JASON DAVID GOVERNO
Facility Characteristics and Design of Windrow Composting Operations
(Under the direction of SIDNEY ALAN THOMPSON)

Waste disposal from all sectors of life has become a significant problem as traditional disposal methods come under economical and environmental scrutiny. As landfill space diminishes and tipping fees increase, alternative methods of waste disposal such as composting are being given more consideration by waste managers. To assist in the development of this industry, an assessment of Georgia's existing composting infrastructure was conducted to more effectively utilize the available resources. The feasibility and design of a new composting operation are critical aspects of the facility's long-term success. The numerous factors that impact composting process design and costs make it tedious and difficult to make accurate feasibility assessments. To address this situation, a computer program was developed which can be used to determine the feasibility of a windrow composting operation as a waste management alternative. This study covers a description of the design program and its validation compared to existing composting facilities.

INDEX WORDS: Composting, Process design, Computer tool, Cost, Survey, Infrastructure, Waste management, Organic

FACILITY CHARACTERISTICS AND DESIGN OF WINDROW COMPOSTING OPERATIONS

by

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# CHAPTER 1

# INTRODUCTION

### *What is Compost?*

The general definition of the word compost is actually rather simple but incomplete when taking into account the wide range of properties of various types of compost. Compost not only describes the completed degradation of a mixture of materials; it also denotes the process that materials undergo before becoming compost. A workable definition for compost is that it is an organic soil conditioner that has been stabilized to a humus like product, is free of viable human and plant pathogens and plant seeds, does not attract insects or vectors, can be handled and stored without nuisance, and is beneficial to the growth of plants (Haug, 1993). A useful explanation of the process of composting is the controlled biological process of the decomposition of organic materials into a humus rich product that can be used beneficially as a soil amendment or in erosion control techniques.

### *Composting Processes*

Compost is produced through the activity of aerobic microorganisms that require oxygen, moisture and food in order to multiply. These microorganisms generate heat, water vapor and carbon dioxide as they transform raw materials into a stable soil conditioner (Alexander, 1996). Effective composting begins with a basic knowledge of the material or feedstock properties, the general principles of decomposition and a method for controlling the process. There are a few basic feedstock characteristics that are most influential in the composting process. These include carbon to nitrogen ratio, often referred to as C:N ratio, moisture content, and the size and distribution of the feedstock particles. Raw materials blended to provide a C:N ratio between 25:1 and 30:1 is ideal for active composting, although initial C:N ratios from 20:1 to 40:1 consistently give good composting results (Rynk, 1992; Dougherty, 1999). When ratios fall outside this range, odor problems and longer composting times can be the result. Too little moisture, as well as too much moisture, can lead to poor composting conditions and decreased microbial activity. A moisture content ranging between 40-60% usually provides the water levels needed by microbes without saturating the required air pore space within the compost matrix (Rynk, 1992). With regard to particle size distribution, a size of 90 percent cumulative passing through 2 to 3 inch openings usually is sufficient to provide a composting substrate with adequate surface area for microbial degradation and with adequate porosity for the storage of oxygen. (Ndegwa, 1999).

Harnessing the natural process of decomposition to best serve a purpose within a set of specific parameters is the basis for composting systems. Nature's decomposition process is highly effective but this form of composting inevitably takes more time than managed systems. As new technology develops, so do better techniques for controlling and maintaining optimum system parameters. Four general composting groups or methods are commonly used by the composting industry to turn feedstocks into finished compost (Rynk, 1992; Haug, 1993). These methods include passive composting, windrows, aerated static piles and in-vessel composting.

Passive composting is probably the most common method used today because it involves simply stacking feedstocks and leaving them to compost over a long period of time. Very little, if any activity is performed on the pile once it has been constructed. Initial composting parameters can be controlled but are not usually maintained during the entire process. Passive composting is relatively easy but can have problems such as odor generation from anaerobic conditions, leachate from too much moisture and the extended duration of time required for complete composting.

Windrow composting is similar to passive composting although the piles of materials are turned or aerated by mechanical equipment to maintain optimum conditions. Materials are placed in long rows where the actual size and shape of the windrow are dependent upon the feedstocks. Dimensions of the windrow normally range from three feet to twelve feet high and anywhere between eight to twenty feet wide. The actual size of the windrows is based on the quantity of feedstocks and the type of equipment used for turning. Windrow aeration is performed primarily through the natural chimney or ventilation effect of warm air rising in the pile and by mechanical turning. Mechanical turning is usually done with a front-end loader or a machine specifically designed for turning windrows. The actual flow rate of air into the pile is determined by the porosity of the feedstocks. Frequent turning helps to maintain a porous media, which allows for the replenishment of oxygen used by the microbes. The area where the composting takes place is commonly referred to as a compost pad. The size of the pad depends on the volume of material handled, the windrow shape and length and the type of equipment used for turning.

Aerated static pile composting modifies the passive composting technique by using blowers to supply air to the composting feedstocks. This process does not include or involve turning and/or agitation of the piles after the initial mixture of feedstocks. Bulking agents are often used to help maintain the porosity structure of the piles, which aids in pile aeration. In this type of composting, the capacity of the blowers and the characteristics of the feedstocks dictate the size of the piles. Electronic feedback controls are often used to monitor the pile temperature and control the operation of aerating blowers.

In-vessel composting refers to any type of composting that takes place inside a structure, container or vessel. Each type of system relies upon mechanical aeration and turning to enhance and decrease the duration of the composting process. The goal of in-vessel composting systems is to combine various composting techniques into one controlled environment, which utilizes the strength and minimizes the weakness inherent to other forms of composting. These systems often times control the moisture and temperature of the feedstock during composting and require frequent turning to maintain a good feedstock mixture (Rynk, 1992). High capital and operational costs are normal characteristics of in-vessel systems, which are often highly automated.

### *Waste Management Option*

Around most major cities urban sprawl is placing a severe infrastructure demand on our waste disposal systems. Industrial, agricultural, commercial, institutional or residential sectors of life all produce waste that must be discarded. Historically the most inexpensive and common method (except for agricultural) of waste disposal is landfilling. However, it is often difficult under current legislative and social scrutiny to construct new economically feasible and adequately sized landfills that pass the publics' discretion. The national average landfill-tipping fee has increased from approximately $10/ton in 1986 to $36.97/ton as of October 2001 (Goldstein and Madtes, 2001). Because economics are normally given top priority in most waste management decisions over less tangible determinants, more consideration is being given to alternative methods of waste disposal like composting. When comparing composting to other processes, it is a successful and safe alternative for certain industries and is becoming a more publicly accepted method of waste disposal (Gray, 1989).

In 1990, the Georgia General Assembly passed the Georgia Comprehensive Solid Waste Management Act. This act stated that by July 1, 1996, Georgia should reduce the amount of materials going to landfill by 25%. While this goal was not achieved, this Act established many new initiatives such as public education and beautification programs, ban on yard trimmings from landfills, annual solid waste reporting and other activities to promote the reduction of waste going into landfills (GA DCA, 2000). Tax credits were also offered to businesses in less developed areas of the state to encourage the creation of recycling or source reduction jobs (EPA, 1998). The need to better describe and understand traditional solid waste streams in Georgia has led to intrastate departmental relationships to synergize solid waste reduction efforts. To assist in achieving Georgia's goal, the Georgia Environmental Partnership was created, which is a partnership between two major universities and a state governmental department whose sole purpose is preventing pollution. Through this partnership, complete waste characterization studies were conducted pertaining to forest products, textiles, food processing industries and municipal biosolids production (Governo et. al., 2000). These studies are the basis for providing extensive outreach and technical assistance to industries in these areas where solid waste can be reduced or recycled.

In 2000, an assessment of Georgia's recovery potential of waste from the food processing and institutional food sectors showed that 231,100 tons/year of food processing waste, mainly fruit and vegetables, and 474,000 tons/year of institutional foodwaste were still being disposed of in landfills with only a small portion being composted or land applied (Magbanua et. al, 2000). A study involving Georgia's municipal wastewater treatment plants, where data was gathered from regulatory departmental records, determined that 378,745 tons of biosolids were still being landfilled each year (Governo et. al, 2000). During 2001, the Georgia Environmental Partnership collectively identified 1,756,359 tons of processed residuals (woodwaste, paper, liquid wastes) that could be diverted from landfills (GEP, 2001). Such waste studies and industrial technical assistance shows the potential feedstocks that could be composted rather than landfilled. Because composting can be used as a very effective waste disposal method, it would be in Georgia's best interest to more fully understand the infrastructure of this industry in order to more effectively utilize these resources.

***Benefits and Problems with Composting***

The correct use of compost can increase a soil's organic matter, humus and nutrient content. When applied properly, compost can also increase the cation exchange capacity of the soil (McConnel, et al., 1993), suppress plant diseases, parasites and weed seeds, while reducing the fertilizer and water requirements (Ndegwa, 1999) as well as the amount of nutrients lost to the groundwater through leaching (Golueke, 1975). Businesses often realize the direct economic benefits of composting their waste in the form of decreased landfill tipping fees and disposal costs. These same companies are often times viewed as environmentally friendly, and benefit indirectly through improved relations with clients, consumers and local officials. The generation and release of methane, a potent greenhouse gas, by the anaerobic decomposition of wastes in landfills can also be avoided by diverting organics from landfill into compost. As more organic material is diverted to composting rather than landfilling, the demand for limited space in landfills and/or the need for current landfill expansion is relieved.

Another major benefit of the application of compost to the soil is derived from the improved physical and chemical properties related to the increased organic matter content (Shelton and Tate, 1999). When used in sufficient quantities, the addition of compost has both an immediate and long-term positive impact on soil structure. In fine textured soils, the addition of compost will reduce bulk density, improve workability and porosity, and increase gas and water permeability of the soil while reducing erosion (Alexander, 1996). Compost also increases the water holding capacity and improves soil aggregation in coarse textured or sandy soils (Alexander, 1996).

As with any waste management issue there are drawbacks that need to be carefully weighed and considered before any waste disposal strategy can be implemented. Location to residential neighborhoods, wind direction, traffic patterns, noise levels and odor generation are all variables that directly affect the success of any waste management operation. Lack of keen observation and maintenance of these community parameters are often times the reason why present operations fail and difficulty exists in starting future ones.

Communities which adopt composting, instead of other waste management alternatives must understand that this technique also has some significant drawbacks. When utilizing composting strategies involving minimum technology, the production time required to make finished compost can be extensive thus requiring large tracts of secluded land. Alternatively, capital-intensive in-vessel technologies decrease production time and foot print size significantly, but these operations can be cost prohibitive from the beginning. Regardless of the technology used, the characteristics of the input feedstock streams can negatively affect the nutritional value, consistency and aesthetic qualities of the finished compost.

### *Compost Facility Design*

The impression, whether positive or negative, that a composting operation gives to the public is critical in the success of the operation. Sometimes even the slightest deviation from acceptability can fuel anti-composting sentiment and make continual operation difficult. The general void of knowledge concerning the design of composting processes could be one of the reasons for this problem. A detailed design coupled with an extensive feasibility study of a proposed composting operation is critical to its success. Lack of advanced understanding regarding the required amount of processing area can lead to throughput restrictions, process bottlenecks, odor complaints, and cash flow problems. The feedstock characteristics, processing equipment and overall throughput all directly correlate to the amount of land required, initial capital outlay, product quality and continual operational costs. Underestimating the size and economic requirements of new compost facilities is often times caused by the exclusion of numerous synergistic design variables.

The total cost of composting is a function of the number of unit operations the feedstocks must undergo, the type of equipment used to perform each unit operation, the number of employees the operation will utilize, the overall throughput, and the site location in relation to feedstocks and markets. All of these factors affect both the initial capital expenditure and continual cost of operation. Operating costs for municipal solid waste and yard trimming composting operations range from $32 to $65 per ton and $2 to $3 per ton, respectively (Curtis et al., 1992; Renko et al., 1994). Total costs for yard trimming composting, including capital and operating, range from $8 to $25 per ton but depend on the amount of feedstock preparation, length of composting and the location of the facility (Steuteville, 1996). Some state environmental regulations (e.g. Florida, Louisiana, North Carolina) require composting of certain feedstocks to be performed on an impermeable surface, such as lime stabilized soils, concrete or asphalt. A comprehensive economic feasibility study is complete when each major factor is correctly incorporated in a conservative manner. An impartial interpretation of the completed economic evaluation should be performed and scrutinized before implementation and startup. If the plan will not demonstrate positive cash flow on paper, it will definitely not generate positive cash flow in reality.

When starting a new compost facility, it is the tendency of planners to base capital payback and operational costs on the "back end" sales of finished compost. In the preliminary design process, it is often assumed that a facility will immediately receive top return on compost sales, while in reality it usually takes market development much longer than planned to realize top financial returns on product sales. When ambitious financial projections are used and later found to be incorrect, it is often difficult for facilities to meet payment deadlines and make financial ends meet. Thus, it is very important to make conservative estimates on all projections, most importantly sales revenue figures.

### *Need for Simple Design Tool*

With so many variables that integrally effect each other, determining the optimum set of composting operating conditions to meet economic parameters, throughput constraints and permit requirements can be extremely tedious and time consuming. Because of the large quantities of mathematical calculations involved and the natural iteration process that accompanies most designs, extensive preliminary studies of proposed composting facilities are often forgone in lieu of more simple best guess approximations and hunches. Although these estimates can work for some experienced system designers, it is not always the case for the inexperienced designer or businessman who simply wants to find out if composting is an economically viable waste disposal option. It is imperative to determine the success of a proposed composting facility under a particular set of circumstances prior to investing capital. There is nothing as harmful to the composting industry as an operation that fails soon after production starts. The lack of a simple and effective design tool for performing compost feasibility studies is apparent as the demand of composting as a waste management option grows.

Because of the wide range of variables that impact the cost, a detailed design feasibility study is required to secure an accurate cost of composting. A small change in any one design parameter can make a significant difference in the total production cost. For this reason, computer software can be very useful for predicting the feasibility of a composting operation. While there are a couple of computer programs that help design composting recipes (Pike, 2000; Brodie, 1994) neither address other unit operations of windrow design. The program COMPOST© is the most comprehensive program available and is used for the design of aerated composting systems (Person and Shayya, 1994). This program uses feedstock characteristics as inputs and provides amendment requirements, finished compost moisture content and aeration requirements as design outputs. COMPOST© does not address turned windrow systems, leachate collection and treatment nor the economics of the composting operation.

In order to address the limitations in available computer tools for compost design, a user-friendly computer program for the design of windrow composting operations was developed by adapting common design techniques from various sources. The design program, called the Compost Wizard©, is intended to be used by waste managers, engineers or business entrepreneurs to evaluate the feasibility of windrow composting as a waste management option. The user must input feedstock properties, geographical location, and a multitude of other parameters specific to the design conditions. The user can quickly vary inputs and rapidly generate multiple design scenarios as the evaluation process progresses. Once the Compost Wizard© has established a preliminary design, the final detailed design can be conducted and/or verified by a professional engineer.

***Goals and Objectives***

The overall goal of this study was: 1) to conduct a detailed evaluation of the composting infrastructure as it presently exists in Georgia, and 2) to validate a computer tool that aids in the determination of feasibility and the design of windrow composting operations. Both of the objectives have been addressed in the chapters that follow in the form of journal articles. The overall supporting literature review has been presented in Chapter 1, while further literature review more pertinent to the objectives is presented in the chapter where that objective is addressed. A user manual for the computer tool is presented in Appendix C as a more detailed account of how to use the tool and actual visual display of the program.

# CHAPTER 2

# A COMPREHENSIVE SURVEY OF GEORGIA'S COMPOST INDUSTRY[1]

[1]Governo, J.D., S.A. Thompson, K.C. Das, B. Faucette and W.C. Merka. To be submitted to Compost Science and Utilization

***Abstract***

An assessment of Georgia's composting infrastructure was conducted in the fall of 2001 and it was found that 38 facilities are composting 553,600 tons of organic waste material each year. Mulching operations were not included in this study. A brief survey completed with the operator during a site visit helped to ensure the highest level of data accuracy possible. Participating in this study were twelve institutions, eight municipalities and eighteen private operations. The primary feedstocks (% of 553,600 tons) for each operation include foodwaste (5.1%), agricultural waste (6.5%), yardwaste (9.0%), animal manure (15.3%), municipal biosolids (28.7%) and industrial wastes (35.5%). The various types of operational permits for composting were compared to facility size and tonnage composted. The survey includes questions concerning marketing, equipment and operational management. The assessment also includes a study on the quality of finished compost from each operation.

***Keywords*****:** Compost, Survey, Waste Management, Organic, Waste, Manure, Biosolids

***Introduction***

The general definition of the word compost is actually rather simple but incomplete when taking into account the wide range of properties of various types of compost. Since no definition is universally accepted, a useful explanation of composting is the biological decomposition and stabilization of organic substrates, under conditions that allow the development of thermophilic temperatures as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to the land (Haug, 1993).

One of the main concerns associated with surveying composting operations arises with yardwaste/woodwaste processors, who commonly dispose of this type of waste by mulching rather than by composting. Therefore, a working definition was developed to differentiate these two types of operations prior to conducting this survey. A composting operation is considered to be any operation that receives organic waste and purposefully mixes and/or processes them in any of a variety of methods in order to achieve and maintain specific temperatures for a length of time, with the final material free of weed seeds, vectors and/or pathogens. A mulching operation is considered to be any operation that receives yardwaste, land clearing debris, green waste and/or wood waste either from private or public sources and reduces the material via mechanical means and/or separates contaminants before end market use. Active turning or processing to reach an elevated temperature (above 113°F) is considered the most significant difference between mulching and composting, and thus, is the main criteria for the study.

A recently published study by Cotton (2001) analyzed California's composting and mulching industries. This study is unique in its endeavor to more accurately characterize and quantify the organics processing industries. Because of the ever-changing dynamics of these industries, information gleaned from such surveys is only a snap shot in time. Yearly surveys are required to keep this type of information up to date. The State of California provided Cotton a preliminary list based on their records of established composting facilities to use as a basis for his survey. Out of the original list of 400 facilities, 148 have exited the organics processing business in the five years prior to the survey. The 104 composting operations in the state composted approximately 3.4 million tons of waste per year.

In 1990, the Georgia General Assembly passed the Georgia Comprehensive Solid Waste Management Act. This act stated that by July 1, 1996, Georgia should reduce the amount of materials going to landfill by 25%. While this goal was not achieved, this Act established many new initiatives such as public education and beautification programs, ban on yard trimmings from landfills, annual solid waste reporting and other activities to promote the reduction of waste going into landfills (GA DCA, 2000). Tax credits were also offered to businesses in less developed areas of the state to encourage the creation of recycling or source reduction jobs (EPA, 1998). The need to better describe and understand traditional solid waste streams in Georgia has led to intrastate departmental relationships to synergize solid waste reduction efforts. To assist in achieving Georgia's goal, the Georgia Environmental Partnership was created, which is a partnership between two major universities and a state governmental department whose sole purpose is preventing pollution. Through this partnership, complete waste characterization studies were conducted pertaining to forest products, textiles, food processing industries and municipal biosolids production (Governo et. al., 2000). These studies are the basis for providing extensive outreach and technical assistance to industries in these areas where solid waste can be reduced or recycled.

In 2000, an assessment of Georgia's recovery potential of waste from the food processing and institutional food sectors showed that 231,100 tons/year of food processing waste, mainly fruit and vegetables, and 474,000 tons/year of institutional foodwaste were still being disposed of in landfills with only a small portion being composted or land applied (Magbanua et. al, 2000). A study involving Georgia's municipal wastewater treatment plants, where data was gathered from regulatory departmental records, determined that 378,745 tons of biosolids were still being landfilled each year (Governo et. al, 2000). During 2001, the Georgia Environmental Partnership identified approximately 1.7 million tons of processed residuals that could be diverted from landfills (GEP, 2001). Such waste studies and industrial technical assistance shows the potential feedstocks that could be composted rather than landfilled.

In 1999, a national Municipal Solid Waste (MSW) study performed by the Environmental Protection Agency, indicated that 61.1% of the total MSW stream is organic in nature (EPA, 1999). The organic portion of the waste stream consists primarily of paper and paperboard (38.1%), yardwaste (12.1%) and foodwaste (10.9%) (EPA, 1999). The rate of MSW organics recycling in the US has increased from 14% in 1992 to 32% in 2001, while during that same time period the number of landfills in the United States decreased nearly 60% from 5,345 to 2,142. During this same time period, MSW generation has increased 145%. (Goldstein and Madtes, 2001; EPA, 1996). In 1999, U.S. residents, businesses and institutions produced approximately 4.6lbs/capita/day of solid waste, up from 2.7lbs/capita/day in 1960 (EPA, 1999). A yearly survey of garbage in America can be used to indicate the levels of yard trimmings composting in the United States (Goldstein and Madtes, 2001). The 2000 survey reported that the number of yard trimmings composting operations has risen 280% in the last decade to over 3,800 facilities across the nation (Goldstein and Madtes, 2000). Even with an increase in yardwaste composting facilities, there is still a tremendous amount of organics, that could be composted that goes into landfills.

The need for organics recycling is recognizable as landfills continue to close, waste generation increases and local and state governments set recycling and reduction goals. Composting is becoming a more desirable waste management alternative as landfill tipping fees increase, new markets develop and as more decision makers learn of the environmental benefits of organics recycling.

