LEAF AND YARD WASTE COMPOSTING GUIDANCE DOCUMENT

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I. INTRODUCTION

Composting is a vital part of the Commonwealth's waste reduction and recycling strategy. Composting is a waste management option which utilizes the natural process of biological decomposition to reduce the volume of organic matter to produce a useful soil amendment. The benefits of composting include:

* reduced volume of waste to be incinerated or landfilled

* reduced adverse environmental impacts from disposing leaf and yard waste

* decreased disposal costs

* production of a beneficial material, compost, which improves the productive potential and condition of soils

* conservation of natural resources

A significant portion of the solid waste stream is organic and can potentially be composted. These organic wastes include leaf and yard waste as well as agricultural waste, wastewater sludge, and industrial and commercial wastes. In Massachusetts, successful agricultural, sludge, and leaf and yard waste composting projects are currently in operation.

The primary benefit of leaf and yard waste composting is the potential for immediate diversion of a significant portion of the state's solid waste stream from disposal facilities. The economic and environmental benefits which result from eliminating this material from disposal facilities and converting it to compost have provided municipalities with the incentive to establish composting operations.

With the promulgation of the Department of Environmental Protection's (Department) Solid Waste Management Facility Regulations (310 CMR 19.00), which banned the disposal (in landfills and incinerators) of leaves as of December 31, 1991 and other yard waste as of December 31, 1992, there is an even greater imperative for communities to divert this material to a beneficial use by composting.

Leaf and yard waste composting is a versatile process that can be conducted at various size sites utilizing different levels of effort and technology. This guidance document is primarily designed to facilitate the establishment and successful operation of a "low-level" technology, municipal-scale, leaf and yard waste composting facility. The Department recommends that most municipalities follow the "low-level" technology method, because this approach balances operational efficiency, time, space and cost effectiveness better than more minimal or higher level technology approaches for leaf composting operations.

The costs and benefits of composting leaves and yard waste vary for different communities. Based on reports from communities composting in Massachusetts, on-site operational composting costs for the recommended approach described herein generally range from about $5 to $30 per ton of incoming material. Collection costs may range from almost nothing for some drop-off collections to an average of $30 per ton for local curbside collection, and possibly more for hauling material to a site out of town.

The purpose of this guidance document is to assist communities and private operators in siting, designing, and operating leaf and yard waste composting projects that are environmentally sound and economically viable. The document will also delineate those issues which must be addressed when complying with the Department's leaf and yard waste composting registration and reporting requirements and the minimum standards which must be followed in siting, designing and operating a leaf and yard waste composting facility.

Properly sited and managed leaf and yard waste composting facilities are not considered to be solid waste management facilities by the Department. These composting facilities are "conditionally exempt" from site assignment requirements (310 CMR 16.05(3)(e)), provided that they have successfully met the Department's registration requirements. These requirements involve submitting a complete Department Leaf and Yard Waste Composting Registration Form to the Department. This form asks for information on the location and design of the composting site, as well as the proposed operation and maintenance of the facility. The Department will review the Registration Form and visit the proposed site to ensure that the proposed facility meets the guidelines that are described in this guidance document. The Department must approve the proposed site and operation prior to the commencement of site preparation or facility operations. Leaf and yard waste composting facilities which meet the Department's registration requirements are not subject to any additional permitting by the Department.

This document represents but one component of the Department's Division of Solid Waste Management's technical assistance program for composting. Other components include:

* technical assistance from Division staff in the planning (including site selection and design) and operations of a composting facility;

* regional training workshops for composting facility operators; and

* other informational materials designed to assist in the planning and operation of leaf and yard waste composting programs.

In addition, the Department encourages source reduction of leaf and yard waste through home composting, mulching and leaving cut grass on lawns. The Department has informational materials to assist residents in composting or managing their own leaf and yard waste. The Department also provides training to a network of volunteer Home Composting Coordinators who promote composting and educate other residents in their communities.

Communities are encouraged to contact the Department for any assistance they made need in establishing a composting facility or in improving its operation.

II. COMPOSTING PRINCIPLES

Composting is a managed process which utilizes microorganisms naturally present in organic matter and soil to decompose organic material. These microorganisms require basic nutrients, oxygen and water in order for decomposition to occur at an accelerated pace. The end-product, compost, is a dark brown, humus-like material which can be easily and safely handled, stored and applied to land as a valuable soil conditioner. The composting process is dependent upon several factors, including: the population of microorganisms, carbon-nitrogen ratio, oxygen level, temperature, moisture, surface area and pH. These factors, which are described below, are dependent upon one another and understanding them is important for managing a successful composting operation.

Microorganisms

Decomposition of the organic material is achieved by billions of microscopic organisms naturally present in leaf and yard waste, including bacteria, actinomycetes, and fungi. These microorganisms multiply rapidly in the organic material, using it as a source of food, and produce heat, carbon dioxide, water vapor, and compost in the process.

Nutrients: Carbon to Nitrogen Ratio

The availability and proportion of nutrients, in particular carbon and nitrogen, can be a limiting factor in the composting process. The microorganisms require carbon for their energy and nitrogen for protein synthesis in order to grow and multiply. The rate of decomposition is dependent on the balance of carbon to nitrogen in the composting material. For rapid decomposition, the ideal carbon to nitrogen ratio is 30 to 1 (30:1). That ratio represents 30 parts carbon to 1 part nitrogen by weight.

If the carbon to nitrogen (C:N) ratio deviates from this ideal ratio, then the rate of decomposition will be slower, resulting in a longer composting time. With a ratio of greater than 30:1, nitrogen becomes a limiting factor, and the rate of decomposition slows. With a C:N ratio lower than 25:1, the excess nitrogen will initially allow for more rapid decomposition, creating anaerobic (lack of oxygen) conditions. This will slow down the decomposition and can cause serious odor problems. Some of the excess nitrogen may be given off as ammonia gas or nitrate. The resulting loss of nitrogen will lower the nutrient value of the compost product.

The carbon to nitrogen ratio in leaves tends to range between 40:1 and 80:1. For example, the C:N ratio of maple leaves is close to 40:1 while that of oak leaves is about 60:1. Depending on the composting method, leaves alone can take from 6 months to 3 years to compost. Organic materials can be mixed to achieve a more optimum carbon to nitrogen ratio for efficient composting. When grass (C:N ratio of 19:1) or other nitrogen-rich materials are mixed with leaves, the carbon-nitrogen ratio can be lowered to around 30:1, accelerating the composting process to 6 months or less.

