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Yard Waste Composting

A Study of Eight Programs

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STUDY AND ASSESSMENT OF EIGHT YARD WASTE COMPOSTING PROGRAMS ACROSS THE UNITED STATES

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I. Introduction

The United States has a municipal solid waste (MSW) management problem of vast dimension. We are quickly running out of places to landfill MSW (i.e., solid wastes from primarily residential sources, as well as commercial, institutional, and industrial sources); however, our residents generate increasing volumes of MSW annually. We are currently generating 160 million tons of garbage per year with an expected increase of 20 percent by the year 2000 (U.S. EPA, 1988). At the same time, nearly one-third of the MSW landfills in this country are expected to reach capacity between 5 and 7 years from now (Porter, 1988), while new landfills are difficult to site. Currently, approximately 80 percent of the MSW stream is landfilled, 10 percent is incinerated, and 10 percent is recycled (U.S. EPA, 1988).

Administrators at all levels of government have stressed source reduction and recycling as sound approaches to help alleviate the increasing burden on landfills. J. Winston Porter, Assistant Administrator for the Office of Solid Waste and Emergency Response at the U.S. Environmental Protection Agency (EPA), has targeted a national goal of 25 percent source reduction and recycling by 1992, as an important step toward reducing this burden on landfills (Porter, 1988).

Yard wastes, i.e., debris such as grass clippings, leaves, brush, and tree prunings, have been estimated to comprise approximately 18 percent of the annual national MSW stream gross discards (U.S. EPA, 1988). Yard waste generation rates and composition vary by season, year, and region. In fact, during the peak months of their generation (i.e., primarily during the summer and fall months), yard wastes can represent 25-50 percent of the MSW stream.

Landfilling and incineration (or combustion in waste-to-energy facilities) are poorly suited to the management of leaves and grass. Since yard wastes are relatively clean, biodegradable material, landfilling them is unnecessary and inefficient, wasting precious landfill space. Also, their decomposition can contribute to problems of methane gas, acidic leachate, and settling at landfills. The seasonal nature of yard waste generation can cause incinerators designed to handle this type of solid waste to be over-sized and operate inefficiently. Furthermore, the high moisture content of this type of waste inhibits complete combustion and results in the availability of little net usable energy for power generation, and its burning contributes to carbon dioxide and nitrogen oxide emissions.

Yard wastes are often source separated and, by a recycling process known as composting, made into a soil amendment or mulch for use by residents, nurseries, park services, government and private landscapers, and other groups. Mixed into the soil as an amendment, compost can improve the soil's physical, chemical, and biological properties. As a mulch, compost can modify soil temperatures, reduce erosion, control weeds, and improve moisture retention (Rosen et al., 1988).

In addition to composting, other methods can be used to divert yard wastes from landfills. Yard wastes, particularly woody materials, can be ground or shredded, and perhaps processed further, to produce a mulch. Yard wastes can also be used as a bulking agent for other types of composting (notably municipal sewage sludge composting). Grass clippings can be left as a mulch on home lawns (McCown, 1988, 1987a,b; Rosen et al., 1988; Strom and Finstein, 1986; and Minnesota Extension Service--Hennepin County, undated). In addition, leaves can be incorporated into the soil to supply organic matter (Prince George's County, undated). However, since the leaves will compete with growing plants for nitrogen, composting is the recommended approach for preparing the material prior to incorporating it into the soil (Flannery and Flower, 1986). These methods for managing yard wastes can reduce the mass and volume of yard wastes by reusing or recycling the material and can also significantly contribute to achieving the national 25 percent source reduction and recycling goal.

Yard waste composting has great potential as a MSW management option in the U.S. It is estimated that there are between 800-1,000 yard waste composting facilities in the nation (Glenn, 1988b) and it is expected that many more will begin operation as the landfill situation becomes more critical (Glenn, 1988a). As the burden on landfills across the U.S. continues (U.S. EPA, 1988) and landfill tip fees continue to soar (Petit, 1988), many communities are beginning to look to yard waste composting to save landfill capacity and landfill disposal (and related) costs, and to produce a useful end product. In addition, several states have already passed legislation prohibiting some or all of their yard waste stream from disposal at landfills; for example, New Jersey passed the Statewide Mandatory Source Separation and Recycling Act banning the landfilling of leaves effective in 1988 (ANJR, 1988; State of New Jersey, 1988; Spielmann, 1988; Mattheis, 1987), and Minnesota has given its Twin Cities Metropolitan area until 1990, and the rest of the state until 1992, to come up with alternatives to landfilling of yard wastes (State of Minnesota, 1988). Other states and counties, as well, have passed or are proposing similar bans (Glenn, 1988a).

This study looks at the methods and products of yard waste composting in the context of 8 programs currently in operation in the U.S., in order to provide information and options to communities faced with difficult choices in the area of MSW management.

II. Elements of the Composting Process

Composting is an aerobic (oxygen-dependent) degradation process by which plant and other organic wastes decompose under controlled conditions. A mass of biodegradable waste, in the presence of sufficient moisture and oxygen, undergoes "self-heating", a process by which microorganisms metabolize organic matter (their food source) and release energy in the form of heat as a by-product. The heating occurs because the waste material also acts like an insulator, provided the pile is large enough. This process is nothing more than an accelerated version of the breakdown of organic matter that occurs under natural conditions, such as on the forest floor (Rynk, 1987; Strom and Finstein, 1986). During the composting process, decomposing waste generally loses between 40 and 75 percent of its original volume, although some communities report the occurrence of even greater reductions, before the microbes exhaust the readily available biodegradable food supply (Massachusetts DEQE, 1986). The reduction in weight during composting is less dramatic since finished compost is more dense than uncompacted leaves. At the end of the process, the compost reaches a stable state, in which no bad odors are generated and the nutritional content is available for plant uptake, when it is applied to the soil.

Since composting is a natural process, it can be carried out with as little, or as much, intervention and attention as the composter desires. When practiced by communities whose intention is to produce compost for their own use, or for sale, the level of technology imposed on the composting process is largely a function of the amount of available land, labor, and capital as well as the desired end product. Generally, yard wastes are collected and formed into elongated piles, called windrows, which are mixed or turned periodically to control oxygen, temperature, and odor levels and accelerate the composting process. After some decomposition and the desired reduction in volume occurs and/or a certain period of time elapses, windrows are combined to form curing piles in which the product remains until microbial activity slows to the point where the compost is deemed stable. Due to the potential time lag between when finished compost is ready for distribution and the market can accept it, the curing piles may also serve as a storage area.

The length of time required for this entire process varies (see discussion below and Table 7), depending on the composition of the yard waste stream, the size of the windrows, the frequency of turning, and the local climate. For example, since grass clippings contain relatively more nitrogen than leaves, they will compost more quickly. In addition, since grass clippings are wetter than leaves, windrows containing grass clippings need to be turned more frequently than those containing only leaves to avoid anaerobic, odorous conditions. Also, composting will occur more quickly in a warm climate than in a cool one.

Various parameters influence the composting process. These are discussed below, with more detailed discussions available in McCown (1988), Rosen et al. (1988), Strom and Finstein (1986), and Royer Industries (1973), among others.

A. Oxygen

Adequate oxygen penetration into windrows (i.e., to maintain aerobic biological conditions -- oxygen levels above 5 percent are recommended by Strom and Finstein [BioCycle, 1988]) is needed for the decomposition of organic wastes, such as yard wastes. Otherwise, anaerobic conditions can occur, resulting in low pH levels (below 6) and generation of malodorous compounds (Strom and Finstein, 1986), perhaps the greatest concern of composting facilities. Frequent turning will help to re-oxygenate the innermost region of the windrows and hasten the composting process. When steps are taken to accelerate the composting process (e.g., shredding to decrease particle size and provide a greater surface area for microorganisms to feed on), the supply of oxygen must be increased to avoid odor generation.

B. Temperature

Internal windrow temperatures affect the rate of composting and destruction of plant pathogens and weed seeds. Windrow turning can keep internal temperatures between 70 and 140 degrees F, the range of temperature favorable to composting (Strom and Finstein, 1986). Temperatures below 70 degrees F will slow composting; temperatures above 140 degrees F for several consecutive days will kill many desirable (i.e., feeding) microorganisms.

There is a tradeoff between oxygen supply and temperature (which are inversely correlated and depend on windrow size). Windrows which are too small will easily supply oxygen to the interior of the pile, but will not achieve sufficient temperature levels in cold weather. Windrows which are too large will insulate their pile interior achieving high -- even excessively high--

temperatures but impede oxygen distribution. Recommended windrow sizes in varying circumstances are discussed below in the section on composting technologies.

C. Moisture

Moisture is needed by microorganisms for growth; therefore, water is a necessary ingredient to the composting process. Leaves may need to be wetted when windrows are initially formed (Strom and Finstein, 1986). Water may also need to be added as windrows are turned and re-formed. Strom and Finstein (1986) recommend moisture levels of at least 50 percent (wet weight basis). As a rough test for this moisture level, it should be possible to squeeze a few drops of water from a fistful of leaves. However, excessive moisture levels (above 60 percent) can lower internal temperatures by inhibiting the proper oxygen flow, resulting in odor problems.

D. Carbon/Nitrogen Ratio

Available nutrients, as gauged by the carbon/nitrogen (C/N) ratio, represent the available food source for the microorganisms. The higher the C/N ratio, the slower the decomposition. In such cases, nitrogen may be added initially, although it is usually not needed (Strom and Finstein, 1986). If nitrogen is added, increased windrow turning is required to maintain aerobic conditions.

Royer Industries (1973) states that decomposition occurs most efficiently at a 30 to 1 C/N ratio. Finished compost has a C/N ratio ranging between 10 to 1 and 20 to 1. Compared with fresh leaves, which have a C/N ratio of 60-80 to 1, grass clippings have a ratio of 20 to 1 (Royer, 1973) and are relatively high in moisture. As a result of their greater supply of nitrogen, grass clippings will decompose faster than leaves and, without an adequate oxygen supply through frequent turning, odors will result.