**Purpose of Study**

Byproducts from agriculture, forestry, industry, business and municipalities have substantial economic value. Agricultural residuals, industrial byproducts, municipal solid wastes, animal wastes, biosolids, and many additional organic materials can be converted into a product through composting. This activity can create sizeable revenue streams and cost savings while yielding significant environmental benefits.

The purpose of this study is to provide a detailed assessment of Georgia's composting facilities. This project identified the number, size, location, and type of processing facilities as well as information concerning existing feedstocks, additional potential feedstocks, market sectors, marketplace dynamics and growth. This information will be used to identify opportunities and impediments to expanding the compost industry in Georgia. Information from this study can be used to connect waste generators and composters, which can potentially benefit both industries economically. Individual site visits were conducted to ensure accurate data, provide educational and technical assistance, and to relieve regulatory concerns about the purpose of the work.

***Selection of Facilities***

The Georgia Department of Community Affairs (DCA) financially supported this assessment of Georgia's compost infrastructure. DCA serves as the state's lead agency in providing comprehensive planning, technical and research assistance to local governments and serves as the lead agency for the state's solid waste reduction efforts (GA DCA, 2000). Each year DCA sends out a solid waste survey to all municipalities to get an update of the status of solid waste management in Georgia. GA DCA (1999-2000) reported that 27 out of 159 counties and 29% of all cities in the state of Georgia compost yard trimmings. In this same survey, 70% of all counties and 66% of all cities mulch residential yard trimmings. Because of the many similarities between the composting process and mulching, it is sometimes difficult for municipal employees to distinguish which process is being performed. DCA was inclined to believe that the number of municipal composting facilities reported was inaccurate and further verification was required. It was believed that the only way to accurately verify operational procedures was to first conduct a telephone survey and then perform a follow up site visit.

To determine those sites that would warrant onsite evaluations, DCA provided a contact list of what they believed were composting and mulching operations. An initial phone survey was performed which determined that many municipalities that reported that they were composting were actually mulching. Only 45 facilities of the original 130 facilities were determined to be similar enough to composting to warrant an onsite visit.

In addition, a number of private composting operations throughout the state were also identified. Those facilities that met the definition and welcomed onsite evaluation to discuss their operation were added to the previous list that DCA provided. Additional operations were determined by speaking with private composters who identified a few additional small facilities that had just recently started.

***Description of Survey***

The goal of the survey was to determine facility-specific data with regards to feedstocks, processing equipment, compost quality and actual design parameters. The survey has six sections, four quantitative and two qualitative. A sample survey used at each operation can be found in Appendix A. The first section asked for general contact information, whether it was institutional, municipal, or private and the type of permit the facility operates under. The second section requested information about the tons per year composted and the origin of each feedstock. The bulk density and the amount of stockpiled finished compost are also addressed in this section. Section three was one of the subjective portions of the survey that considered the quality of the finished compost. Finished compost sales comprised section four. Operators were asked how the final product was used and if it was sold. Section five asked questions about the equipment the operation used. Section six was also subjective and addressed such questions as projected maximum throughput capacity, the general appearance and odor of the site. This section also provided for any additional comments or concerns not addressed elsewhere.

As with all surveys, gathering of accurate data/information was difficult. This fact was especially true for private operations where many of the desired answers are confidential and not able to be disclosed. Where information was considered proprietary, it was left off the survey. Three animal manure composting operations refused to participate in the survey or allow visits. These are relatively small operations and their nonparticipation does not significantly affect the results of this survey.

***Results and Discussion***

Georgia currently has 38 facilities that are composting according to the definition in this study. Figure 1 is a map of Georgia with symbols representing each compost operation grouped as private, municipal or institutional. There are 18 private operations that handle 73.1% (404,854 tpy) of the total composted material (553,600 tpy). Eight municipalities handle 24.3% (134,540 tpy) of the state's compost. The institutional group consisted of eight prisons, three middle schools and one university. This group processed only 2.6% (14,206 tpy) of the state's compost (Table 1). One private operation accounted for 95.8% of the private facility stockpiled compost and 74.6% of the compost for the entire state. Facilities also reported on their maximum potential capacity or throughput that they could handle without upgrading equipment. The cumulative total of compost facilities' present maximum permittable potential capacity is 1,147,530 tons per year, over double what is currently being composted. This figure does not include either new and/or developing facilities.

**Facilities by Feedstock**

There are a wide variety of feedstocks that were composted at each type of operation. The main types of feedstocks were agricultural waste, animal manure, biosolids, foodwaste, industrial waste and yardwaste (Table 2). Agricultural waste, 6.5% of total composted, included cotton waste, vegetable culls, peanut hulls and other crop residuals. Animal manure (15.3%) included broiler litter, horse, cow and hen waste. Biosolids are the waste by-product of wastewater treatment facilities and are the second in total compost processed at 28.7%. Foodwaste (5.1%) included kitchen preparation waste and industrial food processing residuals. Industrial waste included a wide range of materials such as MSW, tobacco processing waste, paper mill sludge and wood processing residuals and was the highest in percentage of materials composted at 35.5%. Yardwaste included any leaf, grass or tree trimmings that are primarily from a residential setting and comprise 9% of the feedstocks composted.

In Table 3 are shown the origins of the primary feedstocks utilized by these operations. Those feedstocks and amendments classified as “Other” feedstocks came from sources other than municipal, industrial or onsite. All institutions derived their material from within their own operation. Municipalities as expected received almost all of their feedstocks from services offered to the public. Private operations derived their feedstocks from numerous sources depending on location, availability, cost, and logistics.

Twelve compost sites were designated as institutional. Eleven of the twelve institutional operations were found to be composting foodwaste while one composted yardwaste, although pilot foodwaste tests had also been conducted at this site. Of the twelve institutional sites, one operation was responsible for 28.2% of the 14,206 tpy composted. Of the eight sites classified in the municipal category, four composted biosolids, two yardwaste and two industrial wastes (MSW and tobacco sludge). At these sites, stockpiled compost was relatively dispersed among these sites except for one operation which accounted for 98% of the stockpiled biosolids compost and 57.5% of all municipal stockpiles. Private facilities composted all types of feedstocks but the predominant ingredients composted were animal manures and yardwaste which comprised 33.3% and 27.8%, respectively (Table 4) of their total capacity. Although only one private operation composted biosolids, it accounted for 33.8% of all private materials composted and 25% of all materials composted in the state.

The methods of composting practiced throughout the state at these 38 facilities varied with twenty-two using windrow composting, ten static-pile, five in-vessel and one aerated static pile. Windrow systems were used regardless of the type or volume of feedstocks composted. Four foodwaste, four yardwaste and two industrial feedstock composting operations utilized static pile systems. These operations used small loaders (bobcat style) and tractors with buckets to turn and aerate their piles. In-vessel systems were used at two biosolids, two animal manure and one industrial waste operations. In-vessel systems tended to be more capital intensive than alternative methods and were predominantly used at sites where the tipping fees for incoming materials could be realized. Tipping fees at the biosolids and industrial sites and ranged from $25-$38/ton.

**Facilities by Size and Feedstock**

For the purpose of this study, facility size was broken down into four main groups; small operations were classified as less than 1,000 tons per year (tpy), medium operations were between 1,001 and 10,000 tpy, large operations are between 10,001 and 25,000 tpy and very large operations were those composting greater than 25,000 tons of material per year (Table 5).

Small and medium operations accounted for 28 of the 38 operations but combined for less than 11% of the total 553,600 tpy composted. Almost half (12 out of 28) of the small and medium facilities composted foodwaste, however the largest quantities of material composted was from animal manures which composted approximately 22,480 tpy (37%) of the total material composted by these operations. Small operations used windrows and static piles as the dominant type of compost system.

Four compost facilities were classified as large operations which accounted for 11% of the total amount of material composted in Georgia. Of these four one composted primarily animal manures, one biosolids, one foodwaste and one yardwaste. The animal manure operation composted the most material at 20,000 tpy. Surprisingly, these large facilities have very little stockpiled material with only a combined 0.44% of the state's total. This could be related to the fact that three out of the four operations are private and the one municipal operation has an extensive marketing program which utilized the finished product.

The very large operations, those composting more than 25,000 tpy account for 78.2% of the total material composted. These six facilities primarily composted industrial and biosolids wastes, which comprised 44.8% and 31.6% respectively of all materials, composted. It is notable that five out of the six operations were privately owned and though they were responsible for stockpiling 80.4% of the state's total, one site had 92.8% of this amount. Privately owned facilities were dominant in the larger categories while institutional operations were more prevalent in the small to mid size sites. Municipal sites were represented in each size category with three small, three medium, one large and one very large.

**Facility by Size and Permit**

Georgia's permitting process for composting facilities can sometimes be difficult to understand. Permits are obtained from various departments within the State Department of Natural Resources. The department, the type of feedstock and in some situations the amount of material processed determines the type of permit required by a facility. The same size and type of facility can require different types of permits depending upon who owns the land the facility is located on. For example, a municipal wastewater plant that composts an arbitrary amount of biosolids on site requires an amendment to its NPDES permit in order to compost. The same amount of biosolids if it was to be composted off site would require a solid waste handling permit, the same type of permit required for a landfill.

Permits for composting fall into one of nine categories: agricultural exemption; NPDES amendment; Permit by Rule; Recovered Materials Processing Facility (RMPF); Solid Waste Handling Facility (SWHF); verbal agreement; written permission; yardwaste exemption and a non descript Others category. Agricultural exemption status is given to operations composting primarily agricultural waste generated on or nearby the site. NPDES permits allow wastewater treatment plants to discharge clean water into surface waters and an amendment to this permit is needed to begin onsite processing of biosolids. Permit by Rule is a unique permit that is done on a case-by-case basis for all types of operations except those composting biosolids. RMPF permits are not common but for sites that have it, they must show that for all material received on site there is a 40% reduction in total volume, either from biological or physical processing, after a period of 90 days. SWHF permits normally pertain to landfills and is required for biosolids and some large-scale composters who handle materials such as MSW and large quantities of foodwaste. Verbal agreement and written permission between the composter and the state are used on a case-by-case basis usually for very small operations or demonstration projects. Facilities that compost yardwaste are exempt from state regulations under a yardwaste exemption.

Table 6 shows the number of facilities categorized by permit type along with the amount of compost processed. Fifteen of the sites were permitted under either agricultural or yardwaste exemption status. Verbal/written permission and Other type permits were used at five operations. Permit by Rule was used with nine facilities. Permit by Rule was most often used at institutions. RMPF permit was only used at one site. Four municipal and one private operation had an amendment to their NPDES permit. Only three operations; two municipal, and one private had the SWHF permit. In Table 7 are shown the facilities classified according to their size along with their permit data.

**Compost Quality and Markets**

Characteristics of product 1) contaminants, 2) odor, 3) heat process, 4) moisture and 5) screening were chosen to evaluate the finished compost. A quality score on a scale of one to five (one is the lowest and five the highest) was given to each characteristic. Each operation was given a compost quality score by totaling individual quality scores. The highest score attainable is 25. Contaminants included plastics, glass, metals, and large inert materials that decrease the aesthetic quality of the compost. Odor was based on the absence of original material scent and how much it smelled like “good soil”. The heat process was judged by touch and the operator’s record of attained temperatures. The squeeze test, a common subjective test that is conducted by squeezing a handful of compost, was used to approximate the moisture content of the compost and points were counted off for being either too moist or too dry. The screening test focused on the large (greater than one to two inches) objects left behind after screening or if the operation screened at all. Table 8 describes the standards used to determine the compost quality scores. To maintain consistency, the authors scored all composts instead of relying upon survey participants to judge their own compost.

Table 9 presents the finding from the compost quality section of the survey. No facility's compost scored below 12 and none scored a perfect 25. The scores were divided into four ranges: 10-13, 14-17, 18-21 and 22-25. The table shows the number of institutional, municipal and private facilities in each range. Only one operation, a municipality, scored in the lowest category. Each type of operation was equally represented in range between 14-17. Private composting operations predominantly comprised those facilities in the highest two ranges, making up 50%, in both of the 18-21 and 22-25 ranges. Institutions ranked second in both upper ranges. There was a distinct inverse relationship between the number of municipalities in a particular range and the level of quality.

Compost samples from the majority of facilities were taken and analyzed for moisture, volatile solids, pH, soluble salts, nutrients and some heavy metals. To protect the anonymity of the individual facilities, basic statistical analysis was performed on the lab data and presented in Appendix B grouped into private, institutional and municipal operations. Average compost pH was consistent between 6.4 to 6.9 regardless of the type of operation from which it was derived. The soluble salts were lowest at the institutional facilities that composted food waste and highest among the private composters, especially those that composted chicken manures. The finished compost C:N ratio was generally lower at the institutional facilities composting foodwaste because of the relatively short composting cycles and the limitation of carbon feedstocks in the initial recipes.

The final market or end use of finished compost was either sold, given away or used internally (Table 10). Institutions used all of their compost generated internally on their own property. Municipal operations varied, using it internally, providing it free to the public, or selling it both by the cubic yard or by the ton. Private sites predominantly sold their compost by the cubic yard, although it was used internally and even given away free at two sites. The two private operations that gave their compost away for free were under contract by cities to provide this service for residence. Of the 11 operations that sold compost by the cubic yard, four bag the majority of their compost.

**Georgia vs. California**

The results of this survey were compared to Cotton's (2001) assessment of California's composting infrastructure. Table 11 displays the comparison of the two studies. According to the US Census Bureau's (2001) population estimates as of July 1, 2001, Georgia's 38 facilities composts approximately 132 lbs/person-yr as compared to California's 104 facilities composting 197 lbs/person-yr. Georgia primarily uses smaller sized facilities averaging 14,568 tons/facility-yr as opposed to California's facility average of 32,759 tons/facility-yr. One attribute of both state's composting facilities is the fact that on average, the overall throughput can be doubled before reaching maximum capacity at present conditions. There are many reasons that can attribute to this excess capacity of which are management practices, design considerations, feedstock logistics or permit limiting capacities.

***Conclusions***

The overall goal of this study was to provide a detailed analysis of Georgia's composting infrastructure. The level of response to this study was very positive with only three small facilities not participating. It was apparent that there is a significant amount of work still needed in educating the operators at many of the sites. This includes both the mulching and composting operators. The lack of education is most prevalent among the institutional and municipal operations. Many times the composting operation is simply an added responsibility for an employee who often receives little or no training in the correct management of compost. This seemed to result in lower quality finished compost and more operational problems. This trend was apparent in the results presented in Table 9. The economic motivator for private operators was readily apparent in the way they manage both the operational and the marketing of the business.

Another major concern of the composting industry stems from the logistical problems associated with feedstock acquisition in relationship to site location. Obtaining economically available land that can be developed for composting in a logistically feasible proximity to high waste producing areas is very difficult and often economically impossible. While at other times, public opposition and lack of knowledge on the part of local decision makers are the greatest deterrent to a new composting facility startup. Compost markets are also a limiting factor for operations. One of the reasons stated by operators for not expanding throughput capacity or including new feedstocks was the regulatory concern of obtaining more permits. The fear of being required to obtain a solid waste-handling permit restricted many operators, mainly the private ones, from exploring many new opportunities in waste management. Present operational throughput capacity at these facilities could easily be doubled, allowing for over 500,000 tons more waste to be recycled through composting rather than going to another type of waste disposal, which is most often landfilling. This would go a long way toward achieving the 25% waste reduction goal Georgia is trying to attain.

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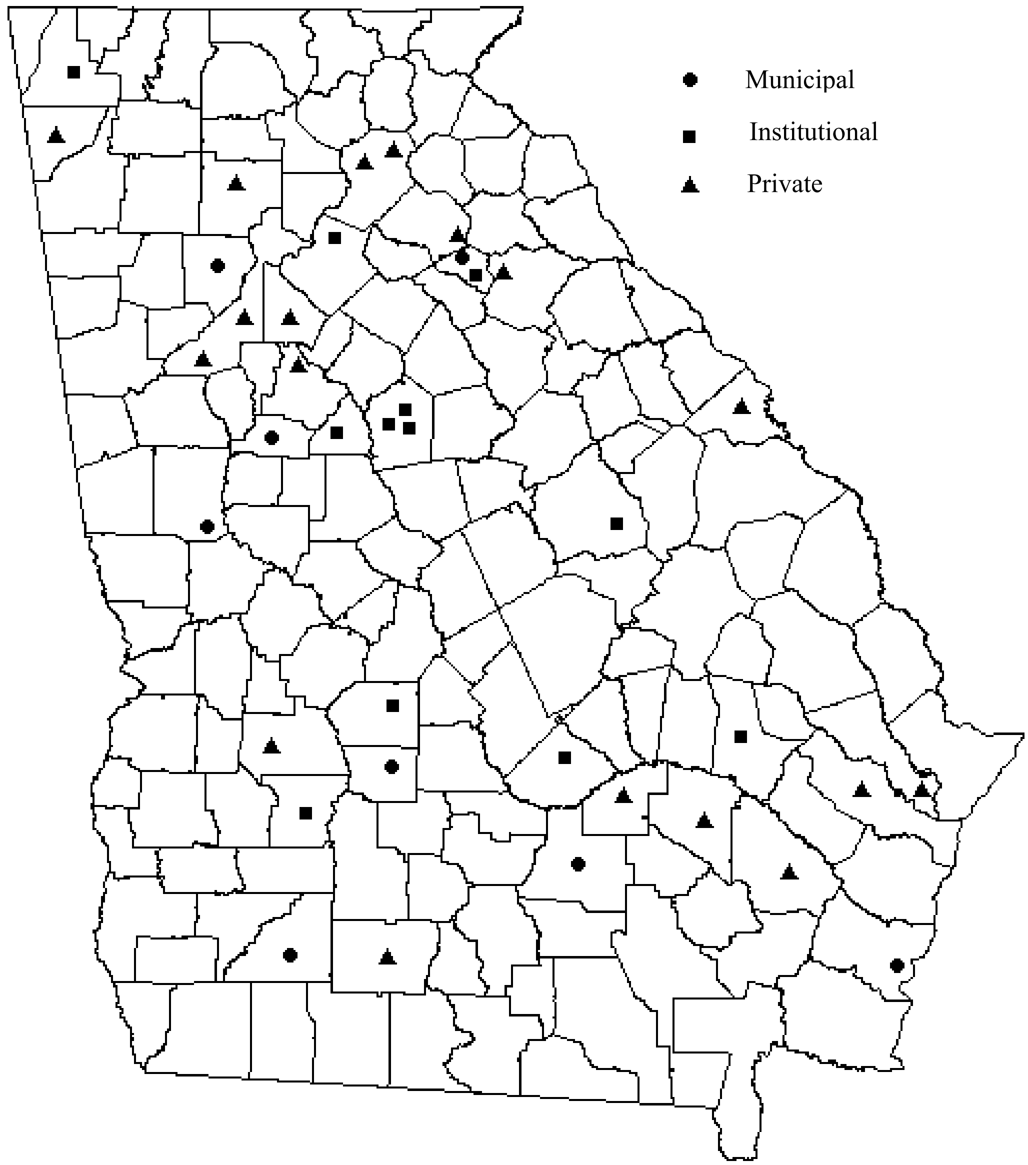


Figure 1. Location of 38 Georgia composting facilities, which participated in the survey, represented as municipal, institutional and private operations.

Table 1. Amount of compost processed and stockpiled at 38 Georgia composting facilities.

| Type of facility | No. of facilities | % of total facilities | Processed (tons/yr) | % of total processed | Stockpiled (yds) | % of total stockpiled |
|---|---|---|---|---|---|---|
| Institutional | 12 | 31.6 | 14,206 | 2.6 | 10,140 | 2.3 |
| Municipal | 8 | 21.1 | 134,540 | 24.3 | 87,000 | 19.8 |
| Private | 18 | 47.4 | 404,854 | 73.1 | 343,021 | 77.9 (3.3)[1] |
| | 38 | | 553,600 | | 440,161 | |

[1] One private facility accounts for 74.6% of the total stockpiled in Georgia. The percent of total stockpiled without the one private facility is 3.3%.

Table 2. Types of feedstocks used by composting facilities in Georgia.

| Feedstock type | No. of facilities | % of total facilities | Processed (tons/yr) | % of total processed | Stockpiled (yds) | % of total stockpiled |
|---|---|---|---|---|---|---|
| Ag waste | 2 | 5.3 | 35,780 | 6.5 | 0 | 0.0 |
| Animal | 6 | 15.8 | 84,820 | 15.3 | 4,110 | 0.9 |
| Biosolids | 5 | 13.2 | 158,684 | 28.7 | 51,000 | 11.6 (0.2)[1] |
| Foodwaste | 13 | 34.2 | 28,206 | 5.1 | 10,290 | 2.3 |
| Industrial | 4 | 10.5 | 196,350 | 35.5 | 354,671 | 80.6 |
| Yardwaste | 8 | 21.1 | 49,760 | 9.0 | 20,090 | 4.6 |
| | 38 | | 553,600 | | 440,161 | |

[1] One municipal biosolids facility accounts for 11.4% of the total stockpiled in Georgia. The percent of total stockpiled without the one municipal biosolids facility is 0.2%.