Oxygen

Composting is an aerobic process, which means that an adequate supply of oxygen is essential for the composting process. The microorganisms primarily responsible for the rapid decomposition of organic material require oxygen to convert organic waste to compost. If the oxygen content falls below 5%, these aerobic (oxygen needing) organisms begin to die off and are replaced by anaerobic organisms (which do not require oxygen). Anaerobic organisms operate less efficiently, resulting in a slower decomposition rate. In addition, under anaerobic conditions the organisms produce methane, ammonia and hydrogen sulfide, resulting in strong, unpleasant odors.

If sufficient levels of oxygen (at least 5%) are maintained during the composting process, odors can be kept to a minimum. Adequate oxygen levels or aerobic conditions are maintained through the aeration of the composting material. The methods used for aerating the organic material depend on the technology used and will be described in the operation guidance section of this document.

Moisture

The microbiological activity occurs in a film of moisture on the surface of the organic material. In leaf and yard waste composting, the optimal moisture content is 40% to 60%, by weight. Moisture is required to dissolve the nutrients utilized by microorganisms and to provide a suitable environment for bacterial population growth. A moisture content below 40% limits the availability of nutrients and inhibits bacterial population expansion. When the moisture content exceeds 60%, the flow of oxygen is restricted and anaerobic conditions begin to develop. Procedures to monitor and increase or decrease the moisture level are described in the operation guidance section of this document.

Temperature

Microorganisms generate heat when they decompose organic material. Much of this heat is maintained in the composting material as a result of the insulating effect of the compost pile or windrow. This results in a temperature increase, which affects the composition of the microbial population. The optimum temperature range for efficient composting is between 100 to 140 degrees F. In addition, in order for pathogens and weed seeds to be destroyed, temperatures in the composting material need to be maintained at 131 degrees F for at least 3 consecutive days.

Temperature is the best indicator of the rate of decomposition occurring in a composting pile. 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 degrees F, the population of thermophilic organisms exceeds that of mesophilic organisms, increasing the rate of decomposition. As the temperature exceeds 140 degrees F, the rate of decomposition begins to decline rapidly as both mesophilic and thermophilic organisms begin to die off or assume dormant forms.

When temperatures move out of the optimum range of 100 to 140 degrees F, it is usually because the level of oxygen has dropped too low (below 5%) or moisture level is no longer optimal (either too dry or too wet). Monitoring the temperatures in a composting pile provide a good guide as to when remedial measures may be needed to maintain or return to an efficient composting process. Monitoring methods will be discussed in the operation guidance section of this document.

Surface Area

The activity of the microorganisms during decomposition occurs on the surface area of organic material. With smaller particles, there is greater surface area per unit volume of material on which biological activity can occur. Also, nutrients are more readily available for the microorganisms when the material is physically broken down. Reducing the particle size results in more biological activity per unit of volume and a corresponding increase in the overall rate of decomposition.

Shredding organic material increases the surface area available for biological activity and therefore speeds up the rate of decomposition. As the decomposition rate increases, so does the oxygen demand and the need for aeration. The smaller particle size also results in greater compaction of the composting material which can restrict the flow of oxygen and result in anaerobic conditions if sufficient aeration does not occur.

pH

During the composting process, the material will become slightly acidic and then return to near neutral conditions as stability is approached. Decomposition is most efficient between a pH of 6.0 and 8.0. If the pH is too high, nitrogen is driven off as ammonia. If the pH drops below 6.0, the microorganisms begin to die off and the decomposition process slows. For leaf and yard waste composting the pH level does not generally need to be monitored, since it rarely presents an operational problem.

III. SITE SELECTION

Proper site selection is a prerequisite to the establishment of safe and effective leaf and yard waste composting facilities. The location of a composting facility has a direct impact on the level of site preparation required and the environmental and public health impacts of operations. Communities should take care in selecting a suitable site as a means of controlling the design/construction costs and operational problems over the life of the facility.

Five primary criteria should govern the site selection process. These are described in this siting guidance section.

A) Protection of water resources

B) Buffer to sensitive land uses

C) Space requirements

D) Site preparation needs

E) Accessibility and land use compatibility

A. Protection of Water Resources

Sites need to be evaluated for their potential impact on waters of the Commonwealth. Of primary concern are proximity to public water supplies (ground and surface), wetlands, floodplains, surfaces waters and the depth to groundwater.

(1) Sites must not be located within 400 feet (Zone I) of a public drinking water supply well or within 250 feet of a private well. For sites located within a Zone II or interim wellhead protection area (1/2 mile radius), the Department may require that extra precautions be taken in the design or operations depending on the quantities and types of material to be composted. Sites within a Zone II may not be allowed under certain circumstances.

(2) Facilities must be sited in accordance with the Massachusetts Wetlands Protection Act. This requires that a 100 foot buffer (Resource Protection Area) be maintained from any wetlands to the composting area. However, a site may be located within the 100 foot buffer of a wetland, provided that a Notice of Intent is filed with the local Conservation Commission and an Order of Conditions is given by that Commission permitting the encroachment into the buffer zone.

(3) Sites should be located at least 100 feet from surface waters to ensure that there will not be any potential adverse impacts from run-off on water bodies. However, as in the case of the wetland buffer described above, a site may be located within the 100 foot buffer zone, provided that a Notice of Intent is filed with the local Conservation Commission and an Order of Conditions is given by that Commission permitting the encroachment into the buffer zone.

(4) Soils should be permeable enough to minimize run-off, yet capable of filtering drainage waters. Excessively well drained soils (i.e., sandy soil) should be avoided, if possible, as they may lack the physical properties necessary for effective filtering of potential contaminants. Highly impermeable soils (i.e., clay) should be avoided, if possible, as this may lead to poor drainage and excessive run-off or erosion of the site, unless significant site preparation is undertaken.

Sites where the groundwater rises closer than 4 feet or where the bedrock is closer than 5 feet from the surface should be avoided. Otherwise, this may lead to an operating surface that is too wet with resultant operational problems, as well as potential ground water impacts if significant quantities of green waste are composted.