Since there are typically seasonal differences in the composition of yard wastes collected, grass clippings which are collected in the summer can be mixed with partially composted leaves which were collected in the fall or spring. Adding this nitrogen source accelerates the composting of leaves. As mentioned previously, mixed windrows need additional turning to ensure adequate oxygenation. The ratio of fresh grass clippings to partially composted leaves should be less than 1 to 1, with Strom and Finstein (1986) recommending a ratio of 1 to 3, though this may depend on whether a high-level composting technology is used (described below). Recent research by university and other specialists has involved testing finished compost for levels of lawn chemicals found in grass clippings, a frequently cited concern (in addition to potential odor problems) about adding grass to composting leaves.

In many areas of the U.S., grass clippings are generated in greater quantities than leaves. As a result of landfill capacity and yard waste composting concerns, several communities and university extension specialists recommend that homeowners let grass clippings remain on their lawns to return valuable nutrients to the soil (e.g., McCown, 1988, 1987a,b; Rosen et al., 1988; Strom and Finstein, 1986; and Minnesota Extension Service--Hennepin County, undated).

Brush and other woody materials have a high C/N ratio (e.g., wood can have a 700 to 1 ratio) and decompose very slowly. In general and depending on the end product, these materials should not be included in windrows, but are better handled by chipping or shredding to produce a mulch or bedding material. The recommended diameter for woody material to be handled in this manner is between one-quarter inch (Rosen et al., 1988) and one inch (McCown, 1987b and Seattle's Solid Waste Utility and the Seattle Tilth Association, undated).

III. Composting Technologies

Composting is a relatively easy, versatile activity which may take place in individual backyards or in centralized facilities operated by communities or private companies. In this document, 4 technologies for centralized composting are discussed: minimal-level technology; low-level technology; intermediate-level technology; and high-level technology. Various definitions of these terms as well as even more advanced technologies have been presented in the literature. The definitions for these technologies, presented below and summarized later in Table 1, are those developed by Strom and Finstein for leaf composting (1986; and based on Strom's interview in BioCycle, 1988). They are currently researching composting with grass clippings and will analyze different ratios of partially composted leaves and fresh grass, different windrow sizes, different composting technologies, end product quality, etc. This and related research is in response to the lack of experience with yard waste (i.e., leaf and grass) composting, as compared to only leaf composting, and a reluctance by communities to compost their annual yard waste stream, particularly grass, due to odor, land, economic, end product, and other concerns.

Backyard composting falls in a slightly different category. There are probably as many types of at-home systems as there are people practicing home composting. Whether performed in a simple or complex manner, backyard composting is economically desirable because it eliminates the costs of collection, transport, and processing which would otherwise be paid by communities (City of Seattle, 1988; Institute for Local Self-Reliance, 1980) though they may incur costs for supplying technical assistance and/or materials.

A. Minimal-Level Technology Composting

Minimal-level technology composting is a very low-cost approach to leaf management, requiring more land, but less labor and capital, than other composting technologies. Generally, leaves are collected and promptly piled into large windrows which remain untouched between annual turnings. The leaves may be wetted before they are initially formed into windrows, but this is not essential.

Strom and Finstein (1986) note that windrows, 12 feet high and 24 feet wide (of any length), may be formed for minimal-level technology composting. The center of a windrow this size will quickly become anaerobic and receive a new oxygen supply only with each turning. An unpleasant odor will develop in the anaerobic region and may begin to emanate from the composting material; hence, a large land area is necessary to buffer residents and businesses from the odor. A quarter of a mile or more between composting windrows and neighboring communities is recommended as an appropriate buffer zone (Strom and Finstein, 1986). Strom and Finstein (1986) recommend a total composting land area (not including buffer zone) of at least 1 acre for an annual collection of 4,000 cubic yards of leaves. (The conversion factor between cubic yards and tons [of leaves] varies depending on the moisture content of the waste and whether it has been compacted, but Strom and Finstein (1986) assume a rough average of 5 cubic yards per ton [see Appendix A for conversion factors used by the composting facilities studied and found in the literature].) Since rapid composting can take place only in the presence of oxygen, the compost normally will require 3 years to stabilize.

B. Low-Level Technology Composting

Low-level technology is the most common approach to yard waste composting in the U.S. at this time and is well represented among the facilities chosen for this study. Within 1-2 days of leaf collection, low-level technology composting calls for the material to be wetted, if necessary, to achieve a minimum 50 percent moisture level, and immediately formed into windrows, about 6 feet high and 12-14 feet wide. These smaller dimensions ensure that the center of the pile is not as isolated from the oxygen supply as it is in the minimal-level technology approach. Windrows may need to be (slightly) larger in cold climates to maintain high temperatures inside the windrow during the winter months (McCown, 1988; Mielke and Walters, 1988; and Chown, 1987). Smaller windrows will not achieve sufficiently high temperatures to kill pathogens and weed seeds, but excessively large windrows can overheat, killing desirable microorganisms and leading to anaerobic conditions.

Strom and Finstein (1986) recommend that after about 1 month, two windrows be mixed and combined into a new windrow, approximately the same size as the initial windrows. Additional turning is needed during the following spring and then about every 4 months (or about 3 turnings over the course of a year). This technology will produce a stabilized compost in 16-18 months.

Curing piles may be formed to conserve space by combining windrows after 10 or more months of enhanced degradation. For a higher quality product, the compost can be shredded and screened before marketing. Odors do not usually pose a problem when low-level technology is used, since the moderate size of the windrows, and the frequent turnings, allow oxygen to reach most of the leaves, keeping the windrow aerobic. Since the individual windrows are smaller and hence more numerous than in the minimal-level technology process, more land area is required for the actual composting; however, since the potential for odor is greatly diminished, a narrower buffer zone suffices so that the total land area required may be smaller than for the minimal-level technology. Strom and Finstein (1986) recommend a total land area for composting (not including buffer zone) of about 1 acre for an annual collection of 3,000-3,500 cubic yards of leaves.

C. Intermediate-Level Technology Composting

Strom and Finstein (BioCycle, 1988) have added this definition to apply to those yard waste composting facilities which use windrow turning machines. In general, windrows are turned on a weekly basis, and a finished compost is ready in 4-6 months. Since these machines straddle the windrows (windrow heights may be limited to 5 feet, though oversized windrow turning machines allow heights up to 7 feet), these facilities may need more than 1 acre per 3,000 cubic yards of leaves. Though these machines are more efficient and better windrow turners than front-end loaders, and provide greater volume reductions (see Tables 6 and 7), the capital costs are higher than for lower level technologies.

D. High-Level Technology Composting

To achieve complete composting within 1 year and save on land space for composting, Strom and Finstein (1986) defined a practice of a high-level technology. Initially, the leaves are wetted. Nitrogen may be added to further accelerate the composting process. Windrows, at least 10 feet high by 20 feet wide, are then formed. They are aerated by forced pressure blowers at the base which are controlled by a temperature feedback system. After composting for 2-10 weeks under these controlled, optimal conditions, the automated system is removed. Windrows then need to be turned periodically to achieve a finished compost within 1 year. With frequent turning by windrow turning machines, composting may be completed within 3-4 months. As a precaution against release of odors during initial windrow formation, a buffer zone similar in size to that required for low-level technology composting is recommended by Strom and Finstein (1986).

IV. Additional Considerations

The composting operation includes the following general steps: (1) pre-processing; (2) processing; and (3) post-processing. Prior to windrow formation, pre-processing steps prepare incoming yard wastes by removing unwanted material with manual or mechanical debagging and/or separation, and conditioning the yard wastes by grinding, shredding, wetting, and/or mixing. During processing, windrows are formed and steps are taken to maintain the proper biological conditions by shredding, mixing, and/or turning the composting material. After the process steps are completed, the compost may need to be shredded and/or screened to remove remaining unwanted material and prepare the compost for distribution. A number of considerations affect, or are involved in, the composting operation and are discussed below.

A. Separation and Collection Methods

Composting operations vary by the manner in which yard wastes are separated and collected, as well as the composition of these materials. The material content of bagged, containerized, or bulk yard wastes left at curbside or dropped off for collection can affect the effectiveness of the composting process. Choice of collection method(s) depends on cost, convenience, household participation rate, and amount and type of yard wastes separated and collected (City of Seattle, 1988). Citizens need to be informed of the need to keep unwanted materials out of the yard waste collection system.

Depending on the separation and collection methods used, pre-processing steps may be needed. For example, non-degradable bags need to be broken open, emptied, and perhaps removed during collection or before windrows are initially formed. This serves to accelerate composting and avert odor generation. Degradable paper or plastic bags may not need to be handled as would non-degradable bags, especially if these bags do not impede composting; however, degradable bags may need to be broken open. Furthermore, remaining shredded or partially decomposed pieces of bags should be screened out of the finished compost. An additional pre-processing step includes grinding incoming yard wastes, especially if brush is included, to decrease particle size and ensure that the material is homogeneous.

B. Product Preparation

As an optional product preparation step, compost can be coarsely shredded and screened to achieve uniform size, remove debris, and improve its quality and appearance prior to its distribution. As an optional final step, the compost can be finely screened to remove virtually all remaining debris, further improving its quality and appearance. Costs of these optional post-processing steps should be compared to additional benefits of selling a higher quality finished product.

Obviously, each of these additional steps for properly handling and processing yard wastes incurs a cost. Descriptions and costs for various types of collection and processing equipment are provided by the City of Seattle (1988) and McCown (1988). Communities can be sole owners of this equipment or share it as a cost saving measure.

C. Marketing the Final Product

When beginning a composting program, it is important to think through the potential end uses of the finished product. In the course of interviews with representatives from the communities involved in this study, a number of interesting uses and markets were found for finished compost. As seen in Tables 7 and 8, compost has been given away or sold to residents, used for public park service projects, sold to private individuals, or traded for nursery stock. In an innovative arrangement, Composting Concepts trades finished compost in exchange for the use of a nursery's land for their operation in Woodbury, Minnesota. Buyers may use compost as a soil conditioner, in planting seedlings, as landscape mulch, as fill, as a re-surface material for eroded parks, as landfill cover, or for any number of other projects.

Pat Berdan, Department of Public Works (DPW) Director in Wellesley, Massachusetts, commented that groups need to develop uses and markets for finished compost prior to its production to avoid the development of an excess requiring storage space. The issue of storage space is evident in the composting operation of Davis Waste Removal Company (DWR) in Davis, California. As Ken Shepard of DWR pointed out, until additional markets and end uses are developed for their compost, DWR will not be able to compost all types of yard wastes generated in Davis.

