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Y2K Composting in the Southeast

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PREFACE

The theme of the Year 2000 Composting in the Southeast Conference and Trade Show - Y2Komposting - is that composting is about to enter a new phase as we enter the new millennium. Composting is a well-established process that has been used for centuries to create agriculturally valuable soil amendments. During the last several decades, composting has attained usefulness as a waste management tool. More recently, the processes that occur during composting have been employed for improving our environment, such as bioremediation, production of soil erosion-controlling materials and foundational materials for constructed wetlands, and reclaiming contaminated soils for establishment of vegetation.

As we enter the 21st millennium, we realize more than ever the interconnectedness of our global systems. The activities of humans affect our entire world and the harnessing of the natural processes of degradation of organic materials provides the potential to reduce methane emissions; improve the quality of soil upon which our food, water, and air supply depends; restore degraded and contaminated lands; produce biodegradable products that will reduce the ever-increasing volume of trash generated by humans; and provide benign sources of energy to maintain quality of life and economic prosperity. The use and promotion of this technology begins at the local level and, as such, this conference is designed to provide practical tools for composting and compost utilization whose ultimate goal is a sustainable society.

Thanks to the many authors who have contributed valuable papers and presentations that continue to expand the knowledge of this important biological process. The sponsoring agencies and members of the Planning Committee recognize and appreciate the support of those attending the Conference. To all of you, I say "Good composting."

Greg Evanylo, Virginia Polytechnic Institute and State University
Chairman, Planning & Organizing Committee
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DISCLAIMER

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ODOR: QUANTIFICATION AND HEALTH IMPACTS

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Odor is an unwanted consequence of municipal waste processing and disposal of sludge. Anaerobic digestion of sludge generates a broad range of odorants during the treatment process. In the first stage (acid fermentation), sugars, lipids, colloidal solids, and dissolved carbonaceous matter are converted to organic acids with the evolution of H_2S and CO_2; pH drops during this stage. In the next stage (acid regression), the organic acids (formed in stage 1) along with some proteins are digested to acetate and ammonia compounds; pH rises slowly during this stage. In the third stage, pH rises to neutral (pH $\approx$ 7) with the generation of large volumes of gases, especially methane, that can be used as fuel. The resultant humic mass has more odor if thermophilic digestion rather than mesophilic digestion is used. The sludge is then stabilized by chlorine or lime to render the material less suitable for microbial growth. It is also heated to reduce the quantity of moisture. Composing of the material and other forms of treatment byproducts can also generate odor.

Questions have been raised about the potential health effects of odors from wastewater treatment plants and the disposal of sludge. On April 16-17, 1998, a workshop sponsored by Duke University, the Environmental Protection Agency (EPA) and National Institute on Deafness and Other Communication Disorders (NIDCD) was held to examine the potential effects of unpleasant odors on health and well-being (Schiffman et al., 2000a). Complaints attributed to unpleasant odors from wastewater treatment (as well as other odor sources) include eye, nose, and throat irritation, headache, nausea, hoarseness, cough, nasal congestion, palpitations, shortness of breath, stress, and drowsiness. These health symptoms attributed to odors are generally acute in onset and self-limited in duration (Schiffman, 1998). Participants at the workshop attempted to determine whether these reported symptoms are caused by the odor (sensation) or the odorant (the chemical which happens to have an odor) or other causes.

Workshop participants concluded that there are at least three ways in which odors may be associated with health symptoms. First, a person may be exposed to an odorant (e.g. exposure to ammonia vapor) at levels capable of producing symptoms by sensory irritation (or other toxicologic mechanisms). In this case, the irritancy (or toxicity) occurs at a level above but within an order of magnitude of the odor threshold (concentration at which it is first detected). At concentrations above the irritation threshold, the experience of odor occurs simultaneously with the more relevant irritative process, but symptoms are caused by irritation rather than "odor-induced." Odor in this first case is simply a warning of potential health effects at elevated concentrations.

The second way in which odors may produce health symptoms is one in which the odorant is part of a mixture. In this case, a co-pollutant, which itself may have no odor, is responsible for the health symptom. An example of such a situation would be simultaneous exposure to odors from sludge and to bacteria. To the extent that symptoms/health effects are a result of bacterial exposure, odor is merely acting as a marker of exposure. That is, odor is a "potential cofounder."

The third situation involves exposure to odorants that are 3-4 orders of magnitude below the levels that cause irritation or classical toxicologic symptoms. Example of such odorant classes include sulfur-containing compounds such as, H_2S, mercaptans, and thiophenes. Empirically there is considerable evidence that exposure to such compounds at concentrations above threshold but below irritant levels is associated with increased symptom reporting. More research is required, however, to understand more fully the complex interplay between biological and behavioral/psychosocial factors on expression of health symptoms from odors. Objective medical tests such as pulmonary function studies must be correlated with objective measures of air quality. Methods for assessing health effects at specific odor/odorant levels will be discussed (see Schiffman et al., 2000b for a review of methods for measuring odor).

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COMPOSTING TRENDS IN THE SOUTHEAST

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ABSTRACT

What does the future hold for composting in the Southeast region? The answer to that question is multifaceted, and revolves around factors such as the following: Disposal capacity and tipping fees; Need for alternative management of various residuals such as animal manures, food residuals, biosolids and mixed MSW; Demand for soil amendments; State of soils in the region; Bans on traditional pesticides and herbicides such as methyl bromide.

At this time, disposal capacity in the Southeast region is abundant. At the same time, the five Southeastern states -- Florida, Georgia, North Carolina, South Carolina and Virginia -- have all surpassed the recycling goals set by their legislatures. Therefore, what will drive more residuals to composting is the need for alternative management methods, consumer demand for soil amendments like compost, a need to remediate soils and stem erosion, and agricultural demand for products like compost that build soil organic matter and offer disease suppression.

Currently, Georgia reports the highest number of operating composting facilities, followed by North Carolina, South Carolina, Florida and Virginia.

INTRODUCTION

BioCycle magazine, Journal of Composting and Organics Recycling, has been covering recycling of organic residuals for over 40 years. Starting in the 1980s, *BioCycle* initiated nationwide surveys to track composting activity -- primarily composting of biosolids, municipal solid waste, and yard trimmings. In the mid-1990s, *BioCycle* editors also began tracking composting of source separated food residuals from the institutional, commercial and industrial sectors (ICI).

In addition to gathering nationwide data on composting projects, *BioCycle* conducts the annual "State of Garbage in America" survey (2000 is the twelfth year the survey has been completed). The survey questionnaire asks state recycling coordinators, solid waste managers and others for a wide range of data -- from the total number of landfills and remaining disposal capacity to the amount of solid waste that is recycled and composted. The compiled data provides *BioCycle* editors with a good sense of trends in solid waste management, including composting.

This paper presents and analyzes survey data relating to composting projects, as well as information on overall solid waste management trends that will impact the growth of composting facilities over the next several years. In addition, the final paper presented at the October conference will discuss data gathered on manure generation, soil quality, population growth (and thus land development) and several other factors that will have an impact on the continuing evolution of composting in the Southeast.

STATE OF GARBAGE IN THE SOUTHEAST

In 2000, *BioCycle* split the survey into two parts. Part I focused on overall MSW generation and disposal and incineration -- the "State of Garbage." The Part I report appeared in the April, 2000 issue of *BioCycle*. Part II focuses on the recycling and composting side of the overall MSW management picture. Data has been compiled (as of 9/30/00) on states' recycling rates (which include composting), the amount of organics currently recovered versus what is still in the waste stream, and legislative and public policy initiatives -- including grant programs -- that are helping to stimulate composting and organics recycling. This paper for the proceedings only has the Part I results. The presentation at the conference will include data for Part II.