Surface and groundwater hydrology are important factors to consider in achieving effective runoff control and surface and groundwater protection. General soil types can be obtained from Soil Conservation Service maps and drainage and groundwater flow direction information can be obtained from U.S.G.S. topographical maps.

B. Buffer to Sensitive Land Uses

Sites should be adequately buffered from sensitive adjacent land uses such as residences, schools, and parks. Buffers, including both distance and visual screening, minimize the impact of any odor, noise, litter and aesthetic degradation.

An adequate buffer zone must be available to screen the facility from sensitive land uses. A distance of at least 250 feet from the nearest residence to the composting area is recommended. However, in each case, the buffer must be adequate to satisfy the concerns of neighbors.

C. Space Requirements

Sites must be large enough to process the annual projected volumes of leaf and yard waste and to provide room for vehicle access and storage of finished compost.

(1) Volume projections can be calculated by several methods. The best method is to use any actual records of quantities of yard waste collected in the past, if such exist. Alternatively, a record of seasonal fluctuation in municipal solid waste generation can provide a reasonably accurate estimate of the volume of leaves collected in the fall.

Another method for projecting the volume of leaves is to take a percentage of the total municipal solid waste collected annually. National statistics show the average percentage of the municipal solid waste stream composed of leaf and yard waste is 18%, one third of which (or about 6%) is assumed to be leaves. This assumes close to a 100% participation and capture rate for leaves; the actual amount collected is usually less than 6%, depending on collection method and participation rate.

Studies of communities composting leaves indicate that the percentage varies tremendously for different types of communities. Massachusetts communities that have reported quantities of leaves collected for composting, indicate quantities that range from 1% to over 10% by weight of their residential waste stream. Most of these communities, however, report figures of 2% to 5%, for leaves collected. The type of collection system used and the extent that residents compost their own leaves will impact this percentage.

In addition, several national studies of communities composting leaves, have found that leaves collected annually usually range from 50 to 200 cubic yards per curb mile and leaves collected per household range from 150 to 500 pounds. Less data is available for grass generation, but some studies have shown a range of 400 to 1,000 pounds of grass per household.

(2) The composting area required for a given volume of leaves depends on the method used to compost the leaves. For most communities the appropriate method is the "low-technology" approach. This is described in detail in the operational and maintenance section of this document, along with a brief summary of other methods.

For the low-technology approach, at least an acre is required to compost 4,000 to 5,000 cubic yards of leaves delivered to the site. This assumes the following: initial windrow height of 8 to 12 feet; 20 feet between windrows for equipment maneuvering; and an on-site residence time of 10 to 12 months from deposition of the leaves to curing. The composted leaves are moved to the curing area where they are further stabilized over the next few months, allowing adequate room for composting a new year's supply of leaves.

Generally assume 4 to 5 cubic yards for each ton of leaves. However, experience has shown that this ratio can vary depending on the method of collection and the resulting amount of grass, moisture, sand and grit that are present. Dry, loose leaves may be up to 8 cubic yards per ton, while leaves that were shredded or compacted prior to delivery may be less than 4 cubic yards per ton.

Consideration should also be given to the space that will be required for maneuvering equipment at the site. At least a 20 foot zone should be allowed around the compost area for this purpose, and additional space may be needed for the turn around of any delivery trucks, and for any separate drop-off of leaves. Adequate space must also be allocated for the on-site storage of finished compost, which is approximately 25% - 30% of the original volume of the leaves.

If there is not an acre per 4,000 to 5,000 cubic yards of leaves available for composting, then a higher technology or more intensive effort approach could be considered, which will shorten the composting time, but will also be more costly.

If significantly more space is available than described above, such as an acre per 2,000 cubic yards, then a longer composting time (from 18 months up to 3 years), can be afforded.

D. Site Preparation Needs

In evaluating a site, the level of site design and alterations required should be considered as they can be a significant cost factor. Sites that are already open areas, are nearly level, and only require minimal or no clearing and grading are clearly preferable. Therefore, topography of the site is important.

A gentle slope (1-3%) is optimal because runoff collects and stagnates in or around a flat composting area. This "ponding" may result in overly wet compost piles, which leads to the development of anaerobic conditions and problems such as odor and reduced rates of decomposition. Further, stagnant water encourages mosquito breeding. Grading and pad material may be required if the existing soil and grade do not allow for proper drainage and support of machinery during wet periods of the year.

Steep slopes also present possible environmental and operational problems. The steeper the slope, the less material can be composted per acre, as the front-end loader will require more space for maneuvering. An overly steep slope can result in erosion problems because surface water is likely to run rapidly off site, carrying sediment with it. This can clog sewers and drainage ditches and pose a threat to surface waters.

E. Accessibility and Land Use Compatibility

(1) Year-round access to the site is essential. A centrally located site that minimizes the distance that vehicles need to travel to deliver leaves and yard waste to the site will reduce collection costs, energy consumption, air pollution and may increase participation for drop-off collection.

(2) The potential traffic impacts from the delivery of leaves and yard waste to the facility can be a real concern for residents and should be minimized. If possible, access to the site over non-residential paved roads is preferable.

(3) The proposed facility must be compatible with the local zoning and preferably also with existing adjacent land use, such as agricultural, commercial or industrial uses. Suitable sites may include: areas adjacent to a landfill, transfer station, wastewater treatment plant, public works garage, cemetery, nursery or farming operation.

(4) Composting facilities should not be located on a site where refuse has previously been disposed, including a closed capped landfill, since operations may damage the cover material and therefore, reduce the impermeability of the cover or cap. This could result in potential ground water impacts. However, in cases where a municipality does not have adequate space adjacent to the filled area and wishes to site a leaf composting operation on top of a landfill, then a written approval must be sought from the DEP Regional Office. In such cases, a DEP registration form and a site plan must be submitted to both the Regional and Boston offices of DEP. The site plan shall describe how the integrity of the landfill cover will be maintained and how the area conforms to any applicable closure plans. Such proposal will be evaluated on a site-specific basis. Site preparations cannot commence without written approval of the DEP Regional Office.

(5) The support of the local community is an important factor. Local opposition can block the siting or stop the operation of a facility. Public education and participation in the planning and siting of a composting facility is invaluable in gaining local support.

