New Jersey's Manual on Composting Leaves & Management of Other Yard Trimmings

Peter F. Strom
Melvin S. Finstein

Department of Environmental Sciences
Cook College and the New Jersey Agricultural Experiment Station
Rutgers University
New Brunswick, New Jersey 08903-0231

Printed on Recycled Paper

Printed on Recycled Paper

BEGIN

New Jersey's Manual on Composting Leaves and Management of Other Yard Trimmings

State of New Jersey
Christine Todd Whitman, Governor

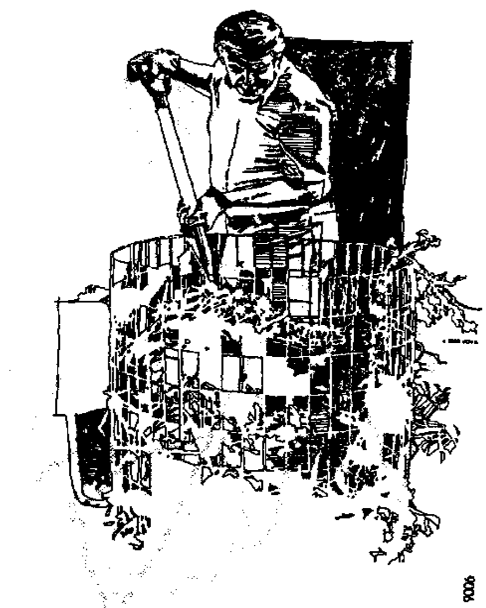
Department of Environmental Protection
Robert C. Shinn, Commissioner

Peter F. Strom
Melvin S. Finstein

THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

Department of Environmental Sciences
Cook College
New Jersey Agricultural Experiment Station
Rutgers University
New Brunswick, NJ 08903-0231

Table of Contents



Edited, Produced, and Distributed by
New Jersey Department of Environmental Protection and Energy
Division of Solid Waste Management
Office of Recycling and Planning
401 East State Street
Trenton, NJ 08625
March 1994

Revised December, 1994
Developed with Recycled Electrons

TABLE OF CONTENTS

APPENDICES

BIBLIOGRAPHY

TABLES

PREFACE

This manual supersedes all previous manuals entitled "Leaf Composting Manual for New Jersey Municipalities". Scientific and technological advances made it necessary to bring the manual up to date. Previous manuals focused primarily on leaves. This revision provides information on the latest recognized technology for leaf and yard trimming composting applications. This manual also provides more information on the management of other yard trimmings, particularly grass clippings.

This manual serves as a useful tool when planning for a leaf and/or vegetative trimmings composting facility on a local, county or regional level; however, we must not ignore the continued benefits of, backyard composting (source reduction). Backyard composting has been widely practced and well accepted for many years. Residents can help our local government by reducing organic (leaf and other yard trimmings) materials at the source through home composting practices. Since leaves in New Jersey are already required to be composted or recycled, backyard composting of other organics naturally follows. Besides, by composting source separated organics and yard trimmings, a rich end product becomes readily available for immediate application around the home and yard.

Back to Table of Contents

PREFACE to the Previous Versions

Leaves fallen to the floor of a forest or woodland undergo a slow process of decomposition. This is brought about through the action of numerous organisms, with microorganisms (including many different kinds of bacteria, fungi and protozoa) playing a dominant role. Forest litter, consisting of partially decomposed material, represents an intermediate step in the process. Eventually, a thoroughly decomposed state is reached, and the organic residue becomes part of the soil. The nutrients that were formerly in the leaves may now be available to plants, closing the cycle of growth and decay.

In contrast, leaves collected in developed residential areas represent a waste management problem. The "easy solution" of open burning was banned by New Jersey air pollution regulations in 1972. This action put an additional burden on landfills and could similarly strain alternate approaches to solid waste management now being considered throughout the State.

Like leaves in the forest, those collected from developed areas also can be decomposed microbially and the organic residue returned to the soil. However, the leaves must be processed in concentrated form, the decomposition accelerated, and residue deliberately applied to the soil. This cycle can be accomplished economically by means of the composting process linked to a compost use program.

This manual is designed to help municipalities in the establishment and operation of leaf composting facilities and programs for use of the compost. It employs the best available scientific information to find technically simple, cost-effective solutions that may be implemented by municipal personnel.

Underlying principles are first explained so that the basis of the "how-to" recommendations may be understood. In this manner, the composting operation may be flexibly adapted to meet site-specific needs.

Back to Table of Contents

ACKNOWLEDGEMENTS

Special acknowledgment is made of the work of graduate assistants William Schulz and Eric Zwerling, whose research provides much of the new technical information included in this manual. We also would like to thank all of the people at the field sites, particularly Don Hansen and Ned Scannel of the Joyce Kilmer Composting Facility, Alan C. Little of Morris County, and Maft Vastano of Middlebush Compost, Inc. who graciously allowed us access and provided needed equipment and manpower. We also owe a great deal to the energy and insight of Clarence "Pete" Peterson of Morris County, and note his passing with deep sadness. For their technical assistance we gratefully acknowledge the contributions of Dr. Harry Motto, Pegi Ballister-Howells, Jonathon Forsell, Daniel Stein, Keun Chan Oh and Roy Meyer. Ellen McShane-Fox, Brian Petitt, Vivette S. Walker, Patricia Ferriola, Timothy Bartle, and Helen Kushner of New Jersey Department of Environmental ProtectionDivision of Solid and Hazardous Waste also made important contributions. Joan Gross and Edith Cheek typed much of this new version. We sincerely thank Dr. Donn A. Derr of Rutgers University for contributing the Addendum on the economics of composting.

The New Jersey Department of Environmental Protection-Division of Solid and Hazardous Waste, the Montclair Organizations for Conservation, and Essex County sponsored field and laboratory studies which provided much of the information incorporated in the original manual. We continue to thank the following people for assisting in those studies and with the preparation of the original manual: Richard M. Abramowitz, Jeffrey Callahan, Jean Clark, Jae-Chun Chung, Mark DiDomenico, Steven W. Fass, Franklin B. Flower, Jonathan H. Forsell, Roger M. Guttentag, John A. Hogan, Ming-Huei (Phillip) Liu, Frederick C. Miller, Paul Pefto, Mary T. Sheil, Aletha Spang, James J. Stefel and Michael Winka.

This work was supported and funded by the New Jersey Department of Environmental Protection, Division of Solid and Hazardous Waste, and the New Jersey Agricultural Experiment Station (Publication No. H-07526-2-92), supported by State funds.

Back to Table of Contents

PREFACE

This manual supersedes all previous manuals entitled "Leaf Composting Manual for New Jersey Municipalities". Scientific and technological advances made it necessary to bring the manual up to date. Previous manuals focused primarily on leaves. This revision provides information on the latest recognized technology for leaf and yard trimming composting applications. This manual also provides more information on the management of other yard trimmings, particularly grass clippings.

This manual serves as a useful tool when planning for a leaf and/or vegetative trimmings composting facility on a local, county or regional level; however, we must not ignore the continued benefits of, backyard composting (source reduction). Backyard composting has been widely practced and well accepted for many years. Residents can help our local government by reducing organic (leaf and other yard trimmings) materials at the source through home composting practices. Since leaves in New Jersey are already required to be composted or recycled, backyard composting of other organics naturally follows. Besides, by composting source separated organics and yard trimmings, a rich end product becomes readily available for immediate application around the home and yard.

PREFACE to the Previous Versions

Leaves fallen to the floor of a forest or woodland undergo a slow process of decomposition. This is brought about through the action of numerous organisms, with microorganisms (including many different kinds of bacteria, fungi and protozoa) playing a dominant role. Forest litter, consisting of partially decomposed material, represents an intermediate step in the process. Eventually, a thoroughly decomposed state is reached, and the organic residue becomes part of the soil. The nutrients that were formerly in the leaves may now be available to plants, closing the cycle of growth and decay.

In contrast, leaves collected in developed residential areas represent a waste management problem. The "easy solution" of open burning was banned by New Jersey air pollution regulations in 1972. This action put an additional burden on landfills and could similarly strain alternate approaches to solid waste management now being considered throughout the State.

Like leaves in the forest, those collected from developed areas also can be decomposed microbially and the organic residue returned to the soil. However, the leaves must be processed in concentrated form, the decomposition accelerated, and residue deliberately applied to the soil.

This cycle can be accomplished economically by means of the composting process linked to a compost use program.

This manual is designed to help municipalities in the establishment and operation of leaf composting facilities and programs for use of the compost. It employs the best available scientific information to find technically simple, cost-effective solutions that may be implemented by municipal personnel. Underlying principles are first explained so that the basis of the "how-to" recommendations may be understood. In this manner, the composting operation may be flexibly adapted to meet site-specific needs.

ACKNOWLEDGEMENTS

Special acknowledgment is made of the work of graduate assistants William Schulz and Eric Zwerling, whose research provides much of the new technical information included in this manual. We also would like to thank all of the people at the field sites, particularly Don Hansen and Ned Scannel of the Joyce Kilmer Composting Facility, Alan C. Little of Morris County, and Maft Vastano of Middlebush Compost, Inc. who graciously allowed us access and provided needed equipment and manpower. We also owe a great deal to the energy and insight of Clarence "Pete" Peterson of Morris County, and note his passing with deep sadness. For their technical assistance we gratefully acknowledge the contributions of Dr. Harry Motto, Pegi Ballister-Howells, Jonathon Forsell, Daniel Stein, Keun Chan Oh and Roy Meyer. Ellen McShane-Fox, Brian Petitt, Vivette S. Walker, Patricia Ferriola, Timothy Bartle, and Helen Kushner of New Jersey Department of Environmental ProtectionDivision of Solid and Hazardous Waste also made important contributions. Joan Gross and Edith Cheek typed much of this new version. We sincerely thank Dr. Donn A. Derr of Rutgers University for contributing the Addendum on the economics of composting.

The New Jersey Department of Environmental Protection-Division of Solid and Hazardous Waste, the Montclair Organizations for Conservation, and Essex County sponsored field and laboratory studies which provided much of the information incorporated in the original manual. We continue to thank the following people for assisting in those studies and with the preparation of the original manual: Richard M. Abramowitz, Jeffrey Callahan, Jean Clark, Jae-Chun Chung, Mark DiDomenico, Steven W. Fass, Franklin B. Flower, Jonathan H. Forsell, Roger M. Guttentag, John A. Hogan, Ming-Huei (Phillip) Liu, Frederick C. Miller, Paul Pefto, Mary T. Sheil, Aletha Spang, James J. Stefel and Michael Winka.

This work was supported and funded by the New Jersey Department of Environmental Protection, Division of Solid and Hazardous Waste, and the

New Jersey Agricultural Experiment Station (Publication No. H-07526-2-92), supported by State funds.

INTRODUCTION

A. Leaves and Yard Trimmings

Leaves differ from much other municipal solid waste (MSW) in that they occur seasonally and are collected separately. In season, leaves may account for over half the municipal solid waste collected and on a yearly basis may comprise 5% to 30% of the total municipal solid waste stream.

Because separated leaves are homogeneous, seasonal, and usually nonÄobnoxious, they lend themselves to treatment by relatively uncomplicated composting procedures. The end product of the process is compost, which can benefit soils as an organic amendment.

