capital cost is multiplied by an annual depreciation factor (ADF), see Table 7, and prorated based on percent of total equipment year dedicated to distribution component.

1. Front End Loader:

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

2. Dump Trucks (for delivering compost):

(_____ units) * ($_____) * (_____ ADF) * (_____%) = $ _____

B. **Equipment Cost:**

Based on the estimated quantity of material to be distributed and an average crew efficiency (delivery time for certain load size), the required hours is multiplied by either hourly O&M costs or rental cost.

1. Front End Loader:

(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____

2. Dump Trucks (for delivering compost):

(_____ tons) . (_____ tons/hr) * ($_____ /hr) = $ _____

C. **Labor Cost:**

The required hours has been calculated above from quantity of leaves and yard waste times equipment efficiency.

1. Site Monitor:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

2. Heavy Equipment Operators:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

3. Drivers:

(_____ persons) * (_____ hrs) * ($_____ /hr) = $ _____

D. **Total Distribution Cost:**

Sum of above costs. = $ _____

APPENDIX C: ECONOMIC WORKSHEETS

TABLE 6—TOTAL PROGRAM COST-BENEFIT SUMMARY

A.	**Avoided Disposal Cost**	
1.	Quantity of Leaves & Yard Waste Collected	_____ tons
2.	Current Disposal Cost	* $ _____
3.	Avoided Disposal Cost	= $ _____
B.	**Avoided Soil Purchase**	
1.	Current Soil & Amendment Purchases	_____ CY
2.	Average Cost per Cubic Yard	* $ _____
3.	Expenditures for Soils & Amendments	= $ _____
4.	Percent Substitution by Compost	* _____ %
5.	Avoided Soil Purchase Cost	= $ _____
C.	**Simple Cost-Benefit Calculation**	
1.	Avoided Disposal Cost	$ _____
2.	Avoided Soil Purchase Cost	+ $ _____
3.	Total Compost Program Cost (Net Collection Cost plus other Component Costs)	+ $ _____
4.	Program Net Cost/Benefit	= $ _____

APPENDIX C: ECONOMIC WORKSHEETS

TABLE 7—CALCULATING ANNUAL STRAIGHT LINE DEPRECIATION

Annual Depreciation:

$$= (c - s) / n$$

where:

c	=	purchase cost
s	=	salvage value
n	=	service life in years

Two other methods that can be used to calculate the annual cost of purchasing equipment are:

Capital Recovery Factor:

$$= \frac{i(1 + i)n}{(1 + i)n - 1}$$

where:

i	=	interest or discount rate
n	=	number of years

Annual Interest:

$$= i(c + s) / 2$$

where:

i	=	annual interest rate
c	=	purchase cost
s	=	salvage value

APPENDIX D: ESTIMATED COSTS FOR SEPARATE COLLECTION OF YARD WASTES

Waste Hauler Survey

Delaware

A survey was conducted of municipalities and haulers in Delaware as well as the surrounding Mid-Atlantic States (DSM Environmental Services) in an effort to estimate representative costs for subscription collection of separated leaf and yard wastes.

A list of the licensed haulers in Delaware was obtained from DSWA, and a telephone survey conducted asking if they currently provided separate collection of yard waste, and if not, whether they could estimate the cost of providing separate collection as part of their subscription service.

None of the hauling companies contacted in Delaware currently provides separate subscription service for yard waste. Only one company was willing to estimate what the costs might be if yard wastes were banned and a separate collection for yard waste were required. Assuming no tipping fee for disposal of the separated yard waste (DSM has estimated that cost separately in Section 5), this hauler estimated that the net cost, after allowing for potential savings in refuse collection costs associated with removing yard waste from the refuse would be approximately $4 - $5 per household per month. Organized curbside collection was estimated to be approximately $3 - $4 less per month.

Companies contacted in Delaware included:

BFI	Blue Hen-Buzzards Dispose-All
Michael Leach Co	Moor Disposal Service
Tri-State Solutions	Waste Management
Independent Disposal	

Surrounding States

Given the difficulty in obtaining estimated costs from Delaware haulers, A survey of municipalities in New Jersey and Maryland in an attempt to learn what households in these municipalities were paying for separate collection. The majority of the municipalities or counties contacted provide the service as part of municipal operations and do not have line item costs for the collection program. Some of the municipalities contract for collection but do not have a separate cost itemized in the overall cost of providing leaf and yard waste collection services.

Maryland

Cecil County – Cecil County officials reported that no waste haulers offer special collection of leaf and yard waste. Instead, homeowners bring separated yard waste to the county drop-off and processing facility.

Wicomico County – Wicomico County operates eleven transfer stations and one landfill within the county. No large haulers offer subscription yard waste collection within Wicomico County. Instead, material is brought to the transfer stations or landfill by landscapers, tree trimmers and the general public. Three businesses actively purchase the resulting mulch for landscaping use.

Baltimore County – Collection occurs on the same schedule as recycling and is performed by 49 different private haulers. The County organized the program and administers the scheduling and collection of 230 different routes out of the Solid Waste Management Offices in Towson, Maryland.

Materials that are collected are brought to the County composting facility for composting and then given away at no charge to customers.

The separate yard waste collection service is offered to about 160,000 household units. The addition of the separate collection program increased the overall cost to the County by $1,000,000 per year. This is the equivalent of $6.25 per year, per household, for a total of 18 collections per year. (9 months, 2 times ea. month).

Laurel Maryland – The Department of Public Works was contacted and it was confirmed that City crews and trucks perform a separate yard waste collection on the same day as the refuse. The City does not keep the two services separated in their line item budgets and was not able to provide a separate yard waste collection cost.

New Jersey

Madison – The Borough of Madison bids out a contract for yard waste collection for residents to use between the months of March and November. The Borough has a 2000 census population of 16,530 and 5,520 households and is located in the northern part of the state, east of Newark.

Separate trucks travel the regular refuse route and collect yard waste set-outs along the route. Waste Management has the contract for 2004 in the amount of $129,880, which includes both collection and disposal. The quantity of yard waste collected in 2003 amounted to 3,472 cubic yards and includes leaves, grass, branches under a certain diameter and length, and garden wastes. The cost per household for this curbside service on an annual basis is $23.53, or $1.96 per month per household (over twelve months, or $2.35 per month over the ten-month collection season).

In addition to curbside collection, the Borough uses their own crews to collect leaves raked to the curb during the fall according to a specified schedule and route.

Kenilworth – The Borough of Kenilworth provides curbside collection of grass only during the summer months and brings the materials to their transfer yard where it is picked up by Rotondi and Sons for processing. There are 2,859 households in the Borough and they use a 25 cubic yard packer with two laborers and one driver to perform the grass collection. Costs are not broken out as a line item for this service.

Montclair Township – Montclair provides separate curbside collection of grass clippings between April 1 and October 31 on a weekly basis. Costs have not been provided but may be available prior to the final draft of this report.

Wyckoff – Wyckoff provides yard waste collection on a weekly basis to the residents of the city between the months of May and September. Costs have not been provided but may be available prior to the final draft of this report.

Conclusion

The survey results, while limited, indicate that subscription service would cost a subscribing household between $4 and $5 per month over the course of the yard waste season. Organized collection would cost between $2 and $3 per month.