Table 3. Origins of feedstocks by type of compost facility in Georgia.

| Type of facility | City/County | Onsite[1] | Industrial/ Commercial | Other[2] |
|---|---|---|---|---|
| Institutional | 0 | 12 | 0 | 0 |
| Municipal | 7 | 0 | 1 | 0 |
| Private | 4 | 7 | 5 | 2 |
| | 11 | 19 | 6 | 2 |

[1] Onsite means materials were received from within their own operation
[2] Other means materials were received from sources other than municipal, industrial or onsite

Table 4. Composting facilities in Georgia by type and feedstock.

| Type of facility/waste | No. of facilities | % of type facility | Processed (tons/yr) | % of type processed | Stockpiled (yds) | % of type stockpiled |
|---|---|---|---|---|---|---|
| Institutional | | | | | | |
| Yardwaste | 1 | 8.3 | 1,300 | 9.2 | 0 | 0.0 |
| Foodwaste | 11 | 91.7 | 12,906 | 90.8 | 10,140 | 100 |
| | 12 | | 14,206 | | 10,140 | |
| Municipal | | | | | | |
| Biosolids | 4 | 50.0 | 21,810 | 16.2 | 51,000 | 58.6 |
| Yardwaste | 2 | 25.0 | 1,730 | 1.3 | 10,000 | 11.5 |
| Industrial | 2 | 25.0 | 111,000 | 82.5 | 26,000 | 29.9 |
| | 8 | | 134,540 | | 87,000 | |
| Private | | | | | | |
| Ag waste | 2 | 11.1 | 35,780 | 8.8 | 0 | 0.0 |
| Animal | 6 | 33.3 | 84,820 | 21.0 | 4,110 | 1.2 |
| Biosolids | 1 | 5.6 | 136,874 | 33.8 | 0 | 0.0 |
| Foodwaste | 2 | 11.1 | 15,300 | 3.8 | 150 | 0.0 |
| Industrial | 2 | 11.1 | 85,350 | 21.1 | 328,671 | 95.8 |
| Yardwaste | 5 | 27.8 | 46,730 | 11.5 | 10,090 | 2.9 |
| | 18 | | 404,854 | | 343,021 | |

Table 5. Compost facilities in Georgia by size and feedstock.

| Size of Facility/Size (x 1000 tons/yr) | No. of facilities | % of size facility | Processed (tons/yr) | % of size processed | Stockpiled (yds) | % of size stockpiled |
|---|---|---|---|---|---|---|
| Small (<1) | | | | | | |
| Ag waste | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Animal | 1 | 9.1 | 680 | 15.2 | 350 | 2.9 |
| Biosolids | 1 | 9.1 | 310 | 6.9 | 0 | 0.0 |
| Foodwaste | 5 | 45.5 | 2,135 | 47.6 | 40 | 0.3 |
| Industrial | 1 | 9.1 | 1,000 | 22.3 | 11,000 | 90.3 |
| Yardwaste | 3 | 27.3 | 360 | 8.0 | 790 | 6.5 |
| | 11 | | 4,485 | | 12,180 | |
| Medium (1-10) | | | | | | |
| Ag waste | 1 | 5.9 | 2,300 | 4.2 | 0 | 0.0 |
| Animal | 3 | 17.6 | 21,800 | 39.4 | 960 | 1.3 |
| Biosolids | 2 | 11.8 | 10,200 | 18.5 | 51,000 | 70.7 |
| Foodwaste | 7 | 41.2 | 12,271 | 22.2 | 10,100 | 14.0 |
| Industrial | 1 | 5.9 | 1,300 | 2.4 | 100 | 0.1 |
| Yardwaste | 3 | 17.6 | 7,400 | 13.4 | 10,000 | 13.9 |
| | 17 | | 55,271 | | 72,160 | |
| Large (10-25) | | | | | | |
| Ag waste | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Animal | 1 | 25.0 | 20,000 | 32.7 | 800 | 41.0 |
| Biosolids | 1 | 25.0 | 11,300 | 18.5 | 0 | 0.0 |
| Foodwaste | 1 | 25.0 | 13,800 | 22.6 | 150 | 7.7 |
| Industrial | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Yardwaste | 1 | 25.0 | 16,000 | 26.2 | 1,000 | 51.3 |
| | 4 | | 61,100 | | 1,950 | |
| Very large (>25) | | | | | | |
| Ag waste | 1 | 16.7 | 33,480 | 7.7 | 0 | 0.0 |
| Animal | 1 | 16.7 | 42,340 | 9.8 | 2,000 | 0.6 |
| Biosolids | 1 | 16.7 | 136,874 | 31.6 | 0 | 0.0 |
| Foodwaste | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Industrial | 2 | 33.3 | 194,050 | 44.8 | 343,571 | 97.1 |
| Yardwaste | 1 | 16.7 | 26,000 | 6.0 | 8,300 | 2.3 |
| | 6 | | 432,744 | | 353,871 | |

Table 6. Number and volumes of Georgia composting facilities by permit type.

| Type of Facility | No. of facilities | % of total facilities | Processed (tons/yr) | % of total processed | Stockpiled (yds) | % of total stockpiled |
|---|---|---|---|---|---|---|
| Ag Exempt | 9 | 23.7 | 135,800 | 24.5 | 5,110 | 1.2 |
| EPD Written | 1 | 2.6 | 13,800 | 2.5 | 150 | 0.0 |
| NPDES[1] | 5 | 13.2 | 105,860 | 19.1 | 379,571 | 86.2 |
| Permit by Rule | 9 | 23.7 | 13,621 | 2.5 | 10,140 | 2.3 |
| RMPF[2] | 1 | 2.6 | 2,300 | 0.4 | 0 | 0.0 |
| SWHF[3] | 3 | 7.9 | 247,874 | 44.8 | 26,000 | 5.9 |
| EPD[4] Verbal | 3 | 7.9 | 585 | 0.1 | 0 | 0.0 |
| Yardwaste Exempt | 6 | 15.8 | 32,460 | 5.9 | 19,090 | 4.3 |
| Other | 1 | 2.6 | 1,300 | 0.2 | 100 | 0.0 |
| | 38 | | 553,600 | | 440,161 | |

[1] NPDES stands for National Pollutant Discharge Elimination System.

[2] RMFP stands for Recovered Materials Processing Facility.

[3] SWHF stands for Solid Waste Handling Facility.

[4] EPD stands for Environmental Protection Division (Georgia's regulatory agency)

Table 7. Permit data for compost facilities in Georgia by size class.

| Size/Permit (x 1000 tons/yr) | No. of facilities | % of size facilities | Processed (tons/yr) | % of size processed | Stockpiled (yds) | % of size stockpiled |
|---|---|---|---|---|---|---|
| Small (<1) | | | | | | |
| Ag Exempt | 1 | 9.1 | 680 | 15.2 | 350 | 2.9 |
| NPDES[1] | 1 | 9.1 | 310 | 6.9 | 0 | 0.0 |
| Permit by Rule | 2 | 18.2 | 1,550 | 34.6 | 40 | 0.3 |
| SWHF[2] | 1 | 9.1 | 1,000 | 22.3 | 11,000 | 90.3 |
| EPD[3] Verbal | 3 | 27.3 | 585 | 13.0 | 0 | 0.0 |
| Yard Exempt | 3 | 27.3 | 360 | 8.0 | 790 | 6.5 |
| | 11 | | 4,485 | | 12,180 | |
| Medium (1-10) | | | | | | |
| Ag Exempt | 4 | 23.5 | 23,300 | 42.2 | 960 | 1.3 |
| NPDES | 2 | 11.8 | 10,200 | 18.5 | 51,000 | 70.7 |
| Permit by Rule | 7 | 41.2 | 12,071 | 21.8 | 10,100 | 14.0 |
| RMFP[4] | 1 | 5.9 | 2,300 | 4.2 | 0 | 0.0 |
| Yard Exempt | 2 | 11.8 | 6,100 | 11.0 | 10,000 | 13.9 |
| Other | 1 | 5.9 | 1,300 | 2.4 | 100 | 0.1 |
| | 17 | | 55,271 | | 72,160 | |
| Large (10-25) | | | | | | |
| Ag Exempt | 2 | 50.0 | 36,000 | 58.9 | 1,800 | 92.3 |
| EPD Written | 1 | 25.0 | 13,800 | 22.6 | 150 | 7.7 |
| NPDES | 1 | 25.0 | 11,300 | 18.5 | 0 | 0.0 |
| | 4 | | 61,100 | | 1,950 | |
| Very Large (>25) | | | | | | |
| Ag waste | 2 | 33.3 | 75,820 | 17.5 | 2,000 | 0.6 |
| NPDES | 1 | 16.7 | 84,050 | 19.4 | 328,571 | 92.9 |
| SWHF | 2 | 33.3 | 246,874 | 57.0 | 15,000 | 4.2 |
| Yard Exempt | 1 | 16.7 | 26,000 | 6.0 | 8,300 | 2.3 |
| | 6 | | 432,744 | | 353,871 | |

[1] NPDES stands for National Pollutant Discharge Elimination System.

[2] SWHF stands for Solid Waste Handling Facility.

[3] EPD stands for Environmental Protection Division (Georgia's regulatory agency)

[4] RMFP stands for Recovered Materials Processing Facility.

Table 8. Compost quality scoring criteria

| Quality Score | | | |
|---|---|---|---|
| Characteristics | 1 | 3 | 5 |
| Contaminants[1] | Large foreign objects/ visually obvious/ aesthetically offensive | Minimum amount of foreign objects | No apparent foreign objects |
| Odor | Strong odor of original feedstocks | Mild odor of original feedstocks | No apparent original feedstock odor/ smells like soil or dirt |
| Heat Process[2] | "Finished" compost is warm/hot to the touch | Low heat in compost process/ short time maintained | Extended heat process / 503 regulations followed |
| Moisture[3] | Won't clump/bleeds excess water/too wet or too dry | [4]Reference | Retains good clump during test |
| Screening | Not screened at all/large particle size/unfinished composted feedstocks/ large foreign objects | Minimum amount of foreign objects and large particle sizes | Consistent particle size for specific market |

[1] Performed by visual inspection
[2] Inspected operators records and felt/touched the finished compost
[3] A squeeze test was used to help determine on-site moisture content
[4] The quality score fell within the extreme parameters

Table 9. Number of facilities in each quality range for composting facilities in Georgia.

| | Compost quality range[1] | | | |
|---|---|---|---|---|
| Type of facility | 10-13 | 14-17 | 18-21 | 22-25 |
| Institutional | 0 | 1 | 5 | 6 |
| Municipal | 1 | 1 | 4 | 2 |
| Private | 0 | 1 | 9 | 8 |

[1] Quality judged on scale (1-lowest, 5-highest) for contaminants, odor, heat process, moisture, and screening. Highest score is 25.

Table 10. Final use of compost for composting facilities in Georgia.

| Type of facility | Internal use only | Free to the public | Sold by the yard[1] | Sold by the ton |
|---|---|---|---|---|
| Institutional | 12 | 0 | 0 | 0 |
| Municipal | 3 | 2 | 2 | 1 |
| Private | 5 | 2[2] | 11 | 0 |
| | 20 | 4 | 13 | 1 |

[1] Four operations that sell by the yard also sell compost in bags
[2] Both of these operations are under contract by municipality to provide compost to public for free

Table 11 Results from Georgia and California compost infrastructure surveys.

| | California | Georgia |
|---|---|---|
| State population | 34,501,130 | 8,383,915 |
| Number of compost facilities | 104 | 38 |
| Materials processed | | |
| (tons/yr) | 3,407,000 | 553,600 |
| (lbs/person-yr) | 197 | 132 |
| Maximum capacity (tons/yr) | 6,100,000 | 1,147,530 |
| Facility Size (tons/day) | | |
| < 50 | 40 | 28 |
| 50 – 100 | 19 | 4 |
| > 200 | 45 | 6 |

# CHAPTER 3

# VALIDATION OF A COMPUTER TOOL FOR COMPOSTING PROCESS DESIGN[1]

[1]Governo, J.D., K.C. Das and S.A. Thompson. To be submitted to Compost Science and Utilization

***Abstract***

Numerous questions accompany the idea of planning and designing new composting operations. Engineers and waste managers often have a difficult time confidently and quickly answering these questions. Interrelated factors such as equipment, land footprint, labor requirements, and feedstock characteristics make historical designs techniques tedious and time consuming. To address this dilemma, an easy to use computer program was developed that can be used to design a windrow composting operation based on current scientific and regulatory recommendations. The program uses critical user inputs such as types of feedstocks and equipment, number of workers and facility location to develop a preliminary design and cost estimate for a composting operation. Many different scenarios can quickly be "run" in order to estimate feasibility. This paper covers validation of the design program, Compost Wizard©, compared to existing windrow composting operations. Results of the validation show that the program predictions matched the actual design with a very high degree of accuracy in sizing and capital costs, and to a lesser degree in operating costs.

***Keywords*****:** Composting, Process design, Computer tool, Cost, Validation

***Introduction***

Composting is a biological process for stabilizing organic waste materials where bacteria and fungi utilize the feedstocks as carbon and energy sources. The product produced by composting is finished compost that is an organic soil conditioner that has been stabilized to a humus like product, that is free of viable human and plant pathogens and plant seeds, that does not attract insects or vectors, that can be handled and stored without nuisance, and that is beneficial to the growth of plants (Haug, 1993). Composting is becoming a popular waste management option because it is environmentally friendly and allows for reuse of natural resources. The number of yardwaste composting operations has risen 280% in the last ten years to over 3,800 facilities nationwide (Goldstein and Madtes, 2000). Many states have implemented 25 to 50% reduction, recycling and/or diversion goals of materials presently going to landfills. As a result of these goals, many small to mid-scale composting businesses have emerged targeting yard trimmings, livestock manure, foodwaste and some industrial organic byproducts.

A properly designed commercial composting operation has seven defined steps; feedstock recovery, feedstock preparation, composting, stabilization, curing, refining and storing (USCC, 1994). Feedstock recovery involves removing the compostable fraction from a mixed waste stream to provide a contamination free feedstock. Feedstock preparation involves processes that initially establish optimum particle size, nutrient balance and moisture content to best facilitate microbial growth and subsequent degradation. Recommended targets include particle sizes of 5 to 25 mm (app. ¼ inch to 1 inch), a C:N ratio of 30 to 45 and a moisture content of 60 to 65% (Haug, 1993). The composting, stabilization and curing are steps where conditions of moisture and aeration are maintained to ensure thermophilic temperatures in the range of 113-149°F. A common method of control is through periodic mixing or "turning" of materials. A process time of between 30 and 180 days is often required but is dependent on the type of feedstock and the level of stability desired in the final product. Stability is achieved when biological activity is minimal and is characterized by low oxygen uptake rates, low biological heat production and minimal odor. Refining of compost involves screening, metals separation and removal of inert and large organic contaminants. The extent of refining and storage is dependent on the final use of the compost and market demands. Each of the seven process steps requires adequate space and equipment that can affect the capacity, efficiency and cost of the operation. When an operation is not designed to meet the process requirements, common problems such as odor, low product quality, high operation costs and capacity limitations can occur.

Composting has many variables that affect both the initial capital expenditure and the cost of operation. The size and throughput capacity, the type and condition of the feedstocks, the location in relation to feedstocks and markets, and the type of equipment and technology used are all contributing factors to the cost. Operating costs for municipal solid waste and yard trimming composting operation range from $32 to $65 per ton and $2 to $3 per ton, respectively (Curtis et al., 1992; Renko et al., 1994). Total costs, including capital and operating, for yard trimming composting range from $8 to $25 per ton but depends on the amount of feedstock preparation, length of composting and the location of the facility (Steuteville, 1996). Some state environmental regulations require composting of certain feedstocks to be performed on an impermeable surface, such as lime stabilized soil, concrete or asphalt. Construction costs for an eight-inch deep lime stabilized pad is approximately $4/sq yard with the majority of the cost in soil manipulation (Sikora and Francis et al., 2000). Asphalt pads suitable for composting with heavy equipment costs can cost approximately $10.50/sq yard, which does not take into account site preparation (Governo, 2002). The cost of a reinforced concrete pad ranges from $22 to $45/sq yard not including site preparation (Sikora et al., 2000; D. Bartles, personal communication, Athens, Georgia, 26 December, 2001).

Because of the wide range of variables that impact the nature of composting, a detailed feasibility study is required to secure an accurate understanding of the needs of a facility. A small change in one design parameter can make a significant difference in the needs of the facility. For this reason, computer software can be very useful for preliminary feasibility studies. There are currently computer programs that help design composting recipes (Pike, 2000; Brodie, 1994) but none of them address other unit operations associated with windrow design. The program COMPOST© is the most comprehensive program available and is used for the design of aerated composting systems (Person and Shayya, 1994). This program uses feedstock characteristics as inputs and provides amendment requirements, finished compost moisture content and aeration requirements as design outputs. COMPOST© does not address turned windrow systems, leachate collection and treatment or the economics of the composting operation.

In order to address the limitations in available computer tools for compost design, a user-friendly computer program for the design of windrow composting operations was developed by adapting common design techniques from various sources. The design program, called the Compost Wizard© (Das et al, 2001), is intended to be used by waste managers, engineers or business entrepreneurs to evaluate the feasibility of windrow composting as a waste management option. The user must input feedstock properties, geographical location, and a multitude of other parameters specific to the conditions. The user can quickly generate multiple design scenarios by varying inputs as the evaluation process progresses. Once the Compost Wizard© has established a preliminary design, the final detailed design can be conducted and/or verified by a professional engineer. Included in this paper is a brief description of the program and it validation against existing composting operations located in the southeastern United States.

***Description of Design Process***

The design process that the Compost Wizard© follows involves fours steps; compost area sizing, runoff collection pond sizing, land treatment system design for captured runoff and economic evaluation. The software program is in Microsoft Excel© spreadsheet format with all sheets linked together for a comprehensive design. Each unit operation of the program utilizes user-inputs and/or previously calculated outputs from other operations for the bases of calculations. Many of the calculations used within the program are rather simple so not all will be described in further detail in the following sections.

**Composting Area Sizing**

The first design choice the user must make is whether the operation will compost as a batch or continuous operation. A batch operation is a facility that will receive material a limited number of times during a single year and the entire composting cycle is most often completed before the next batch of material is received. This type of operation is often used with poultry litter composting because of the house cleaning cycles associated with this type of farming. A continuous system is a facility that will be receiving approximately the same amount of material on a daily basis. An example of continuous flow operation would be a biosolids composting site that receives a consistent tonnage of waste from a wastewater treatment plant day to day. The size required for the compost pad may change dramatically depending upon which system is chosen.

The required land area for composting is calculated by converting feedstock throughput from mass (tons/yr) to volume (yds/yr) using the user defined bulk densities (lb/yrd) of each individual feedstock. The total daily throughput, Y, is calculated by a direct sum of individual feedstock volumes assuming materials are received 250 operating days per year. The predicted compost pad size will be conservative in nature because the sum of volumes was assumed to be additive. In practice, the blending of two materials would actually result in a lesser volume because of void space absorption.

The composting period ($t_c$), anticipated composting volume reduction ($S_c$) and the amount of time for finished product storage ($t_s$) are input by the user. In addition, buffer distance required around the facility, duration and volume reduction for the curing process, and windrow dimensions for composting, curing and storage are also required user inputs. Composting periods for a specific mix of materials are normally based on previous tests, but when this information is not known Table 12 presents some basic guidelines that can be used as estimates.

The dimensions of the windrows, base and height ($B_w \times H_w$) and the spacing between windrows (Sp) are directly dependent on the type of equipment used in the operation. Table 13 presents various sized windrow turning equipment and the corresponding windrow dimensions that each type of equipment can handle. The primary factors that affect windrow turner equipment is cost and capacity. The higher the capacity of the turner, the lower the calculated operator time should be which directly affects the cash flow scenario addressed in the economics module. The windrow length

($L_w$) is specified by the user and is normally based on the maximum straight-run length available at the proposed site. The program calculates the total number of windrows ($N_w$) by dividing the total amount of feedstock on the composting pad by the windrow volume. Windrow volume is calculated using user defined cross sectional dimensions and length. The total amount of feedstock on the compost pad at any one time is determined by $V_c = t_c \times Y \times (1 - 0.5 \times Sc)$, which assumes volume reduction is linear over time. This is a conservative assumption because normally during the composting process the volume reduction is more rapid during the initial stages. The length and width of the compost pad are calculated as $\text{Width} = [Sp \times (N_w + 1)] + [B_w \times N_w]$ and $\text{Length} = [L_w + (2 \times Sp)]$. The curing pad and storage area use similar calculations.

It is a common recommendation to use a wooded buffer around a composting operation as both a visual barrier and for reducing the migration of odors off site. The actual width depends on site-specific characteristics and usually depends on the relative sensitivity of surrounding neighbors.

**Runoff Collection Pond Sizing**

State regulations often require that all surface runoff from a composting site be collected and subsequently treated. Georgia's Environmental Protection Division requires all biosolids or solid waste composting sites to have a collection pond capacity greater that the expected runoff from a 24 hour-25 year rainfall event (GA EPD, 1996). Compost Wizard© designs the collection pond capacity based on the highest monthly rainfall from a 30-year historical weather set. This design criteria provides a design pond volume slightly greater than the required 24 hour-25 year rainfall event.