The objectives of leaf composting as a waste treatment process are a reduction in the mass and volume of the starting material and the destruction of putrescible (odor-causing) substances. For compost production, reduction of the carbon to nitrogen ratio (see Section III.F) and elimination of weed seeds and any plant pathogens also are desirable. As cost effectiveness is always a primary concern, the economic and other advantages of composting leaves are dramatic when compared to many alternative strategies.

Other yard wastes in New Jersey include mainly grass clippings and woody materials such as tree trimmings. Grass clippings may account for 10-20% of the total MSW stream, and woody materials perhaps half that amount. In many cases these historically have not been collected separately. Woody materials degrade too slowly to be amenable to composting, and grass clippings, although readily compostable, are problematic at leaf composting facilities. Recycling of both materials will be discussed further below, particularly in Section VI.

B. Current Management Alternatives

According to the New Jersey Statewide Mandatory Source Separation and Recycling Act (P.L. 1987, c.102, or NJSA 13:1E-99.11 et seq.), leaves must be source separated and recycled. Leaves can be recycled by being composted in the backyard, composted at vegetative or leaf composting facilities, or mixed (sometimes called "mulched") into the soil at land deemed actively devoted to agricultural or horticultural use. Grass clippings also may be included at specially permitted vegetative composting sites, and perhaps soon at mulching sites. The regulations for these practices are available through the New Jersey Department of Environmental Protection and Energy (NJDEPE) Division of Solid Waste Management (DSWM), Bureau of Resource Recovery Engineering (addresses and phone numbers are provided in Appendix D; also see Section IV.A). The state does not regulate backyard composting activities.

Leaf composting requires separated leaf collection. This potentially imposes additional collection costs, but already is commonplace. An economic analysis of leaf composting is provided in a separate addendum by Dr. Donn A. Derr.

1. Source Reduction

[Sentence or two from Ellen]

a. Backyard Composting

Backyard and municipal-scale leaf composting are complementary activities. Municipalities should encourage backyard composting as a part of their overall yard waste management program. All municipal collection, processing, and distribution costs are avoided for leaves and yard trimmings that are composted by residents. Additionally, other materials such as grass clippings and fruit and vegetable scraps can be included in backyard composting, thus reducing handling of these wastes by the municipality as well.

The backyard composting process is similar to a municipal program on a smaller scale. Leaves and yard trimmings are placed in a free-standing pile or contained in a holding or turning unit. The material is turned manually to accelerate the process and allow for the surface layer to be mixed in and undergo the composting process. The compost produced in this manner can be used to enrich the soil around trees and shrubs and within gardens.

Fact sheet FS 074 on backyard leaf composting, published by Cooperative Extension at Cook College, Rutgers University, is available from county extension offices (in New Jersey) or Cook College (single copy provided in Appendix E). The method recommended in the fact sheet is less complex than those suggested by most others, and was designed to make it easier for residents to get started with composting. However, there are numerous suitable publications available.

b. "Grass: Cut It and Leave It"

Grass clippings are another major component of municipal solid waste. However, they can be easily eliminated from the MSW stream, while at the same time producing a healthier lawn. Leave the clippings on the lawn and let nature do the recycling.

The process is simple. Most New Jersey lawns thrive when mowed to a length of about 2 to 3 inches, especially in summer. To maintain the lawn properly, avoid mowing more than the top third of the grass blades. The clippings will then filter down to the soil, acting as a natural fertilizer. The lawn will be healthier, and the taller grass will shade the soil, cooling roots and limiting weeds.

Lawn experts agree that grass clippings will not contribute to thatch problems. Rather, thatch is formed by the accumulation of dead roots and stems. Increased use of fertilizer and water will cause the lawn to grow faster, resulting in greater thatch build up as well as more clippings.

A copy of a DEPE pamphlet on managing grass clippings is provided in Appendix E. For additional copies, contact your county extension office or recycling coordinator (Appendix D).

c. Backyard Mulching

Another way of recycling leaves, grass clippings, and brush is to apply them to gardens or around shrubs and other plantings as a surface mulch. A one inch layer of mulch can help moderate soil temperatures and reduce weed growth, soil spattering and compaction, erosion, evaporation, and runoff. Brush needs to be chipped first, and leaves also make a better mulch after shredding or composting. All of the materials help improve the organic content of New Jersey soils, although with woody materials this will take a longer time.

2. Composting

For many municipalities, composting has proven to be the best and least expensive method for managing leaves. Over 200 such facilities are operating in New Jersey.

In addition to the cost savings compared to other alternatives, the compost produced has some small monetary value. This may be recognized in reduced purchases of organic matter (such as mulch and top soil) by the municipality, free distribution to residents, and even as product sales. In addition, tonnage grants from the NJDEPE/DSWM can be utilized to help offset composting costs.

From an environmental perspective, composting saves valuable landfill space, avoids the cost and concerns of incineration, and produces compost which can be used to improve soil. Composting of leaves and other yard wastes counts towards the State's 60% recycling targets.

Composting is both an economical and an environmentally sound alternative for handling leaves. However, to fully realize these benefits and to avoid some of the potential problems, care must be exercised in selecting a site and designing and operating the facility.

3. Farmland "Mulching"

Collected leaves also can be "mulched" on land deemed actively devoted to agricultural or horticultural use, as per N.J.A.C. 7:26-1.12 (available from NJDEPE/DSWM). This regulation requires that the operation be included in or consistent with the county's solid waste management plan; leaves be delivered unbagged, and spread onto the field in a thin layer no more than 6 inches deep within 7 days of delivery (no stockpiling for longer periods); and layered leaves be incorporated into the soil no later than the next tillage season.

Pregrinding of the leaves is not required, although it may be beneficial. However, the rate of application for preground leaves should not exceed the rate for unground leaves on a mass (or weight) basis - this means that a thinner layer (probably 2-3 inches) must be used because of the volume reduction.

It may also soon be possible to "mulch" grass clippings. Contact NJDEPE/DSWM for the latest regulations for this practice.

C. "Historic" or Previous Management Strategies

1. Open Burning

For many years, leaves were disposed of by residents through open burning. Prompted by the severe air pollution problems in the state, this practice was banned in New Jersey effective January 1, 1972 (New Jersey Air Pollution Control Code, Chapter 2).

2. Landfilling

Although landfilling is currently a primary disposal method for municipal solid waste in New Jersey, according to the New Jersey Statewide Mandatory Source Separation and Recycling Act (NJSA 13:1E-99.11 et seq.), landfilling is no longer an alternative for managing leaves.

There are numerous reasons for banning leaves from landfills. The siting of new landfills has become extremely difficult, and landfill capacity has decreased sharply. Placing leaves in landfills uses up this limited capacity for a relatively innocuous material, rather than saving it for the more obnoxious fraction of the municipal solid waste stream. As the number of remaining landfills declines, the hauling time and distance increase for many municipalities. Likewise, the waiting time for trucks to dump at some landfills is longer. Landfills also exact a high price in terms of increased maintenance costs for the trucks which ride on them - tires, transmissions, fuel tanks, hydraulic lines, and other components receive hard wear.

Ironically, when leaves were placed in landfills their biodegradability, which makes them suitable for composting, added to the gas, leachate, and settling problems which landfills experience. Thus landfilling of leaves is not only expensive but also environmentally unsound.

3. Incineration

According to NJSA 13:1E-99.11 et seq., leaves are banned from incinerators within this state. Leaves are often too wet to burn well, reducing the potential for energy recovery. On the other hand, when leaves are dry, they tend to be too light and fluffy, adding to the fly ash.

Beyond these problems, incinerating leaves may simply be impractical because of their large volume and highly seasonal nature. Designing a mass burning facility to handle this peak loading may be economically infeasible, since the excess capacity would usually have to be idle for the remainder of the year. For economically sized facilities, peak (as well as down-time) refuse loads have to be diverted to landfills.

Back to Table of Contents

DESCRIPTIONS OF PROCESS AND PRODUCT

A. Composting (the Process)

When biodegradable organic materials containing sufficient moisture and inorganic nutrients (especially nitrogen) are placed in a pile or windrow (elongated pile), a natural process known as self-heating often occurs. Microorganisms, mainly bacteria and fungi, begin to grow rapidly on the organics, using them as a food source and decomposing them. Because the microbes are not 100% efficient, some of the chemical energy stored in the organics is wasted and released as heat. A large enough pile will act as an insulator, retaining heat and leading to an increase in temperature, which up to a point helps to speed up decomposition. Thus, the organic material "self-heats" through the intense metabolic activity of the microorganisms. Eventually the readily biodegradable food supply becomes exhausted, growth and heat generation slow down, and the pile cools.

The process which employs self-heating for waste treatment objectives is called composting. It has been used for many years for treatment of agricultural wastes and in more recent times for treating sewage sludge, municipal solid waste fractions, certain industrial wastes, food scraps, and leaves and grass clippings.

B. Compost (the Product)
As composting progresses, the original material becomes less recognizable, although certain structures, such as twigs and the veins of oak leaves, persist longer than others. The material darkens, acquires a granular texture, increases in water-holding capacity, becomes almost neutral in pH, and eventually develops the pleasant odor characteristic of freshly turned soil. Compost bears little resemblance to the original starting material.

Back to Table of Contents

III. UNDERLYING SCIENTIFIC PRINCIPLES

A. Temperature

At any given time, the temperature of the pile reflects the balance between microbial heat generation and the loss of heat to the surroundings. The rate of heat generation is a function of factors such as temperature, oxygen, water, nutrients, and the remaining concentration of easily biodegradable organic materials. The rate of heat loss is a function of factors such as ambient temperature, wind velocity, and pile size and shape.

Temperature is a powerful determinant of the rate of decomposition. Temperatures of less than 20øC (68øF) slow decomposition. Temperatures above 60øC (140øF), which is hotter than the setting of most home hot water heaters, are also unfavorable because they kill most of the desirable microorganisms. The range of favorable temperatures is approximately 20 to 60øC (or about 70 to 140øF). Precise control over temperature usually is not essential for leaf composting, but gross departure from the desired range should be avoided. Maintenance of the proper temperature, along with oxygenation, is the basic consideration underlying the recommendations for windrow size and turning operations (see Sections III. C and V). If precise measurements of pile temperature are required, the County Extension Office should be consulted (see Appendix D).

Grass clippings are a more "energetic" material (capable of generating more heat) than leaves, and are produced and composted during the warmer part of the year. Overheating is thus more likely and under heating less likely than for leaves. This, along with the need for increased oxygen supply, is why a smaller pile size is recommended when grass clippings are included in a windrow.

B. Oxygen

Composting is basically an aerobic process (requires oxygen), although anaerobic (without oxygen) activity also may occur to a significant extent. Most of the heat produced in composting results from the biodegradation of organic materials with consumption of oxygen and production of carbon dioxide and water. Thus, the pile must be sufficiently porous to allow oxygen (from the air) in and carbon dioxide out. For this reason, materials should be placed loosely in the piles and compaction should be avoided.

In the absence of oxygen, anaerobic conditions occur. This can lead to odor production and slowed rates of decomposition.

C. Windrow Size and Turning

For leaves, control over process temperature and oxygen content can be exercised to a useful extent (though they are not optimized) through windrow size and turning. A basic problem is to reconcile the needs for oxygenation and heat conservation, which are somewhat in conflict. The need for oxygenation favors small windrows to minimize the distance that air must penetrate within the pile. In contrast, the need for heat conservation, especially in the winter, argues for large windrows for greater insulation. Excessively large windrows, however, might result in excessively high temperatures and anaerobic conditions. These requirements can be reconciled in part by management of windrow size and turning. Specific recommendations are given in Section V. For almost all composting, windrows should be no more than 6 feet high and 12-14 feet wide.