MSW Generation: Of the five Southeast states, North Carolina, South Carolina and Virginia provided data on total MSW generation. Florida only has the quantity of the MSW collected; Georgia's total comprises the amount of MSW disposed. The data is as follows: Florida -- 28.6 million tons; Georgia -- 11.4 million tons; North Carolina -- 13 million tons; South Carolina -- 9.4 million tons; and Virginia -- 8.1 million tons. All states but Virginia reported an increase.

Landfills, Incinerators and Capacity: The number of solid waste landfills in the Southeastern states breaks out as follows:

State	Total landfills (2000 survey)	Total landfills (1999 survey)	Average Tip Fee ($)
Florida	57	95	43
Georgia	70	76	27
N. Carolina	39	35	31
S. Carolina	19	19	32
Virginia	65	70	n/a

Only Georgia provided an actual number of years for remaining landfill capacity -- 23 years. South Carolina reported that it has 76.3 million tons of capacity remaining. States were asked if they were adding landfill capacity and if there were any legislative restrictions on adding capacity. Florida, Georgia and South Carolina noted their states are adding capacity; North Carolina said no capacity was being added and Virginia didn't respond to this question. All states (except Virginia, which didn't respond) note there are no legislative restrictions on adding landfill capacity.

In terms of incinerators, Florida leads the Southeast region with 13, reporting a total daily throughput capacity of 19,200 tons. Virginia reports have six incinerators in operation; the remaining states only have one each. Daily capacity is as follows: Georgia -- 500 tons/day; North Carolina -- 380 tons/day; and South Carolina -- 700 tons/day.

Unlike a decade ago when landfill capacity was perceived as diminishing and tipping fees were on the rise, the Southeast -- like most other regions of the country -- seems to have adequate, if not abundant, disposal capacity. Florida also has a significant amount of incineration capacity. What does this mean for composting? First, there is no overt need to develop solid waste management alternatives such as composting. Second, and more importantly to how composting evolved in the 1980s and 1990s, there isn't any obvious pressure on state legislatures and policy makers to push for more aggressive composting and recycling -- at least from the standpoint of disposal capacity. That pressure ten-plus years ago led over 20 states in the country to institute bans on the disposal of leaves and/or grass, which was a significant stimulant to development of composting capacity.

CURRENT COMPOSTING ACTIVITY IN THE SOUTHEAST

As noted earlier, *BioCycle* collects data on an annual or biannual basis on the number of composting projects nationwide that are handling the following residuals: Food, MSW, yard trimmings and biosolids. The following table represents composting activity in the Southeast. While *BioCycle* has not surveyed composting activity in the agricultural sector, the number of farm-based projects handling agricultural residuals has definitely been increasing, not only in the Southeast, but across the country.

State	Food[1]	MSW[2]	Yard Trimmings[3]	Biosolids[4]
Florida	0	1	35	9
Georgia	2	2	169	6
N. Carolina	5	0	120	11
S. Carolina	1	0	69	7
Virginia	1	0	11	5

[1]2000 data; does not include on-site composting projects, e.g. at correctional facilities or universities
[2]1999 data
[3]1999 data
[4]1998 data

The nine food residuals composting projects in the Southeast are all fairly small. The two in Georgia take a total of 600 tons/year of food residuals. The five in North Carolina process the most -- over 13,000 tons/year -- while the South Carolina and Virginia projects are handling a very small amount. At this time, North Carolina is most active in developing new food residuals composting projects, although interest appears to be growing in Georgia.

The three MSW composting facilities in the Southeast all process mixed solid waste consisting of residential and commercial feedstocks. The Sumter County, Florida and Cobb County, Georgia facilities both cocompost MSW and biosolids.

The number of biosolids composting projects in the Southeast has remained pretty stable over the past few years. That may change, as more local governments in states such as Virginia and North Carolina consider and/or implement bans on land application of biosolids. As of late 1999, there were ten bans or ordinances prohibiting or limiting land application in Virginia, and four in North Carolina. Over 50 percent of the biosolids generated in Virginia are land applied at this time; 30 percent are incinerated and 10 percent are landfilled. Florida land applies over 65 percent of the biosolids generated; 17 percent are landfilled and 8 percent are incinerated. The state reports that only a handful of bans or ordinances have been adopted to restrict land application. As land application becomes more difficult, it is expected that there will be more movement to composting biosolids.

COMPOSTING DRIVERS

Because disposal capacity and high tipping fees are eliminated as driving factors toward increased composting, other factors need to be analyzed. Some are more immediate, whereas others are expected to evolve over the next decade. These factors are discussed below:

Public policy commitments toward recycling and composting: Despite the lack of legislative and capacity pressures, quite a bit of momentum was created over the past ten years toward maximizing the amount of diversion through recycling and composting. Local governments and state recycling and composting officials continue to explore ways to pull more materials out of the solid waste stream. Some funding -- in the form of grants and/or loans -- is still available to help programs get started or expand. The 1999 State of Garbage in America survey (and the questionnaire for Part II being mailed out in late August) asked states to estimate recovery rates for yard trimmings, food residuals and wood. Three of the five Southeastern states provided estimates of recovery rates:

State	Yard Trimmings (%)	Food Residuals (%)	Wood Residuals (%)
Florida	>50	<10	n/a
N. Carolina	>50	<10	>50
S. Carolina	10-20	<10	20-30

Without a doubt, there is room for growth of diversion through composting and mulch production in these three states. Increased diversion through composting -- both in development of new facilities and increased throughput at existing processing facilities -- is a very viable option.

Need for alternative management of various residuals: In the next five to ten years, it is expected that composting will play an increased role in the management of animal manure and animal mortalities from confined animal feeding operations. The large quantities of manure generated can tax an area's capability to absorb those nutrients in an environmentally sound manner that is protective of public health. Composting is a viable alternative to managing manure and mortalities.

Opportunities also exist for composting food processing residuals that currently are land applied. The potential for increased composting of biosolids was discussed earlier.

Demand for soil amendments: The Southeast region, like so many areas of the country, is experiencing rapid development and population growth. With that development and growth comes a need for soil amendments to establish lawns, green spaces and golf courses, plant gardens, and establish and stabilize roadways. Compost can be a competitive product in the soil amendment marketplace. As markets are established, composting facilities must be positioned to meet that demand on a consistent basis (which thus requires a steady flow of feedstocks to the plants).

State of soils in the region: Compost is playing an increased role in the remediation of contaminated soils as well as building valuable organic matter in depleted agricultural soils. Some data will be gathered on the state of soils in the Southeast, to be presented at the October meeting.

Alternatives to traditional pesticides, herbicides: Compost's role as a disease and weed suppressant is expected to lead to increased demand for compost over the next decade. For example, researchers and growers in Florida are using compost as part of a strategy to replace methyl bromide, which will be banned from use in several years. Others are successfully using compost to suppress plant diseases.

CONCLUSION

Factors that led to a surge in composting in the 1980s and 1990s are less prevalent in this decade. New factors, such as a need to manage problem residuals such as manures, will fuel development of composting capacity over the next few years. Demand for compost products will help move that development along.