Only a brief summary of the pond and land treatment design is explained here, so for additional details, see US EPA (1981) and Crites and Tchobanoglous (1998). The retention pond design is based primarily on site-specific weather data for the particular sector of the state. The user selects the region where the proposed operation will be located. The program then references the 30-year historical weather data for that region and bases the design on the maximum monthly precipitation (Mmp) in conjunction with the size of the total composting area (Tca), and any buffer area, calculated in the previous module. This provides an additional factor of safety for the capacity of the pond.

The projected maximum runoff is calculated as $RO = [(Tca) \times (Mmp - (ET \times RF)]$. Where ET, the evapotranspiration rate, is calculated by the Thornthwaite equation (Gray, 1970) using recommended Reduction Factors (RF) of 0.3 for November to March and 0.5 for April to October (Nutter and Overcash, 1999; Gray, 1970). The collection pond is sized to collect the projected runoff, RO. The pond depth and one length at the surface is specified by the user and can be changed to satisfy the dimensions of available land, e.g. increasing depth in order to reduce surface acreage.

**Land Treatment Design**

The land treatment system design was adapted from regulatory guidelines (GA EPD, 1992; US EPA, 1981). Since the collected runoff (RO) is sprayed directly onto the land, the land area required for treatment is controlled by either the hydraulic budget of the soil, i.e. the water infiltration capacity of the soil, or the nitrogen balance of the cover crop that consumes the applied nutrients. The Compost Wizard© requires that the user input the soil hydraulic conductivity value, which can be obtained from the USDA-NRCS soils database. Typical values for Georgia soils range from $1.4 \times 10^{-6}$ to $14 \times 10^{-6}$ m/sec depending on soil type. Using the hydraulic budget calculation, the total land area required for treatment is calculated as [Weekly treatment volume/Maximum allowable hydraulic loading], where the weekly treatment volume is RO/4 and the Maximum allowable hydraulic loading is the lowest value for any month calculated as Maximum hydraulic loading = Percolation – Precipitation + ET. Percolation is the soil's saturated hydraulic conductivity multiplied by a specified safety factor (Nutter and Overcash, 1999) and precipitation is calculated as [Average monthly precipitation + 0.85 × Standard Deviation].

To address nutrient loading, a nitrogen balance on the cover crop in the treatment area is conducted. The user specifies the cover crop and inputs values of total nitrogen and ammonia nitrogen concentrations in the runoff. Typical values for composting range from 20 to 25 and 1 to 2 mg/L, respectively (Nutter and Overcash, 1999; Cabrera, et al., 1998). The nitrogen balance includes inputs to the system from the applied runoff and precipitation, and losses from the system through ammonia volatilization, denitrification and plant uptake. The amount of land base for treatment and the residual nitrate concentration in ground water are the variables in solving the nitrogen balance. The land base required is varied to achieve the user specified residual nitrate concentration (typically 5-10 mg/L). The plant uptake rates are obtained from Plank (1989) while the ammonia volatilization and denitrification parameters are obtained from US EPA (1981). The greater of the two estimated land treatment areas, based on the hydraulic budget method and the nitrogen balance method, is used as required land area needed for treatment.

**Economic Evaluation**

The cost of composting is a function of the number of unit operations, type of equipment, number of employees and total product throughput of the operation. The economic module allows the user to input a wide variety of choices to more closely design the individual operation. Some typical costs and capacities for equipment are provided in Table 13. Information on wages, land costs and construction costs can be obtained from State labor statistics (GA DCA, 2001), national statistics (USDA, 2000), and estimates from local construction engineering firms.

**Capital Costs**

Capital expenses are those costs generally amortized over a specific period of time and normally occur at the beginning of an operation. Capital costs include land purchases, construction of infrastructure and equipment. The program uses the results of previous modules and requires user inputs for land and construction costs. Construction costs include (if applicable) the composting area, the collection pond, the land treatment system and any additional operation specific requirement. Construction costs can be the most difficult to determine because these costs can be very site specific and are based on regulations that vary between states. The types of feedstocks composted very often determine the need for impermeable composting surfaces, i.e. concrete or asphalt. Need for such surfaces are usually the most economically restraining facet of construction.

Equipment choice is very important in the sizing of the compost pad and determining the number of employees, operating costs and capital costs. The Compost Wizard© calculates working hours for four types of composting equipment; windrow turner, loader, screener and material transport. The number of operator hours for windrow turning is calculated from the total amount of material on the pad, the capacity of the chosen type of turner and the number of turns for a given composting cycle. Similar types of calculations are conducted for loaders, screeners and material transport to obtain a total number of equipment working hours. The program provides suggestions to add additional units for each 2000 working hours calculated for a type of equipment.

**Operational Costs**

Operating costs are the reoccurring expenses that are a part of any working operation. These costs include insurance, utilities, supplies, maintenance and salaries. The program breaks operating costs into three subsections; equipment, employees and miscellaneous and allows the user great flexibility with variable inputs.

Equipment costs are a function of fuel consumption, maintenance, insurance and replacement. Fuel costs are calculated using the total power rating of all equipment, a fuel consumption rate of 0.03 gal/hp-hr, total equipment operating hours and the user input for fuel costs in dollars per gallon. Annual maintenance and equipment replacement costs are user-defined percentages of the facility's total equipment cost. The user also defines a percentage of the total capital cost for yearly insurance. Energy, maintenance and insurance estimations are typical calculations used in engineering cost estimation (Peters and Timmerhaus, 1991; J. Sellers, personal communications, Athens, Georgia, 22 January, 2001).

The minimum required number of employees is calculated assuming one employee for every 2,000 person-hours per year operator time (40 hour per week and assuming 50 work weeks per year). The user can specify additional employees for miscellaneous operations such as quality control, laboratory, management, etc. This module allows for input of various employee pay scales and for benefit packages. Miscellaneous costs section allows the user flexibility to include any additional costs that might be specific to a situation i.e. contract work or feedstock purchasing.

**Cash Flow**

The third portion of the economic module calculates a cash flow statement using adjustable inputs on feedstock tipping fees, product bulk sales, interest rate and life of loan. The user can also include a cost avoidance value to account for materials that are diverted from going to the landfill or other disposal options. The cash flow summary provides a detailed breakdown of costs presenting monthly expenses in terms of capital and operating expenses, total monthly revenue, net yearly income and net yearly benefit. The program provides a bottom line cost per ton ($/ton) which is the cost to compost one ton of incoming material into finished compost and can be used as a benchmark for decision making.

***Validation Cases***

The Compost Wizard© was validated by comparing the program outputs to the design and operation of nine existing composting facilities located in the Southeastern U.S. Because not all of the composting operations required collection ponds and land treatment systems, only the applicable portions of the facilities were validated by the computer program. The nine operations were comprised of the following composting facilities; one biosolids, one agricultural waste, two yardwaste, three foodwaste and two animal manures.

A site visit to each facility was conducted to collect data and ask questions to each site operator. Operators were asked to refer to operational records for feedstock throughput volumes and composting/curing time schedules. Measurements of pad size, windrow dimensions and other pertinent information were gathered using industry standard measuring tools. In validating the computer program, feedstock bulk density and quantities, windrow dimensions and time periods were used as the input for the program input. The total land required output from the program was compared to the actual measured land used on site. Table 14 presents the findings for each validation case.

**Biosolids**

The biosolids composting facility is located in southeastern Georgia and processes 45-ton/day. This facility composts 35 and 10 tons/day of yard trimmings and municipal wastewater biosolids, respectively. The total processing time of 45 days is required to achieve the desired level of stability desired for composting and curing. The facility is located adjacent to a wastewater treatment plant and all the runoff from the site can be diverted to the treatment plant, therefore no collection pond or land treatment system is required. The equipment used on site includes two tractors, a windrow turner, a front-end loader, one small dump truck and two side discharge trailers. Two operators run the facility, which was established in 1996 and was funded with a state grant and a low interest loan.

The Compost Wizard© was able to predict accurately the amount of land required and capital cost required for this facility. The program predicted a required land area of 4.3 acres while the site was actually using 4.2 acres, an over prediction of 2.4%. Because land was available on the site, and minimal construction costs were involved, the total capital costs for this facility was predicted to be $225,000, a value 3.2% lower than actual costs incurred. The program predicted an operating costs of $145,427/year, which was 22.7% higher than what the facility reported. Total processing cost was calculated to be $17.04/ton, which was 45.6% higher than what the facility reported. It should be noted that the facility is a county run operation, costs may be underestimated because of revenue sharing between departments.

**Agriculture Waste**

The Agriculture Waste facility composts on-farm residuals and then uses the compost on site to: 1) help increase the water holding capacity of the soil, 2) reduce fertilizer applications and 3) reduce irrigation requirements. This operation composts approximately 134 tons/day of a wide range of feedstocks including peanut hay, cotton gin trash, vegetable waste, yard trimmings and poultry manure. Because of the availability of land, minimizing the size of the facility was not a concern of the owner/operator. Small windrows, 3.5 ft x 9.5 ft x 600 ft long, are used primarily because of the available equipment that is used for building and harvesting windrows. Meticulous care is given to the aesthetics of the site, which carries over into the quality of the finished product. The composting operation is situated on a 50 acre tract of which 35 acres is used for actual composting. The program under predicted by 6.6% the required land needed for composting, determining that 32.7 acres would be required to sufficiently handle the daily throughput.

**Yardwaste One**

Yardwaste One is a composting operation operated by a university that composts five tons of yardwaste and animal manure per day. The total processing time for composting and curing is 150 days. One purpose of this facility was to conduct research with various mixtures of feedstocks. Because of the nature of some research feedstocks, the site's permit requires that all leachate/runoff from the composting pad be captured in a retention pond and treated using either a land treatment system or in a publicly owned wastewater treatment plant (POTW). Because the site is not in close proximity to a POTW, a land treatment system is used for treating captured leachate.

The university designed the composting pad with extra capacity to accommodate the daily input of yardwaste along with space for additional research projects. The inputs from the research projects are not included in the validation calculations. The program predicted the required land area to be 3.0 acres and the treatment pond to be 0.6 acres. The actual sizes of these components are 3.5 and 0.7 acres, respectfully. As a result, the program calculated outputs were 14.3% less than dimensions observed at the site for both the compost pad and retention pond (Table 14).

The surface area of the pond has been enlarged to the present size since the original construction of the site. Because each original unit operation was constructed at the same time, the land treatment system design was based on the original size of the pond. As a result, the program estimated the required size of the land treatment system to be 7.7 acres, while the actual size of the system is 5.0 acres. This overestimated the size of the land treatment system by 54%. Equipment costs were predicted by the program to be $319,450 versus the value of $268,500 reported by the facility.

**Yardwaste Two**

Yardwaste Two is a municipal owned yardwaste composting facility that uses batch processing instead of continual composting. This site composts 4,500 tons/yr for 360 days in windrows that are 13 ft x 25 ft x 300 ft long. A Linkbelt 2800 trackloader is used to turn the materials twice during the composting period. Materials are stockpiled throughout the year and grinded under contract when ready to build new windrows. The screening of the finished compost is performed under contract and is also done only one time per year. The program predicted a required land area of 1.8 acres for composting. This prediction is 12.5% higher than the actual 1.6 acres that is used by this facility. Although a collection pond is not required for yardwaste composting facilities, this site has a 0.5-acre pond to collect runoff. The program also predicted that a 0.5-acre pond is required for this size and type of operation.

**Foodwaste One**

Foodwaste One is located at one of Georgia's state prisons and composts three tons of foodwaste and yardwaste per day. Foodwaste is screened by hand in the kitchen before being brought to the processing site. The total processing time used at this facility is 105 days and there is a 40% reduction in volume. All finished compost is used on-site. Windrow dimensions are approximately 3.5 ft x 10 ft x 250 ft long. A small tractor pulled turner is used for aerating windrows. The computer program predicted a required compost area of 2.8 acres, which was 3.4% lower than actual 2.9 acres which is currently used.

**Foodwaste Two**

Foodwaste Two is located at a state prison and composts 16 tons/day of self-generated foodwaste; another prison's foodwaste and some of the local county schools' foodwaste. All materials are brought to the compost area which is located adjacent to the prison where it is composted for 115 days and cured for an additional 60 days. This operation uses the same equipment as Foodwaste One; therefore windrow dimensions are also the same. The program predicted that a composting area of 6.6 acres was required while the actual size of the compost site is 6.2 acres.

**Foodwaste Three**

Foodwaste Three is also located at a state prison and is similar in size to Foodwaste One. Five tons of foodwaste and woodwaste are processed each day and inmates perform all labor from collection to harvesting. This site has no limitations on the amount of land available and thus has chosen to spread out its windrows with 50 ft of grassed space between each one. Esthetics is important at this site so inmates handpick contaminants from the windrows and grounds on a daily bases. Windrows are composted for 90 days and cured for an additional 90 days before the finished compost is used as a soil conditioner on the prison farm. The actual size of the composting area is 3.3 acres, the program predicted that 3.8 acres was needed.

**Animal Manure One**

Animal Manure One is a small hen manure composting operation located in Northeast Georgia. This operation mixes woodchips and hen manure from high-rise layer houses. The operator processes multiple batches that are approximately 2,300-tons each. A tractor-towed compost turner is used to mix the 4 ft x 8 ft windrows that are 500 ft in length. The growth potential of this site is limited by the surrounding landscape and this facility suffers from limited space. The compost area of this operation is 4.0 acres. The program predicted an area of 4.4 acres is required to adequately compost this amount of material using the available equipment.

### Animal Manure Two

Animal Manure Two is basically a central curing facility for multiple on-farm dairy manure composting operations. The majority of composting and volume reduction takes place at the various sites and the almost finished compost is brought to this centralized composting site for curing. This validation example compared only the area required only for the curing process and does not address primary land requirements needed for composting at each individual farm. A small tractor towed turner is used to aerate the 4 ft x 9 ft windrows once a week for thirty days. The program predicted a required curing area of 2.5 acres, a value 7.4% lower than the actual 2.7 acres currently used at this site.

### *Results and Discussion*

As was previously stated, not all portions of the program were validated against each facility. Since each composting operations had an area where the windrows are located, each facility was validated based on land use. The two yardwaste operations also have leachate collection ponds, but only one uses a land application system for a method of disposal. Table 14 presents all the data for each site with a percent difference between actual and predicted values recorded in furthest right column. Because there is not enough data to statistically determine significance for pond size, land treatment or economics, only the composting area was analyzed in detail. Further examination and validation of the program against facilities with these processes will be conducted in the future.

A statistical paired t-test was performed on the set of data, actual compost pad size versus program output for compost pad size, resulting in a test statistic of 0.5793. Thus, there is no significant difference between the mean areas of the data. To further test this result, a F-test was also conducted. The critical value of this test is 3.4381 with a test statistic of 1.1647, further demonstrating that the variances are equal and a paired T test is the appropriate test statistic. In trying to find the relationship of the predictability of the model, a regression analyses was performed to better illustrate and visualize the reliability of the model to predict real world situations. A statistical regression model for the composting area was developed and was accurately described by a simple linear equation ($R^2 = 0.99$)

$$CA = 0.355 + 0.926X$$

Where CA = composting area (ac) and X = composting area (ac) of case study site. This model was shown to be significant within 99% of the range of data tested. Outside this tested range of data the model will not be as consistent. It should be stated that variation within unit processes are normal, and through the design interrelationship of these processes, an addition of these variances could be expected in subsequent downstream results.

For the yardwaste pond size validations, the program under predicted the required pond size at the Yardwaste One site by a tenth of an acre and predicted the actual pond size of 0.5 acres used at the site for Yardwaste Two. Because even the best engineering estimates often receive backend safety factors to smooth out the unknown, preliminary pond sizing comparisons such as these were encouraging. Only Yardwaste One had a land treatment system that was used periodically to treat captured runoff water. The program over predicted the actual number of acres required by 2.7 acres, an error of 54%. An explanation for this large error can be related back to the under sizing of the original collection pond. Some years after construction, operators learned that the pond's capacity was inadequate and subsequently an expansion was performed to approximately double the pond's holding capacity. The land treatment system was conservatively designed based on the pond's original holding capacity. The data used in the validation program used present pond capacity, thus increasing the size of the needed land treatment system.

Obtaining accurate data for the economics portion of the program is the greatest obstacle for validation. Poor record keeping for public operations and proprietary confidentiality for private ones made acquiring operational data difficult. Yardwaste One was a public university with accurate equipment data, but construction data was believed skewed because much of the labor was performed in-house. The program over predicted by 19% the cost of equipment. The biosolids operation was a publicly run facility that kept accurate records. All data was retrieved from up-to-date accounting records. Results of this comparison matched with a high degree of accuracy the required capital costs, and to a lesser degree the operating and processing costs for this facility. Operating costs and processing cost were over-predicted by 22.7% and 45.6%, respectively.

***Conclusions***

Composting at the commercial level for waste management is a complex process involving many steps. Because of this complexity of variables, cost and essentially feasibility of a proposed project is often not well understood. In order to facilitate quick, accurate assessments of costs, feasibility and initial design of the operation, a spreadsheet based design program called the Compost Wizard© (Das et al., 2001) was developed. The program requests user inputs on scenarios of the proposed operation, based on these inputs a preliminary design was performed. The program uses state and site-specific weather data for the design of the collection pond and land treatment system The process outputs include the amount of land required for composting, curing, storage, and land treatment, size of runoff collection pond and estimated capital and operating costs.

The Compost Wizard© was validated by comparing unit operations of nine existing southeastern composting facilities to the program's predicted output. Because not every facility uses each unit operation that is designed by the program, only applicable portions of the facilities were used in the validation. Very few facilities used retention ponds and/or land treatment systems in their operations, thus limiting the validation of the program for these unit operations. Compost acreage used by the operations when compared to program predicted values provided a statistically relevant R squared value of 99%. Comparisons of actual facility costs and program predicted economic data are encouraging, though more information needs to be obtained from other facilities in order to more closely evaluate the effectiveness of this portion of the Compost Wizard©.

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Table 12. Suggested duration of composting and curing for different feedstocks[1, 2, 3].

| Predominant feedstock | Typical days to achieve stable compost | Source |
|---|---|---|
| Municipal solid wastes | 56-70 | Wei et al. (2000) |
| Wastewater biosolids | 45-120 | Wei et al. (2000); Epstein (1997) |
| Wood wastes | 90 | Riggle (1991) |
| Food wastes | 21-50 | Jones (1992); Gies (1995) |
| Manures | 40-80 | Epstein (1997) |

[1] Values are approximate estimates obtained from the literature.
[2] Typical volumetric shrinkage during composting is 25-50 %. Exceptions are food wastes with higher shrinkage and wood wastes with lower shrinkages.
[3] Recommended curing times range from 4-10 weeks, unless product quality is not a concern.

Table 13. Windrow turning equipment, size, cost and corresponding windrow dimensions (Rynk, 1992).

| Equipment | Cost × 1000, $ | Capacity Tons/hr | Power rating, hp | Windrow dimension Base × Height, ft × ft | Spacing between windrow, ft |
|---|---|---|---|---|---|
| Small tractor loader | 15 | 16 | 40 | Variable | 20 |
| Medium tractor loader | 45 | 48 | 55 | “” | 20 |
| Large front end loader | 130 | 145 | 135 | “” | 20 |
| Tractor PTO turner | 25 | 950 | 90 | 4 X 14 | 10 - 15 |
| FEL mounted turner | 70 | 1,100 | 177 | 5 X 14 | 10 - 15 |
| Medium self propelled | 89 | 1,250 | 160 | 5 X 15 | 3 - 5 |
| Large self propelled | 100 | 2,600 | 325 | 8 X 18 | 3 - 5 |

Table 14. Comparison of data from nine case study facilities versus the calculated output of the design program

| Case Study Description | Unit Operation | Case Study Data from Facility | Design Program Calculated Outputs | % Difference |
|---|---|---|---|---|
| Biosolids | Land Required (ac) | 4.2 | 4.3 | + 2.3 |
| | Capital Costs ($) | 232,887 | 225,500 | - 3.3 |
| | Operating Cost ($) | 118,527 | 145,427 | + 18.5 |
| | Processing Cost ($/ton) | 11.70 | 17.04 | + 31.3 |
| Agriculture Waste | Land Required (ac) | 35.0 | 32.7 | - 7.0 |
| Yardwaste 1 | Land Required (ac) | 3.5 | 3.0 | - 16.7 |
| | Pond Size (ac) | 0.7 | 0.6 | - 16.7 |
| | Land Treatment (ac) | 5.0 | 7.7 | + 35.1 |
| | Equipment Cost ($) | 268,500 | 319,450 | + 15.9 |
| Yardwaste 2 | Land Required (ac) | 1.6 | 1.8 | +11.1 |
| | Pond Size (ac) | 0.5 | 0.5 | 0.0 |
| Foodwaste 1 | Land Required (ac) | 2.9 | 2.8 | - 3.6 |
| Foodwaste 2 | Land Required (ac) | 6.2 | 6.6 | + 6.1 |
| Foodwaste 3 | Land Required (ac) | 3.3 | 3.8 | + 13.2 |
| Animal Manure 1 | Land Required (ac) | 4.0 | 4.4 | + 9.1 |
| Animal Manure 2 | Land Required (ac) | 2.7 | 2.5 | - 8.0 |

# CHAPTER 4

## SUMMARY AND CONCLUSIONS

The overall goal of this study was to provide a detailed analysis of Georgia's composting infrastructure. The level of response to this study was very positive with only three small facilities not participating. It was apparent that there is a significant amount of work still needed in educating the operators at many of these sites. This includes both the mulching and composting operators. The lack of education is most prevalent among the institutional and municipal operations. Many times the composting operation is simply an added responsibility for an employee who often receives little or no training in the correct management of compost. This seemed to result in lower quality finished compost and more operational problems. This trend was apparent in the results presented in Table 9. The economic motivator for private operators was readily apparent in the way they manage both the operational and the marketing of the business.