IV. SITE DESIGN

Once selected, the site must be designed and prepared. Site design requirements vary with the physical characteristics of the site and the type of operation employed. Facilities must be designed to promote operational efficiency and to minimize potential adverse environmental and health impacts. This may include clearing and grading to provide adequate space for composting, including on-site roads, drop-off area and storage of the finished product. Existing perimeter vegetation, particularly trees and shrubbery, should be retained for noise reduction, natural drainage and visual screening. Other site preparation needs may include providing signs, a water supply and access control. Care taken at this stage is important in the establishment of good relations with neighbors.

Composting Pad

(1) The surface on which the composting will take place, usually known as the composting pad, should be designed to support heavy equipment during all seasons, and to prevent ruts from forming. The pad should be permeable enough to allow water to percolate through the soil and to avoid standing water or "ponding". Gravel, sand with gravel and bluestone, for example, are materials that have been used effectively for composting pad surfaces.

(2) Impermeable pads may be appropriate at sites where soils are highly permeable or groundwater rises to within 4 feet of the surface. These pads: 1) reduce infiltration of drainage into the soil, thereby protecting groundwater; 2) minimize the uptake of water by windrows, which inhibits the onset of anaerobic conditions; and 3) provide a surface capable of supporting heavy equipment. Therefore, paved or clay surfaces can be used given an adequate slope and drainage.

(3) Depending on existing conditions, the composting pad may need grading. Grades of 1 - 5% are acceptable, with a 2% grade being optimal. The grade should be steep enough to prevent "ponding", yet gentle enough to minimize runoff and operational concerns.

Drainage Control

(1) A drainage system may need to be developed to prevent sediment or runoff water from moving off the site and into nearby surface waters or wetlands. Diversion ditches, berms or baled hay should provide adequate runoff control at most sites.

(2) Where ground surfaces upgrade of the site would allow water to run onto the composting pad, this run-off should be diverted to prevent seepage into compost and curing piles.

(3) A run-off drainage system should be designed to accommodate an unusually long and heavy rainfall statistically shown to occur every 25 years.

Location of Windrows on the Composting Pad

(1) Leaves will be formed in elongated or long narrow piles called windrows. These windrows should be formed parallel to the slope to allow rain water to run-off between the piles, rather than through them, to minimize "ponding" between piles and excess water absorption in the windrows.

(2) Windrows formed in pairs, that will later be combined, should have a minimum of 2 feet between piles. A minimum 20 foot lane should be left between pairs of windrows to permit efficient operation of equipment.

Roads

(1) Roads should be designed to permit orderly entrance and exit, and 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 in the fall.

(2) Road surfaces must be capable of supporting delivery or drop-off vehicles and heavy equipment, such as front-end loaders and fire equipment, for all season operations and during episodes of rough weather.

(3) Roads should be designed to minimize erosion. While paving improves all weather mobility, it increases the cost of the facility and may contribute to runoff problems.

Access Control

(1) Access control is required to prevent illegal dumping at the compost site. The required level of security depends on the potential for illegal dumping or vandalism and the presence of natural site barriers.

(2) A gate or cable across the road at all access points is 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. Vegetation around the site also serves to limit access.

Visual Screens

(1) 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 leaf and yard waste composting facilities.

(2) Berms or landscaping can serve this function where natural relief features or tree stands are lacking.

(3) Proper site selection and careful site clearing can eliminate costly landscaping or berm construction.

Signs

(1) A sign should be posted at each entrance of the composting site indicating the:
- * nature of the project
- * facility name
- * operating hours
- * business address and phone number of the operator
- * what materials are accepted

(2) On-site signs should direct vehicles to unloading areas and indicate traffic circulation patterns, indicate where leaves and other yard waste should be deposited, and specify materials that should not be dumped.

Water Supply

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

(2) Water requirements are based on the moisture content of incoming material. Dry leaves, for example, require approximately 20 gallons per cubic yard. In some cases, leaf and yard waste may be at the optimal moisture content upon arrival. However, leaves collected in paper bags require substantial soaking to facilitate their initial breakdown (unless they are shredded mechanically).

V. OPERATION AND MAINTENANCE

In addition to being well sited and designed, leaf and yard waste composting facilities need to be properly operated and maintained in order to ensure minimal impact on the surrounding environment and community and produce a good quality product that can be easily used by municipalities or marketed. This operation and maintenance guidance section is in three parts: the first summarizes different composting methods; the second reviews equipment and staffing needs for the recommended "low-tech" composting method; and the third provides specific minimum operational and maintenance requirements for facilities that employ the recommended composting method.

A. Composting Methods

(1) "Minimal" Technology

The minimal technology method is not usually recommended for communities unless they have a relatively large and well buffered composting area, because of the longer composting time required (at least 2 to 3 years) and the potential for greater odor associated with this method. This method has the least operational or maintenance requirements, and may be applicable for small scale operations that have plenty of remote space for composting but little or no additional resources. Leaves and yard waste are formed into piles (which should be no more than 12 feet high) with a front-end loader. Once or twice a year the piles are turned for aeration and reformed. Since the piles are not turned frequently, anaerobic conditions occur in the piles, which will result in some odors being released when the piles are turned. Therefore, these operations should be sited in remote areas with significant buffers from residential or other sensitive areas. Turning during periods of precipitation will also minimize the effect of odors and may provide the leaves with needed moisture. A minimum of two to three years should be anticipated to achieve proper stabilization. The composting area should be large enough to hold up to 3 years material (i.e., an acre per 2,000 cubic yards). It is particularly important that leaves and yard waste collected be free of contaminants, so that the end product will be useable. Each year's leaves should be kept segregated and finished compost should be removed regularly so that the site remains viable over time and does not become a "dump."

(2) "Low-Level" Technology

This is the <u>recommended</u> operation for most communities. It is characterized by modest operation and maintenance requirements and limited equipment needs. This method utilizes a windrow composting system. Leaves and yard waste are formed into long narrow piles (windrows) and periodically turned, based on temperature and time (averaging every 3 to 4 weeks), by a front-end bucket loader. The turning serves to: mix and break up material, aerate the windrow, and release excess moisture. Proper periodic turning will insure uniform decomposition and result in a good quality product. The time requirements to decompose the material varies, depending on the factors described on the following pages. However, this method done effectively will allow leaves and yard waste to be composted and moved off the composting area into curing piles in 10 to 12 months, allowing the following year's leaves to be composted in the same area. This approach balances time, space and fiscal considerations, and can produce a useable stabilized product in one year.