The 21st Century Organics Revolution

Mitch Kessler, TIA Solid Waste Consultants

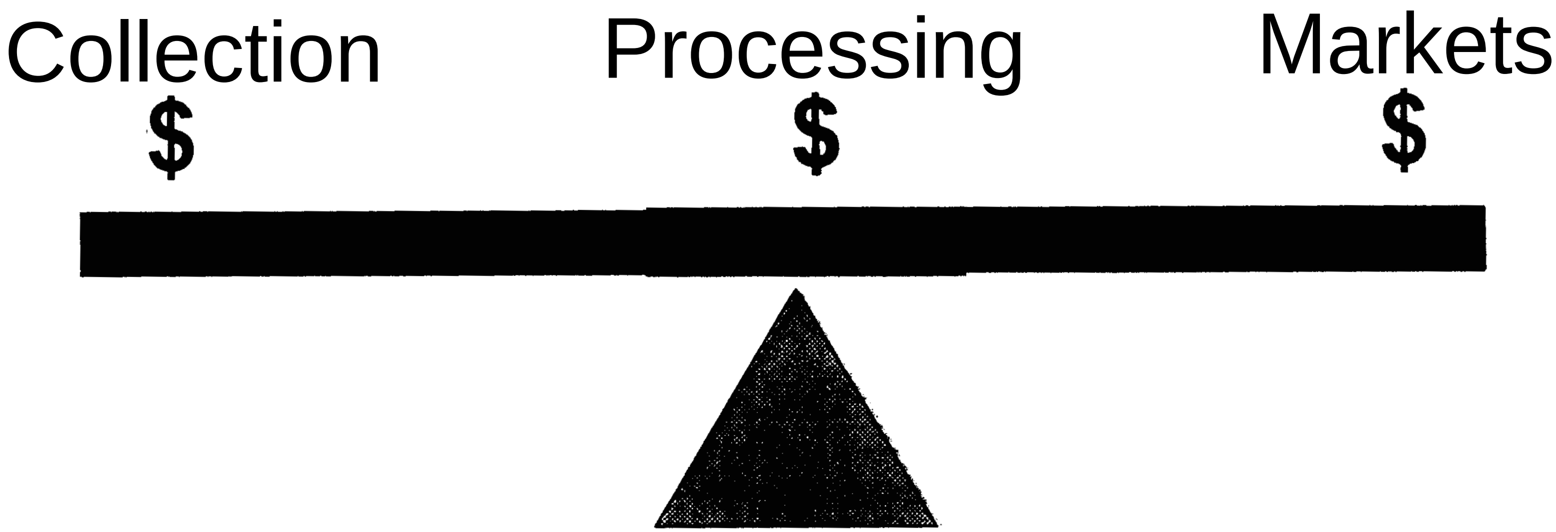
Y2K Cornposting in the Southeast

Conference & Expo

October 10,2000

Charlottesville, VA

Balancing the Components



Organics Recovery Programs

Organic Diversity

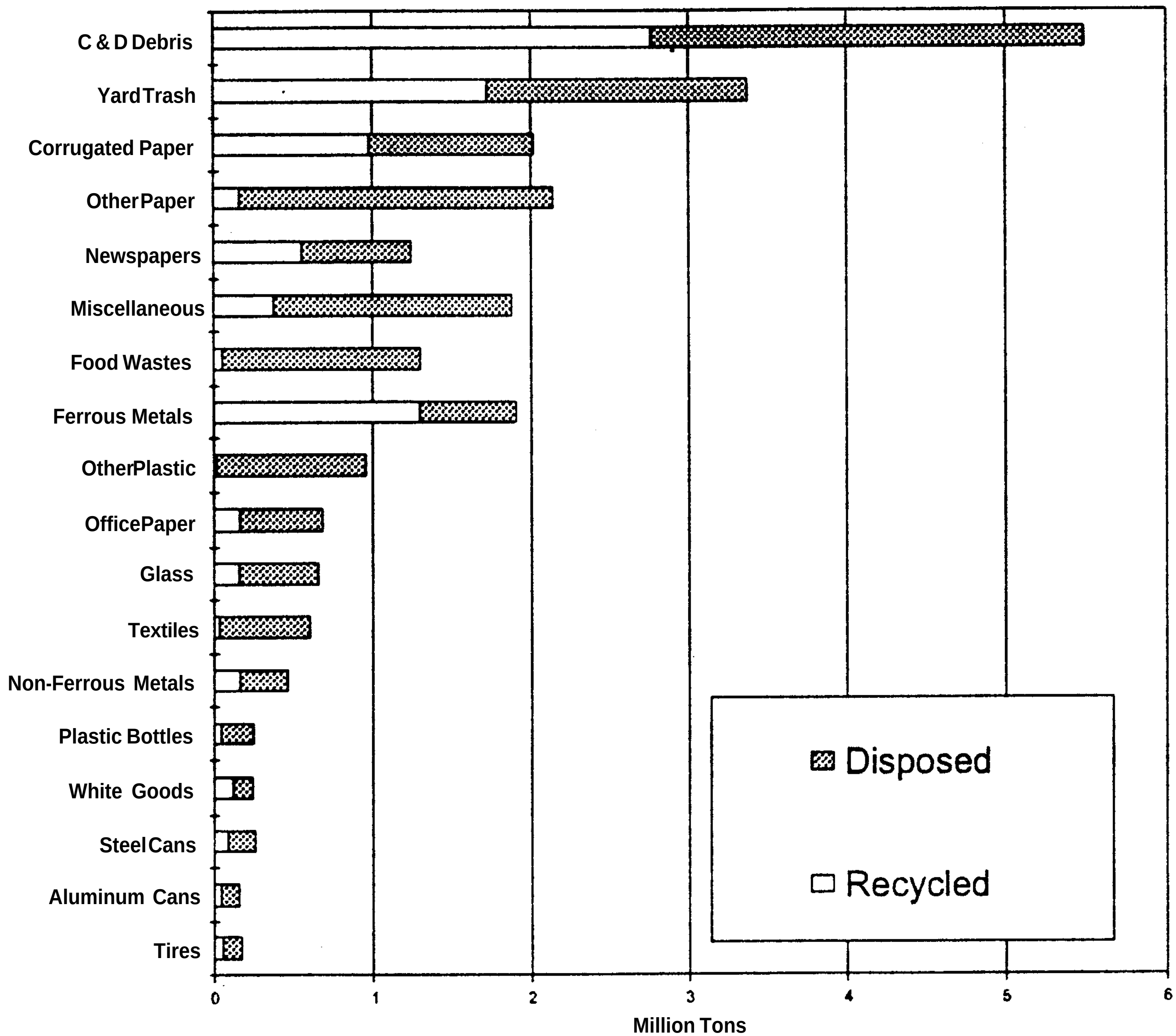
Feedstock	Process	Product
Yard Waste	Size Reduction	Soil Amendment
Animal Manure	Mulch	Fertilizer
Biosolids	Compost	Mulch
Food Waste	Fill Material	Organic Ingredient
Municipal Solid Waste	Feedstock	Energy Recovery
Industry Waste		

Change in Florida's Solid Waste Composition

SFY	Percent of Total Waste per Year: C&D Debris	Food Waste	Tires	Yard Trash	Textiles	Metals	Plastics	Glass	Paper	Misc.
1989	6.0	10.0	2.0	15.0	3.0	6.0	9.0	5.0	39.0	5.0
1990	19.0	8.0	1.0	15.0	3.0	7.0	7.0	4.0	30.0	7.0
1991	16.6	6.5	1.2	15.5	2.9	9.3	6.3	4.2	30.1	7.4
1992	16.3	6.3	0.7	15.4	3.0	10.3	6.6	3.7	30.7	6.1
1993	20.6	5.7	0.7	16.0	3.0	10.2	5.9	3.4	28.7	5.8
1994	21.9	5.5	0.7	14.8	2.8	10.8	5.7	3.0	27.5	7.3
1995	24.2	5.5	0.7	14.3	2.7	10.1	5.4	2.7	26.9	7.5
1995[1]	22.6	5.4	0.8	14.4	2.4	12.1	5.2	2.7	26.3	8.1
1996[1]	23.1	5.1	0.7	14.2	2.5	13.2	5.1	2.7	25.1	8.4
1997[1]	23.1	5.5	0.7	14.2	2.5	12.6	5.0	2.8	25.6	7.9

[1] *Calendar year data.*

Materials Recycled and Disposed in Florida (CY 1997)



* Material recycled as "Process Fuel" was divided equally among the "C&D Debris" and "Yard Trash" categories.