Another major concern of the composting industry stems from the logistical problems associated with feedstock acquisition in relationship to their site location. Obtaining economically available land that can be developed for composting in a logistically feasible proximity to high waste producing areas is very difficult and often economically impossible. While at other times, public opposition and lack of knowledge on the part of local decision makers are the greatest deterrent to a new composting facility startup. Compost markets are also a limiting factor for operations. One of the reasons stated for not expanding throughput capacity or including new feedstocks was the regulatory concern of obtaining more permits. The fear of being required to obtain a solid waste-handling permit restricted many operators, mainly the private ones, from exploring many new opportunities in waste management. Present operational throughput capacity at these facilities could easily be doubled, allowing for over 500,000 tons more waste to be recycled through composting rather than going to another type of waste disposal, which is most often landfilling. This would go a long way toward achieving the 25% waste reduction goal Georgia is trying to attain.

Composting at the commercial level for waste management is a complex process involving many steps. Because of this complexity of variables, cost and essentially feasibility of a proposed project is often not well understood. In order to facilitate quick, accurate assessments of costs, feasibility and initial design of the operation, a spreadsheet based design program called the Compost Wizard© (Das et al., 2001) was developed. The program requests user inputs on scenarios of the proposed operation. Based on these inputs a preliminary design was performed. The program uses state and site-specific weather data for the design of the collection pond and land treatment system The process outputs include the amount of land required for composting, curing, storage, and land treatment, size of runoff collection pond and estimated capital and operating costs.

The Compost Wizard© was validated by comparing compost pad dimensions of nine existing southeastern composting facilities to the program's predicted output. Because not every facility uses each unit operation that is designed by the program, only applicable portions of the facilities were used in the validation. Only two facilities used retention ponds and/or land treatment systems in their operations, thus limiting the validation of the program for these unit operations. Compost acreage used by the operations when compared to program predicted values provided a statistically relevant R squared value of 99%. Comparisons of actual facility costs and program predicted economic data are encouraging, though more information needs to be obtained from other facilities in order to more closely evaluate the effectiveness of this portion of the Compost Wizard©.

**Future Directions**

1. There is a need for further assessments of the compost industry in Georgia. This is a dynamic industry that changes as the environmental situation transforms. The information in this study is simply a snap shot in time of what is happening at the present moment. Further assessments conducted on a continual or yearly basis would provide a real picture of the composting industry.
2. There is a need to acquire more existing compost facility data to further validate the design program's unit operations for collection ponds, land treatment systems and economic evaluations.
3. The Compost Wizard© is available for use in many states and as such, there is a need to acquire data from compost facilities in other states to validate the weather portions of the program.
4. There is a need to extend the capacity of the program to integrate recipe development into the design process as well as to include an integrated database of design values and scenarios to assist in the evaluation process.

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# APPENDICES

## APPENDIX A: GEORGIA COMPOST INFRASTRUCTURE SURVEY

The following survey was used to conduct an assessment of Georgia's composting facilities. The survey was not mailed out to the companies but rather filled out in person during a site visit conducted by the Authors.

# Georgia Compost Infrastructure Survey

**Section 1**

**Facility Name:** ____________________ **Type:** ____________

**Address:** ____________________

**City/Zip:** ____________________ **County:** ____________

**Contact:** ____________________ **Permit:** ____________

**Phone:** ____________________

**GPS Coordinates:** ______ **N** ______ **W**

**Section 2**

| **Feedstocks:** | (Tons/yr) | Feedstock Origin |
|---|---|---|
| 1) | | |
| 2) | | |
| 3) | | |
| 4) | | |
| 5) | | |
| Annual Throughput: | | |

**Finished Compost:** ____________ Bulk Density (lbs/yd) ____________ Current Stock (cu yd)

**Section 3**

**Compost Quality:**

| | | | |
|---|---|---|---|
| Contaminants: | | (5 -1) | 5 = highest 1= lowest |
| Odor: | | (5 -1) | |
| Heat Process: | | (5 -1) | |
| Moisture/Squeeze: | | (5 -1) | |
| Screened: | | (5 -1) | |
| **Total Score:** | | 25 MAX | |

**Section 4**

**Compost Sales:** ____________ ($/ton) ($/yd) Free Internal Use Other

**Section 5**

**Equipment:**

| Owned | Contracted |
|---|---|
| 1) | 1) |
| 2) | 2) |
| 3) | 3) |
| 4) | 4) |
| 5) | 5) |
| 6) | 6) |

**Section 6**

**Max Throughput Capacity:** ____________ (ton/yr) or (cu yd/yr)

**General Appearance:** ____________

**Site Odor:** ____________

Other Potential Feedstocks/Comments

____________________

____________________

____________________

____________________

____________________

____________________

____________________

**Batch/Continuous:** ____________ **Windrows/Static Pile/In Vessel:** ____________

# APPENDIX B: LAB ANALYSES FOR INFRASTRUCTURE SURVEY COMPOST SAMPLES

The following tables present the analysis conducted on compost samples obtained from many of the facilities represented in the survey. The information is organized into institutional, private and municipal to protect the anonymity of individual facilities.

Table 15. Georgia infrastructure survey compost samples lab results

| Facility | Stats | Moist (%) | V.S. (%) | pH | SS (mmhos) | C:N | TKN (%) | P (%) | K (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| Total | Avg | 34 | 26 | 6.6 | 4.4 | 23 | 0.9 | 0.31 | 0.42 |
| | St.D | 12 | 12 | 1.1 | 5.4 | 7.5 | 0.7 | 0.41 | 0.64 |
| | Min | 7 | 0 | 5.9 | 0.1 | 8 | 0.2 | 0.01 | 0.01 |
| | Max | 68 | 51 | 8.6 | 25.2 | 147 | 3.6 | 1.89 | 3.45 |
| | n | 34 | 24 | 34 | 33 | 34 | 34 | 34 | 34 |
| Institution | Avg | 31 | 29 | 6.4 | 2.9 | 19 | 1.0 | 0.12 | 0.23 |
| | St.D | 15 | 30 | 1.0 | 0.4 | 20 | 0.5 | 0.02 | 0.05 |
| | Min | 7 | 0 | 5.0 | 0.1 | 8 | 0.4 | 0.03 | 0.08 |
| | Max | 46 | 51 | 7.8 | 7.5 | 36 | 3.6 | 0.25 | 0.52 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Private | Avg | 34 | 23 | 6.9 | 5.8 | 27 | 0.9 | 0.40 | 0.55 |
| | St.D | 13 | 9 | 1.1 | 7.2 | 33 | 0.8 | 0.54 | 0.82 |
| | Min | 15 | 16 | 4.9 | 0.7 | 9 | 0.2 | 0.01 | 0.02 |
| | Max | 68 | 40 | 8.6 | 25.2 | 147 | 3.4 | 1.89 | 3.45 |
| | n | 17 | 8 | 17 | 16 | 17 | 17 | 17 | 17 |
| Municipal | Avg | 36 | 25 | 6.4 | 3.5 | 22 | 0.8 | 0.31 | 0.36 |
| | St.D | 8 | 10 | 1.4 | 3.3 | 11 | 0.3 | 0.31 | 0.56 |
| | Min | 25 | 18 | 5.0 | 0.1 | 9 | 0.6 | 0.07 | 0.06 |
| | Max | 45 | 45 | 8.4 | 9.9 | 42 | 1.2 | 0.66 | 1.63 |
| | n | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 7 |

Table 16. Georgia infrastructure survey compost samples metals lab results

| Facility | Stats | Al (ppm) | Cd (ppm) | Cr (ppm) | Cu (ppm) | Mg (ppm) | Mo (ppm) | Ni (ppm) | Pb (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| Part 503 Limits[1] | | | 39 | 1,200 | 1,500 | | 18 | 420 | 300 | 2,800 |
| Total | Avg | 9,688 | 2.2 | 14.9 | 68.1 | 1,670 | 1.1 | 11.7 | 11.2 | 292 |
| | St.D | 7,041 | 2.0 | 22.9 | 153 | 1,553 | 1.0 | 22 | 21.6 | 1,079 |
| | Min | 1,219 | 0.2 | 0.5 | 0.5 | 120 | 0.5 | 1.0 | 2.5 | 4.3 |
| | Max | 25,490 | 7.9 | 137 | 677 | 6,869 | 3.9 | 123 | 118 | 6,365 |
| | n | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| Institution | Avg | 10,708 | 2.6 | 8.9 | 9.8 | 845 | 0.6 | 7.1 | 2.5 | 36 |
| | St.D | 1,110 | 3.3 | 10.7 | 13 | 144 | 0 | 16.3 | 0 | 4.7 |
| | Min | 2,130 | 0.5 | 1.8 | 0.5 | 280 | 0.5 | 1.0 | 2.5 | 11.3 |
| | Max | 25,390 | 7.9 | 25.3 | 29.2 | 1,880 | 1.1 | 31.6 | 2.5 | 53.8 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Private | Avg | 8,539 | 1.6 | 10.8 | 109 | 2,239 | 1.4 | 8.3 | 13 | 485 |
| | St.D | 6,406 | 1.4 | 7 | 209 | 1,956 | 1.2 | 11 | 12.8 | 1,520 |
| | Min | 1,219 | 0.2 | 0.5 | 0.5 | 120 | 0.5 | 1.0 | 2.5 | 4.3 |
| | Max | 25,490 | 5.2 | 23.8 | 677 | 6,869 | 3.9 | 42.6 | 40.2 | 6,365 |
| | n | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| Municipal | Avg | 11,020 | 2.9 | 33.6 | 51.7 | 1,467 | 1.2 | 26.8 | 19.1 | 187 |
| | St.D | 8,012 | 1.8 | 46.6 | 41.1 | 774.5 | 1.0 | 43.2 | 43.8 | 133 |
| | Min | 4,577 | 0.8 | 4.2 | 6.9 | 495 | 0.5 | 2.9 | 2.5 | 50.2 |
| | Max | 24,770 | 4.9 | 136 | 106 | 2,945 | 2.7 | 123 | 118 | 372 |
| | n | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

[1] (EPA 1994) Heavy metals limits set forth by EPA in the regulations for biosolids utilization.

# APPENDIX C: COMPOST WIZARD© DESIGN MANUAL

The Compost Wizard© Design Manual is provided as a basic guide to understanding the inputs and parameters that the program used to determine the preliminary design of a windrow composting system.

# Compost Wizard Design Manual

**Table of Contents**

## Tables



## Figures

**User Agreement**

1. The End-user agrees that neither the System nor any of its components shall be used as the basis of a commercial product, and that it shall not be re-written in another computer language or otherwise adapted to circumvent the need for obtaining additional license rights.
2. Use of the System for any purpose other than that specified in this Agreement requires prior approval in writing from the Compost Wizard and/or The University of Georgia.
3. The license granted hereunder and the licensed System may not be assigned, sub-licensed, or otherwise transferred by the End-user. The End-user shall take reasonable precautions to ensure that neither the System nor its components are copied, transferred, or disclosed to parties other than the End-user.
4. Nothing in this agreement shall be construed as conferring rights to use in advertising, publicity, or otherwise any trademark or the names of the System, Compost Wizard, or the University of Georgia.

# Compost Wizard© Design Manual

## Introduction

Compost Wizard, a user-friendly computer program, was developed to address compost facility design questions that face waste management planners and engineers. These questions include how much land, equipment, labor, and investment is required for a proposed windrow composting operation. The numerous factors that impact process design and costs make it tedious to determine these assessments quickly.

This program uses critical user-inputs such as types of feedstocks, types of equipment, number of workers and location of the facility, to help size and develop a preliminary design for a windrow compost facility. Compost Wizard© also provides a detailed economic evaluation useful in the decision making process.

By using the Compost Wizard©, an array of design scenarios can be generated quickly, by varying the user inputs, which will help determine the feasibility and appropriateness of different composting alternatives. Once the Compost Wizard© has established a preliminary design, the final detailed design can be conducted or verified by a professional engineer.

## Special Requirements

This program was developed on Microsoft Excel 2000 and works most effectively using this version. In order to use all the features of the Compost Wizard©, the Solver Add-In must be installed. If this Add-In was not previously installed when Excel was installed, your original Office 2000 CD will be required.

### *How to Install Solver Add-In*

With the Office CD in the drive, open Microsoft Excel. From the Tools menu bar, click on the Add-Ins button (Figure 1). The Add-Ins box will appear (Figure 2). Scroll down and click on the Solver Add-In. Click Ok. Close and restart Excel to insure proper installation. It is important that the Solver Add-In is installed because a portion of the land treatment design page is dependent on using this Add-In.

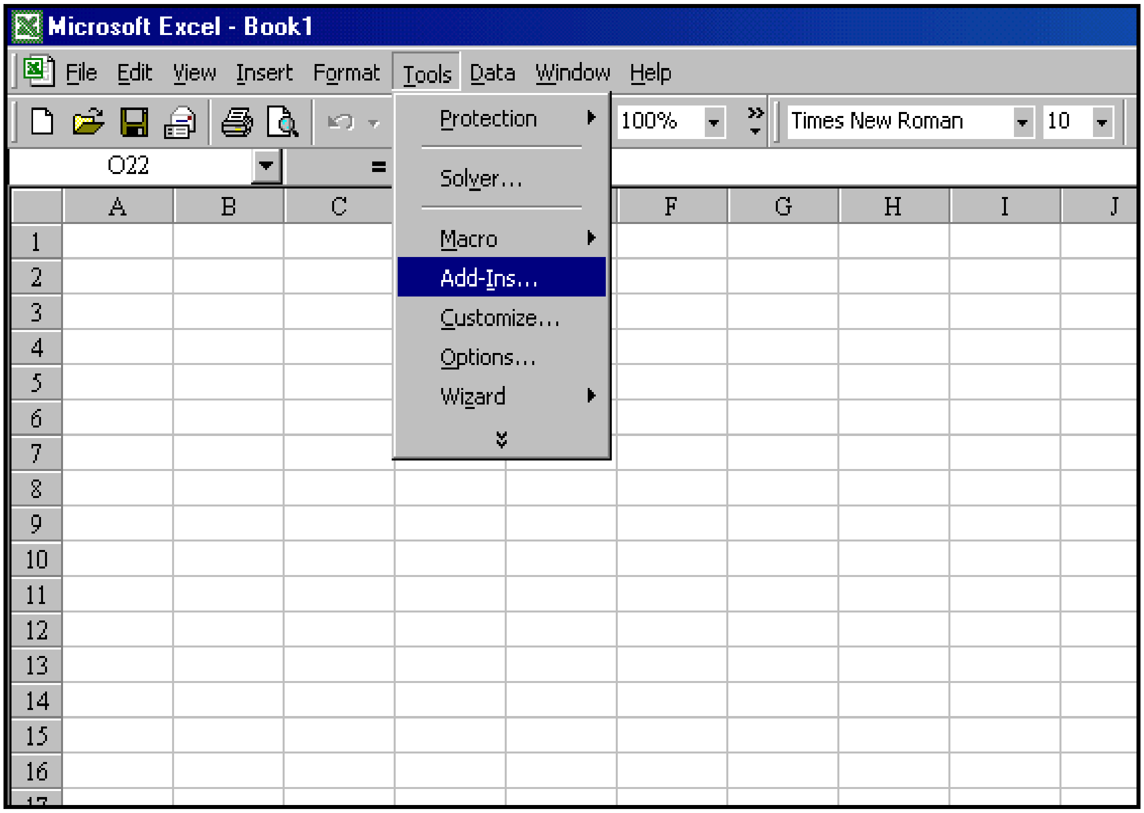


Figure 1. Tools menu bar

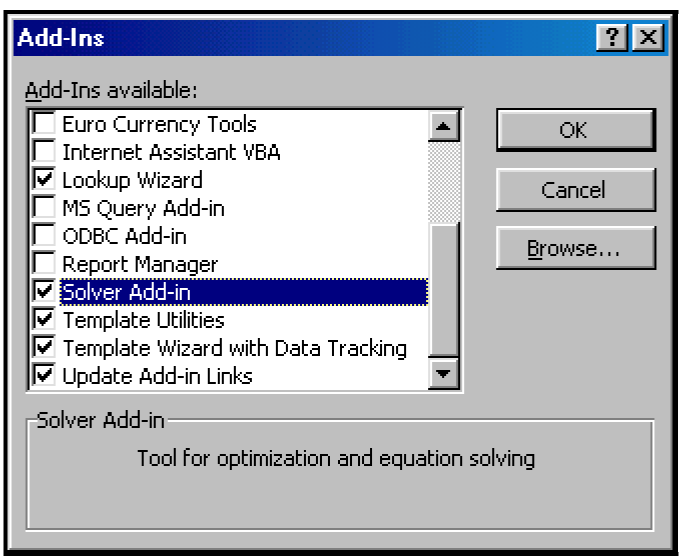


Figure 2. The Add-Ins box

**General Instructions**

The following sections are provided as a basic guide to understanding the inputs and parameters that the Compost Wizard© uses to determine the design of a windrow composting system. A theoretical example based on a municipality run biosolids composting operation is presented in various figures throughout the manual to illustrate important points for each section of the program. Figures show the choices made for each step in the design of this composting operation and are presented simply for demonstration purposes and should not be blindly followed when designing a new operation.

Compost Wizard© has four design modules: Compost Pad, Retention Pond, Land Treatment System, and Economics. You can choose which module you wish to design. If you do not require a particular module in your design, you can simply not answer the questions about that section.

Compost Wizard© uses a series of design questions to determine user inputs specific to your design. Where applicable, you can type information directly into the GREEN boxes found throughout the program. Throughout the program, BLUE boxes can be found which have drop down lists containing data choices. To use the drop down lists, move your mouse over the blue box and a small downward arrow will appear to the right of the blue box. Click on this arrow and a drop down list appears. Scroll down and click on the desired value. In many of the blue boxes (especially on the economics page), the first value in the list can be used as the default input value. This value can be used when you are not sure of what to choose.

Throughout this program, BLACK font is used to indicate input values that were provided by the user. These values were either directly typed in the green boxes or chosen from the blue box drop down lists. A RED font indicates calculated answers. See Table 1.

Table 12. Color representation

| Colors | What they represent |
|---|---|
| Green boxes | Input areas which contain user inputs that were typed directly into the box |
| Blue boxes | Input areas that were chosen from drop down lists contained within the box |
| Black font | Input values that were either directly typed into green boxes or chosen from the drop down lists contained in the blue boxes |
| Red font | Calculated answers |
| Red triangles in cells | Represent cells that have default values as the first number in the drop down list |

Throughout the program, you can access instructions and advice by checking the small blue squares located conveniently near common points of question. If the instructions that appear when the blue square is checked is not sufficient, please refer to this manual for clarification. "Important" answers throughout the program are contained within a thick black box.

**How to begin**

The Compost Wizard© file is in Excel Template form. A template is basically the starting point for the program. Each time Excel opens this template file, the original information will be there. It is important that each time you open the file, you save it as an Excel Workbook file. (Example: Design 1.xls) If you fail to save the file under a different name, you may experience problems reopening the file using the installed shortcuts.

When Compost Wizard© is opened, the start or home screen appears first (Figure 3). Click on the blue word START in the lower right hand portion of the screen. The program will automatically go to the Compost Pad design page. To begin the design process, follow the onscreen instructions starting in Section 1.