D. Costs and Benefits

Assessing and comparing the costs and benefits of a composting project or individual composting steps can determine their net impact in economic terms. As for any waste management practice, there are various types of costs to consider. With respect to yard waste composting, there are typically costs for: yard waste separation, collection, and processing; compost storage and marketing; and administration, public education, and technical assistance. Benefits received from composting include: revenues received from selling the finished compost; avoided costs from using the finished compost as a substitute good (rather than selling it); and avoided tip fees from not landfilling (or incinerating) the yard wastes. These economic variables are discussed in greater detail below.

i. Costs

Costs for composting can be grouped into capital (non-recurring costs for administrative/legal services, land, development/construction, buildings, and equipment) and operation and maintenance (ongoing costs for labor, fuel, utilities, materials, supplies, overhead, and compliance with various requirements) (GPI, 1988). Capital costs may be accounted for in the year of purchase or amortized (i.e., annualized) over the useful life of the good. In some cases, capital and operation and maintenance costs are directly attributed to composting or associated with rental payments or cost contracts with a private contractor and therefore are more easily and likely to be accounted for. In other cases, costs may be shared with other public work operations or communities and are therefore more difficult to estimate; however, one way to estimate these shared costs is on a pro-rated basis for the proportion of the item's time in use for composting during the year. Worksheets for calculating costs of composting and curbside recycling programs are available in reports from Strom and Finstein (1986) and Glass Packaging Institute (1988), respectively.

There are also indirect costs associated with composting. These costs are often less tangible than the direct costs and more difficult to estimate, but should at least be recognized in a qualitative manner. As an example, indirect costs can include: the time spent by households in separating their yard wastes; the impact of the separation method on yard waste collection, the composting process, and the value of the finished compost; and impacts by the composting facility on the environment and neighborhood.

ii. Benefits

Benefits of composting are typically annual streams of revenues or avoided costs. Received revenues or avoided costs associated with selling or using the compost are a benefit to the community mainly if the composting facility is publicly operated. However, typically the largest economic benefit from composting would be the avoided costs of the alternative disposal practice, which is usually landfilling.

The most readily quantifiable short-term avoided cost associated with diverting yard wastes from landfills is the avoided tip fee; however, other longer-term avoided costs include postponement of using a higher-cost replacement facility once the present landfill closes and reduced risk of environmental damage (Greenwood, 1988; Dunbar and Berkman, 1987). Other costs may also be avoided or reduced by composting, e.g., it tends to "even out" the peaks in MSW generation and dampen the impact on the household garbage collection cost; however, MSW management services (e.g., garbage collection) may be subject to contracts which are not likely to be changed in the short run.

V. Composting Program Selection Criteria

Eight composting programs currently in operation were selected to provide examples of the variety of designs, management practices, and technologies which are used in yard waste composting programs in the U.S. The selections were made with the intention of including a diverse group of programs representing:

- diverse geographic (and climatic) regions;
- rural and urban settings;
- different population levels;
- differing compositions of yard waste streams between communities, including yard wastes generated and composted;

- o various lengths of time for program operation;
- o public or private organizations and operations, or combinations thereof;
- o various collection strategies;
- o different composting technologies; and
- o small and large composting capabilities.

VI. Study Approach

Journal articles and referrals from organizations involved in composting provided a list of communities and facilities from which to choose. After a preliminary screening and based on the above criteria, the following communities were chosen for this study: Davis, California; East Tawas, Michigan; Montgomery County, Maryland; Omaha, Nebraska; Seattle, Washington; Wellesley, Massachusetts; Westfield, New Jersey; and Woodbury, Minnesota. Figure 1 displays the location of each of these communities.

In keeping with resource constraints, site visits were made to the composting facilities serving Montgomery County, Wellesley, and Westfield; therefore, much of the information about these 3 programs was compiled with first-hand observation of the operations. Telephone interviews provided information about all of the programs. Public officials at the community (town, city, or county) level and/or private composting facility managers were contacted to discuss their programs.

The contact persons for each composting program are listed in Table 9. Also, articles or documents from which information was extracted, and individuals who provided program information through telephone interviews, are noted at the end of the individual program discussions. Full references are listed at the end of the report. A brief overall discussion of the selected programs is followed by: (1) sections highlighting unique features of the individual selected programs; and (2) Tables 1-8 which contain summary information of various design, effectiveness, and other components of these programs with accompanying discussions.

VII. Programs Selected

The cities and county selected for this study represent a wide range of composting operations, as outlined by the above criteria; however, they need not necessarily be the

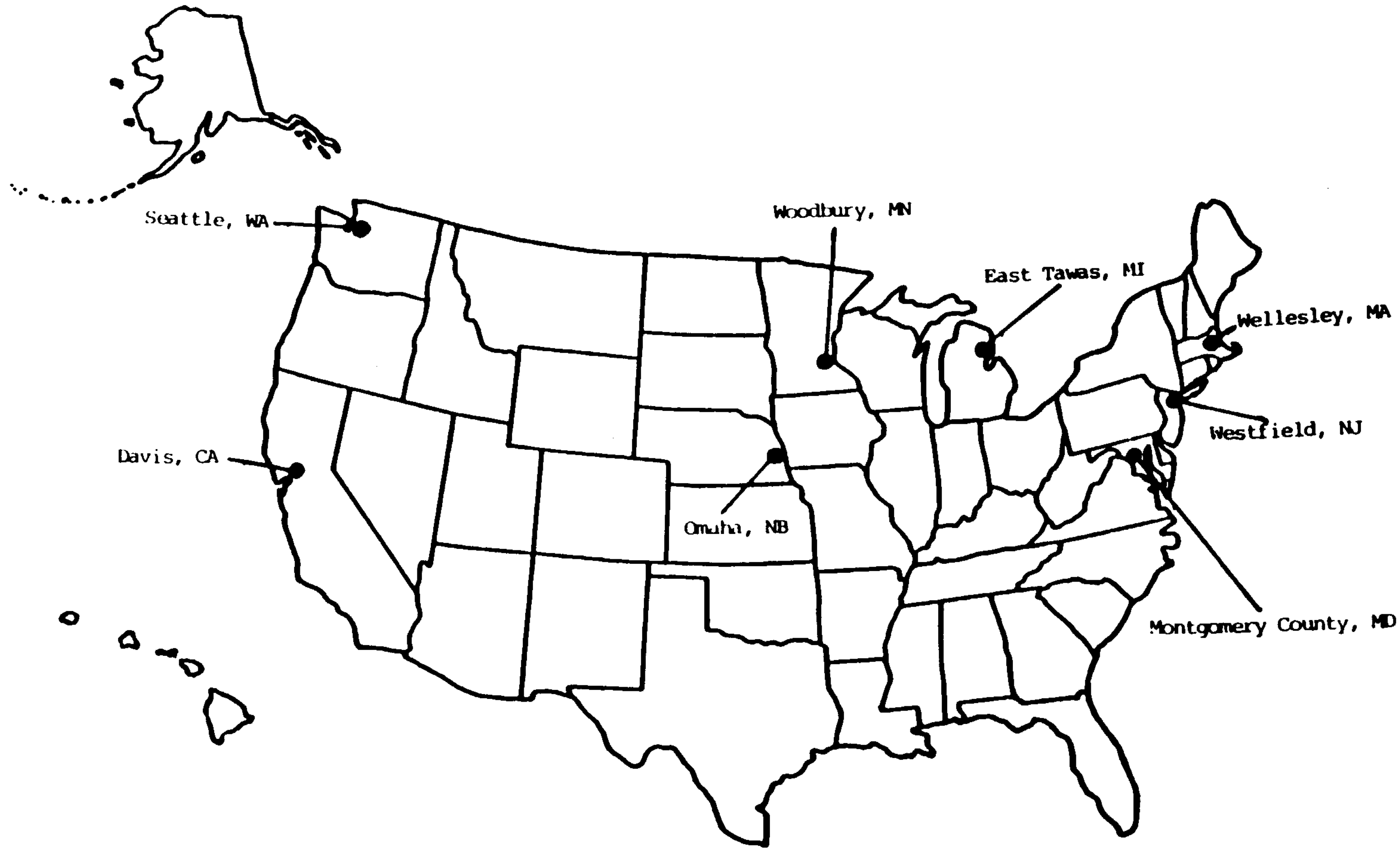

Figure 1: Location of the Study's Eight Yard Waste Composting Programs

biggest and/or longest standing programs. Populations of the sponsoring communities (town, city, or county) vary from 2,600 to 633,000 people and the annual weight of yard waste composted ranges from 116-15,600 tons.

Composting time is between 3 months and 3 years, depending at least in part on the technology used. The landfill tip fees faced by these cities and counties range from $5.25-$137.00 per ton (Westfield's transfer station tip fee), indicating the variation across the country in the urgency of the landfill capacity situation.

The 8 communities compost their yard wastes at a combination of 10 centralized facilities of which 3 practice minimal-level technology, 4 practice low-level technology, 3 practice intermediate-level technology, and none practice high-level technology. Four of the communities also actively promote backyard composting. Six of the 8 programs include some form of curbside collection and 4 communities allow private landscaping companies to drop off their collected yard wastes at their composting facilities (typically for a fee). Of course, private composting facilities are available to public and private clients alike. In addition to bulk collection, containers used for curbside pickup include: degradable paper bags, degradable and non-degradable plastic bags, and wheeled plastic bins. All of the programs accept yard wastes at least during the fall and spring (by curbside pickup or centralized drop-off). Four of the 8 programs accept significant portions of grass for composting at their centralized facilities.

VIII. Highlights of Programs Selected

A. Davis, California

Davis (pop. 44,000) contracts out its municipal garbage collection (including yard waste pickup) and yard waste composting to a private hauler, Davis Waste Removal Company (DWR). DWR runs a separate route for yard waste collection where, for example, homeowners rake leaves out to the curb weekly and a device called the "Claw" (designed in Davis) lifts the piles (which are not to exceed 5 feet X 5 feet X 5 feet) into a 32-cubic yard rear-loading packer truck for transport to the composting facility. The Claw is a device with "jaws" that swing open to scoop up the leaves from the roadside. Although participation is voluntary, yard waste pickup service has been available for over 15 years and is accepted and utilized by residents. The city distributes pamphlets to residents describing the benefits of composting and techniques for curbside pickup and backyard composting. Since yard wastes are generated year 'round in California, this service is available in all 4 seasons; however, there is some variation through the year in the composition of the yard wastes generated. For example, the yard waste stream contains a high concentration of leaves in the fall season, whereas grass and brush are disposed of all year.