D. Water

Water is essential for biological functions in general, and composting is no exception. Adding water (when needed) at the start of composting is very important to insure adequate moisture throughout the pile at the time of its formation and thereafter. Rainfall, even if heavy, penetrates the pile only slowly and cannot be relied upon to remedy initial dryness. Similarly, once a pile is formed, the interior material is not easily wetted by applying water to the surface. Unless a pile is turned during or shortly after wetting, much of the water will simply evaporate to the air. Initial dryness is a common and serious cause of slow leaf composting rates, and as such should be prevented. An initial moisture content of at least 50% (wet weight basis) is recommended.

Leaves also can be excessively wet, slowing oxygen penetration (see Section III.B). This condition is self-correcting, as excess water drains from the pile. Depending on weather conditions prior to collection, the leaves might be sufficiently moist upon receipt, but this cannot be relied upon in routine operation. In general, it is better to start with a pile that is too wet than to risk dryness.

Specific recommendations for providing a water supply and for adding water prior to windrow formation are given in Sections IV.I and V.B.3 and Appendix A.

E. pH

Fresh leaves are close to being chemically neutral (neither acidic nor basic, pH near 7), which is desirable for rapid microbial activity. However, with the onset of decomposition even prior to composting, the production of organic acids causes the pH to decline to suboptimal levels, possibly to as low as 4.2 if extensive anaerobic conditions develop. The pH subsequently recovers to a neutral or slightly alkaline level (perhaps pH 7.5) as the acids decompose in the presence of oxygen. A persistently acidic pH is indicative of prolonged anaerobic conditions. Adjustment of the pH with limestone or other additives is not ordinarily necessary.

Composting of high nitrogen materials such as grass clippings may lead to pHs as high as 8.5-9.5 as ammonia is released. Mixing with leaves will help control this excessive pH rise, as well as reduce ammonia loss.

F. Inorganic Nutrients

Microbial activity also requires a variety of other elements, such as nitrogen and phosphorus. Leaves have a high carbon-to-nitrogen ratio (C/N), which can slow microbial action early in the composting period. This nutritional imbalance rights itself as carbon is lost in the form of carbon dioxide, while nitrogen is conserved within the system. Supplementation with nitrogen at the outset would accelerate decomposition, but this measure is not generally necessary. It might be justified, in conjunction with other measures, if the resultant saving in process time were essential for the success of the overall operation (see Section V.D). The increased rate of decomposition from nitrogen addition could lead to other problems, such as an increased need for oxygen supply, which would also then have to be addressed. Otherwise, slow decomposition and odors might result. Appreciable deficiency of other nutrients such as phosphorus is not likely.

Supplementing the end-product compost with nitrogen, phosphorus and potassium would increase its quality in terms of plant nutrition. This benefit has to be weighed against the costs of such additions.

Grass clippings, on the other hand, contain excess nitrogen and thus have an undesirably low C/N. Unless sufficient available carbon (such as from leaves) is added, ammonia will be lost from the material, producing potential odor problems. The nitrogen also may contaminate ground or surface waters.

G. Microorganisms

Microorganisms found on leaves and yard trimmings are fully capable of starting the composting process and carrying it forward. A variety of commercial "inocula", "starters", and "bioaugmentation" products are offered for sale, and based on testimonials, these are often claimed to be beneficial. However, there is no support for these claims in scientific journals. Properly controlled experimentation indicates that inoculation has no useful effect on the process. Therefore, such products should not be purchased for leaf or yard trimmings composting operations.

H. Leaf Type

Maple leaves decompose more rapidly than oak leaves, and other leaf types doubtless differ in this respect. Mixtures would ordinarily be received at a leaf composting facility, and no specific recommendation is made based solely on leaf type.

I. Pregrinding

Pregrinding or shredding of leaves make them more susceptible to microbial attack, potentially speeding up the composting process. This is not desirable in most cases, unless provision has been made for very frequent turning or blowers to supply the extra oxygen that will be needed, and remove the extra heat that will be generated. It is normally not recommended, and the guidelines given later assume no pregrinding. If any pregrinding is done, smaller piles are recommended. The equipment typically used for the final shredding of finished compost (see Section V. B.8) usually is not suitable for shredding of leaves prior to composting.

Back to Table of Contents

IV. FACILITY SITING AND INITIAL PREPARATION

Site selection is an extremely important decision that should be made only after careful consideration, as each situation is unique. The deliberation over site selection should take into account proximity to residences and streams, prevailing winds, traffic patterns, travel distance and its effect on equipment and labor costs, and other factors, such as local zoning requirements. Many of these are discussed below, yet familiarity with local circumstances is essential and cannot be reduced to written instruction. It is suggested that the County Extension Office be involved in the early stages of planning. The siting of the facility must be approved by the host county and included in the county's Solid Waste Management Plan before the application can be submitted to the NJDEPE/DSWM. Some counties have blanket plan inclusion policies to facilitate this requirement (contact your county's Solid Waste Management Office).

A. Public Participation

When selecting a site, the importance of public participation must be stressed. Concerns raised may include odor, traffic, noise, litter, water pollution, and health issues, such as the fungus Aspergillus fumigatus. Surrounding property owners and the general public should be educated as to the benefits of composting, and assured that their concerns will be addressed. They also need to be informed about the proposed facility, including site capacity, type of material which will be accepted, and the level of technology, including what type of equipment will be utilized.

It is very important to have support within the community; an informed public is less likely to oppose the siting and operation of a facility. It also may be necessary to deal with the emotional reaction of some community members. An open dialogue should be maintained throughout the planning and operational phases of the project. This can be accomplished by providing educational and informal discussion sessions during hours convenient to the public. The county Cooperative Extension office may be very helpful with special programs and expertise. Many sites offer the finished compost free of charge to residents, further increasing knowledge and support within the community.

B. Permits

In New Jersey a state permit or letter of approval is required for all solid waste facilities, including vegetative and leaf composting facilities. The type of permit or approval required depends on the amounts and types of materials accepted. In October, 1988, the State adopted an emergency rule which enabled the NJDEPE to expeditiously authorize the operation of leaf and vegetative waste composting facilities. One subsection, N.J.A.C. 7:26-1.11, applies to facilities with a capacity not in excess of 20,000 cubic yards annually which compost leaves only.

NJDEPE allows the development of leaf composting demonstration projects for educational purposes on lands owned or operated by recognized academic institutions. Such facilities may accept up to 500 cubic yards of leaves, only. The Soil Conservation District (SCD - see Appendix D) may assist in developing and submitting the site plan.

SCDs may help develop site plans for the construction, operation, and maintenance of leaf composting facilities (leaves only) located on agricultural or horticultural land, or on lands owned or operated by a recognized academic institution. The SCD must then conduct annual inspections of these facilities to ensure compliance with NJDEPE regulations.

For further information on obtaining a permit or approval for composting facilities, please contact the NJDEPE/DSWM, Bureau of Resource Recovery Engineering. A pre-application meeting is strongly recommended. Composting facilities also must be incorporated into the district solid waste management plan. Please contact your county Solid Waste Management Office (Appendix D) for further information on including your composting facility in your district's plan.

Backyard composting activities do not require a permit or approval from the NJDEPE provided that they are limited to the composting of family waste on the premises of one or two family dwellings.

C. Area Requirement

A minimum of an acre per 3000-3500 cubic yards of leaves collected is required for the actual composting operation. This assumes the use of the low or intermediate level technology described later, and is in addition to the requirement for a buffer zone (see Table 1). Calculation of site capacity is shown in Appendix A.

Use of the intermediate level of technology may require additional space, since smaller windrows are needed to accommodate many turning machines. However, this must be determined individually for the type of equipment chosen. Windrows often can be assumed to have the approximate cross-sectional shape of a semi-circle. Necessary aisle space depends again on the type of equipment used.

D. Buffer Zone

A buffer zone is required between the site activities and neighboring land use to minimize possible odor, noise, dust and visual impacts. Other than "the larger the better", it is difficult to generalize exact buffer zone requirements for composting. It would seem prudent to provide at least 50 feet between the composting operation and the property line. At least 150 feet must be allowed between composting activities and any sensitive neighboring land uses, such as residential property lines. Additionally, at least a 250 foot buffer is needed between composting activities and a place of human occupancy (house, school, etc.). If grass clippings will be brought to the site, at least 1000 foot buffer zones from the staging and grass clipping handling areas are probably necessary (see Section VI). Calculations of area requirements for buffer zones are shown in Appendix A.

The buffer zone may include a berm (often of finished compost) to serve as a visual barrier, help control vehicular access, and reduce noise levels off-site. A landscaping plan, including plantings, is strongly recommended to enhance the appearance of the facility.

E. Location

A centrally located facility is preferable to reduce transportation time and costs, although such sites are not often available or otherwise practical. Access is preferably over non-crowded, non-residential, hard surface roads.

While siting on Green Acres land is not strictly prohibited, it only will be considered as a last resort. Contact the Green Acres Program Office (see Appendix D) for more information.

F. Stream Encroachment and Water Pollution

Siting of a leaf composting facility in a flood plain normally is not allowed by state regulations. During times of high water the windrows might impede water flow, and/or leaves and leachate might wash into the stream. Flooding of the site could pose serious operational difficulties, including problems with equipment access and operation. Flooding of the windrows also may lead to extensive anaerobic conditions and attendant problems of odor and lower decomposition rate. Flood plain maps are available through the Federal Emergency Management Agency or the NJDEPE, Land Use Regulation Program (see Appendix D).

Runoff into nearby streams or other surface waters is another concern because of the water pollution potential of leachate (see Section VII.B). If grass clippings are composted, nitrogen contamination of groundwater also must be considered (Sections VI.A and VII.B).

G. Slope and Grading

Steep slopes are unsatisfactory because of problems with erosion, vehicular access, and equipment operation. A gentle slope, however, is desirable to prevent ponding of runoff and leachate. The Soil Conservation Service (SCS) allows a minimum slope of 0.5%, and a maximum of 10%, although 2-3% is usually desirable. Initial site preparation usually requires grading, and yearly maintenance should include regrading where necessary. Windrows should run up and down rather than across slopes to allow leachate and runoff to move between piles, rather than through them.

Drainage characteristics of a site can be determined from U.S. Geological Survey topographic maps and a plot plan survey. The New Jersey Department of Agriculture's "Standards for Soil Erosion and Sediment Control" (N.J.A.C. 2:90) provides information on grading to promote drainage and prevent erosion and sedimentation. The local Soil Conservation District (see Appendix D) should be contacted for information on permits or approvals that may be required for any soil disturbance in excess of 5000 square feet.

H. Percolation

High soil percolation rates are desirable so that excessive rainwater and leachate will not run off the site. Where percolation is poor, soil modification techniques may be used to improve drainage. With poor percolation, or where an impervious surface is used, particular care must be taken to prevent ponding. While an impervious surface such as pavement may offer advantages in terms of vehicle access and equipment operation, these may be outweighed by the greater difficulties in leachate management. The Soil Conservation District (see Appendix D) may be consulted to determine soil characteristics of sites under consideration.