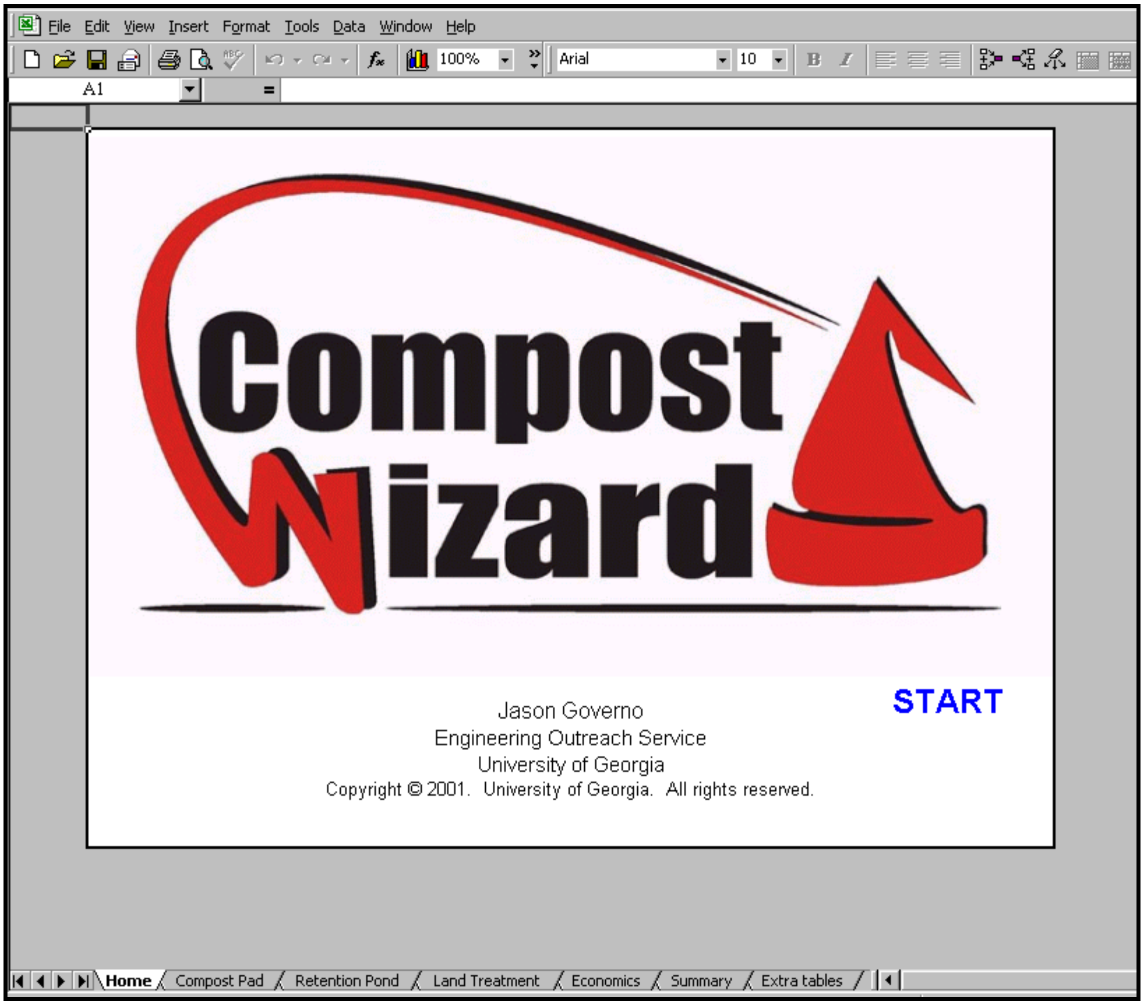


Figure 3. Home page

To advance to the next page, simply click on the blue message located in the lower right hand corner of each design page or click on the appropriate tab at the bottom of the screen.

After you have completed each design module, a summary page containing the pertinent information from each previous section is shown. This page can be printed and used for comparison purposes for different designs.

*Module 1. Compost Pad*

The composting pad is the heart of a windrow composting facility. Ensuring the proper size to adequately handle throughput is important to a facility's performance efficiency.

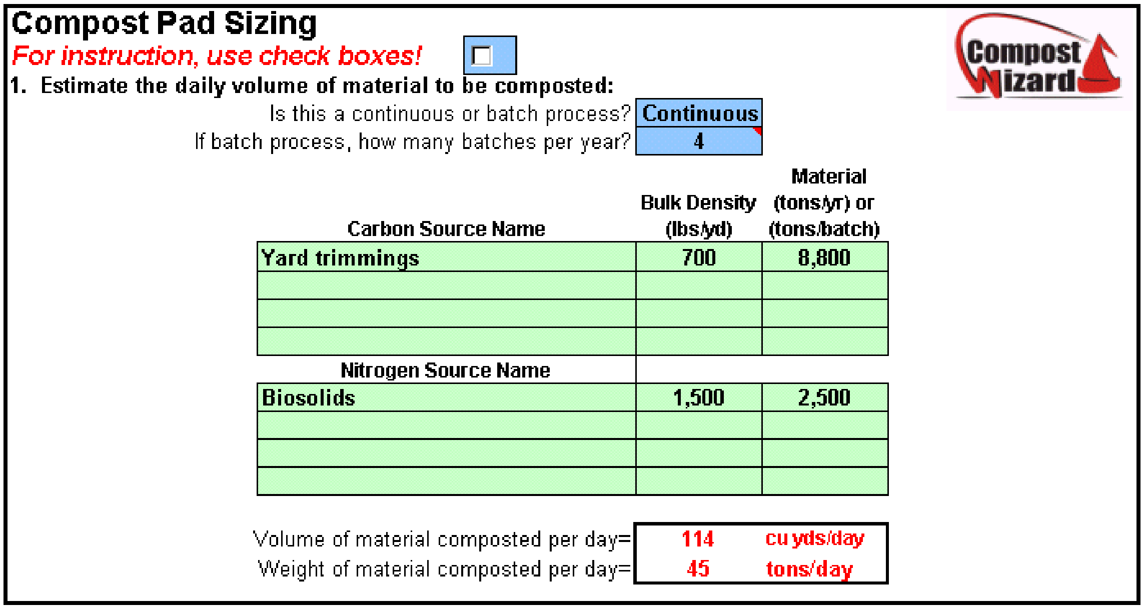


Figure 4. Compost pad sizing

**Section 1. Estimate daily volume of material**

**Continuous or Batch?**

The first decision that you need to make is whether the compost facility will be a continuous or batch type operation (See Figure 4).

<u>A continuous operation</u> is loosely defined as a facility that will be receiving approximately the same amount of material on a daily basis.

<u>A batch operation</u> is defined as a facility that will receive material once every so often. An example of a batch operation would be that of a broiler chicken producer who cleans out his houses and compost his chicken litter. For that operation, a new quantity of compostable materials would be available only after a clean out operation. This would occur only every 6, 12, 18, etc. weeks. For example, for a composting period of 40 days, the maximum number of batches per year that can be composted is 9.

For a batch operation, the maximum number of batches that can be composted per year is the default value (first number) listed in the drop down list in the blue box located below the continuous/batch selection box. This value is based on the length of the compost period (the first user input in Section 2). If this value is changed significantly, the default value in the maximum number of batches will also change.

**Carbon and Nitrogen Sources**

The Compost pad design requires you to enter all feedstocks, feedstock bulk densities and the yearly tonnage of each feedstock.

Carbon sources are those feedstocks that have a high carbon content. Examples of such feedstocks include, but are not limited to, most wood products, leaves, yard trash and municipal solid waste (MSW).

Nitrogen sources are those feedstocks that have predominantly higher nitrogen content. Examples of such feedstocks include but are not limited to most manures, grass clippings, and food waste. Compost Wizard© does not use the difference in the types of material in any of the calculations but it is convenient to keep the material separated for clarity reasons.

Bulk density (lb/cu yard) is the amount of weight materials have per unit volume. It is important to assume a close value for the bulk density because it is a significant factor in pad sizing. You must type the value for each feedstock's bulk density into the corresponding bulk density green box. Table 2 shows bulk densities for common feedstocks used in composting. If a material to be composted is different then those provided in Table 2, choose a feedstock from the table that has similar physical properties and use that bulk density.

If the material is not found in Table 2, there is a simple process that can be used to determine the bulk density of the material. The bulk density can be determined by filling a five-gallon bucket with the feedstock. The bulk density is equal to the weight of a filled five-gallon bucket minus the empty bucket weight divided by the volume (5 gallons) times a conversion factor (0.0049).

$$\text{Bulk Density (lbs/cu yrd)} = \frac{\text{(Filled bucket (lbs)) - (Empty bucket (lbs))}}{\text{5 (gallons) X (0.0049)}}$$

The bulk density plays a significant factor in the sizing of the compost pad, therefore these values must be estimated as close as possible to the real value. For each feedstock, the bulk density must be input into the appropriate green input box.

Table 13. Common bulk densities for feedstocks

| Carbon Feedstocks | Bulk Density (lb/cu yd) | Nitrogen Feedstocks | Bulk Density (lb/cu yd) |
|---|---|---|---|
| Bark, hardwood | 900 | Biosolids | 1,500 |
| Bark, softwood | 700 | Chicken litter | 860 |
| Cotton waste | 250 | Cull potatoes | 1,540 |
| Corn cobs | 560 | Cow manure | 1,400 |
| Dry leaves | 260 | Crab waste | 240 |
| Dry sawdust | 430 | Cranberry waste | 1,000 |
| MSW | 430 | Egg shells | 1,400 |
| Paper pulp | 1,400 | Fish waste | 1,200 |
| Peanut hulls | 350 | Grass clippings | 750 |
| Rice hulls | 200 | Horse manure | 1,400 |
| Straw | 225 | Layer manure | 1,480 |
| Wet leaves | 500 | Pig manure | 1,500 |
| Woodchips | 600 | Turkey litter | 780 |
| Yard trimmings | 700 | Vegetable waste | 1,200 |

Tons per year of materials or the tons per batch are required for each feedstock used in the process. It is important that the amount of each feedstock composted per year/batch coincides with your compost recipe which you are planning to use. For example, if the recipe calls for 3:1 ratio of woodchips to manure, then the tons per year should also represent that proportion.

**Section 2. Determine the volume of material on compost pad**

One of the key parameters used in the sizing of the compost pad is the duration or time the feedstocks are required to complete the composting process (Figure 5). Table 3 presents typical range of days required to achieve a stable compost for some common predominant feedstocks. In some cases the range is quite variable. To ensure a conservative design, it is suggested that you choose a value near the upper end of the range (upper 1/3 of the range).

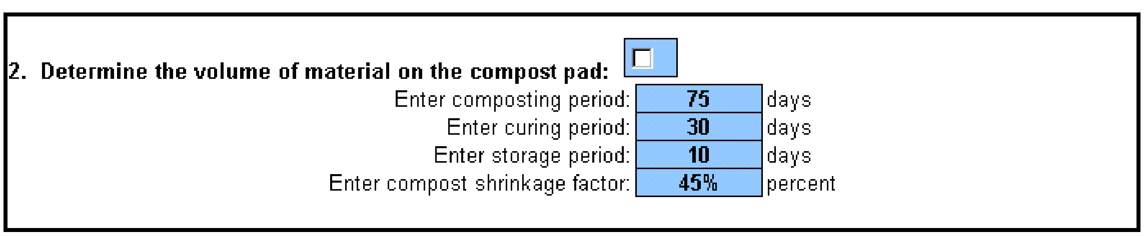


Figure 5. Determine volume of material on the compost pad

Compost period is the length of time the feedstocks are on the compost pad and are going through an active composting process. Table 3 presents values for the estimated composting periods for common feedstocks obtained from the literature. If unsure of the composting periods for your particular feedstock, use a composting period of 90 days. This takes into account the time period required to achieve stable compost for most feedstocks. It is better to use a more conservative estimate (longer period).

Table 14. Duration of composting and curing for different feedstocks

| Predominant feedstock | Typical days to achieve stable compost | Source |
|---|---|---|
| Municipal solid wastes | 56-70 | Wei et al. (2000) |
| Wastewater biosolids | 45-120 | Wei et al. (2000); Epstein (1997) |
| Wood wastes | 90 | Riggle (1991) |
| Food wastes | 21-50 | Jones (1992); Gies (1995) |
| Manures | 40-80 | Epstein (1997) |

Curing period is the length of time materials are on the curing pad but are not going through an active composting process although curing materials maintain some microbial activity. Recommended curing times for most compost range from 4-10 weeks. If product quality is not a concern, shorter time periods can be used.

Storage period is the length of time the finished cured compost is stored before end use. There is not an exact amount of time required, rather this is based on management and end markets for the compost.

Compost shrinkage factor is the amount of shrinkage the material experiences during the composting phase of the process. Typical volumetric shrinkage during composting is 25-50%. Exceptions are food wastes with higher shrinkage and wood wastes with lower shrinkages.

**Section 3. Determine composting windrow dimensions and volume**

The dimensions of windrow piles and the spacing between piles are directly dependent on the type of equipment used in the operation. Table 4 presents various sized windrow turning equipment and the corresponding windrow dimensions that each type of equipment can handle. Use these values as the basis for your selection of windrow dimensions. Equipment choice is the second most important factor in determining the compost pad size. Figure 6 shows where windrow values need to be entered.

Table 15. Windrow turning equipment, size, cost and corresponding windrow dimensions (Rynk, 1992)*

| Equipment | Cost X 1000, $ | Capacity tons/hr | Power rating, hp | Windrow dimension Height X Base, ft X ft | Spacing between windrow, ft |
|---|---|---|---|---|---|
| Small tractor loader | 15 | 16 | 40 | Variable | 20 |
| Medium tractor loader | 45 | 48 | 85 | Variable | 20 |
| Large front end loader | 130 | 145 | 135 | Variable | 20 |
| Tractor PTO turner | 25 | 950 | 90 | 4 X 14 | 10 - 15 |
| FEL mounted turner | 70 | 1,100 | 177 | 5 X 14 | 10 - 15 |
| Medium self propelled | 89 | 1,250 | 160 | 5 X 15 | 4 - 10 |
| Large self propelled | 100 | 2,600 | 325 | 8 X 18 | 4 - 10 |

*Approximate values

The compost windrow length is strictly determined by land restraints and management strategies. Windrow lengths should be chosen that best suit the available site. Remember that while longer windrows will reduce the total number of windrows required, it may also increase the amount of land needed, thus increasing capital and construction costs. This should be taken into consideration when selecting the windrow length.

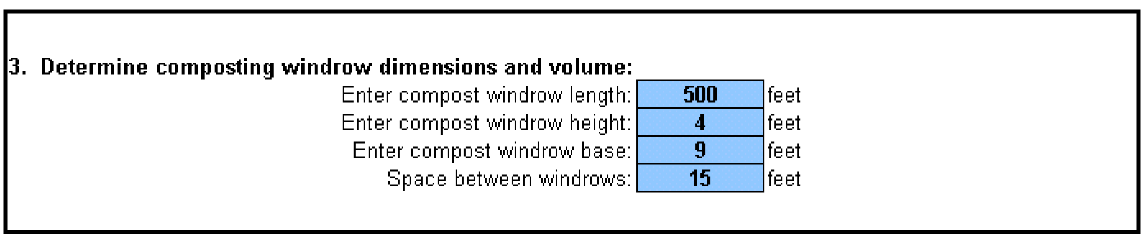


Figure 6. Determine composting windrow dimensions and volume

The compost windrow height and base (width) are based on the type of equipment used to turn the windrows. The predominant windrow shape is assumed to be triangular in cross section. Although the Compost Wizard© allows the user to input a wide range of windrow dimensions that cannot work, it is assumed that the user has some working knowledge of the stacking limitations of compost and will make informed decisions.

Table 4 shows various types of equipment and the pile sizes that they can handle. Capacity and cost are directly related. Generally speaking, the more a turner costs, the more throughput it can handle. It is also important to remember that capital and operating costs are directly related to the equipment one chooses.
Another thing to keep in mind is that just because a vendor says that a turner can handle a 6’ x 12’ windrow, it may not be wise to “max out” the capacity of the turner. The larger the windrow, the harder the turner has to work which correlates into higher operating

costs through increased wear and tear on the equipment. For example, if the maximum capacity of a turner is 6’ x 9’ windrow, you may want to run a design using a 5’ x 8’ windrow and see the difference it makes. This small size reduction may actually increase production by increasing the speed at which the turner can work while reducing the maintenance costs associated with running your equipment at full capacity.

**Section 4. Composting and feedstock processing area**

No inputs are necessary in this section (Figure 7). Section 4 simply presents calculated values of the composting window volume, the volume of compost in this area, the number of composting windows and the amount of land required based on user inputs.

**4. Composting and feedstock processing area:**

| | | |
|---|---|---|
| Composting window volume= | 444 | cu yds |
| Volume of compost in composting area= | 6,621 | cu yds |
| Number of composting windrows= | 15.0 | windrow(s) |
| Windrow area square footage= | 240,488 | sq feet |
| Composting and feedstock processing area= | 5.5 | acre(s) |

Figure 7. Composting and feedstock processing area

**Section 5. Determine compost curing area**

After the composting process is finished, the windrows can either be combined where they are (on the compost pad) or moved to another location (curing pad) for curing. The size of the curing pad is based on the length of time required for this stage of the process. Since curing windrows do not require turning, they can be significantly larger than compost windrows (Figure 8). For calculation purposes, the program simply assumes that the curing window length is half of the compost window length. The height and base (width) of the curing windows should be determined by the type of loader used on site. Like windrow turners, the larger the windrow, the larger the loader you will need.

**5. Determine compost curing area:**

| | | |
|---|---|---|
| Curing windrow length= | 250 | feet |
| Enter curing windrow height: | 10 | feet |
| Enter curing windrow base: | 20 | feet |
| Enter curing shrinkage factor: | 5% | percent |
| Enter space between curing windrows: | 15 | feet |
| Curing windrow volume= | 1,235 | cu yds |
| Volume of compost in curing area= | 1,832 | cu yds |
| Number of curing windrows= | 2.0 | windrow(s) |
| Curing area square footage= | 19,600 | sq feet |
| Curing area= | 0.4 | acre(s) |

Figure 8. Determine compost curing area

Curing shrinkage factor is the amount of shrinkage the material experiences in the curing phase of the process. Typical volumetric shrinkage during curing is 5-15%. Exceptions are food wastes with higher shrinkage and wood wastes with lower shrinkages.

Section 5 (Figure 8) also provides calculated curing windrow volume and length (half of the windrow length), volume of material on the curing pad, the number of curing windrows and the acreage required for the curing pad.

If material is going to be left in place and not transported to another location for curing, the curing period in Section 2 should be zero. It is assumed that the windrows will be combined and the compost shrinkage factor (input in Section 2) is the process shrinkage factor which takes into account both operations.

**Section 6. Determine the compost storage area**

After the curing process is finished, the windrows can either be left in place where they are (curing pad) or moved to another location (storage pad) for storage before end use. This section allows one to determine the windrow size used for storage (Figure 9). Like curing windrows, storage windrows do not require turning so they can be considerably larger than compost windrows. There should be no microbial activity during the storage phase. Therefore, the storage windrow length is also assumed to be half the compost windrow length. The height and base (width) of the storage windrows are determined by the type of loader used on site. The pile size for storage is very often similar in size to curing windrows because the same loader is normally used to build both type of piles.

| | | |
|---|---|---|
| **6. Determine compost storage area:** | | |
| Storage windrow length= | 250 | feet |
| Enter storage windrow height: | 15 | feet |
| Enter storage windrow base: | 30 | feet |
| Enter space between storage windrows: | 20 | feet |
| Storage windrow volume= | 2,778 | cu yds |
| Volume of compost in storage area= | 595 | cu yds |
| Number of storage windrows= | 0.2 | windrow(s) |
| Storage area square footage= | 13,464 | sq feet |
| Compost storage area= | 0.3 | acre(s) |

Figure 9. Determine compost storage area

Section 6 provides the calculated storage windrow volume and length (the same as the curing windrow length), volume of material on the storage pad, the number of storage windrows and the acreage requirements for the storage pad.

**Section 7. Total area required for composting pad**

The buffer zone around the compost pad (usually consisting of trees) is used primarily as an odor control measure. The more odor control needed, the greater the buffer zone should be. Typically, the more rural an area, the less buffer required. If your compost pad is located in a highly populated area, you may need a larger buffer around the pad to disperse any odors and keep down odor related complaints.

Section 7 (Figure 10) compiles all the required areas and presents the information in graphic form showing both dimensions and acreage for each phase of the operation. The graph in this section is not to scale but simply represents the basic size of layout required for your windrow operation.

To go to the next phase of the design, click on the link at the bottom right hand corner of the page that reads "Proceed to Retention Pond Page."

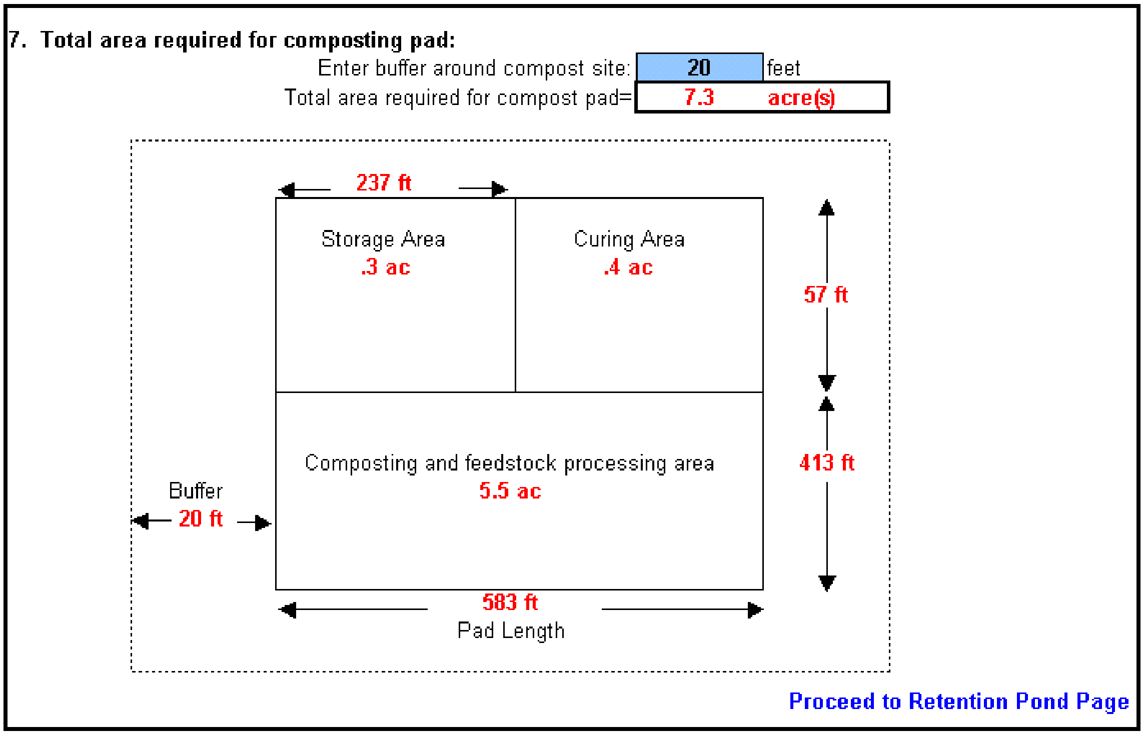


Figure 10. Total area required for composting pad

***Module 2. Retention Pond***

Retention ponds are used, depending upon the nature of the material composted, to capture runoff water from the compost pad. Size requirements for the pond are based on capturing all of the water from the 30-year historic maximum monthly rainfall. It is assumed that each month all the water in the pond is either used as additional water for the windrows or is applied to land.