The method used in Davis involves curbside collection of yard wastes throughout the year and transport to their buffered 2.5-acre composting site, followed by grinding of the leaves with a tub grinder to accelerate the composting process. Currently, only leaves are composted, representing approximately 10 percent of the yard wastes picked up; bagged grass is pulled out prior to grinding. Windrows, 6-8 feet high by 10 feet wide, are then formed and turned every 2 weeks with a front-end loader. The warm climate of California accelerates the composting and the product is ready in 3-4 months, although the composting process may not be completed.

DWR does not currently have a commercial market for their compost, so city residents are allowed to use it at no charge as a soil amendment in the community garden. The main motivation behind composting is environmental concern rather than economic gain, as Davis does not currently face the high landfill tip fees seen in other parts of the country. Ken Shepard of DWR explained that grass and brush will not be composted until a market is found for the end product, because these additional components would cause the volume of compost produced to far exceed the community gardening demand. Shepard also pointed out that some exotic components (such as eucalyptus leaves) go into the compost in California, and these materials may shift the pH out of the range in which plants will grow well. If marketed, the finished product would need to be monitored carefully to ensure consistent quality.

References: Gertman, 1988; Shepard, 1988; Metrocenter YMCA, 1987; Gertman, 1985; City of Davis, undated

B. East Tawas, Michigan

East Tawas (pop. 2,600) was the smallest community chosen for this study, and serves as an example of how composting may be incorporated into the activities of a small town's DPW. In 1986, the town received a $20,000 grant from the Clean Michigan Fund with which they bought a front-end loader to mix and turn their windrows, which are 4 feet high and 8 feet wide. No additional labor was hired by the town when composting activity began.

Yard wastes are centrally composted at the site of an old covered landfill, using 2.5 acres of the 40-acre site.

composting also takes place in the yards of a few residents who produce their own mulch by backyard composting. Leaves, grass, and brush are delivered to the composting facility in two ways: 1) separate curbside collection of the bagged yard wastes in the fall and spring seasons; and 2) drop-off by residents, who are allowed to borrow a key to the composting area for this purpose. The collected bags are opened by town crews and checked for garbage which is then removed. These crews also form the windrows and turn them when their normal work is slow.

East Tawas does not currently shred or grind leaves or grass as part of their composting process; however, brush is chipped and used as a road base in a swampy area. City manager Jacob Montgomery estimates that the participation rate in the pickup program is 70 percent. Currently, the finished compost is used by the city's park service for planting trees and regenerating flower beds.

References: Montgomery, 1988; Logsdon, 1987

C. Montgomery County, Maryland

Montgomery County (pop. 633,000) is the most heavily populated community included in this study; however, the program currently serves nearly one-half of the county's households. The entire program is administered by the county's Department of Environmental Protection. Responsibility for curbside leaf collection (and drop-off at the transfer stations) belongs to the county's Department of Transportation. Leaf-loader vacuums have been used to pick up (and partially shred) leaves for composting since 1984. The same trucks that push the snowplows in winter are used to pull the curbside vacuums on their route twice in the fall and once in the spring. The curbside collection program has received an excellent response from residents who participate voluntarily by raking leaves to their curbsides. Residents are informed of the scheduled collection route by notices which are posted on trees and telephone poles in each neighborhood. The county discourages residents from bagging leaves prior to pickup, but some plastic bags are put out at curbside and these are broken open prior to vacuuming.

The composting facility is located in the town of Dickerson which is in the western part of the county. The facility lies within 270 acres of county-owned land and consists of a 47-acre asphalt pad and 3 sedimentation ponds to collect runoff. It was originally built for composting municipal sewage sludge and was switched to leaf composting in 1984. Responsibility for hauling the leaves from the transfer stations to the compost facility, operating the compost facility, and selling the finished compost rests with a private contractor.

The only reported problem with this facility is the tendency of soil to erode from around the sedimentation ponds, as a result of runoff from the asphalt pad during heavy rains. The contents of the ponds are monitored regularly for compliance with the facility's surface water discharge permit, and are consistently found to comply. A double fence surrounds the facility to prevent the wind from carrying plastic debris off-site.

Windrows, 6 feet high by 12-15 feet wide, are formed, and then shredded, aerated, and turned monthly with a roto-shredder. Water is not added during the composting process since rainfall provides sufficient moisture. The compost is shredded and screened to remove contaminants which include shredded plastic bags, tennis balls, and brush. Composting of leaves presently takes between 6 and 12 months, depending on whether the leaves are collected in the fall or spring. Since finished compost is more likely to be sold during spring than fall, it may need to be stored on-site for 6 months. The finished compost is sold in loads of 10 cubic yards or more, primarily to landscapers and nurseries as a soil amendment.

At present, Montgomery County is pilot-testing combining grass and partially composted leaves in various proportions. This addition of grass will increase the required frequency of turning, but it is hoped that it will also speed up the composting process. The finished compost will be tested for heavy metals, weed seeds, residual herbicides, and pesticide levels before a final decision is made on composting grass with leaves.

References: Goldberg, 1988; Spielmann, 1988; Wagaman, 1988; Franklin Associates, 1987

D. Omaha, Nebraska

Omaha (pop. 350,000) operates a yard waste composting program in which grass clippings are composted along with leaves. Dan Slattery of the Department of Public Works estimates that 60 percent of the yard wastes composted in Omaha consist of grass. Yard wastes are also accepted from lawn service companies but are turned away if found to be contaminated with, e.g., tree stumps, rocks, PVC pipe, lawn mower handles, or tires. Partially composted and fresh grass are mixed by tub grinder with newly received leaves and tree trimmings and then wetted. Grinding this material decreases particle size to a maximum diameter of one-tenth inch, reduces yard waste volume, aerates the composting material, and accelerates composting. A front-end loader (shared with the county) piles the material into windrows, 6 feet high by 12-15 feet wide, which are left until the following year when they are turned.

The biggest concern of most facilities that refuse to compost grass is the odor generated as it decomposes (discussed earlier and in Strom and Finstein, 1986); however, Omaha has not experienced a problem with odor complaints from the public (except infrequently from lawn service companies at drop-off) due to their facility's remote location, wide buffer zone (the 2-acre facility is at the 80-acre county landfill), and relatively small operation. It is reported that odors are not a problem for workers at the facility either. Odors are strong when material is ground in November which is the only time during the composting process that these windrows are turned, but the buffer zone protects residents from being affected by the operation.

Currently, just 3 subdivisions of the city (or approximately 1 percent of its population) are involved in the program; however, Omaha looks forward to expanding this program. The finished compost is used by the county (whose land is used for the operation) as a substitute for landfill topsoil and a soil amendment at county parks.

An interesting aspect of Omaha's program is the container in which homeowners leave yard wastes for pickup. Residents rent 90-gallon plastic yard waste bins or carts (from the city for $12 per year) which can be wheeled to the curb. A special hoist lifts and dumps the yard waste bins into the packer trucks used for collection and returns them to the sidewalk for reuse. No shredding takes place in this step. Initially, the bins were susceptible to being crushed by the hoist because it was lifting at an excessive speed. To solve the problem, a control was installed on the trucks to limit the speed of lifting, and also the structure of the carts was reinforced by their manufacturer (without charge). This year, Omaha has distributed 5,000 free degradable cornstarch plastic bags with instructions to households that they should only be used when the carts are full.

References: Slattery, 1988; Spielmann, 1988

E. Seattle, Washington

Seattle (pop. 500,000), the second largest community included in this study, has developed a multi-faceted approach to yard waste composting, including: 1) public education and encouragement for backyard composters; 2) special "Clean Green" hours at the transfer stations during which residents may leave yard wastes for a discounted disposal fee; and (3) plans to implement curbside collection of yard wastes in 1989. In addition to the economic incentive for composting yard wastes, Seattle is dedicated to composting out of concern for the environment.

Pacific Topsoils, Inc., a private composting facility, accepts Seattle's yard wastes for $22.50 per ton, whereas the landfill, which is closer to the transfer stations, charges $31.50 per ton. Six acres of Pacific Topsoils' 34 acres (including buffer) are devoted to its composting operation. The facility accepts yard wastes from at least 6 cities, either by direct contract with the cities or their contract haulers. Incoming yard wastes are visually inspected for plastics, rocks, etc. and then processed by grinding to accelerate the composting process. The yard wastes are then placed in piles, 25 feet high and 40 feet wide, which are not subsequently turned. Screening is used to prepare the compost for distribution. Material which does not pass through the screen, i.e., oversized, not fully composted material, is returned to the piles. The compost is supplemented with organic matter and other amendments and sold as a topsoil primarily to landscapers. The quality of the finished compost depends on that desired by the buyer.

The community composting education program offers training to 25 volunteer "master composters" each year who in turn instruct others in backyard composting techniques. Seattle has constructed 4 demonstration sites where up to 16 different composting methods are on display for residents who want to look and learn. In 1989, Seattle will also supply backyard composting bins to approximately 1,100 households involved in an expanded version of this program. As an additional financial incentive, households which backyard compost avoid a $2 per month fee for curbside yard waste collection.

Seattle's program is apparently becoming stronger as both the city and residents increase efforts to promote composting programs. In 1989, the "Clean Green" hours at the transfer stations have been extended to include all hours of station operation. A consultant's survey performed for the Seattle Solid Waste Utility (City of Seattle, 1988) suggests the following improvements to the composting effort: (1) that 17,000 tons, or 18.5 percent of the city's yard wastes generated, be composted in the backyards of 30 percent of Seattle's households; and (2) that 51,700 tons, or 56.5 percent of the yard wastes generated by Seattle's population, be composted centrally. These two programs would divert 68,700 tons, or 75 percent of the city's yard wastes from the landfill.

References: Carlson, 1988; McBride, 1988; Smith, 1988; Watson, 1987a,b

F. Wellesley, Massachusetts

Wellesley (pop. 27,000), too, has more than 1 method for diverting yard wastes from their landfill. Wellesley encourages backyard composting, allows residents to drop off yard wastes in a centralized location, and runs a special drop-off program for private landscapers and others in the lawn service business who collect leaves. The encouragement of backyard composting and the drop-off area for residents are part of an extensive community recycling agenda.