I. Water Table

A high water table is undesirable because it may lead to flooding of the site. Flooding will make operation more difficult and can lead to extensive anaerobic conditions. A high water table also reduces the distance for percolation of leachate. Wetlands and wetland buffer areas especially should be avoided. The New Jersey Department of Agriculture's Division of Soil Conservation (see Appendix D) publishes a local soil conservation district "Soil Survey" booklet for each county containing information on depth to ground water. This information is general, however, and a more site specific determination may be necessary. The SCS requires the seasonal high water table to be at least 2 feet below the surface.

J. Water Supply

The ability to supply water is critical since it usually is necessary to add water to the incoming leaves during much of the collection season. Water can best be supplied by using a hose from a fire hydrant or by pumping from a nearby lake, stream, or well. Use of a water truck usually is not practical because too much water is needed. Approximate average water requirements are 20 gallons per cubic yard of leaves (see Appendix A2).

K. Security

Vehicular access to the site must be controlled to prevent illegal dumping. A gate across the entrance road is a minimum precaution. In some cases the entire site may have to be fenced, but usually preexisting features such as streams, trees, and embankments will provide partial security. A berm consisting of earth and finished compost often can serve in place of a fence at other points. Vandalism may be of concern, especially if equipment is to be left on site.

L. On-Site Roads

Because of the heavy truck traffic during the collection period, a limited road network (possibly paved) within the site may be desirable to improve all-weather access. A circular traffic flow pattern may be advantageous at heavily used sites. The purpose of the on-site roads is to help prevent trucks from getting stuck during muddy conditions. An extensive on-site road network is not required.

M. Fire Safety

Normally, windrowed leaves burn poorly, since the interior of the pile is wet. While vandals may be able to ignite the dry surface leaves, a major fire is unlikely. Fire safety is further accommodated by having a ready water supply and delivery capacity, initial wetting of the leaves, and providing aisles between windrows as a fire break and for access.

N. Other Safety Considerations

Safety precautions usual to any operation involving heavy machinery should be exercised. Road layout should be designed with safety in mind. Public access should be restricted.

Back to Table of Contents

V. APPROPRIATE LEVEL OF TECHNOLOGY

Four levels (minimal, low, intermediate, and high) of composting technology can be considered. The particular one which is most appropriate for a given application will depend mainly on the quantity and types of material accepted and the site selected, although the equipment and manpower available are also factors. Table 1 indicates that the lower the level of technology, the greater the requirements for available space and composting time, but the lower the cost.

The level of technology refers to the extent to which the ideal conditions for composting are met. Minimal technology meets the conditions poorly, leading to slow processing and a strong odor potential. However, if site conditions permit this type of operation, it can be highly cost effective. It might be considered for leaves only, or for some agricultural wastes.

The low-level technology provides somewhat better composting conditions, cutting the time requirements and odor potential. This is considered acceptable in many cases for smaller operations handling leaves only. It is discussed in the greatest detail below as a point of comparison for the other methods.

Intermediate-level technology invests more effort into speeding up the composting process. It is appropriate for larger sites, and is necessary where grass clippings are accepted at a site.

The high-level of technology approaches optimum processing conditions. While not used for leaves, it is normally required to handle other municipal solid waste fractions, sludges, and other highly putrescible wastes.

A. Minimal Technology

If a large area that is well isolated from sensitive neighboring land uses is available, a very low-cost approach to leaf composting is possible. Leaves brought to the site are formed into large windrows (for example, 12 feet high by 24 feet wide) using a front-end loader. Once each year the windrow is turned and reformed. An additional windrow is constructed with the new leaves each fall. After three to five years the material in a windrow is usually sufficiently well stabilized to be used as compost.

With this "minimal" technology the necessary conditions for rapid composting are not achieved. Much of the pile remains anaerobic for a full year at a time between turnings. The center of the pile will probably also reach inhibitively high temperatures, especially the first year. However, the greatly reduced rate of activity is compensated for by providing a prolonged composting time.

Using this approach, odors can be expected for the first year, and serious odors likely will be released during the first turning. Usually by the second turning, odors have diminished. Because of these odors, an extensive buffer zone is required. Up to a quarter mile distance or more to sensitive neighboring land uses is recommended.

The obvious advantage of this approach is that it is extremely inexpensive. Only a 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. The large piles will conserve moisture, and the long time period ensures 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. For example, using 12 foot high by 24 foot wide piles, a single windrow 60 yards long would contain approximately 1500 cubic yards of leaves. Even though the leaves must stay on site for at least three years, a one acre site (excluding buffer) is expected to be adequate for a yearly collection of 4000 cubic yards.

However, because of the odors produced, a large buffer zone is needed. Thus, a very large total area is required, although only a small portion of it is actually utilized for the composting. This might be useful in a wooded area, so that only a small clearing would be required, or at an isolated industrial site or public works yard.

B. Low-Level Technology

In densely populated New Jersey, siting of a minimal technology facility is rarely possible. Therefore, the necessary conditions for rapid and nuisance free composting have to be more nearly met. In particular this means that a better job must be done of ensuring adequate moisture content, oxygenation and temperature control.

The simplest way to achieve the desired temperature range would seem to be to build piles large enough to conserve sufficient heat, but not so large as to overheat. On the other hand, adequate oxygenation by passive diffusion of air from the outside of the pile could be achieved if the piles were small enough. Unfortunately no single pile size completely reconciles these conflicting goals. However, the desired conditions can be approached by starting with moderate size piles (6 feet high by 12-14 feet wide), then combining two piles after the first burst of microbial activity (which lasts approximately one month). Water addition at the outset is usually necessary to provide adequate moisture.

Using this approach it is possible to produce a thoroughly decomposed (finished) compost in 16-18 months. The compost is ready for use in the spring, which is the time of peak demand for the product. Slight odors may be produced early in the composting cycle, but these usually are not detectable more than a few yards away from the windrows. After 10-11 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 four operations with a front-end loader are required after initial windrow formation (one combining, one or two turnings, and one curing pile formation). Despite the fact that more space is required for the actual composting (roughly 1 acre per 3500 cubic yards of leaves) compared to the minimal technology, less total area is needed overall because of the reduced buffer requirement.

Unless otherwise indicated, the low-level technology is recommended for small to medium size sites composting leaves only. This is the technology that NJDEPE/DSWM prescribes in its permit exemption regulations (N.J.A.C. 7:26-1.11). However, this technology generally is not acceptable at larger sites, or if grass clippings are accepted.

Table 2 summarizes the scheduling and estimates of manpower and equipment requirements for a moderate-sized leaf composting facility (15,000 cubic yards of leaves per year) employing the low level technology. The individual steps are discussed in more detail below. A summary sheet, meant for distribution to field personnel, is provided in Appendix B.

As indicated, a number of assumptions went into Table 2. The manpower and equipment time estimates, in particular, should be considered only as a general indication of the needs at a specific site, since they may be highly variable. More details are given below.

1. Site Preparation

Prior to each collection season the site must be readied to allow all necessary truck access and front-end loader operation. The one part of the operation which has little scheduling flexibility is delivery of the collected leaves. Once leaves are collected, they must be promptly processed through the staging area and formed into windrows (Section V.B.2-4). It is critical, therefore, to prevent operational bottlenecks, such as an area becoming so muddy that trucks get stuck trying to drop off their loads.

The yearly site preparation should include regrading and road and leachate system (if any) maintenance. All refuse and debris from the previous year's operation should be removed. Normally this step will require at most a few days work. It can be scheduled any time after the active site has been cleared of the leaves from the previous year (by formation of the curing piles), but before the new collection season begins.

2. Delivery of Leaves

It is recommended that trucks dump their loads of leaves in a staging area, rather than trying to form windrows directly. Although a staging area involves additional labor, its use is justified for several reasons.

Leaves are normally collected in several ways and delivered in a variety of trucks including garbage compactors, roll-offs, and vacuums. If the windrows are formed directly by dropping off loads from these trucks, highly non-uniform size, moisture, and compaction - and hence decomposition - results. This can be minimized by the operations performed in a staging area. Wetting is virtually impossible in directly formed windrows since most of the water simply runs off the outside. Use of a staging area also leads to a more uniform windrow size and shape, giving both a better appearance and more efficient composting. Keeping trucks on the firmer surfaces, rather than backing into windrows, decreases their chance of getting stuck during wet weather. Even in good weather the staging area can speed the delivery process. It may be feasible to move the staging area periodically (weekly for example) to minimize the distance to the active windrow forming area.

Windrow formation must take place immediately after leaves are received. If freshly dumped leaves are allowed to sit for more than a day or so in the staging area, odor problems may develop.

Supervision may be required to prevent dumping in undesired locations. Also, a monthly record of the amount of leaves delivered must be kept. The collection log must be submitted to the municipality of origin for the Tonnage Grant Program. A daily tabulation of the number of loads for each individual truck of known capacity may be the best accounting method. A copy of the collection log developed by the NJDEPE/DSWM is provided in Appendix C.

The staging area also provides an opportunity to inspect loads as they are dropped off, and to remove incidental contamination from litter or other refuse. Heavily contaminated loads should be rejected, if possible, to avoid sorting and disposal costs, and to encourage better collection practices in the future. As indicated earlier (Section IV.L), plastic bags should not be accepted at the site.

3. Wetting

Wetting of the leaves will be required during much of the collection season. Adequate wetting can only be achieved prior to or during windrow formation, or when windrows have been opened up for turning or other purposes. Most of the water applied to the outside of a windrow is simply shed by the leaves, or quickly re-evaporated to the air. The water should be sprayed on the leaves with a firehouse (see Section IV.I) as the loader breaks the masses apart in the staging area, and/or as they are placed in the windrows.

If the moisture content of the delivered leaves is known, the amount of water that must be added to get any particular desired moisture content can be calculated (Appendix A). On a more informal level, the rule of thumb is that it should be possible to squeeze a few drops of water from a fistful of the leaves. As a rough approximation, perhaps 20 gallons of water will be required on average per cubic yard of leaves collected.

4. Forming Windrows

Once the leaves have been dropped off in the staging area, the front-end loader can be used to break apart and spread the compacted materials to facilitate wetting. Plastic bags, branches, curbing, and other incidental debris can be removed by hand. The front-end loader can then be used to place the uncompacted leaves in windrows.

The windrows initially should be 6 feet high by 12-14 feet wide. Any convenient length can be used. Two windrows can be formed side by side, with only 1-2 feet between, to conserve space. Sufficient aisle space between pairs of windrows (typically 12-16 feet) should normally be allowed for loader operation. Although in some cases it may be possible to have fewer aisles if space is limited, this may make turning operations awkward.

Neatly formed windrows with well maintained aisles give a professional appearance to the facility, while messy windrows give the impression of a "leaf dump." Care should be taken that equipment, especially the loader, does not ride up on the windrows, compacting them. Loosely piled leaves are required in order to ensure sufficient pore space for adequate air penetration into the windrows.

5. Combining Windrows

After approximately one month, much of the initial oxygen demand of the leaves has been exerted and the piles have been reduced to about half their original size through decomposition and self-compaction. At this point, two windrows can be combined to form a single one that is still only about 6 feet high by 14 feet wide (about the same size as each of the initial windrows). Combining the windrows will help conserve heat during the colder weather. Portions of the center of the new, combined windrow may go anaerobic temporarily, but significant odors and acidification are not expected because much of the readily degradable material has already been consumed by the microorganisms.