Future Trends

- Increased Economic Scrutiny
- Program Efficiency / Accountability
- One-Stop Shopping
- Regionalization
- Increasing Composting and C&D Recycling

What’s Left To Do

- Revise State compost rules
- Create uniform standards
- Increase organics recovery
- Produce higher-value material
- Demonstrate benefits to markets
- Move from puberty to adolescence

THE NORTH CAROLINA COMPOST PROMOTIONAL INITIATIVE

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The North Carolina Compost Promotional Initiative (Initiative) was developed as a means to stimulate market demand for North Carolina compost, and other recycled soil amendment type, products. The project goals were accomplished by completing a variety of statewide compost market development and educational activities which would both stimulate product demand and increase product value. Project efforts were broken down into four major areas of focus:

- Promote compost to North Carolina professional "end-users" and "specifiers"
- Promote compost to North Carolina “homeowners” and “gardeners”
- Develop a Compost Use web-page
- Coordinate efforts with the United States Composting Council’s (USCC's) Promotional Initiatives

A major focal point of the project was to develop a ‘Compost Use’ web-page. The web-page was important because of our ability to refer both professional and non-professional end users and specifiers to it for specific technical data. Development of the Compost Use web-page was completed with funds made available through the NC DPPEA, the US EPA, as well as other regional funders. The USCC co-sponsored the development of the web-page and allowed the use of its copyrighted documents, "The Field Guide to Compost Use" and "Landscape Architects Specifications for Compost Utilization" in its development. The USCC hosts and manages the web-page on its web site (www.compostingcouncil.org). All data found within the two previously mentioned USCC technical documents had been extensively peer reviewed, and are based on a variety of university research completed throughout the United States. The Compost Use web-page will also be hyper-linked directly to the North Carolina DENR’s web-site. The Compost Use web-page itself contains close to 200 pages of text and more than 50 color pictures. The Compost Use web-page provides compost use information, which is appropriate for both professional and non-professional end users, as well as companies and entities that can specify the use of compost.

The web-page itself provides information (and graphics) pertaining to:

- Benefits of compost and its effects on growing systems
- Compost feedstocks
- Compost characteristics/parameters
- Compost selection
- Comparing compost to other horticultural and agricultural products
- Compost use guidelines for various compost end uses, including:
  - Various landscape applications (planting bed establishment, mulching, planting backfill mix, topsoil blending)
  - Turf Management (turf establishment and renovation, upgrading marginal soils)
  - Nursery applications (growing media component, nursery bed and field nursery production)
  - Other (establishing vegetable crops, erosion control, silviculture, sod production)
- Landscape Architecture Specifications for Compost Utilization

A series of 'hands on' promotional and educational activities were also completed within this project to improve both compost awareness and stimulate market growth. The activities within the project (and listed below) concentrated on more conventional landscape based applications for compost, because within the State of North Carolina, landscape related (horticultural) applications currently represent the highest value compost markets. However, neither professional, nor non-professional horticultural markets have been properly engaged on a statewide basis to allow for a more long-term and sustained infrastructure to be developed. In fact, North Carolina's two largest composters sell the majority of their compost in topsoil blends. While this strategy certainly improves the marketability of their compost products, it also means that the composters are not focussing their educational efforts on promoting the benefits of 'pure' compost, which over time will more greatly benefit compost market development and improve product value. Within the projects promotional and educational efforts, compost was not only promoted as a viable horticultural and agricultural product, but also as an environmental product that promotes water quality and soil conservation.

During the early stages of the project, contact was made with various composters across the state of North Carolina (as well as the DPPEA Organic Recycling Coordinator) to develop a working group to provide feedback, and assist with specific efforts, within the project.

Specific NC CPI Project Components/Tasks

A. Promote compost use to professional 'end users' and 'specifiers'
   1. Engage end user trade associations
      a. Attended state trade shows to promote compost use, North Carolina programs (obtained booth) - Turfgrass Council of NC Show and the Green & Growing Trade Show (sponsored by the NC Landscape Association, NC Association of Nurserymen)

   b. Identified and educated retail/wholesale firms that sell bulk products
   c. Developed an updated list of North Carolina 'commercial' composters
   d. Introduced compost use information and list of composters in North Carolina to end users and conference attendees
2. Engage end user specifiers
   a. Presented papers at 3 regional chapter meetings and the state conference of the North Carolina Chapter of the American Society of Landscape Architects (ASLA)
   b. Promoted compost use data/specifications to select North Carolina landscape architecture firms
   c. Engaged the N.C. Department of Transportation regarding expanding composting usage, and new applications
   d. Promoted compost use data/specifications to North Carolina universities teaching landscape architecture
   e. Distributed landscape architect specs developed by USCC (computer CD) and promoted web-site to specifiers

B. Promote compost use to ‘homeowners’ or ‘home gardeners’
   1. Focussed efforts through North Carolina members of the Garden Writers Association of America (GWAA)
      a. Engaged specific North Carolina GWAA members
      b. Worked with North Carolina GWAA members, and engaged the national organization (GWAA), as well as the Raleigh news media about International Compost Awareness Week
      c. Promoted North Carolina composters and programs, USCC tools, Compost Use web-site, etc. and associated efforts
      d. Promoted purchase of bulk product to retail/wholesale firms that sell bulk compost, wherever possible
   2. Engage Garden Clubs
      a. Promoted North Carolina composters, compost benefits, North Carolina organics recycling initiatives, Compost Use web-site, etc.
      b. Primarily engaged management of The Garden Clubs of North Carolina, Inc. and the National Council of State garden Clubs – providing tools and data to which they can distribute to members
      c. Completed an article for the national organization's newsletter promoting compost use, and the end use tools available
   3. Engage Extension Service
      a. Promoted web-page information as source for end user assistance and education

Throughout the project, major composters within the state were engaged and asked to be involved with the Initiative. As meetings and events were planned, these groups were offered the ability to provide input and, where possible and appropriate, attend. By involving the composters, they will be better prepared to promote and educate potential end users, specifiers, and compost advocates regarding the benefits of composting and compost use in the future.

The overall project objective was to stimulate demand for compost, and other recycled soil amendment type products, through a variety of educational and promotional efforts focussed towards specific end users, specifiers and compost advocates. Through these efforts, it was a further objective to enhance the diversion of organics wastes in the State of North Carolina.