(3) "Intermediate-Level" Technology

This type of operation also involves windrow composting, as in the "low-level" method, but utilizes more sophisticated and expensive windrow turning machines instead of front-end loaders for aerating and turning the windrows. Front-end loaders may be used to initially form the windrows, but a windrow turning machine is used to shred, turn and aerate the leaves, resulting in a more thorough and efficient blending and aerating than a front-end loader can achieve.

This results in a more rapid decomposition of the organic material, requiring turning every week or two to maintain sufficient oxygen in the windrows. Leaves can be composted in 4 to 6 months, approximately half the time of the "low-level" approach. This method is more appropriate for large scale operations (i.e., 4,000 tons or more) where it can be more cost effective given the greater efficiency of the windrow turning machines.

(4) "High-Level" Technology

There are several different systems which consist of a "high-level" technology method. These require less space and provide greater operational control and usually result in shorter composting time than the composting methods described above. However, given the greater capital investment in equipment and higher operation and maintenance requirements, these methods are not usually considered appropriate for leaf and yard waste composting alone, and therefore, are not recommended. However, if leaf and yard waste are being used as a bulking agent for sludge or manure composting then this method is appropriate.

The static aerated pile is an example of a higher technology approach, widely used in sludge composting. In static aerated pile or forced aeration composting, piles of organic material are aerated from below by blowers, controlled by timers or temperature feedback, moving the air through perforated pipes. Turning is required periodically to exchange inner and outer material. This process maintains near optimal levels of oxygen and temperature to maximize the rate of decomposition. The composting process can be completed in 2 to 4 months, depending on the degree of aeration and the concentration of green or high nitrogen waste being composted.

In-vessel composting is the highest technology approach consisting of different proprietary systems that usually involve mechanical agitation and forced aeration, as well as being enclosed in a building. These are the most capital intensive and result in the greatest level of process and odor control, as well as the shortest composting time required. These systems are generally used for composting sludge and/or solid waste.

B. Equipment and Staffing Needs

(1) For the recommended "low-tech" composting method, most communities already own the basic equipment needed, except for a long stemmed thermometer. Communities are encouraged to use their existing equipment as much as possible, given that new equipment costs can be significant. In addition, communities may want to establish equipment sharing programs with neighboring communities. The equipment needs and options for the "low-tech" approach are reviewed below.

(a) The key piece of equipment needed for a leaf and yard waste composting operation that employs the "low-technology" method is a front-end bucket loader. The front-end loader is used for forming, combining and turning windrows, as well as forming curing piles. Loaders that have buckets of at least 2 cubic yards and are articulating with a reach of 12 feet high or more are most effective. At a minimum, the front-end loader should be available one day (or a portion thereof) per week during the collection season (i.e., mid-October to mid-December, for leaves) for small operations and up to 5 days a week for larger operations. For the remainder of the year the loader must be available to accommodate turning and pile reconstruction when needed, an average of every 3 to 4 weeks.

(b) Water equipment, such as water trucks, hydrants and hoses, or backpack spray units, is required for wetting organic material and for fire fighting purposes.

(c) A 3 foot stem thermometer is recommended for monitoring windrow temperature, the prime indicator of active composting. (A list of suppliers is available from DEP).

(d) Facilities accepting tree prunings or other woody materials need a chipper to prepare these materials for composting or mulch. Woody materials break down slowly, thus increasing the time of the composting process. Wood chips are good for mulch, but are not generally recommended for composting by themselves or with leaves because of their long decomposition time. However, they make a good bulking agent for composting green waste or other high nitrogen materials.

(e) Shredders are optional but useful pieces of equipment for leaf and yard waste composting. They can be used to reduce the size of the material prior to windrow formation. This step serves to accelerate the process of decomposition by increasing the amount of surface area exposed to air. Shredding leaves, however, also causes greater compaction, which limits the supply of oxygen within the pile and results in a need for more frequent turning. Shredding after composting aids in creating a uniform fine product capable of being assimilated more quickly into soils to which it is applied.

(f) Screens or sieves can be used in the final step of the composting process to remove any contaminants or non-compostables, improving the quality of the compost. Screening can also be useful for blending sand or loam with finished compost, and for production of a uniform fine product.

(2) A municipal or large scale composting operation requires "dedicated" staff. Staff availability and performance will make a difference between a successful operation and a series of potential nuisance and/or environmental problems. Training of the staff is important in helping them understand both the material they are working with and the process by which leaves are made into compost. On-site staff responsibilities include: monitoring the deposition of leaves and yard waste; wetting, forming, combining and turning of windrows; monitoring and record keeping; quality control; and any final processing and storage of the compost.

For most communities, staffing requirements are only part time. However, large operations (i.e., >4,000 tons) will probably need full time staff to operate a facility. In addition, availability of back-up personnel is recommended for those who have direct responsibility for composting operations.

C. Operation and Maintenance Requirements

(1) Deposition and Quality Control of Incoming Material

The type of organic material to be accepted at a facility must be clearly described to residents and haulers. Materials typically considered leaf and yard waste are: leaves, grass clippings, garden wastes, weeds, hedge clippings and brush. (For handling brush, see p. 16 (d)). Incoming waste should be carefully monitored to control the dumping of inappropriate waste. In addition to taking care to minimize the amount of non-leaf and yard waste material incorporated into the windrows, monitoring and removing any unacceptable material should continue throughout the composting process.

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

* easier removal of unacceptable materials before they get mixed into windrows;
* easier formation of more uniform windrows which increases space efficiency;
* easier and more efficient wetting of the material while windrows are being formed;
* faster delivery of material if vehicles do not have to deposit directly into windrows; and
* greater quality control, resulting in a more attractive and marketable product.