Combining should be done by moving and turning both piles, not by placing one on top of the other. The maximum degree of mixing and "fluffing" is desired.

To conserve space, combining may begin before leaf collection has been completed. In this way some of the space freed by combining windrows (formed with leaves collected in early November), can be used for new windrows made with leaves collected late in the season (mid-December).

6. Turning Windrows

As early as is practical in March or April, each windrow should be turned. Turning mixes the material, re-wets the dry outer edges, re-oxygenates the interior, and exposes the formerly cool edges to the hotter internal temperatures. The result is an increased rate of decomposition and improved destruction of any pathogens and weed seeds.

As with the prior combining operation, maximum mixing and "fluffing" is desired during turning. At this time additional water may be added if the material is too dry. (However, every effort should be made to provide sufficient water initially.)

Additional turnings throughout the summer would further enhance composting rate and product quality. At least one such turning is recommended in order to prevent any weed growth on the windrows from going to seed.

7. Curing

Using the low-level technology described here, much of the material will not be completely stabilized by the end of the summer, yet the composting area must be cleared to allow for site preparation for the next year's leaves. This does not represent a problem since the material is now moderately well decomposed, has little oxygen demand, and is unlikely to produce odors.

At this time, therefore, the material can be moved and formed into a large curing pile around the perimeter of the site. The curing pile may be made as large as 12 feet high by 24 feet wide to conserve space, but should not be compacted when formed. Moving the material also provides additional turning and mixing, while the large pile exposes a relatively small surface area to drying and freezing conditions. Additional weed and pathogen destruction is achieved at the temperatures reached within the large, well-insulated curing pile. This material is expected to be well stabilized by the following spring, but may be left in place longer if convenient.

8. Shredding or Screening

Once composting is completed (post-curing), shredding or screening is a final optional step to improve the physical quality and appearance of the finished compost, making it more acceptable for many home and commercial uses. Depending on the equipment, this step breaks up clumps and separates out rejects consisting of any uncomposted leaves, branches, rocks, plastic, and other extraneous materials. The "rejects" may be composted for an additional period, then re-shredded or screened to minimize the amount requiring disposal.

This step is fairly labor intensive. Leaf compost can only be processed at about half the rated capacity of some of the equipment. Typically, a front-end loader is required for filling the hopper, and at least one person is required to operate the shredder/screener itself.

Shredding and screening will proceed more rapidly if the compost is not too wet. Overly moist material to be shredded might be spread out to dry for a day or two beforehand.

The major advantage of using a shredder or screener is that it yields a more uniform and debris-free final product. In some cases it also can be used to mix finished compost with soil. Disadvantages include the labor and equipment requirements, the need to dispose of rejects, and the capital cost of the specialized machine. For amending final landfill cover or sale to top soil companies (where it will be shredded during blending), shredding or screening is not needed.

One way to reduce costs is to share a single unit among several sites or communities through an interlocal agreement. Sharing is possible since the specialized equipment is only needed for a month or two per year, and scheduling can be flexible.

C. Intermediate-Level Technology

More frequent turning of the windrows will speed the composting process through improved aeration and the physical mixing and grinding (particle size reduction). Because of the increased rate of biological activity, turning must be continued regularly once it is started. If not, acid-anaerobic conditions and odors quickly develop, and the next turning releases the odor. During the first few weeks, two turnings per week may be required. This later can be reduced to one per week, then one every two weeks. The need for turning should be monitored by measurement of oxygen content and temperature within the windrows. Turning should be scheduled to prevent oxygen in the windrows from dropping below 5% for prolonged periods, and to prevent temperatures from exceeding 60øC (140øF). Once the operator becomes familiar with his system, turning can be based on a schedule, with only periodic monitoring. Following this approach, finished compost can be produced in as little as 6 months or even less.

Except for very small sites, such frequent turning by front-end loader is impractical. The turning takes too much time, equipment and labor costs are too high, and the mixing and grinding is not very thorough. Also, compaction of the windrow is likely, and the soil at most sites would get too rutted or muddy. For these reasons, specialized turning machines must be used.

Several commercially available turning machines currently are in use in New Jersey. Some are mounted on a tractor or front-end loader, and driven first along one side of the windrow and then the other, turning half of it at a time. Others straddle the pile, turning the composting material all at once and displacing it backward. Another approach used by some equipment is to lift the material and displace it to the side.

Before investing in expensive dedicated equipment, careful thought should be given as to its advantages and disadvantages. A major advantage may be the shorter composting period. This results from faster biological action, due to more thorough aeration, mixing and grinding. However, this is really an advantage only if the site is required for another use (such as a beach parking lot) during the summer.

In addition to the expense, an important disadvantage to consider is that (perhaps surprisingly) this approach may require more land than the low level technology process. This is because in many cases windrow height is limited to only 5 feet or less for the turning machines. Some larger models can accommodate a 7 foot high windrow, but piles of this size are prone to odor generation. Also, paired windrows cannot be used with types that are tractor or front-end loader mounted because of the need to turn windrows from both sides. However, straddle type and side displacement turners may only require narrow aisles, saving space.

Contrary to what might be expected, turning may have the effect of reducing average overall oxygen levels within a windrow. Although the turning itself does incorporate additional oxygen, the higher rate of decomposition which results from the concurrent mixing and grinding can lead to rapid (a few hours) oxygen depletion and anaerobic conditions.

Specialized turning machinery may require a better graded surface for efficient operation. On the other hand, such equipment may create fewer ruts and less muddy conditions than front end loaders.

Another point is that some of this equipment is very noisy. This should be mitigated to the maximum extent possible if residences or other sensitive land uses are located nearby. Noise levels must not exceed 65 dB(A) at the receptor's property line as set forth in the New Jersey Noise Code (N.J.A.C. 7:29-1 et seq.). These considerations also apply to front end loaders.

A staging area is not as important for an intermediate level of technology. Turning can be used to help reduce differences in initial windrow size, compactness, and composition. Frequent turning also makes initial water addition less critical. If inadequate moisture is present, turning during or immediately after it rains (or snows) can be used to incorporate water. This may make an on-site water source unnecessary (if fire officials approve).

Grass clippings (other than those incidental to fall leaf collection) should not be accepted at a site unless frequent turning is available (see Section VI.A). Specialized turning equipment then is required.

Finally, the overall economic impact of accelerated composting should be examined. The increased turning efficiency (time, energy, and labor) of the specialized equipment may justify the initial expense at larger sites even if the shortened composting period is not a major factor. For sites of 10,000 cubic yards or less, they may be uneconomical unless shared, but at sites of 30,000 cubic yards or more they may be a necessity.

D. High-Level Technology

In order to approach a maximal rate of decomposition, near optimal levels of temperature and oxygenation are required. This also minimizes odors, as the putrescible (odor-causing) materials are quickly decomposed, and anaerobic conditions are minimized. These desired conditions can best be achieved by using an approach originally developed for sewage sludge composting, known as the Rutgers process control strategy. While this strategy has been successfully field tested for leaf composting, exact design and operation details for this application have not been developed.

Briefly, this approach consists of using forced pressure aeration of the composting pile, with the blower controlled by a temperature feedback system. When the temperature at a specific monitoring location within a pile exceeds a preset value, the blower automatically comes on to remove heat and water vapor and cool the pile. This control strategy ensures 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 2-10 weeks of composting, the aeration system would be removed, and the windrows turned periodically. Additional information on the Rutgers strategy is provided in some of the papers listed in the Bibliography.

An advantage of this approach is that large windrows can be formed initially, thus using less space, yet extensive anaerobic conditions do not develop because of the good aeration. Therefore, serious odors and slowed decomposition do not occur. The largest pile tested to date was 10 feet high by 20 feet wide, which may be close to the maximum feasible. A second advantage is that as a result of the rapid decomposition which occurs early in the season, composting can be completed within several months (perhaps one month of ventilation followed by a period of frequent turning).

Nitrogen addition may be beneficial, since the temperature and oxygen limitations are largely overcome with this control strategy (unlike the case with the minimal, low, and intermediate levels of technology). This would further speed decomposition without leading to odor problems. As a first approximation, 5 pounds of nitrogen per ton of wet leaves (about one pound per cubic yard) could be tried.

However, since the incoming leaves may themselves be odorous and since these odors may be released during initial windrow formation and start up, a moderate size buffer zone (as with the low-level technology) is still required. Also, the need for the blowers, timers, and controllers (several hundred dollars per set-up) and the additional labor for installation and security requirements will increase the cost of this approach relative to the low-level technology. Although the overall cost still is expected to be moderate, in general this approach does not seem to be warranted for leaves.

On the other hand, a high level of technology may be warranted for grass clippings, and is probably necessary for food wastes. The high level of technology lends itself well to enclosed systems, and in fact some of the best composting "tunnel" systems developed in the mushroom industry are now being adapted for solid waste applications. These systems, in addition to employing temperature feedback control and being totally enclosed, are capable of recirculating a portion of the blower air stream. This makes odor control much more efficient, and will minimize any potential problem with vermin.

Back to Table of Contents

VI. MANAGEMENT OF OTHER YARD WASTES

A. Grass Clippings

Grass clippings represent another significant seasonal solid waste. In some suburban New Jersey communities they may account for nearly one-third of the total municipal solid waste load during peak grass-growing periods. Although grass clippings are readily compostable, the odor problems they pose make this treatment option difficult to implement for most communities. State permitting requirements are more stringent, particularly with respect to buffer zones, staging, and odor control, and collection costs may be substantial.

Therefore, the best alternative for grass clippings is not to collect them at all (see also Section I.B.1 and Appendix E3). Residents and lawn care services should be encouraged to leave grass clippings on the lawn. Turf grass specialists, such as Dr. Henry W. Indyk (Professor Emeritus) and Dr. James A. Murphy at Cook College, recommend mowing frequently enough so that the short clippings filter through the growing grass and return their nutrients to the soil. This is best for the lawn, as well as for reducing collection and disposal costs. Clippings also can be incorporated in moderate amounts in backyard leaf composting piles or used as a garden mulch.

If grass clippings are to be composted at a municipal facility, extra care must be taken to ensure that the windrows do not become anaerobic. Grass clippings are still alive when first cut, and are relatively high in nitrogen, moisture content, and readily degradable organics compared to the fallen leaves collected in autumn. For these reasons they decompose more rapidly, have a higher oxygen demand, and quickly go anaerobic. They are often highly odorous by the time they are delivered to a composting site. Therefore, it is especially important to properly implement and strictly enforce the odor control measures discussed in Section VII.A. Additional precautions such as expanding the buffer zone and improved management of leachate also will be necessary.

If the grass clippings could be delivered to a composting site without causing odor problems, they could be incorporated (before the end of the day) into the partially composted leaf windrows. A ratio of no less than 3 volumes of partially composted leaves to 1 volume of grass clippings is recommended. Good mixing is essential and can be achieved with a front-end loader by working together 20-30 bucketfuls of material at a time, then forming a windrow with the mixture. The windrow should then be turned with a specialized windrow turning machine. Alternatively, a smaller amount of clippings might be placed on top of a windrow and then thoroughly mixed in with two passes of a windrow turning machine. In either case, it is preferable that a 1 foot layer of leaves without grass clippings be left on the bottom of the windrow initially, as grass clippings in direct contact with the soil have a greater potential for odor production. Windrows containing grass clippings should not be constructed to a height of greater than 6 feet or width of 12 feet, and 5 feet by 10 feet or less is preferable.