Additional project objectives were to:

- Encourage the production of greater volumes of 'quality' compost
- Improve the awareness and marketability of North Carolina produced compost
- Increase product accessibility to professional and non-professional end users in North Carolina
- Educate professional and non-professionals end user on compost use
- Improve the infrastructure for compost market development

Through enhancing market demand, the compost marketing 'pie' will grow, so individual composters will not focus on competing over who has the largest piece of the 'pie'. Instead, composters have a method to work together in a coordinated manner to stimulate overall market growth, which benefits the composting industry as a whole. Through working with project partners such as the USCC, DDPEA staff, state composters and the various North Carolina horticultural trade associations, not only were the marketing efforts in the program leveraged, and they should become more sustainable.

At the conclusion of the project, a report will be provided to the NC DENR/DPPEA that summarizes all of the activities undertaken during the Initiative, any conclusions drawn, project successes, future needs, follow-up steps, as well as lists of various types of individuals contacted.

RESIDUAL EFFECT OF MUNICIPAL SOLID WASTE AND BIOSOLID COMPOST ON SNAP BEANS PRODUCTION

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ABSTRACT

The residual effects of compost (mixture of municipal solid waste and biosolid) on snap bean 'Opus' (*Phaseolus vulgaris* L.) production and soil nutrients concentration was evaluated from compost applied in the autumn of 1995 and winter 1996. Compost treatments applied 8 month early were considered the main plots and two fertilizers level the sub-plots (0 vs. 100 $kg \cdot ha^{-1}$ of N). Main plots for 1996 consisted of 3.8 (49 $t \cdot ha^{-1}$), 7.5 (99 $t \cdot ha^{-1}$), 11.3 (148 $t \cdot ha^{-1}$), and 15 cm (198 $t \cdot ha^{-1}$) thickness of 4-week-old immature MSW compost applied as a mulch, and an untreated control. The second experiment consisted in 3.8, 7.5, and 11.3 cm thickness of 8-week-old MSW immature compost and an untreated control. Main plots for 1997 consisted of 2 (26 $t \cdot ha^{-1}$), 3.8, 7.5, and 11.3 thickness of 4-week-old immature MSW compost, and an untreated control. The second experiment consisted in 2, 3.8, 7.5, and 11.3 cm thickness of 8-week-old MSW immature compost and an untreated control. In 1996, plant stand, marketable bean, and yield per plant were not different among 4 or 8-week-old compost and fertilizer treatments for 4-week-old compost. However, marketable yield and yield per plant was higher on the fertilized plots than unfertilized plots for 8-week-old compost. There were not differences on soil pH, OM, and nutrient concentration among 4 or 8-week-old compost treatments. In 1997, marketable yield and yield per plant increased linearly with increasing 4 or 8-week-old compost rate. Plant stand increased linearly as 4-week-old compost increased, however, there were no differences for 8-week-old compost. Plant stand, marketable yield, and yield per plant was higher in the fertilizer plots than unfertilized plots in both compost ages. Soil pH, OM, P, Ca, Zn, and Mn increased linearly as 4 or 8-week-old compost rate increased. There were no differences on K, Mg, and Fe between compost treatments and the control for 4 or 8-week-old compost. Positive residual effect of compost on snap bean production can be expected under normal irrigation practice.

INTRODUCTION

Solid waste disposal in has become a concern, since population is increasing, strong environmental regulation that require landfills lining to protect ground water, and expensive tipping fee (Smith, 1995b). In 1993, 21.4 million metric tons of solid waste were produced in the united States approx. 4.3 kg per person per day (Smith, 1994b and 1995). Waste materials such as municipal solid waste (MSW), yard trimmings (YT), and biosolid (B) are high-volume wastes that could be composted instead of landfilled or incinerated (Smith, 1994c). Nationally, composting may be an attractive waste management tool, since 30-60% of the waste materials can be composted in an environmentally safe matter (Smith, 1994a). Potential compostable organic material represent 65% of the MSW stream (Smith, 1990; Smith and Cisar, 1993). The largest potential compost user is the agricultural industry (Parr and Hornick, 1992). Florida is a major vegetable-producing state, with 149,850 ha under cultivation each year (FASS, 1997). Sandy soils used for agriculture in Florida have low native fertility (Brady, 1974). Proper fertilization is necessary to maximize yield and fruit quality (Hochmuth and Albregts, 1994), therefore to obtain high crop production, fertilizer inputs are high. Minimizing fertilizer leaching or runoff has become important due to potential negative environmental impacts. Soil-application of compost provides an alternative to current methods of waste disposal, and at the same time may decrease the amount of water and fertilizer applied to crops (Ozores et al., 1994b). Municipal solid waste compost can also play a significant role in the development and maintenance of soil organic matter content (Parr and Hornick, 1992). Amending soil with mature and stable composted materials such as biosolids, MSW, and YT has been investigated extensively, and has been reported to increase vegetable crop yields on beans, blackeye peas (*Pisum sativum* L.), okra (*Abelmoschus esculentus* L.) (Bryan and Lance, 1991) tomato (*Lycopersicon esculentum* Mill.), squash (*Cucurbita maxima* Duch. Ex Lam.), eggplant (*Solanum melongena*) and beans (Ozores-Hampton and Bryan, 1993a and b; Ozores-Hampton and Bryan, 1994; Ozores-Hampton et al., 1994a and b), watermelon (*Citrullus vulgaris* Schrad.) and tomato (Obreza and Reeder, 1994; Obreza et al., 1994), corn (*Zea mays* L.) (Gallaher and McSorley, 1994a and b), and pepper (*Capsicum annuum* L.) (Roe et al., 1993; Stoffella, 1995). Most benefits of soil-applied compost have been attributed to improved physical properties due to increased organic matter concentration, rather than nutrient value (Gallardo-Lora and Nogales, 1987; Hernando et al., 1989; McConnell et al., 1993).

The objectives of this investigation were to evaluate the residual effect of MSW and biosolids compost incorporated the previous year with a combination of inorganic fertilizer on snap beans production.

MATERIALS AND METHODS

Two field experiments were conducted during 1996 and 1997 at Southwest Florida Research and Education Center in Immokalee, Fla. Soil type is a Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquods). Snap beans 'Opus' were planted on the same site as the previous (fall, 1995 and winter 1996) biological weeds control plots to determine if there were residual effects of MSW and BS on a second crop. The fields (1996 and 1997) experiments were a randomized complete block split-plots experimental design with four replications. The compost utilized for the experiments were provided by Bedminister Bioconversion of Tennessee, Inc., Sevierville, TN. The MSW and BS are co-processed through a three-compartment Eweson digester in an aerobic environment for 3 days and then cured for 8 weeks using the windrow composting methods. Compost chemical and physical properties were analyzed by the Soil and Water Science Department, University of Florida, Gainesville. The chemical and physical properties of the compost are presented in Table 1.

1996 experiments: Two field experiments were conducted simultaneously utilizing compost treatments applied on the fall of 1995. Compost treatments applied 8 month early were considered the main plots and two fertilizers level the sub-plots (with and out fertilizer). Main plots consisted of 3.75 (49 $t \cdot ha^{-1}$), 7.5 (99 $t \cdot ha^{-1}$), 11.3 (148 $t \cdot ha^{-1}$), and 15 cm (198 $t \cdot ha^{-1}$) thickness of 4-week-old immature MSW compost applied as a mulch, and an untreated control. The second experiment consisted in 3.75, 7.5, and 11.25 cm thickness of 8-week-old MSW immature compost and an untreated control. In both experiments immature compost was place in both side of the beds 90 cm wide and 4.8 m long. Sub-plots consisted of 100-0-113 (N-P-K $kg \cdot ha^{-1}$) and no fertilizer application. Granular fertilizer applications were divided in 3 equal single application at planting, 2 and 4 week after planting. Sub-plots size area consisted of 3 single 2.4 m long center row and 2 border row. After removing polyethylene beds 240 days after treatment (DAT), compost was incorporated about 15 cm deep with a rototiller, and snap beans seeded. Beans were direct seed in a single row on beds 0.3 m wide and 15 high. Beans were planted at 5 cm between seeds and 90 cm between beds or equivalent to 222,000 $plants \cdot ha^{-1}$. Beans were planted on 27 Sept, 1996 and harvested 25 Nov, 1996. Harvested beans area consisted of 4 m long center rows. The plants were irrigated by maintaining a water table about 0.6 m below the soil surface, and were monitored for insects and diseases according to Univ. of Florida guidelines.