Leaves received in plastic bags must be de-bagged and the plastic removed and disposed. The bags should be dropped off in a separate area to facilitate the de-bagging and maintain quality control prior to windrow formation. De-bagging is generally done by hand and can easily be done by residents dropping off their leaves. However, if leaves are collected curbside then de-bagging can be very labor intensive and can result in much plastic getting into the windrows if care is not taken to de-bag thoroughly and keep the plastic separate from the loose leaves.

This process can prove costly and problematic. Labor costs for manually de-bagging leaves and yard waste should be considered. Equipment such as the Scat windrow turning machine have proved effective in de-bagging leaves, but also requires significant labor to remove the plastic from the machine. Another option is to de-bag the leaves directly into a packer truck while collecting them at curbside.

Biodegradable paper bags (30 gallon size) can be used to avoid the de-bagging step, as they will decompose with the leaves. However, using paper bags requires additional wetting and turning of the bagged leaves in the first 1 to 2 months, compared to loose leaves, to insure that the bags break open quickly and do not increase the composting time required. Shredding paper bags is an option that will insure that the composting process is not delayed. "Biodegradable" plastic bags have not yet demonstrated their claims of being truly biodegradable, and leave small pieces of plastic in the compost, which requires screening of the finished material.

An effective public education campaign is important, not only for encouraging high participation by residents, but also for promoting quality control and minimizing the collection of unacceptable materials. This will reduce the potential for mixing trash with compostable leaf and yard waste.

Monitoring and controlling incoming leaf and yard waste material serves to minimize potential contaminants in the final product. Inorganic material tends to appear at the top of the pile as the volume of organic material decreases during the process of decomposition. These materials should be removed during temperature monitoring, windrow turning and curing pile formation (which are described later). The last opportunity for removing inorganic from the compost occurs when there is final screening, which is an optional procedure.

It is likely that non-compostable material will be found during the composting process. A container should be placed on the site for storage of such materials, and operators should develop a procedure for disposing of the materials off site.

Controlling access to the site to avoid vandalism and/or illegal dumping must be ensured.

(2) Record Keeping

Operators should keep a log to track the volume or weight of incoming leaf and yard waste and its origin. This data will be useful for: 1) estimating the amount of compost that will be produced; 2) projecting future estimates of incoming material; 3) determining the adequacy of the site for handling projected levels of leaf and yard waste; 4) isolating the origin of contamination problems; and 5) developing a cost/benefit analysis.

Records should also be kept of the temperatures taken in the windrows to monitor the rate of decomposition occurring in the windrows (see pages 19-20). This can help guide appropriate steps that should be taken to maintain an ongoing active decomposition process and avoid potential nuisance or environmental problems.

(3) Windrow Formation, Size and Combining

Leaves and yard waste should be formed into windrows (elongated piles) that are initially 8 to 12 feet in height using a front-end bucket loader. Proper windrow heights are a function of climate and geography as well as the compaction potential of the material. Oversized piles can cause odor problems at composting facilities, since they tend to compact, thereby reducing aeration. Undersized piles are susceptible to heat loss. In Massachusetts, piles lower than 8 feet may be adversely affected during the winter by cold temperatures. Windrow heights should be allowed to go down with the onset of spring and summer. During the warmer seasons optimal windrow height is closer to 6 feet. Volume reduction during the composting process may necessitate combining of windrows for proper size maintenance.

Windrows should be approximately 10 feet to 18 feet wide at the base for convenience in turning and haystack-shaped (or triangular) in cross-section to shed water. Piles can be as long necessary, depending on the size and shape of the site and operational convenience.

(4) Moisture

Moisture becomes a limiting factor to accelerated decomposition when the water content of the composting material is too low. The moisture level should be between 40-60%. As a general rule of thumb, the material should feel damp like a wrung out sponge and it should not be possible to squeeze more than a drop or two of water from a fistful of moist decomposing leaves.

Leaf and yard waste may be adequately moist upon receipt, eliminating the need for wetting. If not, material should be wetted prior to windrow formation or during turning or pile reconstruction. Water should not be applied to formed piles, as only a small amount penetrates the surface of the windrow and the remainder becomes runoff which must be managed. For dry leaves, wetting prior to formation not only provides needed moisture for adequate decomposition, but also prevents blowing of leaves and reduces any potential fire hazard.

During the compost process, if the leaves are determined to be too dry, turning during periods of precipitation will aid in providing moisture.

(5) Temperature Monitoring

The key factor in determining the rate of decomposition within the windrow is temperature. It must be carefully monitored and controlled. Decomposition is most efficient at temperatures of 100 to 140 degrees F.

When the temperature in the center of pile drops below 100 degrees F, prior to stabilization, the windrow should be turned to re-establish proper aeration. Temperatures in excess of 140 degrees F cause the rate of decomposition to slow as desirable microorganisms begin to die off. The windrow should then be turned to release the excess heat. If temperatures soon again exceed this upper level, piles should be reformed into smaller windrows (at least 6 feet high) which allow more heat to escape.

The temperature should be monitored preferably twice a week or at least once a week to provide sufficient data for establishing trends. The thermometer should be inserted 3 feet toward the center of the pile at mid height. Readings should be taken every 50 to 70 feet along the length of the windrow to check for variation in temperature. Temperature variation is common in leaf and yard waste windrows and is not a problem as long as all readings remain in the 100 to 140 degrees F range.

(6) Windrow Turning

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 and dropped to allow it to cascade down for greater aeration and mixing.

The turning schedule should be based on temperature and moisture levels. When the temperature drops below the 100 degree F threshold or exceeds 140 degrees F, the pile should be turned. If the moisture content exceeds 60%, 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. Generally, the more frequent the turning the more rapid the decomposition will be. Turning every 3 to 4 weeks, even if the temperatures do not fall out of the optimum range, is recommended for efficient composting.

(7) Incorporating Grass or Green Waste

To avoid odors and nitrogen releases, green wastes such as lawn clippings and garden wastes should not be composted alone, nor stored alone for more than 1 to 2 days. Green yard waste, especially grass clippings, should be mixed into windrows within 48 hours of being deposited on-site. Unless the material is dry, vigorous decomposition begins within 48 hours and considerable odor may result and excess nitrogen may be released as ammonia or nitrate. Grass clippings must be thoroughly mixed with leaves (or other carbon-rich material) in a mixing ratio of at least 3 or 4 parts leaves to 1 part green waste by volume. The higher the ratio of leaves to grass, the less potential for odor or nitrogen release. Operations should already be composting leaves before accepting grass or green waste so that there will be an on-site supply of leaves for mixing with the incoming grass clippings. Grass clippings can also be composted with chipped or shredded brush. This combination must also be mixed thoroughly and may require a longer period before a stable product is formed. For better aeration, windrows containing grass may be built on 4-6 inches of wood chips.