Wellesley provides its citizens with the opportunity to recycle many elements of the solid waste stream, from cans to books to wood waste, in a 90-acre landscaped area known as the RDF (Recycling and Disposal Facility) at its transfer station. Residents stop at appropriate areas to deposit specific items as they drive through the RDF. The residential yard wastes are composted on a 1.5-acre site by minimal-level technology at the RDF and the finished product is available for use in residents' gardens and yards, with the remainder being traded to a nursery for merchandise credit. Yard wastes are formed into a large windrow, 10 feet high by 30 feet wide, with a front-end loader and bulldozer which are also used to turn the windrow about once per year. Water is not added to the windrow. Wellesley has found that residents are much more interested in the finished product at the RDF if it has been screened, but there is not always time and manpower for this task. Use of a tub grinder to shred brush is currently being considered.

The composting of landscapers' leaves takes place on a 1-acre area (with a minimum 50-foot buffer) in the DPW yard. Landscapers pay $200 per vehicle for a permit to dump truck loads of leaves, and may continue to drop off leaves until the composting area is full for the season. These permits can be taken away if incoming loads are determined to be contaminated. The leaves collected in this program are composted using low-level technology. A front-end loader is used to turn the windrows once per month. After 1 year, the compost is moved into a curing pile and screened. The finished product is used as a soil amendment or conditioner by the town in planting and landscaping projects.

Wellesley aggressively supports and encourages home composting practices; in fact, according to a survey, 39 percent of the residents reported that they compost in their backyards. However, in the past the town's approach met resistance from Massachusetts' state government. In an effort to encourage home composters, the town circulated information suggesting that fallen fruit and vegetable debris from backyard gardens be incorporated in compost piles of grass and leaves. The Massachusetts Department of Health contacted Wellesley and informed the town that composting food wastes is against regulations. DPW Director, Pat Berdan, would like to see more unity among different levels of government on goals of recycling and composting.

References: Berdan, 1988, 1987; Metrocenter YMCA, 1987; Wellesley DPW, undated

G. Westfield, New Jersey

From the early 1970's until 1987, Westfield (pop. 30,000) composted its leaves at the town conservation center. Due to large increases in volume, Westfield now uses a combination of private operations to compost yard wastes in compliance with New Jersey's mandatory composting requirement (i.e., the ban on landfilling leaves). Although the town does not provide pickup services for general MSW, 3 rounds of leaf pickup from town curbsides are performed each year by front-end loaders and dump trucks. Residents, alerted by mailings and advertisements, rake their leaves to the curb on the appropriate days. Leaves mixed together with household trash will not be picked up by the privately contracted garbage haulers. Residents may also separate and drop off their grass and brush for a fee at the town's conservation center where it is collected for transport.

During 1988, the town transported all collected yard wastes to one of three private composting (or, in the case of brush, shredding) facilities: 1,730 tons of leaves to Middlebush Compost Inc. for composting; 1,400 tons of grass clippings to Woodhue Ltd. for composting; and 1,423 tons of tree trimmings and brush to Alternate Disposal Systems Inc. for shredding. These facilities also accept yard wastes from other communities in New Jersey. In fact, Middlebush Compost has recently been the object of pressure (from county residents) to close, because they accept leaves from outside the county.

Middlebush Compost is located on a 25-acre site (including a 150-foot buffer surrounding residential areas), of which 15 acres are used for composting leaves from approximately 10-12 New Jersey communities (including a few served by contract haulers). A large windrow turning machine is used to form windrows, 7 feet high by 16-18 feet wide, after shredding, aerating, and fluffing the material. Middlebush Compost is currently investigating a modification in its state solid waste facility permit to allow it to also compost grass clippings. The finished compost is sold as a soil amendment, mulch, or potting soil for $25 per ton.

Woodhue Ltd. is the site of a privately run 126-acre farm, which also operates a 4.5-acre yard waste composting facility under a solid waste permit issued by the state of New Jersey. In 1988, Woodhue accepted grass clippings from Westfield and 2 other communities and mixed them at a 1 to 2 ratio with partially composted leaves received from approximately 10 other communities. A windrow turning machine is used to shred, aerate, and fluff the composting yard wastes and to re-form windrows, 6 feet high by 12 feet wide. Only 1 odor complaint has been received since Woodhue began composting in October 1986. Between 12 and 25 percent of the total incoming yard debris (the highest among the composting facilities studied) is reject material, i.e., non-compostable material, and disposed of in a landfill. This relatively high percent of rejects is influenced heavily by the community's source separation, collection, and street-cleaning procedures. The finished compost is screened, tested (for pH, heavy metals, and toxicity), and then field-applied on-site as a soil amendment and fertilizer supplement (but not a fertilizer) to save ($35-65 per acre) on the amount of fertilizer used.

Yard waste generation and composting activity, participation rates, and other general data presented in the summary tables refer specifically to the town of Westfield; however, the composting processes are reported as described by the private composting facilities for all of their yard wastes received. Westfield faces the steepest landfill tip fee of any community in this study at $137 per ton (at the transfer station); hence, there is a strong financial incentive to comply with New Jersey's Statewide Mandatory Source Separation and Recycling Act.

References: ANJR, 1988; Gottko, 1988; Hayes, 1988; Kennedy, 1988; Nicholson, 1988; Strom et al., 1986; Derr, 1985

H. Woodbury, Minnesota

Woodbury's (pop. 13,520) yard wastes are collected and composted by Composting Concepts. When the program began in April 1987, bags were provided free of charge as an incentive to residents to participate in the yard waste composting program. Degradable paper bags are preferred by waste haulers since they eliminate the need for manual debagging or purchasing special debagging or shredding equipment. Workers load the bags into packer trucks which are also used for regular garbage pickup. Use of the degradable paper bags was discontinued by Composting Concepts because most residents opted to buy regular plastic bags rather than use the free paper bags and debagging costs were therefore still incurred. Composting Concepts also sells cornstarch plastic bags which are claimed to degrade in 4 months. Since the leaves require a 12-month composting period, the bags are not expected to hinder the process. These bags are recognized during yard waste collection by their distinct color and insignia which distinguishes them from bags of household garbage set out at curbside.

Windrows, 5 feet high and 15 feet wide, are initially formed using a front-end loader. Later, to prepare for winter, the material is wetted and then three windrows are combined into one, 12-15 feet high and 25 feet wide. After winter, the windrows are turned once each month. Composting Concepts exchanges finished compost with Bailey Nursery as a soil amendment in return for the use of 2 acres for composting at the nursery's 500-acre site. The facility operates subject to a local land use permit and is required of commercial activities around Woodbury.

Minnesota Extension Service--Hennepin County has written and distributed brochures encouraging residents to leave grass clippings on their lawns rather than raking and bagging them and to also compost in their backyards. These management methods might be very effective in reducing the volume of yard wastes to be collected and centrally composted, thereby saving on community collection, transportation, and composting costs.

Yard waste composting is currently mandatory in 4 of the 18 communities served by Composting Concepts. Although composting is not currently mandatory in Woodbury, the town is getting a head start now, with the knowledge that Minnesota has passed legislation that will make yard waste composting mandatory in the Twin Cities Metropolitan area by 1990 and for the rest of the state by 1992.

References: Eisinger, 1988; Madole, 1988a,b; State of Minnesota, 1988; Minnesota Extension Service--Hennepin County, undated

IX. Summary Tables

In this study, a community (town, city, or county) perspective, rather than a facility perspective, has been taken. Therefore, where a community has more than 1 way of diverting its yard wastes from disposal in a landfill (e.g., some combination of a publicly operated facility, backyard programs, and/or a privately operated facility), every effort has been made to present information on all facets of the program. However, information about the number of households served, level of household participation, etc., when there is more than 1 method of yard waste collection (curbside or drop-off) or more than 1 method of yard waste composting (backyard or centralized), is not separated out.

Some of the data for these individual programs are presented on separate lines in the tables (e.g., Westfield). This separation leads to some difficulty in accurately presenting such items as operation costs and land area used for composting. Land area devoted to composting at private facilities is used to compost yard wastes from several communities, not just those included in this study. Furthermore, some of the operations described are well-established or independent of other community functions; therefore, city or county officials have an excellent idea of the annual costs of the program. Others have recently incurred start-up costs for equipment which must be amortized across an expected service life, or simply are not yet operating efficiently or at capacity. In some cases, costs are embedded in the budget allotted for more than one DPW project.

In all cases, every effort has been made to provide detailed, accurate data and information, as displayed in Tables 1-9. Definitions of yard composting technologies as defined by Strom and Finstein (1986) are listed in Table 1. Background information about the 8 communities included and their yard waste composting programs is provided in Tables 2-4. Data pertaining to the composting facilities and their effectiveness are shown in Tables 5-7. Cost comparisons of composting versus landfilling for each community are given in Table 8. Contact names are listed in Table 9.

A. Table 1: Definitions of Yard Waste Composting Technologies

As discussed above, Strom and Finstein (1986, and <u>BioCycle</u> interview in 1988) defined 4 levels of technology for yard waste composting: minimal, low, intermediate, and high. Except for the high-level technology, each of these technologies is used in at least 1 of the composting facilities included in this study.

B. Table 2: Background Information on Cities/County Selected

General background information for the 8 communities selected is shown in Table 2. The communities are spread across the country: 3 are in eastern states, 3 are in central states, and 2 are in western states. No community selected is located further south than Davis, California. Communities and state agencies were contacted as far south as Florida, but attempts to uncover active yard waste composting programs were unsuccessful. As indicated, there is a wide range of

Table 1: Definitions of Yard Waste Composting Technologies

Technology Type	Turning Frequency	Windrow Size
Minimal-level	Once/year	12' high x 24' wide
Low-level	3-5 times/year	6' high x 12'-14' wide
Intermediate-level	Once/week with windrow turning machine	5'-7' high x 10'-14' wide
High-level	First 2-10 weeks with automated system, turned periodically thereafter	10' high x 20' wide, initially

Sources: Strom and Finstein, 1986 and Strom interview in BioCycle, 1988.