Since the leaves collected in the fall typically have lost half their original volume by the grass clipping collection season, the 3 to 1 ratio means that the amount of grass clippings which can be handled is only one sixth of the collected leaves. Generation ratios are often closer to 1 to 1. This serves to further emphasize the need to minimize the amount of grass clippings collected by educating residents about the benefits of recycling them in their own yards. There may be some potential for reuse of windrows already containing grass clippings, but this is probably limited to a minimum overall ratio of 2 to 1.

Once the leaves and grass have been mixed in this way, no further odor problem is expected. The partially composted leaves act as a bulking agent to improve penetration of oxygen to the grass clippings, and as a sorbent to trap small amounts of odorous compounds. Because of their high C to N ratio, the leaves also tie up ammonia as it is released from the decomposition of the clippings, minimizing both ammonia odors and the release of nitrogen to leachate and groundwater or surface waters. The grass in turn speeds the decomposition of the leaves by providing needed nitrogen. The end result is a higher quality compost product which is ready in a shorter period of time.

However, these benefits must be balanced against the increased potential for odor problems. Only facilities that can provide an adequate buffer zone (1000 feet or greater from the grass handling areas; a smaller buffer zone might be considered where demonstrated to be acceptable), and that have the flexibility to turn the windrows on a more regular basis than is required for leaf composting alone, should attempt to compost grass clippings. Facilities that compost grass clippings also should monitor nitrogen levels in leachate and groundwater, including background sampling both upgradient from the site, and on-site prior to receiving materials.

Other bulking agents have been proposed for composting of grass clippings, and might serve as a partial or complete substitute for partially composted leaves. However, in addition to providing bulking for better aeration, any such materials or mixtures also must maintain a sufficient supply of available carbon to tie up ammonia as it is released from the clippings. If not, ammonia odors (even under completely aerobic conditions) and nitrogen contamination of water may occur. Woody materials, in particular, do not normally supply sufficient available carbon for this purpose, even though their C to N ratios are high. (The C is relatively unavailable to microorganisms.)

B. Woody Materials

Wood tends to decompose very slowly, making composting of woody materials impractical in most cases. Thus woody materials should not be intentionally incorporated in leaf or leaf/grass composting windrows unless there is an end use for a mixed wood/compost product. (Separation by screening usually is too expensive.) Small amounts of incidentally included branches and twigs pose little problem.

Tree trunks and large branches often can be given away or even sold as firewood if cut to reasonable lengths. For smaller diameter woody materials, chipping, alone or followed by composting (with or without leaves or grass clippings), may produce a usable mulch. Direct incorporation of woodchips or other woody materials into the soil is not recommended because of the slow rate of decomposition and the high C to N ratio.

C. Other Organic Materials

Many other organics, such as most agricultural and food wastes, are potentially compostable. However, these materials may not be suitable for the composting technologies being used at yard waste composting facilities. Contact the NJDEPE DSWM Bureau of Resource Recovery Engineering (see Appendix D) for further information on specific materials.

Back to Table of Contents

VII. POTENTIAL PROBLEMS AND THEIR SOLUTIONS

Table 3 summarizes the more common problems at leaf composting sites, their causes, and recommendations for their remedy. Most problems can be prevented by proper facility siting, design, operation, and maintenance. Grass clippings present additional concerns, which are also addressed in the discussion below.

A. Odor

The major problem encountered even at leaf only composting sites is odor. Those unfamiliar with handling large masses of leaves may be surprised at how serious a problem this can be. Starting with relatively innocuous leaves, it is possible to generate odors comparable to those of a barnyard or worse. Grass clippings greatly intensify both the odor strength and its unpleasantness.

In general, odor problems develop in four stages:

1) odorous compounds must be present initially or be produced during processing;
2) these odors must be released from the pile;
3) the odors must travel off-site; and
4) they must be detected by sensitive individuals (receptors).
An odor problem can be prevented by eliminating any stage.

With the minimal technology described previously (Section V.A), stages 1-3 all occur, but since no receptors are present (stage 4), there is not a problem. Except where very large buffer zones are present, however, this approach to odor "control" is not possible.

In most cases, prevention of odor problems can best be achieved by preventing odor formation in the first place (Stage 1). For leaf composting this means avoiding prolonged anaerobic conditions. Under anaerobic conditions, volatile organic acids (which have vinegar, cheesy, goaty, and sour odors), alcohols and esters (fruity, floral, alcohol-like), and amines and sulfur compounds (barnyard, fishy, rotten) can be produced. In contrast, with aerobic conditions only a mild earthy odor is expected. If excessive ammonia or urea-based fertilizer, grass clippings, or other high nitrogen materials are added, an ammonia odor also may be produced even under aerobic conditions. Prevention of anaerobic conditions is virtually impossible with grass clippings.

The major cause of odor production at leaf composting sites is making the windrow too large, especially when first assembled. Because of the initial high concentration of readily degradable material, there is a high demand for oxygen. If the piles are too large, sufficient oxygen cannot penetrate from the outside, and a large anaerobic core develops. Decomposition slows down, switching over to the odor-producing acid fermentation described above.

A second important source of odor production is failure to form windrows quickly enough once the leaves are collected. Leaves cannot be simply dropped at the site for later composting, or collected and stored elsewhere. Although the intention might be to store them, temporary storage of leaves, unless they are very dry, can result in vigorous decomposition within one to two days, leading to anaerobic conditions and the production of offensive odors. Grass clippings, as discussed earlier (Section VI.A), are almost always odorous already when they are delivered to the composting site.

If odors should be produced at a site, or if odorous materials are dropped off at the site (such as occurs with grass clippings, or previously stored leaves), the second line of defense is to prevent their release (Stage 2). This might best be accomplished by leaving the odorous mass undisturbed until oxygen has penetrated sufficiently to destroy the odors. However, this may take several months or even years. Shaving off thin (1-2 foot) layers from the edges as they become aerobic may help speed this process.

If a long wait is not practical, another approach may be possible. Since many of the odorous compounds in leaf composting are acidic in nature, raising the pH (neutralizing the acids) will convert them to an ionized (negatively charged, dissociated) form. In this form they cannot be released to the air and will remain in the pile. For example, with the most commonly formed organic acid, acetic acid (vinegar), the reaction is:

CH3COOH ö CH3COO- + H+

Application of pulverized limestone is probably the best way to raise the pH. Sprinkling the limestone in powdered form directly onto surfaces from which odors are escaping may be the simplest approach, although a liquid slurry of limestone in water might be more effective. A layer (1 foot) of finished compost spread over the odorous material also helps to reduce odor release, serving as a "bio-scrubber".

The use of limestone may be ineffective with odors generated from grass clippings or other high nitrogen wastes. Ammonia and amines are weak bases rather than acids, and raising the pH may therefore actually increase odor release:

NH4+ ö NH3 + H+

If odors are still produced and released despite these precautions, it may still be possible to minimize their off-site impact (Stage 3). This approach relies on timing odor-releasing operations to coincide with favorable wind conditions. A wind sock should be installed at the site to determine wind direction, and odor releasing operations performed only when the site is downwind of residences and other sensitive neighboring land uses. Also, higher winds are preferable to calm and light wind conditions because the higher the wind speed, the greater the dilution of any released odors.

Some commercially available products claim to mask or eliminate composting odors when sprayed onto windrows. Masking agents try to use another odor (lemon, pine, roses, etc.) to hide the objectionable odors. To our knowledge, they have not been successful at composting sites. Odor elimination agents, with the exception of limestone noted above, are also unsuccessful in our experience.

B. Leachate

One way in which leachate may pose a problem is by forming small pools or "ponds." Ponding is a concern because it can create an odor problem (since anaerobic conditions are likely to develop both in the pool and in the base of any water saturated piles), serve as a place for mosquito breeding, and interfere with operations on the site (soft, muddy areas). Prevention, by properly grading the site, is the best remedy. Also, windrows should run down slopes rather than across, making it easier for the water to run off rather than accumulate between windrows. If ponding occurs and odors are released from the pools, adding pulverized limestone may be helpful.

Pollution of surface waters (lakes, streams) is the other major concern with leachate. While leachate from leaf composting is generally not toxic, it may deplete the dissolved oxygen in the water, possibly even to the point where fish kills could occur. Because of its dark color, it might also lead to a discoloration of the water.

In order to prevent this potential pollution, leachate should not be allowed to enter surface waters without prior treatment. This treatment might consist of simple percolation down into or through the soil, or passage through a sand barrier constructed to intercept any horizontal flow. In passing through the soil or sand, the leachate is both physically filtered and biologically degraded to remove a substantial portion of the pollutants. Contamination of ground water does not appear to be a problem associated with leaf composting.

With grass clippings, however, leachate may contain high levels of nitrogen. This may pose a problem of nitrogen contamination for both surface and groundwaters, and may not be adequately treated with simple soil or sand filters. Such contamination must be prevented either by limiting the nitrogen in the leachate (through control of the carbon to nitrogen ratio - by minimizing the amount of grass clippings, for example), or by more sophisticated (and expensive) leachate collection and treatment systems. NJDEPE will consider both depth to groundwater and proposed treatment methods when reviewing permit applications.

Treatment of high nitrogen leachate on site is not a simple matter. Initially the nitrogen may be in a reduced form (either as ammonia or as organic nitrogen), but under aerobic conditions it will be converted to nitrate. Nitrate is the number one groundwater contaminant both in New Jersey and nationally, mainly as a result of agricultural practices. In theory the nitrate can be removed by cycling back and forth between aerobic and anaerobic conditions (nitrate may be converted to harmless nitrogen gas under anaerobic conditions); by taking it up as a nutrient in plants (either aquatic plants or algae, or through use of the treated leachate in controlled amounts for irrigation of crops); or by incorporating it into the composting of low nitrogen wastes (such as leaves). Full scale application of any of these alternatives may be problematic and seasonally limited, and may require large retention or treatment ponds. In some cases, discharge to a municipal sewage treatment plant may be another option.

C. Inadequate Composting Rate

Occasionally composting will progress too slowly in some windrows, usually because the material is too dry. Sufficient water should be added initially, either before or as the windrows are being formed. Other opportunities to add water are during the combining operation (low level technology) and scheduled or extra turnings. Adequate wetting usually cannot be accomplished simply by spraying water on the outside of the piles. Similarly, rainfall is not effective within the required time frame unless it is followed almost immediately by turning.

Another cause of slow composting is piles which are too large. Once acidic anaerobic conditions occur, the material tends to be preserved ("pickled") rather than decomposed. To avoid this problem, follow the recommendations in Sections V.

D. Bags

Some communities have found bagging of leaves and grass clippings to be a convenient collection method. (Collection of grass clippings should be discouraged - see Section I.B.1b.) Plastic bags, however, pose a major problem at composting sites because they must be removed from the compostable material. Even so-called "degradable" plastic bags are incompatible with composting because they degrade far too slowly. If plastic bags are to be used, it is very strongly recommended that they be removed prior to delivery of the material to the composting site (for example, by opening and dumping them curbside, at the point of collection). In New Jersey, facilities are required to empty plastic bags prior to windrow formation - and properly recycle or dispose of the plastic.