(8) Stability

After about 10 months, the operator should begin to monitor the level of stabilization of the compost. The composting material should look more like peat or soil than like leaves. Two simple procedures can be used for this purpose. The first test involves turning the windrow and monitoring the internal temperature. If the pile re-heats, the product is not yet stable enough for curing. If it does not re-heat, the material may be ready for curing. In the second test, a sample of the compost that is wet 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 in not yet stable. Careful monitoring promotes efficient space utilization at the site.

(9) Curing and On-Site Storage of Finished Product

When the composting material is fairly stable and passes one or more of the above tests for stability, then the biological activity has slowed down sufficiently such that the material no longer needs to be monitored for temperature or moisture. At this stage the material can be moved out of the windrow shape into larger curing piles for the final and slower stabilization before the compost is land applied as a growing medium.

Adequate space must be allocated for the on-site curing of compost and the storage of finished compost, which is approximately 25% of the original volume of leaves. Since stabilized compost is unlikely to produce strong odors, it is advisable to designate perimeter locations for curing piles. The curing pile may be built higher than the windrows, given that levels of oxygen or moisture do not need to be maintained, in order to conserve space. However, piles should not be made so high as to cause excessive compaction. Heights up to 15 feet are generally suitable.

(10) Compost Analysis and Quality

Depending on end-use, cured compost should be analyzed for stability, nutrient value, and potential contaminants. Leaf and yard waste compost has been found to be a safe and valuable soil amendment. Contaminants should not be a problem, however, testing for them can be used as an extra safety measure, especially if the compost is to be distributed to the public or marketed. Insuring stability is important if the compost is to be used as a growing medium. Tests for stability include volatile solids (which indicate organic content), carbon/nitrogen ratio, moisture, and pH.

If the compost is to be sold, then 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 values, the compost is an excellent soil conditioner. The addition of compost increases the water and nutrient-holding capacity of sandy soils and helps to lighten heavy, clayey soils.

Leaf and yard waste may contain trace levels of certain heavy metals, such as lead or cadmium. Heavy metals do not degrade in the composting process. However, the level of heavy metals have been found to be very low in leaf and yard waste compost. These levels are well below the strictest state and federal standards for land application of organic materials and are comparable to background soil levels. Therefore, heavy metals should not be of concern. However, when leaves are swept or vacuumed from roadways and the product is being used by the public or marketed, it is advisable to have the compost analyzed for heavy metals as a precautionary measure. The presence of lead and cadmium are possible contaminants from leaves collected from roadways.

Organic residue from herbicides and pesticides may be present in grass clippings brought to the site. While preliminary studies indicate that these materials break down after two or three months of aerobic decomposition, if the facility composts significant quantities of green wastes then a generic screen test for volatile organics (VOCs) is suggested.

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

(11) Contingency Plans

Operators should develop alternate plans for managing leaf and yard waste in the event that the composting operation is disrupted. If the composting facility becomes inoperable for a longer period than the site storage capacity will allow, no additional leaf and yard waste should be accepted. The contingency plan must comply with the ban on landfilling and incineration of leaf and yard waste as specified in 310 CMR 19.

APPENDIX A

ENVIRONMENTAL IMPACT CONTROL MEASURES

This appendix outlines measures to avoid potential pollution and nuisance problems which may arise if the siting, design or operation of leaf and yard waste composting facilities is done poorly.

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

Siting:
* Provide an adequate buffer between the composting operation and sensitive land uses.
* Locate sites down wind of sensitive uses.

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

Operation:
* Build windrows to proper height and shape.
* Form incoming leaf and yard waste into windrows promptly.
* Maintain proper temperature, moisture and oxygen content with an effective turning schedule based on temperature and moisture monitoring.
* Time pile turnings to coincide with favorable wind conditions.
* Monitor incoming waste to limit the amount of putrescible material incorporated into windrows.

RUN-OFF: *Leaf and yard waste may contain trace quantities of heavy metals, pesticides, and inorganic nutrients. Generally, the composting process will evaporate most available moisture from the windrows and the pad material should allow excess liquid to percolate through it, providing physical and biological filtration and resulting in minimal run-off. However, the following measures should be taken to minimize any potential impact that run-off could have on surface and ground water.*

Siting:
* Facilities must be sited in compliance with the Massachusetts Wetlands Protection Act.
* Avoid sites adjacent to lakes, rivers, and reservoirs.

RUN-OFF/Siting (cont.)

* Avoid sites where the water table rises closer than 4 feet to the surface.
* Avoid steep slopes.
* Choose a site with soils capable of attenuating leaf drainage water.
* Avoid sites where the bedrock is less than 5 feet from the surface.

Design:

* Design a method to divert run-off from compost and curing piles.
* Design a method that will contain run-off on-site, and that will handle the run-off with minimal impact to the groundwater.

Operation:

* 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.
* 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 runoff entering surface water is a related concern.*

Siting:

* Avoid sites in close proximity to surface waters.
* Avoid steep slopes.
* Choose a site with moderately permeable soil.

Design:

* Grade the site properly, preferable with a 1-2 percent grade.
* Retain as much vegetation as possible when clearing the site.
* Design access and on-site roads properly.
* Use diversion ditches and baled hay to contain runoff.

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

Siting: * Provide adequate buffer between the operation and sensitive land uses.

* Locate the site downwind of sensitive uses.

Design: * Construct access roads with improved surfaces.

Operation: * Maintain proper moisture content in the windrows.

* 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: * Provide an adequate buffer zone.

* Locate site downwind from sensitive land uses.

Design: * Retain perimeter vegetation or design berms to act as wind screen.

Operation: * Form leaf and yard waste into windrows promptly.

* 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: * Maintain an effective composting process.

* Properly store and promptly remove and dispose putrescibles 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: * Adequate wetting and minimum disturbance of windrows.