Table 2: Background Information on Cities/County Selected

City or County	State	Density (a)	Total City/ County Population	Total Households	Total Yard Waste Stream (tons/yr)	Yard Wastes as % of MSW Stream	Composition of Total Yard Waste Stream (% weight) Leaves	Grass	Brush	Other (b)
Davis (c)	CA	U/S	44,000	10,000	5,475	25	n/a	n/a	n/a	n/a
East Tawas	MI	R	2,600	1,350	350	10 (d)	50	5	45	n/a
Mont. Co. (e)	MD	U/S/R	633,000	244,000	110,000	19	40	35	25	n/a
Omaha	NB	U/S	350,000	100,000	48,000	33 (d)	n/a	n/a	n/a	n/a
Seattle (c)	WA	U/S	500,000	229,000	92,000	12	20	33	25	22
Wellesley	MA	S/R	27,000	8,500	8,000	28	50	31	19	n/a
Westfield	NJ	U/S	30,000	10,400	n/a	n/a	n/a	n/a	n/a	n/a
Woodbury	MN	U/S	13,520	4,790	1,092 (f)	18 (f)	36	64	(f)	n/a

Notes:
(a) U - urban, S - suburban, R - rural
(b) includes garden material, weeds, sod, dirt, etc.
(c) estimate of total yard waste stream does not include amount generated and collected by lawn service companies and public work crews
(d) yard wastes are estimated as percent of residential solid waste stream
(e) population and household estimates based on 1986
(f) yard waste estimate does not include brush
n/a: not available

community sizes, population densities, and yard waste characteristics among the communities selected. In addition, the reported share of yard wastes as a percentage of the total MSW stream gross discards for these communities (i.e., those which reported total yard wastes as a percent of their MSW stream) ranges from 12-28 percent. However, total yard waste stream estimates for Davis and Seattle may be underestimated because yard wastes generated and collected by lawn service companies and public crews are not included. An estimate of the average percent share of yard wastes in the MSW stream for these communities is 15 percent, approximately the same as EPA's (1988) national average estimate.

C. Table 3: Participation in Yard Waste Composting Programs

The scope of the composting programs studied is presented in Table 3. Most of these composting programs, backyard or centralized (which use curbside pickup and/or resident drop-off), extend to all households in the communities, while some programs included may currently be targeted to specific areas in the community. Household participation rates are estimated based on a community's entire composting program, including any combination of backyard and centralized composting activities. Participation of households served is high, averaging around 80 percent; however, the percent of total yard wastes composted is not as high. Reasons for this include: (1) the fact that not all households are served by the composting programs; (2) the variation in the composition of these communities' yard wastes and the percentage of each type of material being composted; (3) the inconsistent participation of some households; and (4) the uneven generation and composition of yard wastes across households.

D. Table 4: Yard Waste Separation and Collection Methods

As indicated in Table 4, some communities give residents 2 options for composting their yard wastes: backyard composting; or source separation followed by centralized composting, i.e., separating yard wastes from other solid wastes for curbside pickup and transport by the community to, or self-haul and drop-off by the household at, a composting facility or transfer facility. Separation and collection methods chosen by these communities will depend on convenience, costs, and amount of yard debris which can be diverted from landfills. Only 1 of the composting programs (Westfield's) has mandatory source separation of yard wastes (requiring that leaves be separated from household garbage prior to curbside pickup). As a result, Westfield claims that 100 percent of its leaves are handled by composting; in

Table 3: Participation in Yard Waste Composting Programs

City or County	State	Startup Year of Program	Total Population Served	Total Households Served	% of Households Served	Participation of Households Served (%) (a)	Total Yard Waste Composted (tons/yr) (b) (c)	% of Total Yard Waste Composted (c)	Year of Data
Davis	CA	1981	44,000	10,000	100	70 - 80	500	9	1987
East Tawas	MI	1984	2,600	1,350	100	70	138 (d)	39 (d)	1987
Montgomery Co.	MD	1984	282,000	75,000	48	90 - 95	15,600	14	1987
Omaha	NB	1987	3,735	830	1	66	500	1	1988
Seattle (e) •	WA	1987	500,000	229,000	100	n/a	3,600	4	1988
Wellesley	MA	1969	27,000	8,500	100	90 - 95	6,500	81	1987/ 1988
Westfield	NJ	1970	30,000	10,400	100	100: 25 (f)	3,130 (d)	n/a	1987/ 1988
Woodbury	MN	1987	2,329	825	17	80	~116	11 (d)	1987

Notes:
(a) estimated by local officials
(b) reported as % of the total yard waste stream of the city or county currently being composted
(c) does not include amount backyard composted
(d) does not include amount of brush chipped or shredded
(e) although 100% of households are served, the program is not yet in full swing
(f) participation rate was 100% for curbside collection of leaves and 25% for drop-off of grass and brush with the remaining households having their grass backyard composted or picked up by landscaping services
n/a: not available

Table 4: Yard Waste Separation and Collection Methods

City or County	State	Mandatory Program? (Y/N)	Collection Method (a)	Frequency of Collection (b)	Collection Seasons (b)	Means of Raising Awareness and Support for the Program in the Community
Davis	CA	N	backyard	n/a	Sp,Su,F,W	public ed
		N	curbside - claw	1/week	Sp,Su,F,W	public ed
East Tawas	MI	N	curbside - plastic bag resident drop-off	1/week	Sp,F	newspaper ad
Montgomery Co.	MD	N	curbside - vacuum	1/Sp,2/F	Sp,F	pickup schedule signs
Omaha	NB	N	curbside - wheeled bin and degradable bag	1/week	Sp,Su,F	neighborhood assoc
			landscaper drop-off	n/a	Sp,Su,F	
Seattle	WA	N	backyard	n/a	Sp,Su,F,W	hotline, public ed
		N	resident drop-off	n/a	Sp,Su,F,W	
		N	landscaper drop-off	n/a	Sp,Su,F,W	
Wellesley	MA	N	backyard	n/a	Sp,Su,F,W	public ed, newspaper, bill stuffers
		N	resident drop-off	n/a	Sp,Su,F,W	public ed, newspaper, bill stuffers
		N	landscaper drop-off	n/a	Sp,Su,F	word-of-mouth
Westfield	NJ	Y	curbside - front loader	2/F	F	hotline, newspaper ad
		Y	resident drop-off	n/a	Sp,Su,F	newspaper ad, mailings
		Y	landscaper drop-off	n/a	Sp,Su,F	newspaper ad
Woodbury	MN	N	backyard		Sp,Su,F	public ed
			curbside - degrad.bag	1/week	Sp,Su,F	free bags yr 1, mailings

Notes:

(a) "backyard" refers to backyard composting

(b) Sp - spring, Su - summer, F - fall, W - winter; (2/F - 2 collections per fall, etc.)

Y/N: yes/no

n/a: not available for collection

addition, grass clippings and brush which are not dropped off to be composted or shredded are either composted or mulched in backyards or collected by landscaper services. Also, half of the programs allow drop-off by commercial landscapers.

Several communities use more than 1 collection method but, as seen from Table 3, this does not imply that a greater percentage of households participate than in those communities relying on only 1 collection method (e.g., compare Davis and East Tawas). However, the collection method can affect the composting process (e.g., curbside pickup by vacuum versus drop-off in plastic bags can affect whether incoming yard wastes need to be processed prior to windrow formation). Collection service frequency for yard wastes varies from weekly to seasonally and occurs during 1, 2, 3, or all 4 seasons. Choice of seasons for collection service is in part determined by the type of yard wastes composted; e.g., Montgomery County currently only composts leaves (see Table 5) and therefore collects during the fall and spring when leaves are available for pickup at curbside. In addition, some collection equipment (e.g., curbside vacuum) is not suited for year-round yard waste pickup. In each of these cases of curbside collection, yard wastes are collected independently of the normal trash collection.

Various methods (e.g., media ads, education, bill stuffers, and posted signs) have been used to raise public awareness and support for participation in these composting programs. Nevertheless, there is no apparent indication of whether any particular method influences the rate of household participation the most, nor whether multiple methods are more effective than single methods in maximizing the participation rate (e.g., compare Montgomery County to Seattle and Wellesley).

E. Table 5: Yard Waste Composting Facilities

Composting operations serving the 8 selected communities are described in Table 5. They are split between publicly and privately owned and operated facilities. Facilities referred to as public are those which are owned and operated by towns, cities, or counties. (However, Montgomery County's facility is operated by a private contractor on public land.) Private facilities are privately owned companies which perform composting on their land for 1 or more clients which may include other private companies (such as landscapers or private haulers), as well as communities. Ownership affects location of these facilities -- publicly operated facilities are located within the community's boundaries; however, this need not be true in the case of privately operated facilities.

Table 5: Yard Waste Composting Facilities

City or County	State	Public/ Private Facility	Location of Compost Facility	Size of Compost Area (acres)	Total Yard Waste Composted (tons/yr)	Composition of Yard Waste Stream Composted (% by wt.) Leaves	Grass	Brush	Permit Required (Y/N)
Davis (a)	CA	private	inside city	2.5	500	100	0	0	N
East Tawas	MI	public	at closed landfill	2.5	138	91	9	(b)	N
Montgomery Co.	MD	public/ private	city outskirts	47	15,600	100	0	0	N (c)
Omaha	NB	public	at landfill	2	500	20	60	20	N
Seattle (d) (e)	WA	private	out of city	6	3,600	n/a	n/a	n/a	N
Wellesley (f)	MA-RDF	public	at transfer stat.	1.5	n/a	62	38	0	N
	MA-DPW	public	at DPW yard	1	n/a	100	0	0	N
Westfield (g)	NJ-MCI	private	out of city	15	1,730	100	0	(b)	Y (h)
	NJ-WL	private	out of city	4.5	1,400	0	100	(b)	Y (h)
Woodbury (i)	MN	private	out of city	2	~116	36	64	0	Y (j)

Notes:

(a) a private facility, Davis Waste Removal, is used for composting

(b) brush is chipped; at East Tawas, it is used for road fill; at Westfield, it is sent to Alternate Disposal Systems Inc., a private facility

(c) however, permits are required for surface water discharges from facility's sedimentations ponds

(d) a private facility, Pacific Topsoils, Inc., is used for composting

(e) it is impossible to provide accurate data on the amount and range of backyard composting performed

(f) MA-RDF - Wellesley's yard waste composting facility located at its Recycling and Disposal Facility
MA-DPW - Wellesley's yard waste composting facility located at its DPW yard

(g) NJ-MCI - Middlebush Compost, Inc., a private facility used by Westfield
NJ-WL - Woodhue Ltd., a private facility used by Westfield

(h) state solid waste facility permit

(i) a private facility, Composting Concepts, is used for composting

(j) land use permit

n/a: not available

Y/N: yes/no

There is no clear relationship evident between the size of the composting facilities and the amount of yard wastes composted. At least 3 factors may explain this: (1) land area is in part determined by the technology used (and vice versa) and efficiency with which land is used; (2) private facilities may accept yard wastes from many communities to benefit from the economies of scale -- however, Table 5 only includes yard wastes for communities included in this study; and (3) the facility's land and equipment (e.g., East Tawas) may also be used to grind rather than compost brush. For these reasons, sufficient data are not available to estimate tons (or cubic yards) of yard wastes composted per acre of composting area.