1997 experiments: Two field experiments were conducted simultaneously utilizing compost treatments applied on the winter of 1996. Compost treatments applied 8 month early were considered the main plots and two fertilizers level the sub-plots (with and out fertilizer). Main plots consisted of 2 (26 $t \cdot ha^{-1}$), 3.8, 7.5, and 11.3 thickness of 4-week-old immature MSW compost, and an untreated control. The second experiment consisted in 2, 3.75, 7.5, and 11.3 cm thickness of 8-week-old MSW immature compost and an untreated control. In both experiments, immature compost was place in both side of the bed 6.6 m long and 90 cm wide average. Sub-plots consisted of 100-0-113 (N-P-K $kg \cdot ha^{-1}$) and no fertilizer application. Granular fertilizer applications were divided in 3 equal single application at planting, 2 and 4 week after planting. Sub-plots size area consisted of 2 single 3.3 m long center row and 2 border row. After removing polyethylene beds 240 days after treatment (DAT), compost was incorporated about 15 cm deep with a rototiller, and snap beans seeded. Beans were direct seed at 5 cm between seeds and 53 cm between rows or equivalent to 374,000 plants$\cdot$ha^{-1}. Beans were planted on 20 Feb, 1997 and harvested 14 April, 1997. Harvested beans area consisted of 4 m long center rows. The plants were irrigated by drip irrigation to mantain uniform soil moisture level to the crop. Insects and diseases were monitored according to Univ. of Florida guidelines.

Plant stands and marketable yield was measured at the time of harvest. Plots were manually harvested by removing the beans from the plants. Soil samples (500 g) were collected before planting in the composted non-fertilized areas and analyzed at Soil laboratory at Southwest Florida REC, Immokalee. Samples were oven dried at 28^{o}C and extracted with Mehlich-1 solution for Ca, Mg, P, and K (Hanlon and DeVore, 1989). Soil pH was determined by 1:2 soil:water saturated extract and organic matter by ignition (Dellavalle, 1992). Cooper, Mn, Fe, and Zn were determined by inductively coupled-argon plasma spectroscopy.

Concentration of volatile fatty acids such as acetic, propionic, butyric, isobutyric, valeric and isovaleric acids were performed by Wood End Research Laboratory, Inc Vermon, Maine 04352. The compost extract were prepared with 20 g compost dry weight and 50 ml of distilled water. At the laboratory the samples were diluted 1:10-1:1000 with distilled water and run through and HPLC anion column, eluted with 0.15mM H_2SO_4.

Data were subjected analysis of variance to determine treatment effects and interactions. Orthogonal contrast was utilized to describe the response of plant stand, marketable yield and soil nutrients to increasing rate of compost.

RESULTS AND DISCUSSION

Compost maturity tests. The biological cress germination methods was utilized to determine compost maturity 240 DAT. The cress test resulted in a germination index of 100 indicating the absence of phytotoxic compounds associated with immature compost (Zucconi et al., 1981b). Physical examination of the compost indicated a dark brown to black color and absence of unpleasant odor associated to immature and unstable compost that can cause seed or plant dead and/or N-immobilization. Thus, after 240 DAT composts was mature and stable. Both the 4 and 8-week-old composts complied the U.S. Environmental Protection Agency's criteria for "exceptional quality," indicating no restrictions on use or application rate (Kidder and O'Connor, 1993).

Soil analysis: There were no effects of compost on pH, OM, and nutrients concentration for 1996. In 1997, soil pH, OM, P, Ca, Zn, and Mn were higher in the compost treatments than the control for 4-or 8-week-old compost (Table 2). There were no differences on K, Mg, and Fe between compost treatments and the control for 4 or 8-week-old compost. Soil pH, OM, P, Cu, Zn, and MN increased linearly as 4 or 8-week-old compost increases. No differences were obtained in soil Cu concentration between 8-week-old compost treatments and the control, but Cu concentration increased linearly as compost rate increased. Soil Cu concentrations differ between 8-week-old compost treatments and the control, and Cu concentration increased as compost rate increased. Soil Ca concentration increased linearly as 4-week-old compost rate increased, but did not increased for 8-week-old compost.

1996 bean production: There were not interactions between compost and fertilizer, and no effects of 4 or 8-week-old compost or fertilizer effects for 4-week-old compost for any of the variables measured (Table 3). For the 8-week-old compost, higher marketable yield and yield per plant were reported from fertilized plots than unfertilized plots. Similar plant stand were reported from the fertilized plots and unfertilized plots for 8-week-old compost. Roe et al (1990) reported higher broccoli yield with 168 than 84 $kg \cdot ha^{-1}$ of N and not effects of compost. The addition of MSW and biosolids compost to the soil provides N almost completely in organic forms, therefore availability occurs only over extended period of time. However, incorporation of inorganic fertilizer which is mainly water-soluble and is almost immediately available to the crops. Results from our experiments indicated no residual effect of 4 or 8-week-old compost and no fertilizer effect of 4-week-old compost on plant stand, marketable yield or yield per plant. This may have been due to suboptimal soil moisture by a poor water tables management during the crop production, especially on the 4-week-old compost. Marketable yield was lower than southwest Florida commercial average on 4 or 8-week-old compost, indication the effects of poor irrigation. Lack of adequate irrigation system can diminish the residual effects of compost and fertilizer on snap bean production.

1997 bean production: There were not interactions between compost and fertilizer on 4 and 8-week-old compost for any of the variables measured (Table 4). There were effects of compost and fertilizer on 4 and 8-week-old compost experiments. Marketable yield, and yield per plant increased linearly as 4 or 8-week-old compost rate increases. Plant stand increased linearly as 4-week-old compost rate increases. Plant stand was similar on 8-week-old compost. Higher plant stand, marketable yield and yield per plant was obtained from fertilized plots than unfertilized plots for 4 or 8-week-old compost experiments. Residual effects of composted materials such as biosolids, MSW, and YT had produced positive results in a wide variety of crops. Municipal solid waste compost rates of 90 $t \cdot ha^{-1}$ applied early in the year resulted in crop yield increases for bean (Ozores-Hampton and Bryan, 1993b). Residual effects of compost of MSW, BS, and MSW and BS combination applied a year early resulted in squash yield increases of 23% over the control (Ozores-Hampton et al., 1994). Application of 112 $t \cdot ha^{-1}$ MSW 90 days before planting increased watermelon production by 30% as compared to southwest Florida commercial average (Obreza and Reeder, 1994). Compost may increase yield by improve long term physical and chemical properties such as water-holding capacity, cation exchange capacity, bulk density, and percentage organic matter, and can increase the microbial population rather than the value as a fertilizer (Gallardo-Lara and Nogales, 1987).