* Screen job candidates at the composting facility for allergic conditions.

APPENDIX B

GLOSSARY OF COMPOSTING TERMS

AEROBIC COMPOSTING. Decomposition of organic materials in the presence of oxygen.

ANAEROBIC DIGESTION. Decomposition of organic materials in the absence of oxygen.

BUFFER ZONE. Area of land between the composting facility and homes or other sensitive land uses, which shields these abutting uses from potential impacts of the operation. The buffer zone could include vegetation.

COMPACTION. Compressing of solid waste to reduce its volume, allowing for more efficient transportation. Compaction limits the availability of oxygen and moisture in organic material.

COMPOST. Organic matter which has been decomposed to produce a humus-like material suitable for use as a soil amendment. Depending on the materials from which it was made, compost has varying nutrient value.

COMPOSTING. A process of accelerated biodegradation and stabilization of organic material under controlled conditions.

COMPOSTING FACILITY. A facility which produces compost from the organic fraction of waste stream.

COMPOSTING PAD. The surface area within the composting site upon which the organic materials are composted.

CONTAMINANT. A substance capable of polluting a primary material by contact or mixture.

CUBIC YARD. A standard measure for the volume for leaves, which is roughly equivalent to 400 to 500 pounds or 1/5 to 1/4 ton, assuming an average rate of compaction.

CURING. The final stage of composting, after much of the readily metabolized material has been decomposed, in which the compost material further stabilizes at a slower rate and lower temperature than during the active composting phase.

FRONT-END LOADER. A tractor or wheeled vehicle with power-driven loading equipment at the front of the vehicle. Sometimes referred to as a bucket loader.

GROUNDWATER. The water below the land surface in a zone of saturation.

HEAVY METALS. Metallic elements with higher molecular weights. At certain concentrations, some elements present human health risks, may be toxic to plants, or adversely effect livestock.

INORGANIC. Matter in which there are no carbon-to-carbon bonds, such as minerals, which therefore will not undergo biological decomposition.

LEAVES. Deciduous and coniferous seasonal deposition.

MESOPHILIC. Favoring an environment of moderate temperature between 40 to 110 degrees F. Mesophilic microorganisms are the most common at the beginning and later stages of the composting process.

MICROORGANISM. Living organisms that are so small that they can only be seen with a microscope.

N:P:K RATIO. Refers to the ratio of nitrogen to phosphorus to potassium in a compost product, indicating its fertilizer value.

NON-COMPOSTABLE. Incapable of decomposing naturally or of yielding safe, non-toxic end products. Non-compostable materials include glass, plastic, cans, etc.

ORGANIC WASTE. Waste composed of materials which contain carbon-to-carbon bonds and are biodegradable. Includes paper, wood, food wastes and yard wastes.

PATHOGENS. Organisms that are capable of producing infection or diseases, often found in waste materials. Pathogens are killed by the high temperatures (131 degrees F or more for three consecutive days) of the composting process.

PERCOLATION. Downward movement of water through the pores or spaces of rock or soil.

PERMEABILITY. The ability of water to percolate through a material or soil.

pH. A measure of how acidic (pH less than 7) or basic (pH above 7) a material is. A pH of 7 is considered neutral.

PUTRESCIBLE. The tendency of organic matter to decompose with the formation of foul smelling byproducts.

RUNOFF. Any liquid originating from any part of the facility that drains over the land.

SCREENING. The process of passing compost through a screen or sieve to remove large organic or inorganic materials and improve the consistency and quality of the end-product.

SHREDDER. A mechanical device used to break up waste materials into smaller pieces, usually in the form of irregularly shaped strips. Shredding devices include hammermills, shears, drum pulverizers, wet pulpers and rasp mills.

SOIL AMENDMENT/SOIL CONDITIONER. A soil additive which stabilizes the soil, improves its resistance to erosion, increases its permeability to air and water, improves its texture and the resistance of its surface to crusting, makes it easier to cultivate or otherwise improves its quality.

STABILIZATION. The decomposition of compost to the point where it does not re-heat when wetted nor give off offensive odors.

STAGING AREA. A temporary holding area where newly delivered leaves and yard waste are received, mixed or de-bagged before being moved to the composting pad.

STATIC PILE COMPOSTING. A method of composting in which oxygen and temperature levels are mechanically controlled by forced aeration using blowers.

THERMOPHILIC. Favoring higher temperatures ranging from 113 to 155 degrees F. Thermophilic microorganisms thrive and are predominant at the above temperature range in composting.

VECTOR. Any organism capable of transmitting a pathogen to another organism.

VOLUME REDUCTION. The processing of waste materials to decrease the amount of space they occupy. Compaction, shredding, composting and burning are all methods of volume reduction.

WINDROW. An elongated compost pile, usually about six to 12 feet high and up to hundreds of feet long.

WINDROW COMPOSTING. The composting of organic materials in a series of elongated piles called windrows. The windrows are turned periodically to aerate and mix the waste materials to speed up decomposition and reduce odors.

YARD WASTE. Leaves, grass clippings, garden wastes, weeds, prunings and brush.

APPENDIX C

DEP CONTACTS

Compost Staff:

Sumner Martinson	(617) 292-5969
Ann McGovern	(617) 292-5834
	Fax: (617) 292-5778

State Office:

Department of Environmental Protection
Bureau of Waste Prevention
One Winter Street, 9th floor
Boston, Mass. 02108
(617) 292-5960

Regional Solid Waste Planners:

Joanne Bissetta	Northeast: (978) 661-7667
Edith DeMello	Southeast: (508) 946-2725
John McMichael	Central: (508) 767-2833
Amy Gilburg	Western: (413) 784-1100 x286

Regional Offices:

DEP, Northeast Regional Office
205A Lowell St.
Wilmington, MA 01887
Tel: (978) 661-7600 Fax: (978)661-7615

DEP, Southeast Regional Office
20 Riverside Drive
Lakeville, MA 02347
Tel: (508) 946-2700 Fax: (508)947-6557

DEP, Central Regional Office
627 Main St.
Worcester, MA 01608
Tel: (508) 792-7650 Fax: (508) 792-7621

DEP, Western Regional Office
436 Dwight Street
Springfield, MA 01103
Tel: (413) 784-1100 Fax: (413) 784-1149