The level of composting activity at these facilities ranges widely, from 116-15,600 tons per year. The majority of yard debris accepted by these facilities is leaves; however, several facilities accept significant quantities of grass.

Of these 10 yard waste composting facilities, only the New Jersey facilities operate subject to state solid waste facility permits. The Woodbury facility is subject to a permit but this relates more to its land use activity as a commercial-type enterprise. The Montgomery County facility has a permit but it applies only to surface water discharges from its sedimentation ponds.

F. Table 6: Yard Waste Composting Facility Operations

The previously discussed definitions for the composting technologies (see Table 1) have been modified in Table 6 to fit the technologies used at these facilities. Every facility is different, therefore, the division of these 10 facilities into 3 technology groups has been performed somewhat loosely. For purposes of this report, minimal-level technology includes windrow turning frequencies of at most 2 times per year; low-level technology includes windrow turning frequencies of at least once every 2 months; and intermediate-level technology requires a windrow turning machine and turning at least once per month.

Most of these facilities either grind or shred the incoming yard wastes or shred during the windrow turning process. This serves to accelerate the composting process and reduce the volume of yard wastes. Six of the 10 facilities screen their compost to improve product quality. As seen from Tables 6 and 8 (revenues earned from marketing compost), use of these processing steps depends, in general, on the selling price or value of the finished compost.

Table 6: Yard Waste Composting Facility Operations

City or County	State	Type of Compost Tech Used	Turning Frequency	Grind/ Shred/ Screen Material	Monitor/ Testing During Composting Process	Monitor/ Testing Frequency	Facility Control (a)	Water Added
Davis	CA	Low	1/week	grind	none	n/a	none	N
East Tawas	MI	Low	6/year	none	temp	1/1-2 mos	none	N
Montgomery Co.	MD	Intermed	1/month	shred screen	temp compost	1/month 1/year	RO,W	N
Omaha	NB	Minimal	2/year	grind	temp compost	1/2weeks 1/year	none	Y
Seattle	WA	Minimal	1/year	grind shred screen	temp compost	1/month 1/3months	none	N
Wellesley (b)	MA-RDF	Minimal	1/year	screen	temp compost	1/2weeks 1/1-2years	none	N
	MA-DPW	Low	1/month	screen	temp compost	1/2weeks 1/1-2years	none	N
Westfield (c)	NJ-MCI	Intermed	>1/week	shred screen	temp moisture oxygen compost	1/day 1/day 1/week 1/month	none	Y
	NJ-WL	Intermed	as needed (d)	shred screen	temp moisture oxygen compost	1/ 2days at start 1/10days varies	none	Y
Woodbury	MN	Low	1/month	none	temp compost	1/2month 1/year	none	Y

Notes:
(a) RO - collects runoff, W - wind fence to collect pieces of plastic bags
(b) MA-RDF - Wellesley's yard waste composting facility located at its Recycling and Disposal Facility
MA-DPW - Wellesley's yard waste composting facility located at its DPW yard
(c) NJ-MCI - Middlebush Compost, Inc., a private facility used by Westfield
NJ-WL - Woodhue Ltd., a private facility used by Westfield
(d) turning occurs as needed, based on temperature inside the windrow
n/a: not applicable
Y/N: yes/no

Only Montgomery County indicated the presence of environmental controls at their facility -- (1) sedimentation ponds for collecting runoff, installed when the facility previously composted municipal sewage sludge; and (2) a wind fence to collect pieces of plastic. Several facilities add water when windrows are initially formed or turned, generally independent of technology used and frequency of windrow turning. No other additives were mentioned. Most of the facilities monitor windrow temperature as an indicator of the composting process and test the quality of the finished compost. Monitoring is generally more extensive and frequent for the private composting facilities and, as such, is related to the value of the end product (see Table 8 for revenues per ton of compost sold).

G. Table 7: Yard Waste Composting Results

As seen in Table 7, volume reduction of yard wastes generally depends on composting time and the type of technology used (refer back to Table 6). To achieve a specific percent reduction of yard wastes, composting time can be decreased if the technology is "upgraded" to a more advanced level (e.g., through more frequent turnings). The time required to produce finished compost is influenced by the frequency of turning, as well as climate.

Markets for the finished compost include local residents, local governments, nurseries, and landscapers. There is sometimes a time lag between when the finished compost is ready to be marketed and when the market will buy the product. This is evident in the case of Montgomery County which collects leaves in the fall and spring and can produce finished compost by the following fall, but may have to store its finished compost for 6 months on-site and wait until the next spring to sell it.

Reject materials, e.g., plastic bag debris, tennis balls, and rocks, which are not composted, is separated manually (e.g., during debagging) or mechanically (e.g., during screening) and sent to a landfill for disposal. This material constitutes between negligible levels and 25 percent of the incoming yard waste stream at these facilities and is highly dependent on the methods used for yard waste source separation, collection, and processing, and to some extent on street sweeping in the case of curbside pickup.

H. Table 8: Costs and Revenues of Yard Waste Composting

Costs and revenues reported by these yard waste composting programs are provided in Table 8. Yard waste collection and transport costs for these communities range

Table 7: Yard Waste Composting Results

City or County	State	Composting Time (months)	Yard Waste Volume Reduction (%)	Tons of Finished Product (tons/yr)	Compost Uses & Markets (a)	Rejects (as % of Incoming Volume of Yard Wastes)	Year
Davis	CA	3 - 4 (b)	50 - 60	250	R	2 - 5 (c)	1987
East Tawas	MI	24 - 36	65	70 - 80	C	1	1987
Montgomery Co.	MD	6 - 12	85	3500	L,N	5 - 10	1987
Omaha	NB	18 - 24	50 - 60	350	C	n/a	1988
Seattle	WA	6 - 8	80	(d)	L,R,C	1 (e)	1988
Wellesley (f)	MA-RDF	24	60-65	1800	R,N	neg	1987
	MA-DPW	12	60-65	800	C	5	1987
Westfield (g)	NJ-MCI	3 - 4	80	(h)	L,N,R	1	1988
	NJ-WL	5	50 - 70	(h)	F	12 - 25	1988
Woodbury	MN	12	70	(i)	N	1	1987

Notes:

(a) C - city/county, F - farm, L - landscapers, N - nurseries, R - residents
(b) however, the composting process may not be completed after 3-4 months
(c) by weight
(d) Pacific Topsoils, Inc. composts yard wastes for Seattle and other cities; hence, it is not possible to separate out data for Seattle alone
(e) reject material gets used on-site or sold
(f) MA-RDF - Wellesley's yard waste composting facility located at its Recycling and Disposal Facility
MA-DPW - Wellesley's yard waste composting facility located at its DPW yard
(g) NJ-MCI - Middlebush Compost, Inc., a private facility used by Westfield
NJ-WL - Woodhue Ltd., a private facility used by Westfield
(h) Middlebush Compost, Inc. and Woodhue Ltd. compost leaves and grass, respectively, from Westfield, and primarily leaves from other communities and private clients. It is not possible to separate out data for Westfield alone
(i) Composting Concepts composts yard wastes from Woodbury and other communities; hence, it is not possible to separate out data for Woodbury alone
neg: negligible

Table 8: Costs and Revenues of Yard Waste Composting

City or County	State	Collection &Transport Cost for Yard Wastes ($/ton)	Processing Cost for Yard Wastes ($/ton)	Total Compost Cost (excl. revenue) ($/ton)	Buyers& Users of Compost (a)	Compost Revenues by Market ($/ton) (b)	Garbage Collection &Transport Cost ($/ton)	Local Landfill Tip Fee ($/ton)	Year
Davis	CA	n/a	n/a	n/a	R	$0.00	n/a	$8.00	1987
East Tawas (c)	MI	$10.00	<$10.00	<$20.00	C	$0.00	n/a	$5.25	1987
Mont. Co. (d)	MD	$83.33	$18.46	$101.79	L,N	$19.20	$54.00	$46.00	1987
Omaha	NB	$40.16	$3.60	$43.76	C	AC	$30.30	$6.40	1988
Seattle (e)	WA	$12.00	$22.50	$34.50	L,R,C	$7.50-$12.50/ cu yd	$71.50	$31.50	1988
Wellesley (f)	MA	$0.00	$11.11	$11.11	N R C	$0.50 $0.00 AC	$0.00	$52.00	1987/ 1988
Westfield (g)(h)	NJ-MCI	$16.79/c y	$7.50/cu yd	$24.29/ c y	L,N,R	$25.00	n/a	$137.00	1988
Westfield (g)	NJ-WL	(i)	$10/cu yd	n/a	F	AC	n/a	$137.00	1988
Woodbury	MN	$43.00	$15.00	$58.00	N	AC	$65.00	$30.00	1987

Notes:

(a) C - city/county, F - farm, L - landscapers, N - nursery, R - residents

(b) AC - avoided cost of topsoil for landfill cover, park services projects, private use, use of land, etc. For example, avoided costs for landfill cover and soil amendment for Omaha are $8-$10/ton plus $1-$5/ton for transport of topsoil; avoided cost by $15/cu yd for Wellesley as substitute for loam; avoided cost by $35-$65/acre for farm use as fertilizer supplement at Woodhue Ltd.; avoided cost of land for Woodbury by exchanging compost for use of nursery's land

(c) costs for equipment shared with DPW are not included in composting costs

(d) processing costs do not include costs for land, amortized capital costs, nor disposal costs for reject material

(e) collection cost not included in 1988 estimate, $56/ton in 1989; conversion factor for Pacific Topsoils, Inc. ranges between 1/2-3/4 tons/cu yd for finished compost

(f) yard wastes are dropped off at composting facilities; therefore, zero municipal costs for collection and transport; costs do not include landfill disposal of rejects, nor costs of land; $52/ton tip fee includes transport cost to landfill

Table 8 (cont.): Costs and Revenues of Yard Waste Composting

Notes:

(g) NJ-MCI - Middlebush Compost, Inc., a private facility used by Westfield
NJ-WL - Woodhue Ltd., a private facility used by Westfield
conversion factor used by New Jersey is 700 lbs/cu yd, or 1 ton/3.3 cu yds
$137/ton is tip fee at the transfer station

(h) collection cost includes rented equipment, labor, fuel; does not include shared equipment

(i) collection cost of grass for Westfield is $0 with resident drop-off; cost for transport to WL was not estimated by Westfield

n/a: not available

cu yd: cubic yard

c y: cubic yard

from $0 per ton (for drop-off) to over $80 per ton, while processing costs are generally much lower, spanning a narrower range, approximately $4-$23 per ton. Footnotes to Table 8 indicate what costs are and are not included in these cost estimates. Although collection, transport, and processing costs to a community are $0 per ton for backyard composting, costs may still be incurred if it provides technical assistance and/or materials to residents.