An acceptable alternative is the use of paper bags. These do not have to be removed, since they decompose at about the same rate as the composting material. Plastic bags have a lower initial unit cost than paper bags, but the expense of removing them may exceed the price differential.

E. Aspergillus fumigatus

One relatively new concern with leaf composting is the release of spores of Aspergillus fumigatus. This is a common, widespread, naturally occurring fungus found in soil and on vegetative materials. Its airborne spores may produce an allergic response in some people, and in a few cases they are capable of causing infection in individuals with a compromised (weakened) immune system. Because these spores have been found to be of some limited concern in sludge composting, research has been conducted to examine their importance in yard waste composting.

Based on these findings, A. fumigatus appears to pose relatively little risk to neighbors of composting sites with adequate buffer zones (see Section IV.C). However, workers at a site may receive high exposures, and therefore some precautions seem warranted. Potential workers at the composting site should be screened for conditions that might predispose them to infection or allergic response. Such conditions include asthma, a history of allergic responses, a weakened immune system, the taking of antibiotics or adrenal cortical hormones, and a punctured eardrum. Workers having such conditions should not be assigned to the composting operation (nor any other tasks putting them at similar elevated risk) unless a health specialist is consulted.

Additionally, wearing an approved dust mask during leaf drop off, windrow formation and turning, screening, and similar dust-generating operations is recommended. Air conditioner filters in loaders and turning machines should be cleaned frequently. It also is expected that adequate wetting and minimum disturbance of the windrows, as recommended here, will help to reduce potential exposure.

F. Toxic Contaminants

Leaves as collected may contain low levels of some toxic materials. Lead, for example, is present because of its former use in gasoline and paint. Limited testing to date, however, has found only low levels, and these appear to be dropping as use of lead has decreased. Lead levels in leachate typically meet drinking water standards.

Some pesticides also may be present, particularly in grass clippings, but again the levels ordinarily are expected to be too low to pose any concern. An unconfirmed 1991 study in Illinois found low levels of 19 pesticides in composting yard wastes. The concentrations were so low that all except one of the 44 samples met the levels allowed in raw agricultural commodities for the 13 detected pesticides for which such levels have been established. (No levels are set for the other 6, which were mostly banned pesticides no longer in use.) In samples from 6 sites in New Jersey only one pesticide, chlordane, was detected. Since chlordane is no longer used, and since it is not taken up by plants, it is believed that this came from the residential soil mixed with the yard waste during raking or bagging.

Based on these considerations and findings, yard waste compost is considered safe for residential use without specific testing. The only exception to this would be for composts containing materials from golf courses, where more intensive use of more toxic and persistent compounds is common. Such materials may require testing for specific metals and pesticides before general use.

We know of no cases in which hazardous wastes have been intentionally mixed with leaves for illegal disposal. If such an incident is suspected, NJDEPE's Emergency Response Hotline (609-292-7172) should be contacted.

G. Other Potential Problems

There are several other potential problems which may arise at leaf and yard trimmings composting facilities. These include noise, dust, and traffic.

Noise may be a concern depending on siting, buffers, and the equipment used. Noisy operations should be performed as far from sensitive receptors as possible, and at the least objectionable times. Berms can be effective in decreasing off site noise.

Dust from the windrows can be minimized by proper wetting. Dust from the roads and aisles, however, may be a problem during dry weather.

Traffic must be considered during original siting of the facility. Limiting hours of operation may be necessary in some cases.

H. Technical Assistance

To assist municipalities and counties in the proper management of composting facilities, technical assistance is available through the County Cooperative Extension Offices. County Extension Agents are available to assist in the siting of composting facilities, to visit composting sites to identify problems and recommend remedies, to assist in marketing the final product, and to provide public education programs. They have received training and equipment to make the following measurements: temperature, oxygen content, combustible gas content, pH, and moisture content. Appendix D lists County Cooperative Extension phone numbers.

Back to Table of Contents

VIII. USE OF LEAF AND YARD TRIMMINGS COMPOST

Early in the development of a composting facility, it is desirable to plan for distribution of the end product. The county department of solid waste management and Cooperative Extension Agents may be helpful in developing markets and other outlets. The benefits of using leaf compost as a soil additive or a mulch are summarized in a fact sheet (FS117) prepared by Cooperative Extension Specialists at Cook College, Rutgers University, which is available through the county Cooperative Extension office. A single copy has been included in Appendix E. Composts produced from leaf/grass mixtures would have similar uses.

While the nutrient content of leaf compost is too low for it to be considered a fertilizer, it does act as a soil conditioner and organic amendment, improving the physical, chemical and biological properties of the soil. Most New Jersey soils benefit considerably from the increase in organic matter content which leaf compost can provide. If grass clippings have been included in the composting material, the final product would be expected to be similar to leaf compost, but with a higher nitrogen content.

Most municipal leaf and yard waste composting facility managers like to make a portion of their finished compost available to individual users in the community. Some allow public access to the site itself, while others prefer to make the compost available at some other location, such as the public works yard or recycling center.

The New Jersey Statewide Mandatory Source Separation and Recycling Act (NJSA 13:1E-99.11 et seq.), states that all State and local agencies responsible for the maintenance of public lands must give consideration and preference to the use of compost material in all land maintenance activities which are paid for with public funds. The municipality, particularly the parks and roads departments, may use the compost in place of purchased organic soil amendments. The compost also may be blended with poor soils to produce a good quality topsoil. Additionally, Executive Order No. 91 requires that all state agencies utilize, where technically feasible, competitively priced and environmentally sound, compost, mulch and other soil amendments in lieu of any chemical fertilizer or soil amendment.

Other bulk users may include farmers, nurseries, landscapers, builders, top soil companies, and landfills (for amendment of final cover). The compost may be offered to such users at no cost, or a modest charge may be imposed.

Back to Table of Contents

GLOSSARY

Aerobic - Oxygen present.

Anaerobic - Oxygen absent.

Buffer zone - Area between the composting operation and homes or other sensitive land uses.

Compost - Thoroughly decomposed, humified, organic matter produced through composting and suitable for application to soil.

Composting - Process of accelerated organic matter decomposition based on microbial self-heating.

Curing - Late stage of composting, after much of the readily metabolized material has been decomposed, which provides additional stabilization.

Decomposition - The breaking down, or destruction, of dead organic materials such as fallen leaves.

Fermentation - Anaerobic decomposition involving only organic compounds.

Inorganic - Substance in which carbon-to-carbon bonds are absent; mineral matter.

Leachate - Liquid, often highly colored, which has passed through or been in contact with a composting pile.

Metabolism - Chemical processes necessary for life.

Metabolizable substance - A material which can be metabolized, or digested, to the benefit of the organism.

Microbe - Living organism of a size such that it can be seen only with a microscope.

Organic - Substance which includes carbon-to-carbon bonds.

Oxygen demand - The requirement for oxygen exerted in aerobic decomposition.

Percolation - Passage of water down through soil.

pH - A measure on a scale of 0-14 of how acid (pH less than 7) or basic (pH above 7) a material is.

Putrescible - Organic materials prone to degrade rapidly, giving rise to obnoxious odors.

Self-heating - Spontaneous increase in temperature of organic masses resulting from microbial action.

Stabilization - Used synonymously with decomposition.

Staging area - Area where newly received leaves are decompressed (if compacted) and wetted, prior to forming windrows.

Windrow - An elongated pile.

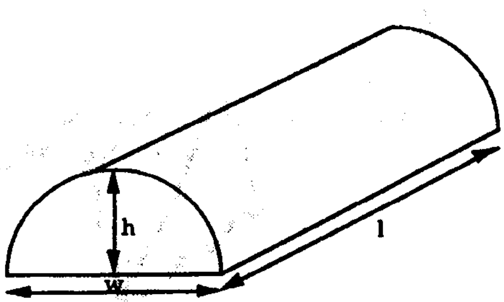
Back to Table of Contents

Appendix A

1. Site Capacity and Buffer Zone Requirement Calculations

Assumptions:
1). windrow cross section is approximately a semi-circle
2). site is rectangular
3). all windrows are the same size

For individual windrow, let:
w = width
h = height
l = length
Ac = cross-sectional area
Ab = area of base
V = volume



Then for an individual windrow:

$w = 2h$

$A_c = 1 / 2 \pi h^2$

$A_b = w1=2h\ l$

$V = A_c l = \frac{\pi h^2\ 1}{2}$

For the site, let:

w_s = width

l_s = length

$A_s = w_s\ l_s$

V_T = total volume of windrows

V_a = volume of windrows per acre, for portion of site used for windrows (including aisles but not

buffers, staging, etc.)
a = aisle width (average if variable)
N = number of windrows

For a large site, assuming that windrow runs entire length of site, with an aisle on each side (one aisle per windrow, although aisle width may vary):

$l = l_s$

$N = \frac{W_s}{2h+a}$

$$V_T = N\,V = \left(\frac{w_s}{2h+a}\right)\left(\frac{\pi h^2 l}{2}\right)$$

$$= \left(\frac{\pi h^2}{2h+a}\right)\left(\frac{w_s l}{2}\right)$$

$$V_a = \left(\frac{V_T}{A_s}\right)(4840\ \text{yd}^2/\text{acre}) = \frac{\left(\frac{\pi h^2}{2h+a}\right)\left(\frac{w_s l}{2}\right)}{w_s l_s}(4840\ \text{yd}^2/\text{acre})$$

$$= 2420\,\pi\left(\frac{h^2}{2h+a}\right)(\text{yd}^2/\text{acre})$$

Notes:

Assumption 1). Assuming a triangular shape will underestimate windrow volume, while a rectangular shape will overestimate. For some turning machines, using a trapezoidal shape may give a slightly better estimate. However, the value calculated will be nearly the same, and probably not worth the extra effort.

Assumptions 2) and 3). These assumptions are made for ease of calculation, and do not directly affect the result.

Table A1 shows the resulting site capacities, in cubic yards, for various windrow and aisle sizes, considering the area used for windrowing only (including aisles between windrows, but not buffer zones, staging areas, roads, etc.). For example, for 6 foot high windrows with average 14 foot wide aisles, 3509 cubic yards per acre can be composted.

Table A2 can be used to determine the acres of site capacity (for windrowing only) required for a given leaf collection (in cubic yards). For a given windrow size and aisle width, find the acres needed per thousand cubic yards of leaves collected. Then multiply by the thousands of cubic yards collected. For the example above (6 foot high windrows, 14 foot aisles), 0.285 acres is required per 1000 cubic yards of leaves. For a leaf collection of 18,000 cubic yards, therefore, 18 x 0.285 = 5.13 acres is needed.

Table A3 can be used to determine the approximate additional acreage required to provide a buffer zone of a specified width on all sides of a site. For a given buffer size and windrowing area find the additional acres needed from the table. For the example above, if a 150 foot buffer zone is needed in addition to the approximately 5 acres used for windrowing, this would require an additional 8.5 acres. The total acreage required would then be 5.13 + 8.5 , as well as 1 or 2 acres for staging, roads, etc., or about 15 acres.

Table A4 shows the dramatic effect of increasing buffer zone requirements on site capacity. For a given size site, with a specified buffer zone on all sides, the table gives the percentage of the total acreage that is available for composting. For example, for a 5 acre square site, a requirement for a 150 foot buffer on all sides would limit the available composting area to only 13% of the total site (Table A4a), or about 0.65 acres - enough space to compost only about 2000 cubic yards of leaves. A 50 foot buffer would make 62% of the site available, or 3.1 acres, giving a capacity of over 10,000 cubic yards. Sites which have a long rectangular (rather than square) shape have less available windrowing area.