**Section 1. Weather information for retention pond**

The retention pond design is based primarily on site-specific weather data. Compost Wizard© is only available for certain states. The following is a list of states with data available at the time of this printing:

| | | | |
|---|---|---|---|
| Arizona | Georgia | New Mexico | Pennsylvania |
| California | Indiana | New York | Texas |
| Colorado | Iowa | North Carolina | Virginia |
| Delaware | Louisiana | Ohio | Washington |
| Florida | Michigan | Oregon | |

The design process begins by selecting the geographical region where the facility will be located as shown in Figure 11. Based on your selection, Compost Wizard© then automatically references the 30-year historical weather data and bases the retention pond design on the largest maximum monthly projected runoff value for that region.

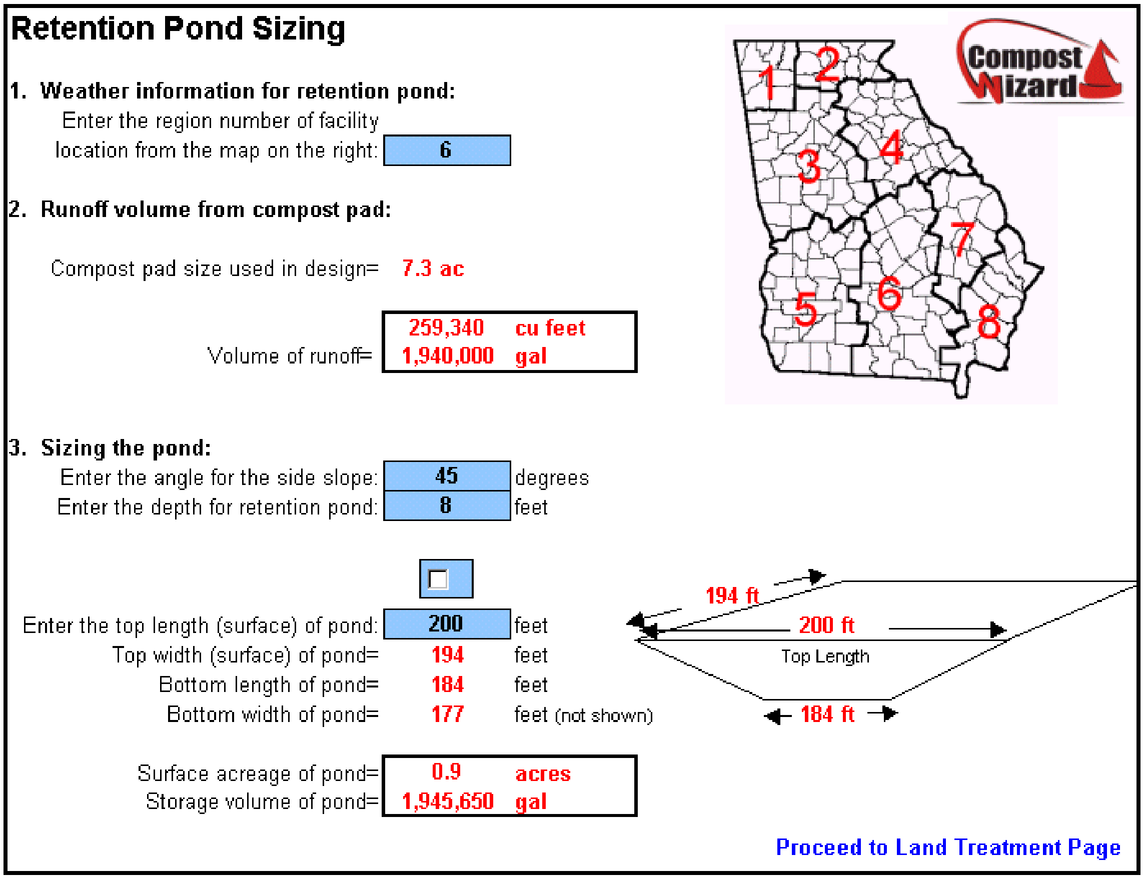


Figure 11. Retention pond sizing

### Section 2. Runoff volume from compost pad

The retention pond is sized to collect the projected maximum runoff for the region using historic data (Figure 11). Section 2 displays the region selected and the compost pad size. The volume of runoff is calculated as if all the water that falls on the pad is captured in the pond, therefore helping to ensure a conservative design. The volume of runoff is presented both in cubic feet and in gallons.

### Section 3. Sizing the pond

You are asked to input an angle for the side slope of the pond. Side slope refers to the steepness for the sides of the pond from the horizontal. A 25% slope is very gradual, a 45% slope is average and a 75% slope is considered very steep. The contractor and the type of land on which the pond will be built will determine the actual angle of the pond. Retention pond depth is a necessary input for the model. Once again this value will be determined by actual land characteristics. Use approximate depths of other ponds in the area as a basis for retention pond design depth.

The last input required is the surface top length of the pond. From this value, Compost Wizard© calculates the surface top width, the bottom width and the bottom length. To minimize the pond surface area, adjust the surface top length of the pond to make it as square as possible. You can do this by adjusting the top length until it is approximately the same dimension as the top width.

The surface acreage of the pond and the storage volume of the pond are both calculated values. The volume of runoff from the compost pad shown in Section 2 will always be less than the calculated storage volume of the pond in order to provide a small buffer. Section 3 (Figure 11) also presents the calculated pond dimensions in a graphical form. This graphic is not to scale.

To go to the next phase of the design, click on the link at the bottom right hand corner of the page that reads, “Proceed to Land Treatment Page.”

*Module 3. Land Treatment*

**Section 1. Weather information for land treatment system**

Like the retention pond, the land treatment design is dependent on the weather data of the site location. Compost Wizard© again automatically references the same 30-year historical weather data for the region you chose previously and bases the design on this information.

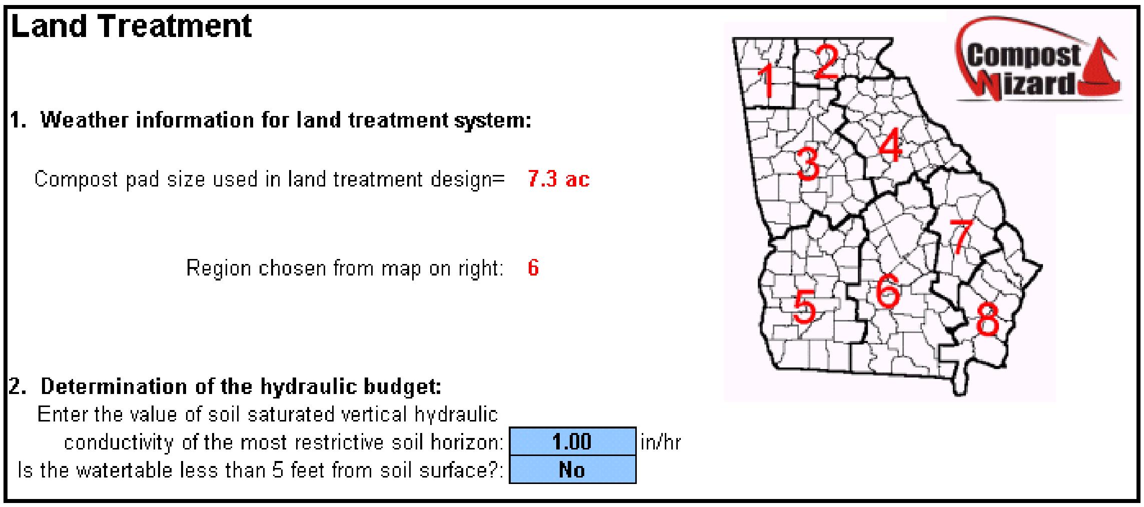


Figure 12. Weather information and hydraulic budget

**Section 2. Determination of the hydraulic budget**

The land treatment system design is adapted from regulatory guidelines (GA EPD, 1992; US EPA, 1981). Since the collected runoff is normally sprayed directly onto the land, the acreage required for treatment is controlled by either (A) the hydraulic budget of the soil, i.e. the water infiltration capacity of the soil, or (B) the nitrogen balance of the cover crop that consumes the applied nutrients (Figure 12).

<u>Soil Hydraulic Conductivity</u> is the speed that water can flow through soil. It is a major design parameter used by this program. Enter the soil hydraulic conductivity value for the specific land treatment site. Soil hydraulic conductivity values for individual states can be obtained from the USDA-NRCS soils database. For example, typical values for soils in Georgia range from 0.19 to 1.9 in/hr depending on the soil type. A rule of thumb is the more sandy the soil, the higher the soil hydraulic conductivity rate.

<u>Water Table</u> is the level of ground water on the site. Compost Wizard© asks if the water table on the land application site is less than five feet from the surface. If the water table is indeed less than five feet from the surface, the site may not be suitable for land application without some sort of drainage improvement. A message stating this fact will appear.

The result of the hydraulic budget is compared to the result of the nitrogen budget.

**Section 3. Determination of the nitrogen budget**

The amount of nitrogen rich water that the land can retain without excessive runoff is called a nitrogen balance. A nitrogen budget or balance on the land cover or crop in the treatment area is used to address nutrient loading issues (Figure 13).

******This section requires that the Solver Add-In be correctly installed in order to complete. ******

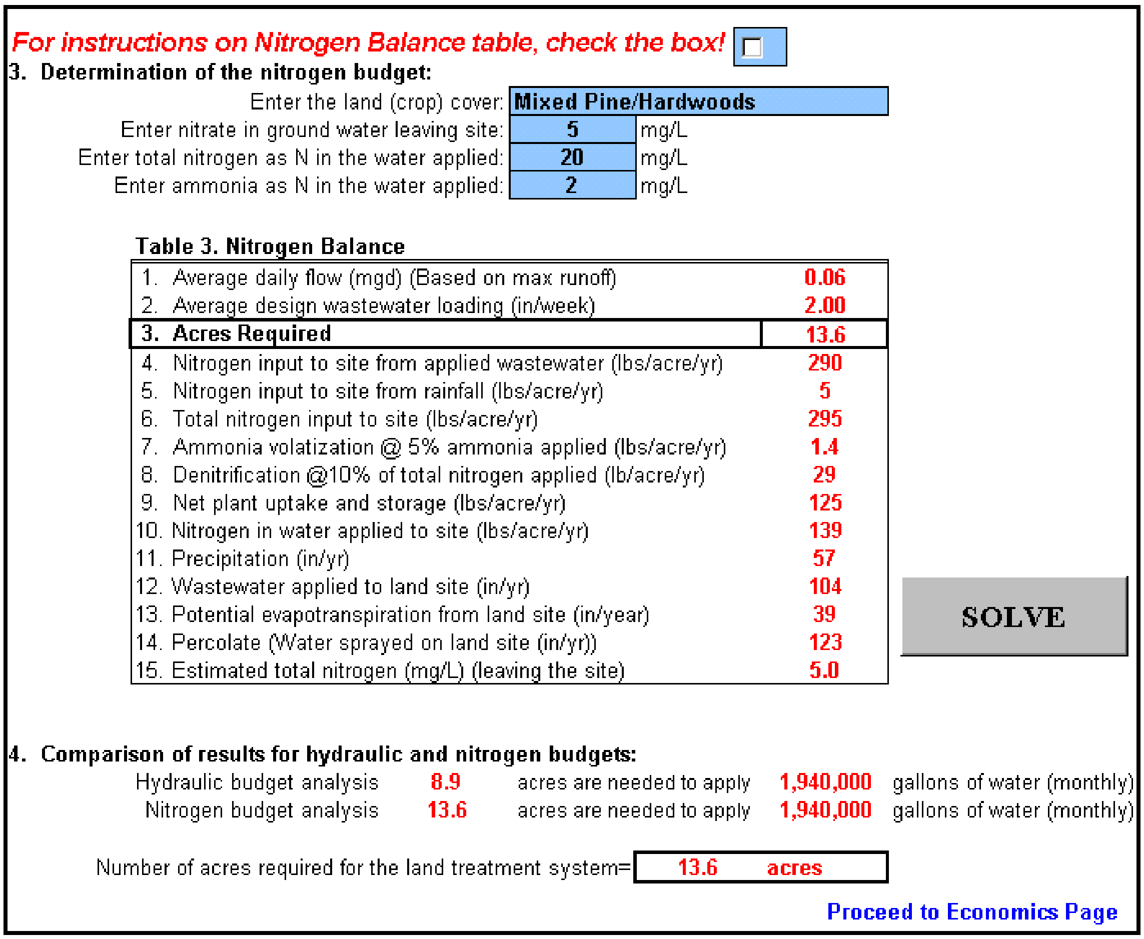


Figure 13. Determining the nitrogen budget

To determine the nitrogen budget, specify land cover or crop for the site and Compost Wizard© assigns a nitrogen uptake value (lb/acre/year) accordingly. The approximate amount of nitrogen uptake for each crop choice is presented in Table 5.

Table 16. Land covers and their approximate nitrogen uptake values

| Crop cover | Nitrogen uptake (lb/acre/year) |
|---|---|
| Fescue | 75 |
| Pine | 100 |
| Mixed Pine/Hardwood | 125 |
| Coastal Bermuda Grass | 300 |
| Coastal Bermuda/Winter Rye Mix | 500 |

Total nitrate in groundwater is a critical parameter and must be entered. The maximum value set for drinking water regulations (in Georgia) is 10 mg/L of total nitrate leaving a site in the groundwater. Check your state regulations to determine this limit. In order to ensure a conservative design, the choice allowed is 0-7 mg/L. The lower the number, the more conservative the estimate is for the amount of land required (i.e. the more land required for treatment).

Total nitrogen as N is another value that must be determined. Although the program allows for a wide range of values for this input, typical values for composting leachate or runoff are between 20 and 25 mg/L of total nitrogen as N. If a value is chosen outside 20-25 mg/L, a message reminding the user of the typical range of values is displayed but does not affect the ability to choose values outside this range. Accurate data for various types of feedstocks and the combinations thereof is lacking in literature. This is one area where more research is required to better quantify leachate/runoff quality.

Ammonia as N in the water applied is another difficult value to quantify. Typical values for composting leachate or runoff are between 1 and 2 mg/L. Exact data is similarly lacking for this required input in the literature.

Once the necessary parameters are set, look at Table 3 Nitrogen Balance on the Land Treatment page in Section 3. (Tables 1 and 2 are located on the Extra Tables worksheet.) Tables 1 and 2 are primarily used for the permitting process and only Table 3 Nitrogen Balance is included on the Land Treatment page.

Most regulatory agencies want to see a layout of data used to determine the site design. Although each state's regulations and requirements may vary, these tables are presented in such a manner that are consistent with many states requirements. Check your own state's regulations to make sure.

The nitrogen balance table determines the amount of land required to spray all the runoff collected by the retention pond in one month. In order to determine the acreage required, Compost Wizard© uses an iterative approach. The goal of the iterative process is to coincide your input for maximum nitrogen concentration limit in the groundwater leaving the site with the amount of land required to achieve this limit. As Compost Wizard© changes the acreage value in the iterative process, all nitrogen inputs and outputs from the system change because each is calculated on a per acre bases. This iterative process is repeated until the estimated nitrogen leaving the site reaches the target value.

A small notation ("Press the Solve Button") below the Solve button will appear (Figure 13) when it is necessary to engage the iterative process. This notation disappears once Compost Wizard© determines the required amount of land for the nitrogen budget. Press the SOLVE button located to the right of the table to begin the iterative process and determine the required acreage.

For example: If the target value of nitrogen leaving the system is set to 5 mg/L, but due to inputs, it is higher than 5 mg/L, shown in Line 15 of Table 3. When the SOLVE button is pushed (assuming the Solver Add-In has been installed correctly), Compost Wizard© rapidly changes the amount of acreage until the target value for nitrogen leaving the site is achieved. After Compost Wizard© has determined the answer, a pop up box titled "Solver Results" appears on the screen (Figure 14). Click OK to finish the process. The number of acres required is found on Line 3 in Table 3.

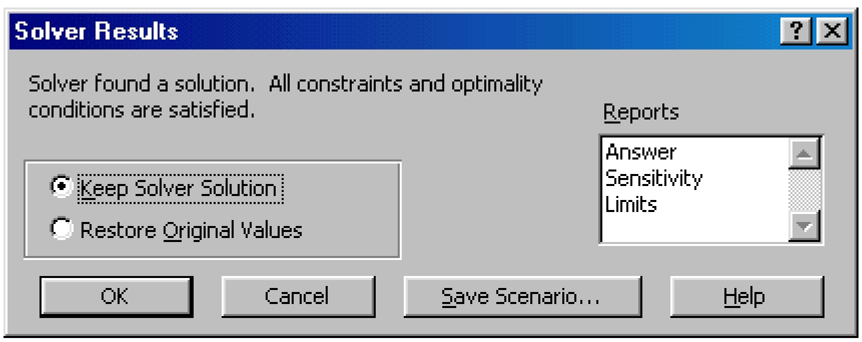


Figure 14. Solver results

**Section 4. Comparison of results for hydraulic and nitrogen budgets**

This section simply compares the results of the hydraulic and nitrogen budgets for the amount of runoff that potentially may need to be land applied (or utilized back into the composting process) beach month (Figure 13). Compost Wizard© uses the larger of the two values as the final answer. To go to the next phase of the design, click on the link at the bottom right hand corner of the page that reads, "Proceed to Economics Page."

***Module 4. Economics***

The cost of composting is a function of the number of unit operations, type of equipment, number of employees and throughput of the operation. The economics design module of Compost Wizard© allows input of wages for skilled and unskilled labor, equipment, number of windrow turns per cycle, optional road access, land costs, construction costs, insurance, etc (Figure 15).

**Section 1. Equipment and Labor costs**

The number of turns per windrow per cycle (or period) is key to calculating equipment maintenance and operating costs. The number of turns is calculated assuming that the compost is turned five times during the first fifteen days of composting and then one time for each five day period during the remainder of the compost period. The first value in the drop down list is the **calculated** default value. This value will change if the length of the compost period changes (Compost Pad Section 2). You can change the number of turns by using the drop down list provided. The greater the number of turns, the greater the operating costs will be. (Turners in Section 1 are presented in tons/hr rather than yds/hr).

**Economics**

**1. Equipment and labor cost estimates:**

Enter the number of turns per windrow per cycle: 17

Include a tractor to pull this turner in Section 2 Capital Cost table under equipment in the green box.

| Equipment | Name | Cost/unit | Hp | yds/hr | # of Units | Hours | Total Cost |
|---|---|---|---|---|---|---|---|
| Turners | Tractor towed (PTO) | $ 25,000 | 90 | 950 | 1 | 577 | $ 25,000 |
| Loader | Med wheel loader (2 yrd) | $ 83,000 | 110 | 70 | 1 | 864 | $ 83,000 |
| Screener | Trommel, small | $ 40,000 | | 20 | 1 | 712 | $ 40,000 |
| Trucks | Small Dump (10 yrd) | $ 20,000 | 200 | 10 | 1 | 1,424 | $ 20,000 |
| | | | | | | 3,577 | $ 168,000 |

Figure 15. Equipment and labor costs

<u>Equipment</u> choice is very important in the sizing of the compost pad and determining the number of employees, operating costs and capital costs. In this section, choices of type and number of equipment units that are necessary for the operation must be made. Based on the equipment chosen and your previous inputs, the Compost Wizard© calculates the working hours per type of equipment and the total cost of equipment. It is recommended that in choosing the number of equipment units, an additional unit of equipment is added for each 2000 equipment working hours per type of equipment.

For example: The Compost Wizard© determines that the windrow turner you choose needs to work 3000 hours a year to perform all the turning for the operation. In order to operate 3000 hours per year, the turner must be operated approximately 12 hours per day, 5 days a week. Realistically, this is not possible. One should increase the number of turners by using the drop down list for turners under the # of units column. This reduces the working hours required for each machine, however it may require an additional employee to operate the second piece of equipment. If you do not wish to add more employees, the design may require a turner that has a larger throughput capacity.