The lack of differences among compost treatments in soil nutrients and suboptimal soil moisture resulted in no significant yield responses to compost for 1996 experiments (Table 3). Higher soil pH, OM, and nutrient concentration due to compost treatments resulted in higher marketable bean yield for

1997 experiments (Table 2 and 4). Benefits from compost utilization to improve crop yield and soil chemical and physical properties have been reported, although the response is not always predictable.

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Table 1. Elemental concentration and chemical analysis of immature compost.

Characteristic	4-weeks		8-weeks	
	1995	1996	1995	1996
	----------(% dry weight)[x]---------			
C	40.4	38.1	38.0	38.0
N	1.24	1.22	1.31	1.18
P	0.37	0.21	0.37	0.26
K	0.32	0.31	0.34	0.30
Ca	2.21	2.04	2.21	2.27
Mg	0.24	0.18	0.24	0.23
Fe	0.86	0.88	0.97	0.96
	----------($mg \cdot kg^{-1}$ dry weight)[x]------			
Cd	2.0	3.0	2.0	3.0
Cu	197	303	550	207
Mn	219	303	226	207
Pb	182	238	192	268
Ni	39	33	38.5	40
Zn	567	487	550	459
Moisture (%)	39.7	37.5	42.0	64.0
C:N	35.5	31.3	29.0	31.8
pH	6.6	8.0	6.7	7.9
E.C. (dS/m)	10.1	8.4	9.5	10.5
G.I[z]	0	0	0	0

[x] Soil and Water Science Department, University of Florida, Gainesville.

[z] Germination Index (Zucconi et al., 1981a and 1981b).

Table 2. Residual effect of 4 and 8-week-old compost on soil pH, organic matter and soil nutrient concentration for 1997.

Treatments		pH	OM (%)	P	K	Ca	Mg	Cu	Zn	Mn	Fe
				------mg·kg⁻¹------							
			------4-week-old compost------								
Control		6.0	1.8	16	14	671	10	4.4	3.0	1.7	20.8
Compost, 1.9 cm		6.3	2.0	23	13	789	21	3.8	4.5	2.1	17.3
Compost, 3.8 cm		6.6	2.1	25	11	933	16	5.0	6.6	2.8	19.8
Compost, 7.5 cm		7.3	2.6	35	17	1,399	18	6.5	15.2	4.5	34.1
Compost, 11.3 cm		7.5	2.5	43	13	1,621	19	5.2	18.7	5.9	32.1
Compost		**	**	*	NS	**	NS	**	**	*	NS
Contrast:											
Control vs. compost		**	**	**	NS	**	NS	NS	**	**	NS
Compost:	Linear	**	**	*	NS	**	NS	*	**	**	NS
	Quadratic	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
			------8-week-old compost------								
Control		6.3	1.7	20	7	740	13	2.2	2.6	1.7	46.2
Compost, 1.9 cm		6.6	1.8	22	8	730	15	3.0	3.9	2.0	43.4
Compost, 3.8 cm		6.9	1.9	27	10	1,147	19	2.9	6.0	2.6	50.1
Compost, 7.5 cm		7.1	2.0	31	13	1,015	14	2.9	8.6	2.8	53.7
Compost, 11.3 cm		7.5	2.2	39	10	1,194	16	4.0	12.2	4.1	60.3
Compost		**	**	**	NS	*	NS	*	**	**	NS
Contrast:											
Control vs. compost		**	**	**	NS	*	NS	**	**	**	NS
Compost:	Linear	**	**	**	NS	NS	NS	*	**	**	NS
	Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**, *, ^{ns}: Significant at P = 0.01, P = 0.05, or not significant, respectively.
OM = organic matter

Table 3. Residual effects of compost and fertilizer rate on plant stand, total yield and yield per plant for 1996.

Treatments		Plant stand (No./4 m rows)	Bean yield ($t \cdot ha^{-1}$)	Yield/plant (g/plant)
		------------------------4-week-old compost-----------------------		
Control		38	3.9	37.4
Compost, 3.8 cm		40	3.3	30.0
Compost, 7.5 cm		40	3.4	30.0
Compost, 11.3 cm		42	3.5	31.0
Compost		NS	NS	NS
Contrast:				
Control vs. compost		NS	NS	*
Compost:	Linear	NS	NS	NS
	Quadratic	NS	NS	NS
Fertilizer (lb/acre)				
0		40	3.1	32.0
90		41	4.0	31.8
		NS	**	NS
Interactions				
Compost X fertilizer		NS	NS	NS
		------------------------8-week-old compost-----------------------		
control		44	7.0	57.4
Compost, 3.8 cm		43	5.7	48.5
Compost, 7.5 cm		42	5.7	50.0
Compost, 11.3 cm		43	6.4	52.7
Compost		NS	NS	NS
Contrast:				
Control vs. compost		NS	NS	NS
Compost:	Linear	NS	NS	NS
	Quadratic	NS	NS	NS
Fertilizer (lb/acre)				
0		43	5.0	42.2
90		43	7.3	62.1
		NS	**	**
Interactions				
Compost X fertilizer		NS	NS	NS

**, *, ^{NS}: Significant at P = 0.01, P = 0.05, or not significant, respectively.

Table 4. Residual effects of compost and fertilizer rate on plant stand, total yield and yield per plant for 1997.

Treatments		Plant stand (No./4 m rows)	Bean yield ($t \cdot ha^{-1}$)	Yield/plant (g/plant)
		------------------------4-Week-old compost	----------------------	
Control		30	1.4	15.9
Compost, 2.0 cm		32	2.4	30.4
Compost, 3.8 cm		35	3.1	32.4
Compost, 7.5 cm		40	4.6	43.1
Compost, 11.3 cm		42	6.9	60.1
Compost		*	**	**
Contrast:				
Control vs. compost		*	**	**
Compost:	Linear	**	*	**
	Quadratic	NS	NS	NS
Fertilizer (lb/acre)				
0		39	3.4	30.8
90		33	4.0	42.0
		*	*	**
Interactions				
Compost X fertilizer		NS	NS	NS
		-----------------------8-week-old compost	-----------------------	
Control		30	0.9	9.9
Compost, 2.0 cm		43	2.0	16.0
Compost, 3.8 cm		39	1.9	18.6
Compost, 7.5 cm		37	3.8	31.6
Compost, 11.3 cm		50	5.8	41.9
Compost		**	**	**
Contrast:				
Control vs. compost		**	**	**
Compost:	Linear	NS	**	**
	Quadratic	*	*	NS
Fertilizer (lb/acre)				
0		36	2.4	19.9
90		43	3.4	27.2
		*	**	**
Interactions				
Compost X fertilizer		NS	NS	NS

**, *, ^{ns}: Significant at P = 0.01, P = 0.05, or not significant, respectively.

EFFECTS OF COMPOST ON THE GROWTH OF FRASER FIR CHRISTMAS TREES IN NORTH CAROLINA

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INTRODUCTION

It has often been said that it is easier to pull a rope than it is to push a rope. The same is true for marketing of recycled materials, including the marketing of compost. It is much easier to market a product that is being pulled through the market by the demand for the product. The purpose of this project was to better quantify the effects of compost on Fraser fir Christmas tree growth in North Carolina as a means of providing a research-based marketing tool to increase demand for compost. North Carolina harvests six to seven million Christmas trees per year from nearly 4,000 acres, which is about 15 percent of the total national Christmas tree output.