Table A1. Maximum Initial Site Capacity
(cubic yards per acre of windrowing area)

windrow height		**average**	**aisle**	**width**	**(feet)**			
(feet)	2	4	6	8	10	12	14	16
4	4055	3379	2896	2534	2253	2027	1843	1689
4.5	4665	3948	3421	3019	2701	2444	2231	2053
5	5280	4525	3960	3520	3168	2880	2640	2437
5.5	5897	5111	4509	4035	3650	3333	3066	2839
6	6517	5702	5068	4562	4147	3801	3509	3258
6.5	7138	6298	5635	5099	4655	4283	3966	3692
7	7761	6899	6209	5644	5174	4776	4435	4139
7.5	8385	7503	6788	6198	5702	5280	4916	4598
8	9011	8109	7372	6758	6238	5792	5406	5068

Table A2. Minimum Required Site Size
(acres of windrowing area needed per 1000 cubic yards)

windrow height (feet)		average	aisle	width	(feet)			
	2	4	6	8	10	12	14	16
4	0.247	0.296	0.345	0.395	0.444	0.493	0.543	0.592
4.5	0.214	0.253	0.292	0.331	0.370	0.409	0.448	0.487
5	0.189	0.221	0.253	0.284	0.316	0.347	0.379	0.410
5.5	0.170	0.196	0.222	0.248	0.274	0.300	0.326	0.352
6	0.153	0.175	0.197	0.219	0.241	0.263	0.285	0.307
6.5	0.140	0.159	0.177	0.196	0.215	0.233	0.252	0.271
7	0.129	0.145	0.161	0.177	0.193	0.209	0.225	0.242
7.5	0.119	0.133	0.147	0.161	0.175	0.189	0.203	0.217
8	0.111	0.123	0.136	0.148	0.160	0.173	0.185	0.197

Table A3. Buffer Zone Area Requirements
(additional acres needed for specified buffer size)

buffer zone (feet)			Windrowing	Area	Required	(acres)		
	1	2	3	5	10	20	30	50
50	1.2	1.6	1.9	2.4	3.3	4.5	5.5	7.0
100	2.8	3.6	4.2	5.2	7.0	9.5	11.4	14.5
150	4.9	6.1	7.0	8.5	11.2	14.9	17.8	22.4
200	7.5	9.1	10.3	12.2	15.8	20.8	24.7	30.8
250	10.5	12.5	14.0	16.5	20.9	27.2	32.0	39.6
500	32.5	36.5	39.6	44.4	53.3	65.8	75.4	90.7
1000	111.0	118.9	125.0	134.7	152.4	177.5	196.8	227.3

Assumes site is square; if length = 2 x width, add 5%; if 3 x, add 10%.

Table A4. Buffer Zone Area Requirements
(percent of site available for composting depending on buffer size)

a. Site Shape = Square (length = width)

buffer zone(feet)			Site	Size	(acres)			
	1	2	3	5	10	20	30	50
50	27	44	52	62	72	80	83	87
100	0	10	20	33	49	62	68	75
150	0	0	3	13	30	46	54	63
200	0	0	0	2	16	33	42	53
250	0	0	0	0	6	22	32	44
500	0	0	0	0	0	0	2	10
1000	0	0	0	0	0	0	0	0

b. Site Shape = Rectangular (length = 2 x width)

buffer zone (feet)				Site	Size	(acres)		
	1	2	3	5	10	20	30	50
50	21	40	49	59	70	78	82	86
100	0	2	13	27	45	59	66	73
150	0	0	0	5	24	42	51	61
200	0	0	0	0	8	27	38	50
250	0	0	0	0	0	15	26	40
500	0	0	0	0	0	0	0	2
1000	0	0	0	0	0	0	0	0

c. Site Shape = Rectangular (length = 3 x width)

buffer zone (feet)				Site	Size	(acres)		

	1	2	3	5	10	20	30	50
50	12	33	44	55	67	76	81	85
100	0	0	3	19	39	55	63	71
150	0	0	0	0	16	36	46	57
200	0	0	0	0	0	19	31	45
250	0	0	0	0	0	5	18	33
500	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0	0

2. Water Requirement Calculations for Leaf Composting

Let r = wet weight of leaves as received (tons).

Let b = initial moisture content (%, wet basis) before wetting.

Let w = weight of water added during wetting (tons).

Let a = desired final moisture content (%, wet basis) after wetting.

Then because the dry weight has not changed during wetting:

$$(100-b)r = (100-a)(r+w)$$

Rearranging:

$$r+w = \frac{(100-b)r}{(100-a)}$$

$$w = \frac{(100-b)r}{(100-a)} - r$$

The tons of water (w) which must be added per ton of leaves received (r), to go from moisture content "b" to moisture content "a", is:

$$\frac{w}{r} = \frac{1}{r}\left(\frac{(100-b)r}{100-a} - r\right) = \frac{(100-b)}{(100-a)} - 1$$

Conversion factors:

1 ton of water is about 240 gallons.

1 ton of leaves varies widely, but let us use as a rough average 5 yd3.

Then:

$$\text{Water Requirement (gal added/yd}^3\text{ of leaves)} = \left(\frac{(100-b)}{(100-a)} - 1\right)\frac{240\text{ gal/ton}}{5\text{ yd}^3\text{/ton}}$$
$$= 48\left(\frac{(100-b)}{(100-a)} - 1\right)$$

Table A5 shows the calculated water requirement (gallons of water per cubic yard of leaves) for leaves coming to a site at moisture contents of 20-50%, with a desired final moisture content of 50-60%.

Table A5. Added Water Requirements
(gal/yd3 to go from initial % moisture content to desired final % moisture)

Initial Moisture Content (%)	Final	Moisture	Content (%)
	50	55	60
20	29	37	48
25	24	32	42
30	19	27	36
35	14	21	30
40	10	16	24
45	5	11	18
50	0	5	12

Example

If a 15 cubic yard truck of leaves comes in at a moisture content of 35%, and the desired moisture content is 55%, then from Table A5 it can be determined that 21 gallons/yd3 must be added. For the truck load this means 15 yd3 x 21 gal/yd3 = 315 gal.

BIBLIOGRAPHY

Clark, C.S., H.S. Bjornson, J. Schwartz-Fulton, J.W. Holland, & P.S. Gartside. Biological health risks associated with the composting of wastewater treatment plant sludge. J. Water Pollution Control Federation 56: 1269-1276 (1984).

Finstein, M.S., F.C. Miller, P.F. Strom, S.T. MacGregor, & K.M. Psarianos. Composting ecosystem management for waste treatment. Bio/Technology 1:347-353 (1983).

Finstein, M.S., F.C. Miller, & P.F. Strom. 1986. Waste Treatment Composting as a Controlled System. Chapter 10 in Biotechnology, Volume 8: Microbial Degradations: 363-398. Verlag Chemie (German Chemical Society).

Finstein, M.S., F.C. Miller, J.A. Hogan, & P.F. Strom. 1987. Analysis of EPA Guidance on Composting Sludge: Part I - Biological Heat Generation and Temperature, BioCycle 28(1):20-26; Part II - Biological Process Control, BioCycle 28(2):42-47; Part III - Oxygen, Moisture, Odor, Pathogens, BioCycle 28 (3):38-44; Part IV - Decomposition Rate and Facility Design and Operation, BioCycle 28(4):56-61.

Strom, P.F., M.L. Morris, & M.S Finstein. Leaf composting through appropriate, low-level, technology. Compost Science (now BioCycle) 21(6):44-48 (1980).

Strom, P.F., F.B. Flower, M.H.P. Liu, & M.S. Finstein. 1986. Municipal Leaf Composting: Recommended Methods. BioCycle 27(9):48-52.

Back to Table of Contents

Table 1
Appropriate Leaf and Grass Clippings Composting Technology

Level of Technology	Capacity[a] (yd3/ acre)	Buffer (feet)	Time (months)	Relative Cost	Use for Grass Clippings[c]
Minimal	4000	1000*	36-60	very low	no
Low	3500	50/150/250**	16-18	low	no
Intermediate	3000[b]	50/150/250**	4-6	low-moderate	perhaps[d]
High	6000	50***	3-4	moderate	perhaps

[a]Based on fall collection of leaves in one year.
[b]Assumes 5 foot pile height, 10 foot width, and 10 foot aisles.
***** From operations to sensitive neighboring land uses.
****** From operations to: property line/sensitive neighboring land uses/place of human occupancy.
******* From operations to property line for totally enclosed system with odor control; otherwise, same as for intermediate.
[c]With additional requirements.

[d]Buffer zone of 1000 feet from staging and grass clipping handling areas to sensitive neighboring land uses.

Table 2

Generalized Schedule, and Equipment and Manpower Requirements for a Moderate Sized (15,000 cubic yard) Low Level Technology Leaf Composting Operation

Operation	Months	Flexibility	Front Loader(days)	Laborer(days)
Prepare site	Sep.-Oct.	Yes	2	2
Form windrows	Nov.-Dec.	No	30	30
Combine windrows	Dec.-Jan.	Yes	10	--
Turn windrows	Mar.-Apr.	Yes	5	--
Additional turnings	May-Aug.	Yes	5 each	--

Form curing piles	Aug.-Sep.	Yes	5	--
Shredding/screening	Mar.-May	Yes	20	20

General assumptions and notes:
(1) site has been prepared to allow all necessary truck access and loader operation under any expected weather conditions;
(2) leaves delivered in bulk or in paper bags (no plastic bags);
(3) adequate supply of water on site (average of 20 gallons water per cubic yard of leaves);
(4) daily supervision during periods of activity and regular checks at other times also needed;
(5) distribution of finished compost not included;
(6) other equipment, such as a grader, may be required;
(7) windrow size 6 feet high by 12-14 feet wide (avoid compaction);

(8) aisles 1-2 feet for pairs of windrows, 12-16 feet between pairs.

Table 3
Problems Encountered at Leaf and Yard Trimmings Composting Sites

Problem	**Cause**	**Recommendation**
Odor	Piles too large	- Initial windrows should be no larger than 6 feet high by 14 feet wide.
	Leaf storage	- Allow no more than 1-2 days between collection and windrow formation.
	Leachate ponding	- Eliminate ponding. - Add lime.*
	Plastic bags	- Do not accept plastic bags at the site.
	Grass clippings	- Do not accept grass clippings at the site. - Immediately incorporate into leaf windrows. - Mix at least 3 yd3 decomposed leaves per 1 yd3 grass.
Leachate ponding	Inadequate slope, poor grading	- Regrade site.
	Improper windrow alignment	- Run windows down slope, not across it.
Surface water pollution	Leachate discharge	- Treat leachate before it leaves site by passing it through soil or sand.

Ground water pollution	Nitrogen leaching into groundwater	- Limit grass clippings. - Mix at least 3 yd3 decomposed leaves per 1 yd3 grass. - Collect leachate for treatment.
Slow composting	Material too dry	- Add sufficient water initially, or as corrective measure during turning.
	Acid anaerobic (piles too large)	- Make piles smaller, adding lime* if needed to raise pH and control odors.
Illegal dumping	Uncontrolled access	- Limit access to site (gate).

* Pulverized limestone, dry or as water slurry.

Back to Table of Contents