In order to operate additional equipment, consideration must be made to add additional employees. This goes for each piece of equipment. The number of pieces of equipment is directly related to the number of employees. In Section 3 of Economics, the number of skilled and unskilled employees is required as a user input. The number of employees should reflect the required personnel needed to operate all equipment. The type of management used on site will also be part of the decision making process.

Table 6 (Table 4 reprinted again in this section) has various windrow turner specifications such as cost, horsepower, throughput capacity and windrow dimensions. If one chooses a Tractor PTO driven turner, one should realize that the cost information includes only the turner and does not include the tractor to pull the turner. A "large" tractor with a creeper gear is needed to pull the turner. Therefore a tractor is needed. A tractor must be added to the list of equipment in Section 2 Capital cost summary table under Equipment. Since tractor prices are so variable, default values were not given.

If one chooses a front-end loader mounted turner, one should realize that the cost information includes only the mounted turner and does not include the front-end loader on which the turner is mounted. A large front-end loader is required. Therefore, a front-end loader must be added to the list of equipment in Section 2 Capital cost summary table under Equipment if not already chosen in Section 1. Front-end loader cost information from Table 7 can be used.

Table 17. Windrow turning equipment[1], size, cost and corresponding windrow dimensions (Rynk, 1992)*

| Equipment | Cost X 1000, $ | Capacity tons/hr | Power rating, hp | Windrow dimension Height X Base, ft X ft | Spacing between windrow, ft |
|---|---|---|---|---|---|
| Small tractor loader | 15 | 16 | 40 | Variable | 20 |
| Medium tractor loader | 45 | 48 | 85 | Variable | 20 |
| Large front end loader (FEL) | 130 | 145 | 135 | Variable | 20 |
| Tractor PTO driven turner | 25 | 950 | 90 | 4 X 14 | 10 - 15 |
| FEL mounted turner | 70 | 1,100 | 177 | 5 X 14 | 10 - 15 |
| Medium self propelled | 89 | 1,250 | 160 | 5 X 15 | 3 - 5 |
| Large self propelled | 100 | 2,600 | 325 | 8 X 18 | 3 - 5 |

*Approximate values

One drawback to most windrow compost facilities is the amount of material handling that is required. Probably the most used and important piece of equipment for a compost facility is the front-end loader. Obtaining the correct loader that meets all the needs of the facility is crucial. The loader is used in almost all phases of the composting process including building, combining and harvesting windrows, loading screeners, moving screened materials and all manner of loading and transporting for bagging and sales operations. Table 7 presents some loader specifications. Actual scoop capacities may vary with different brands of loader.

Table 18. Loader equipment specifications*

| Equipment | Cost X 1000, $ | Capacity, Yrd$^3$/hr | Power rating, hp | Windrow Height, |
|---|---|---|---|---|
| Small (skid steer) (1 yrd) | 25 | 30 | 25 | Variable |
| Med wheel loader (2 yrd) | 83 | 70 | 110 | “” |
| Large wheel loader (3 yrd) | 130 | 120 | 170 | “” |

*Approximate values

The type of screener used in your operation depends greatly on your final market for the finished compost. The higher the quality of compost that is required, the more time it will take for the screening process. For example, if a ¼ inch particle size is desired, the compost may have to go through one or two prior screenings before being screened for ¼ inch. Each additional screening takes time for employees and equipment.

Many vibrating screeners, as well as trommel screeners, have the ability to screen to multiple particle size on the same pass. The capacity of the machines will then be dependent in the screen sizes used. When actually purchasing a screener, make sure the finished particle size and the amount of compost that needs to be screened daily will meet the daily requirements of the facility. Table 8 presents some screener specifications.

Table 19. Screener equipment specifications*

| Equipment | Cost X 1000, $ | Capacity, Yrd$^3$/hr |
|---|---|---|
| Trommel, small | 40 | 20 |
| Trommel, medium | 75 | 45 |
| Trommel, large | 135 | 100 |
| Vibrating, small | 50 | 50 |
| Vibrating, medium | 78 | 100 |
| Vibrating, large | 120 | 135 |

*Approximate values

Trucks may or may not be required equipment needed for the compost operation, depending upon the end markets and management strategies. Many facilities use tractors or trucks to pull trailers that move feedstocks and compost from one process to another. Table 9 presents two different size trucks that may be included in the design. Actual trucks available on the market may differ in cost, capacity and horsepower.

Table 20. Truck specifications

| Equipment[1] | Cost X 1000, $ | Capacity, $Yrd^3/hr$ | Power rating, hp |
|---|---|---|---|
| Small Dump Truck (10 yrd) | 20 | 10 | 200 |
| Large Dump Truck (20 yrd) | 39 | 20 | 350 |

[1]Hrs based on moving compost 30 min (1 hr round trip)

**Section 2. Capital cost summary table**

Capital expenses are those costs that normally are not allocated over just one year with most occuring at the beginning of an operation. Capital costs include land purchases, construction of infrastructure and equipment. The capital cost table summarizes these costs and allows one to determine common capital costs for an operation (Figure 16).

The Land Required portion of this table summarizes the amount of land each part of design needs (Figure 16). Many times the pad site or pond site is already owned and does not require purchasing. Compost Wizard© allows one to choose the cost for each acre of the different portions of the facility. The green and blue boxes are provided to allow you to add additional acres.

2. Capital cost summary table:

| Capital Costs | # of units | $/unit | Total Cost |
|---|---|---|---|
| **Land Required (acres)** | | | |
| Compost Pad | 6.3 | $ 750 | $ 4,725 |
| Pond | 0.9 | $ 750 | $ 675 |
| Land Treatment | 13.6 | $ 750 | $ 10,200 |
| Buffer | 1.0 | $ 750 | $ 750 |
| Other | 3.0 | $ 750 | $ 2,250 |
| | 24.8 | Total Land | $ 18,600 |
| **Construction** | | | |
| Compost Pad | 6.3 | $ 6,000 | $ 37,800 |
| Pond | 0.9 | $ 15,000 | $ 13,500 |
| Land treatment | 13.6 | $ 5,000 | $ 68,000 |
| Road (sq yrds) | 0 | $ - | $ - |
| Shed | 0 | $ - | $ - |
| | | Total Construction | $ 119,300 |
| **Equipment** | | | |
| Tractor towed (PTO) | 1 | $ 25,000 | $ 25,000 |
| Med wheel loader (2 yrd) | 1 | $ 83,000 | $ 83,000 |
| Trommel, small | 1 | $ 40,000 | $ 40,000 |
| Small Dump (10 yrd) | 1 | $ 20,000 | $ 20,000 |
| Tractor | 1 | $ 20,000 | $ 20,000 |
| Trailer | 1 | $ 8,000 | $ 8,000 |
| Other | 0 | $ - | $ - |
| | | Total Equipment | $ 196,000 |
| | | TOTAL CAPITAL COSTS = | $ 333,900 |

Figure 16. Capital cost summary table

The Construction portion of this table may be the most difficult to determine because these costs are so site-specific. Estimated default construction costs have been provided as the first value in the drop down list. The only way to ensure accurate estimates is to check on state regulations and contact local contractors in the area that construct these types of facilities. The green and blue boxes are provided to allow for additional facilities that may be needed (buildings, drainage, etc.). The option for the building of a road is available under the construction section. If some type of asphalt or concrete work is needed, it can be added here. This is included in addition to the extra green box for other construction.

The Equipment portion of this table summarizes the equipment selected in Section 1. The number of units and cost of each piece of equipment is shown. The green and blue boxes are provided to allow one to add additional equipment as needed.

**Section 3. Operating cost summary table**

Operating costs are the reoccurring costs that are a part of doing business. These costs include insurance, utilities, supplies, maintenance and salaries. The operating cost table summarizes and allows you to determine many of the operating costs for the facility (Figure 17). The table is broken down into three main headings: Equipment, Employee, and Miscellaneous.

**3. Operating cost summary table:**

| | %/yr | $/unit | Total Cost (yr) |
|---|---|---|---|
| **Equipment** | | | |
| Fuel Cost ($/gallon) | | $ 1.50 | $ 32,192 |
| Maintenance & Repair | 10% | | $ 19,600 |
| Facility Insurance | 1% | | $ 3,339 |
| Equipment Replacement | 10% | | $ 19,600 |
| | | **Total Equipment** | $ 74,731 |
| **Employee** | # employees | | |
| Skilled Labor | 2 | $ 10.00 | $ 40,000 |
| Unskilled Labor | 1 | $ 6.00 | $ 12,000 |
| | %/wages | | |
| Employee Benefits | 37% | | $ 19,240 |
| | | **Total Employee** | $ 71,240 |
| **Miscellaneous** | hrs/yr | | |
| Contract Work | 75 | $ 250 | $ 18,750 |
| Other costs | 0 | $ - | $ - |
| Feedstock Costs | tons/yr | $/ton | |
| | 0 | $ - | $ - |
| | 0 | $ - | $ - |
| | 0 | $ - | $ - |
| Landfill Costs | 0 | $ - | $ - |
| | | **Total Miscellaneous** | $ 18,750 |
| | | **TOTAL OPERATING COSTS ($/YR) =** | $ 164,721 |

Figure 17. Operating cost summary table

**Equipment**

Fuel cost is an important aspect of operating expenses. The default value is $1.50 per gallon. This cost can be adjusted to correlate with the present day market. Fuel cost is estimated utilizing equipment fuel consumption rates, fuel cost and total equipment operating hours. The cost of fuel, the number of windrow turns and working hours are the major contributors to this cost estimation.

Maintenance and Repair is determined by choosing a percentage, 3-25% per year, of the total cost of the original equipment. The default value is 10%. The cost for maintenance and repair is dependent on the number of working hours and working conditions for equipment. As machines age and wear out, the amount of repair required may also increase. As with any equipment, routine maintenance is important in keeping maintenance costs at a minimum.

Facility Insurance is determined by choosing a percentage, 0-5% per year, of the total capital cost for the facility. The default value is 1%.

Equipment Replacement is a cost that must be set aside each year in order to purchase new equipment when the old equipment needs to be replaced. This value is determined by choosing a percentage, 0-25% per year, of the original capital cost of the equipment. The default value is 10%. This value will depend on the depreciation schedule you use when you calculate your taxes. For example, if you determine that your equipment will have a 5 year life, you should choose 20% as your equipment replacement percentage to ensure that adequate funds will be available to purchase new equipment in the future.

**Employee**

Skilled labor is defined as those individuals that are trained and able to operate all pieces of heavy equipment.

Unskilled labor is defined as those who do not run heavy equipment. An example of unskilled labor may be employees used to sort and separate incoming feedstocks. Actual duties will vary with management strategies.

You must choose the number of skilled and unskilled employees the facility employs. The annual salaries are based on an employee working 2000 hours a year. Compost Wizard© estimates the minimum number of skilled employees and provides this as the first value in the drop down list for skilled employees only. You must decide whether the facility will require more or less employees to perform all duties

You must also determine the dollar per hour figure that each type of employee will be paid. Default values for skilled and unskilled labor are ten and six dollars an hour, respectfully.

Employee Benefits including insurance and health care are often provided for employees. Benefits are determined as a percentage of total salaries provided to both skilled and unskilled labor. The range provided is 0-50% per employee per year. The default value is 37%.

**Miscellaneous**

Contract Work section is provided to account for outsourced jobs. Examples of contract work may include feedstock grinding (tub grinders) and screening. Depending on the operation, it may be more cost effective to contract others to perform these jobs rather than purchasing the equipment and doing the job in house. If one would like to use this option, one can input the number of hours in the first blue box under # of units and input the dollar per hour rate that will be charged in the second blue box under $/unit.
Other Costs section is provided to account for additional reoccurring costs (office supplies, permits, lab analysis etc.) that may not be specifically addressed other places.

Feedstock Costs section is provided to account for any additional feedstocks that may have to be purchased for the operation. Be sure to include any transportation costs for these feedstocks.

Landfill Costs section is provided to account for any undesirable material that may be required to go to a landfill. For example, a facility that will compost Municipal Solid Waste (MSW) may have as much as 50% of incoming feedstocks that needs to be landfilled. Determine the total tonnage that will be removed and assign a dollar per ton figure.

**Section 4. Revenue generation summary table**

When starting a new facility, the author has observed the tendency of planners to base financial loan payback on "back end" sales. In the design process, it is often assumed that a facility will immediately receive top return on compost sales. While in reality, it often takes market development much longer than planned to realize top sales. When this happens, it is difficult for facilities to meet payment deadlines and make ends meet. Thus, it is important to make conservative estimates on back end or sales revenue figures. If a facility can meet financial demands on paper using conservative estimates, then the operation is more likely to be sustainable in the real world. Section 4 (Figure 18) allows you to set prices for tipping fees and product sales.

**4. Revenue generation summary tables:** ☐

| Revenue Generation | tons/yr | $/ton | Total |
|---|---|---|---|
| **Tipping Fees** | | | |
| Yard trimmings | 8800 | $ - | $ - |
| | | $ - | $ - |
| | | $ - | $ - |
| | | $ - | $ - |
| Biosolids | 2500 | $ 28.00 | $ 70,000 |
| | | $ - | $ - |
| | | $ - | $ - |
| | | $ - | $ - |
| Other | 0 | $ - | $ - |
| | | | $ 70,000 |
| **Product Sales** | cu yrds/yr | | |
| Bulk Sales | 14,239 | $ 10.00 | $ 142,390 |
| TOTAL REVENUE FOR FACILITY ($/YR) = | | | $ 212,390 |

Figure 18. Revenue generation summary table

Tipping fees are "front end" fees for organic feedstocks or materials accepted on site that will be used in the compost process. One of the keys to operating a sustainable operation (if applicable) is to insure consistent revenue generation from the materials used in the process or a cost avoidance by not having the material disposed of in an alternative manner. If tipping fees can be obtained for incoming feedstocks, the first portion of this table allows one to assign a dollar per ton figure to the feedstocks entered on the Compost Pad page. Once again, assuming a conservative and realistic amount for tipping fees is important. A green box is provided for any other materials for which the facility may receive a tipping fee not included elsewhere.

Product sales are calculated on a cubic yard per year basis rather than a ton per year basis as are tipping fees. Compost Wizard© estimates the amount of product that may be available for sales using your inputs from the Compost Pad page. One is asked to input a dollar per cubic yard figure for compost sales if the final product will indeed be sold.

## Section 5. Evaluation table

The evaluation table is the culmination of all phases of the Compost Wizard© (Figure 19). This is where the decision is made about whether a facility will be sustainable or not. Parentheses indicate an expense or loss.

**5. Evaluation Table:** ☐

| | | | |
|---|---|---|---|
| Enter capital cost interest rate: | | | 6.75% |
| Enter capital cost loan life: | | | 10 |
| Capital Costs Recovery ($/mth) | | | |
| Land & Construction ($/mth) | | | $ (1,583) |
| Equipment ($/mth) | | | $ (2,251) |
| Operating Costs ($/mth) | | | $ (13,727) |
| Total Monthly Expenses ($/mth) | | | $ (17,561) |
| Total Monthly Revenue ($/mth) | | | $ 17,699 |
| | tons/yr | $/ton | |
| Cost Avoidance ($/yr) | 2,500 | $ 25.00 | $ 62,500 |
| Net Yearly Income ($/yr) | | | $ 1,661 |
| Net Yearly Benefit ($/yr) | | | $ 64,161 |
| **COST PER TON ($/TON)** | | | $ (18.65) |

**Proceed to Summary Page**

Figure 19. Evaluation table

A great deal of capital is often required to start most compost facilities. Often loans are used for start up capital. If this is the case with your facility, you are asked to enter the <u>interest rate</u> and <u>length of time</u> for the loan obtained. Lending agencies usually only lend money for the expected life of the equipment, which is normally limited to less than 10 years.

Since most companies operate on a month-to-month basis with regard to bill payments, the first half of the table presents dollar figures per month. <u>Capital Costs</u> are usually financed with a loan. Using your entered interest rate and loan life, Compost Wizard© breaks down the land & construction and equipment into a monthly expense.

<u>Operating Costs</u> are also presented as a dollar per month expense. These costs include fuel costs, maintenance & repair, facility insurance, contractual work, salaries & benefits and other extraneous costs. Operating costs are not usually specifically financed with a loan so the total yearly operating cost from Section 3 is simply divided by twelve months a year to get this figure.

<u>Total Monthly Expenses</u> is the sum total of land & construction, equipment and monthly operating costs. In order for a facility to succeed, an operation should be able to meet this monthly expense.

<u>Total Monthly Revenue</u> is the total revenue for a facility found in Section 4 divided by twelve months a year. This value should exceed the total monthly expenses in order for an operation to be sustainable. Although revenue is presented on a monthly basis,

compost sales are usually seasonal and as such, actual accounting techniques used should account for this to ensure adequate cash flow.

Cost Avoidance is a method to account for materials that are diverted from going to the landfill. An example of this would be a municipality that presently pays a landfill to take a specific amount of material each year. If the municipality chooses to compost some of the material rather than landfill it, the avoided cost of landfilling can be taken into account here. Though this is not a hard accounting number, it can lend weight to the decision making process when choosing between disposal alternatives. One can include the total tons per year that would be landfilled and the approximate dollar per ton as if that material was landfilled (or disposed of in another manner).

Net Yearly Income is the amount “left over” after all expenses, including salaries, have been paid for the entire year. A portion of this value should be set aside for purchasing of new equipment, if not accounted for in the operating cost section under equipment replacement.

Net Yearly Benefit includes the cost avoidance figure. This is not a hard accounting number but rather an expression of benefit. Net yearly benefit is the sum of net yearly income and the avoided cost of landfilling materials.

Cost per ton (also referred to as the bottom line) represents the cost for one ton of incoming material to be processed into finished compost. This is the value that many people go by when determining which disposal alternative to choose. For continuous systems (Compost Pad Section 1, Figure 4) Cost per ton is calculated using the Total Yearly Expenses divided by the total tons of incoming compostable material per year (assuming 250 days a year operation). For batch systems, cost per ton is calculated using the Total Yearly Expenses divided by the total tons composted in all batches.

Before making a decision, there are many other intangible factors that have you need to consider that the Compost Wizard© has not addressed. Such factors like permitting requirements, land availability, public perception, feedstock availability, logistics, available skilled labor, economic support, potential markets, marketing ability and basic knowledge needed to operate a facility. Doing all of your “homework” related to these issues before deciding to build an operation cannot be stressed enough.

### *Module 5. Summary Page*

The summary page takes vital “answers” from each of the design pages and presents them in orderly fashion. Each time you change a variable throughout the program, the bottom line changes. The degree that the bottom-line change is dependent on the “weight” of the variable you adjust.

If you wish to compare many scenarios together, before going back and changing parameters, print out the summary page or save the workbook with a different name. By doing this, you will have a saved copy of the choices you have made.

As a reminder, a more complete and detailed assessment should be performed if the preliminary design provided by this program shows economic feasibility based on the user inputs. The University of Georgia, the Engineering Outreach Program nor the author takes responsibility for the improper use of program results.

## *Glossary*

Batch operation is defined as a facility that will receive material once every so often. An example of a batch operation would be that of a broiler chicken producer who cleans out his houses and compost his chicken litter.

Buffer zone is an area around the compost pad (usually consisting of trees) used primarily as an odor control measure.

Bulk density (lb/cu yard) is the amount of weight materials have per unit volume.

Carbon sources are those feedstocks that have a high carbon content. Examples of such feedstocks include, but are not limited to, most wood products, leaves, yard trash and municipal solid waste (MSW).

Compost period is the length of time the feedstocks are on the compost pad and are going through an active composting process.

Compost shrinkage factor is the amount of shrinkage the material experiences during the composting phase of the process.

Continuous operation is loosely defined as a facility that will be receiving approximately the same amount of material on a daily basis.

Contract Work section is provided to take into account all outsourced jobs. Examples of contract work may include feedstock grinding (tub grinders) and screening.

Curing period is the length of time materials are on the curing pad but are not going through an active composting process although curing materials maintain some microbial activity.

Curing shrinkage factor is the amount of shrinkage the material experiences in the curing phase of the process.

Employee Benefits including insurance and health care are often provided for employees.

Feedstock Costs section is provided to account for any additional feedstocks that may have to be purchased for the operation.

Landfill Costs section is provided to account for any undesirable material that may be required to go to a landfill.

Nitrogen sources are those feedstocks that have predominantly higher nitrogen content. Examples of such feedstocks include but are not limited to most manures, grass clippings, and food waste.

Other Costs section is provided to account for additional reoccurring costs (office supplies, permits, lab analysis etc.) that may not be specifically addressed other places.

Side slope refers to the steepness for the sides of the pond from the horizontal.

Skilled labor is defined as those individuals that are trained and able to operate all pieces of heavy equipment.

Soil Hydraulic Conductivity is the speed that water can flow through soil.

Storage period is the length of time the finished cured compost is stored before end use.

Tipping fees are “front end” fees for organic feedstocks or materials accepted on site that will be used in the compost process.

Unskilled labor is defined as those who do not run heavy equipment. An example of unskilled labor may be employees used to sort and separate incoming feedstocks.

Water Table is the level of ground water on the site.

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