As mentioned above, users of compost material include local residents (at a small fee or no charge), local governments, nurseries, and landscapers. The material is used primarily as a soil amendment or landfill cover by these communities. In all cases, the finished compost is distributed to users in bulk, rather than in bags. Generally, the product is picked up by the buyer, although, in some cases, delivery is available as well.

Revenues from selling the finished compost range from $0 (e.g., it is given free to residents) to $25 per ton. In addition, when revenues are not received, there may be avoided costs, as in the cases of using compost: (1) as a landfill cover material and soil amendment for county parks (at Omaha, $8-$10 per ton plus $1-$5 per ton transport costs saved for topsoil); (2) as a soil amendment (at Wellesley, $15 per cubic yard savings); (3) for private use as a supplement to fertilizer (at Woodhue Ltd., $35-$65 per acre savings); or (4) in exchange for use of another facility's land (at Woodbury, with a nursery's land). Total revenues earned by the communities (i.e., for the publicly operated facilities) can be subtracted from the total costs of composting (collection plus transport plus processing) to give the net total costs of composting (not shown in Table 8). In New Jersey, there is also a tonnage grant for recycling -- the state will pay communities $1-$2 per ton of MSW diverted from landfill as a recycling incentive as well as a tracking mechanism for the level of recycling activity.

Costs and revenues can be reported in total amounts or on a per ton basis. However, when revenues are reported as the price received per ton of finished compost sold, and costs are reported as expenditures per ton of yard wastes received, a conversion is needed so that these individual per ton estimates are compatible to estimate the net per ton cost of composting. The conversion is as follows: multiply the ratio of tons of finished compost sold to tons of yard wastes received, by the revenue earned per ton of finished compost. This revenue figure can now be subtracted from the cost of composting, per ton of yard wastes received, to estimate the net costs of composting, per ton of yard wastes received. Similar steps would be needed if the cost and revenue figures were based on cubic yards rather than tons.

Landfill tip fees have been steadily and substantially increasing nationally (Petit, 1988). These costs are generally expected to continue to increase in the future. In some areas, these costs have recently skyrocketed. These high landfill disposal fees, as seen by Westfield's $137 per ton fee at the transfer station, offer strong economic (as well as the environmental and landfill capacity) reasons for yard waste composting.

By integrating composting into their overall MSW management strategy, communities are able to divert yard wastes from landfills (or incinerators) and derive cost comparisons for strategies with, and without, composting. The total cost of composting is derived by adding the costs for collecting, transporting, and processing yard wastes (similarly, adding their costs per ton multiplied by the amount of yard wastes diverted). The total net cost of composting is determined by subtracting revenue (or avoided cost from use of compost as a substitute product) to the community for the sale of compost from the total cost of composting. The total MSW management (with composting) cost is calculated by adding the total net cost of composting and the cost of managing the remaining MSW, and then subtracting the avoided landfill disposal cost due to composting. This total MSW management cost estimate should then be compared to the MSW management without composting scenario (e.g., use MSW tonnage and per ton collection, transport, and landfill disposal costs or total costs for each of these activities) to determine if yard waste composting is a cost-effective MSW management alternative.

Many communities are becoming increasingly aware that yard waste composting will save them landfill disposal costs and precious landfill space. As stated above, cost savings by diverting yard wastes from landfills, i.e., avoided tip fees, can be subtracted from the total net cost of composting to estimate the real, or "true" cost of composting. Of course, this assumes that the cost of landfilling (and composting) reflects its true cost. To avoid double-counting costs, the true cost of composting should not be compared again to the cost of landfilling since both cost measures include estimates of landfill disposal costs, whether avoided or to be paid.

Direct cost comparisons between these 8 community composting programs may not be appropriate because their cost figures may be based on different accounting, estimation, and/or financial procedures (GPI, 1988). For example: (1) East Tawas' cost estimates only reflect costs solely applicable to composting, i.e., costs for equipment shared with their DPW were not estimated; (2) Montgomery County's estimate for its processing cost does not include the opportunity cost for land nor amortized capital costs, the latter being paid in single lump sums; (3) Montgomery County's and Wellesley's processing costs do not include costs for landfill disposal of reject material; (4) Wellesley does not include the cost of land; and (5) Westfield does not include the cost of shared equipment, only rented equipment (as well as labor and fuel), in its processing cost estimate. Furthermore, cost per ton estimates for composting can be highly variable over time, depending on, among other things, annual fluctuations in the amount of yard wastes generated.

I. Table 9: Contact Information

Names, affiliations, and phone numbers of the representatives interviewed from each composting program are listed in Table 9.

X. Conclusions

The yard waste composting programs examined in this study represent some of the options available for designing such programs. The components of these programs are apparently site-specific, affected by local factors, community composting experience, etc. The summary highlights of the programs studied and assessed include the following findings:

- the percentage of yard waste diverted from landfilling is highly dependent on community and household participation levels, composition of the yard waste stream, and types of yard wastes composted (or, in the case of brush, shredded);

- volume reductions of the yard wastes composted range between 50 and 85 percent;

- the number of process steps, including technology used, shredding, screening, monitoring, testing, etc. is related to the available land, labor, and capital and the desired quality and value of the end product;

- composting costs (excluding revenues earned) range from $11-$102 per ton, and avoided landfill disposal fees range between $5-$137 per ton; and

- in several cases, revenues were generated through sale of the finished compost (up to $25 per ton)-- in other cases, costs were avoided by saving on costs for landfill cover, soil amendment, private use, or land.

Table 9: Contact Information

City or County	State	Contact Name	Agency or Company	Phone Number
Davis	CA	Ken Shepard	Davis Waste Removal Co.	(916)756-4646
East Tawas	MI	Jacob Montgomery	City of East Tawas	(517)362-6161
Montgomery Co.	MD	Dave Wagaman	Montgomery County Gov't	(301)217-2380
		Bob Goldberg	Montgomery County Gov't	(301)217-2380
Omaha	NE	Dan Slattery	City of Omaha	(402)734-6060
Seattle	WA	Nora Smith	Seattle Solid Waste Utility	(206)684-7638
		Leo Carlson	Pacific Topsoils, Inc.	(206)486-3201
		Dorran McBride	Pacific Topsoils, Inc.	(206)486-3201
Wellesley	MA	M.R. "Pat" Berdan	DPW Director	(617)235-7600
Westfield	NJ	Edward Gottko	Town Engineer Westfield DPW	(201)789-4100
		Pat Kennedy	Middlebush Compost Inc.	(201)560-0222
		Joseph Hayes	Woodhue Ltd.	(609)723-6211
		G. "Nick" Nicholson	Woodhue Ltd.	(609)723-6211
Woodbury	MN	John Madole	John C. Madole Assoc.	(612)489-5779
		Richard Eisinger	Composting Concepts	(612)436-5994

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Appendix A: Sample Conversion Factors

Conversions Used by the Composting Facilities

Montgomery County, Maryland:

incoming leaves (after vacuuming)	400 lbs/cu yd

Omaha, Nebraska:

incoming yard wastes	600 lbs/cu yd

Seattle, Washington--Pacific Topsoils, Inc.:

gross material at entry	400 lbs/cu yd
after composting for about 2 months and shredding	1,000 lbs/cu yd
finished compost sold as topsoil	1,500 lbs/cu yd

Wellesley, Massachusetts:

uncompacted fresh leaves	400-450 lbs/cu yd
after composting for one year	1,272 lbs/cu yd
finished compost	1,500 lbs/cu yd

Westfield, New Jersey--Middlebush Compost Inc.:

loose fresh material	250 lbs/cu yd
stockpiled compost material	800 lbs/cu yd

Westfield, New Jersey--Woodhue Ltd.:

incoming yard wastes	600 lbs/cu yd

Woodbury, Minnesota--Composting Concepts:

compacted dry leaves	320 lbs/cu yd
compacted pure new grass	1,500 lbs/cu yd
partially compacted gross material at entry	400 lbs/cu yd
after 2 months composting and shredding	1,000 lbs/cu yd
density of material sold	1,500 lbs/cu yd

Conversions Found in the Literature

City of Seattle (1988):

compacted yard debris	600 lbs/cu yd
grass	800 lbs/cu yd
leaves	420 lbs/cu yd
prunings	210 lbs/cu yd
yard debris	390 lbs/cu yd

Fliesler (1987):

leaves, assuming average rate of compaction	500 lbs/cu yd

McCown (1988):

loose leaves	250 lbs/cu yd
vacuumed leaves	350 lbs/cu yd
compacted leaves	450 lbs/cu yd
bagged grass (30 gallon bag at 80% capacity = 50 lbs)	421 lbs/cu yd

Mielke and Walters (1988):

compacted leaves	400 lbs/cu yd

Public Technology, Inc. (1988):

uncompacted leaves	500 lbs/cu yd

Strom and Finstein (1986):

leaves in open truck	250 lbs/cu yd
vacuumed leaves	350 lbs/cu yd
compacted leaves	450 lbs/cu yd
leaves--rough average	400 lbs/cu yd