The premise for the study was that the addition of compost could have several potential positive impacts on tree production, including faster growth, denser growth, and the potential for suppressing plant diseases. The study was divided into two parts: one part studied the growth effects of compost, and a second part studied the disease suppression qualities of compost. It was expected that the results of this study would have positive lateral effects in increasing demand for compost for other conifer trees grown throughout the State.

LITERATURE REVIEW

Past research does not sufficiently provide practical effects of compost for Christmas tree production, nor does it provide guidelines for appropriate application rates. This research proposal refines past research by limiting the range of compost blends and specifically targets a valuable tree species. Research shows that high blending rates (greater than 30 percent by volume) in most cases do not provide added benefits for plant growth and in some cases hinder plant growth through excessive soluble salt levels and high fertility.

The literature provides sparse information regarding the response of evergreen trees to compost application. There is evidence that some compost will suppress certain plant diseases, but the mechanisms for this suppression and, consequently, the amount or type of compost needed to suppress diseases are not well understood.

Dunlap, et al. (1986) found that Ponderosa pine seedlings responded to compost treatment, with significant treatment effects on height and dry weight, while Douglas fir and noble fir did not show any significant effects. F. R. Gouin (1977) measured the germination and growth of Norway spruce and white pine in response to three levels of screened and unscreened compost compared to an inorganic fertilizer in Maryland. Soils amended with screened compost produced taller seedlings than those treated with unscreened compost. Soils amended with compost had higher levels of pH, phosphorous, and magnesium when compared with those plants receiving inorganic fertilizer. An additional study by Gouin (1993) provides key findings for horticultural crops, including that biosolids compost can effectively provide initial plant needs for both macro and micro nutrients; high application rates of compost can cause soluble salt problems in container-grown plants; mulching conifer seedlings with 112 tons of biosolids compost per hectare stimulated growth; and compost can suppress "damping-off" organisms to the extent that fungicides are not needed.

In a separate study by Hoitink (1997), three mixtures of Technagro™ compost (10, 15, and 20 percent v/v) were applied to seven different species of nursery plants. Results showed that at all locations, most plants treated with the compost grew significantly faster (P=0.05) than the control mixture. Additional work by Devitt, et al. (1991) on periwinkle shows that compost can result in greater plant growth. More recent work by Ingham on strawberries shows that compost can help suppress certain plant diseases. DeCeuster, et al. (1999) suggested that the age of compost could have an effect on disease-suppression qualities.

AREAS OF STUDY

From seed to harvest, the life cycle of a typical Fraser fir Christmas tree is 12 to 15 years. During this time, the tree is transplanted twice prior to harvest. Seeds are initially planted in a seedbed (75 to 120 plants per square foot) where seedlings develop and grow for three years. The seedlings, anywhere from 6 to 12 inches tall, are then transplanted into larger transplant beds. The transplants are kept in the transplant beds for two years, where they reach a height of 16 to 24 inches. From here, the transplants are planted in fields, where they remain for seven to ten years until harvest.

The following two topics were investigated for this research project:

- Study 1 – The response of Fraser fir field transplants to compost
- Study 2 – The effect of compost on the viability of Phytophthora cinnamomi root rot in transplanted Fraser fir seedlings

PROJECT DESCRIPTION AND RESULTS

The compost used in this study was a biosolids-based compost furnished by the City of Morgantown, North Carolina. The compost was well within the USEPA Table 3 limits for pollutants. Additional analysis is presented Tables 1 and 2.

STUDY 1 – THE RESPONSE OF FRASER FIR TRANSPLANTS TO COMPOST

Field-grown trees (previously transplanted trees) in a permanent field location were treated with four rates of compost as mulch (0, 2.2, 4.4, and 8.8 gallons per tree, which corresponds to application rates of 0, 0.5, 1.0, and 2.0 inches of compost on the soil surface, respectively). The experiment was initiated on March 31, 1999 in a plantation of Fraser fir Christmas trees in Ashe County, North Carolina. Spacing of trees was five feet by five feet, and trees had been in the field for about four years. Average tree height was about four feet. Standard cultural practices included annual shearing. Biosolids compost from the City of Morgantown, North Carolina was spread in a circle around each tree out to the drip-line of the crown.

TABLE 1 – Compost Analysis

% Total Solids	49.0
% Volatile Solids	67.3
% Total Kjeldahl Nitrogen	1.8
Carbon-to-Nitrogen Ratio	21.1
Bulk Density (lb/yd^3)	1,168
Conductivity (mmhos/cm)	8.4
% Total Nitrogen	4.07
% Phosphorus	1.81
% Potassium	0.44
% Sulfur	0.91
% Magnesium	0.31
% Calcium	1.03
% Sodium	0.16
Boron (ppm)	17
Iron (ppm)	20,161
Manganese (ppm)	415
pH	7.0

TABLE 2 – Bacterial and Fungal Biomass Analysis

Parameter	Level	Rating
Total fungal to total bacterial biomass	0.03	Poor
Active to total fungal biomass	0.16	Low
Active to total bacterial biomass	0.14	OK
Active fungal to active bacterial biomass	0.03	Poor

The experimental design was a randomized complete block with six replications and four compost rates. Each plot consisted of 20 trees (five trees by four trees). Excluding controls (no compost), all plants received compost. Trees received no inorganic fertilizer during the experiment. Measurements were made on the interior six trees in each plot, with perimeter trees acting as a border between plots. In two plots, to ensure having six good measurement trees, it was necessary to begin with 24 trees rather than 20 trees.

The following measurements were made on September 1, 1999 in each plot:

1. Number of leaders emerging from the top node
2. Length of the best leader
3. Number of lateral buds on the best leader
4. Number of subterminal buds at the apex of the best leader
5. Average diameter (mm) of the best leader two centimeters above its base
6. Bud density on the best leader = 3) 2
7. Twig length in upper crown*
8. Length and weight of a single needle from the branch used in #7*
9. Foliage color: 1 (light) to 4 (dark green)

**See description of "Twig sampling in upper crown."*

Soil samples were collected in each plot and composited (Replicates 1 through 3 and 4 through 6). Two six-inch cores were taken in each plot underneath the compost near the drip line. Root samples were collected for mycorrhizal analysis.

RESULTS AND DISCUSSION – STUDY 1

Of the measurements that were taken (above), there were no significant differences (P=< 0.05) for Variables 1 through 6 and 9. Results for Variables 7 and 8 are described below.

Twig Sampling in Upper Crown (Field Trees). We hypothesized that compost treatment might influence the quantity or quality of foliage. In early September, one dominant branch tip (current-year growth) was taken from a major branch in the second whorl below the terminal of each tree. The following variables were measured on each branch:

1. Length (cm)
2. Number of lateral buds
3. Number of terminal and subterminal buds
4. Needle length at the mid-point of the twig

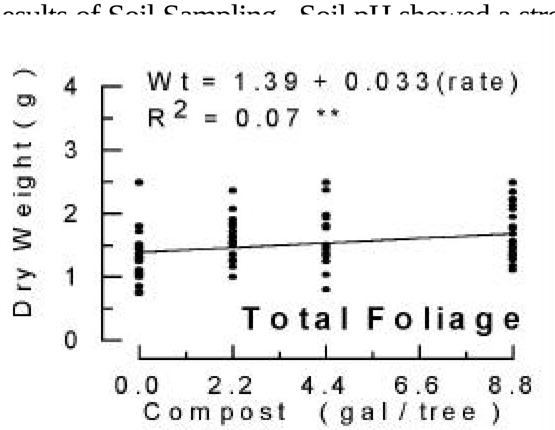
Needles that were used for measurement of length were taped to three-inch by five-inch cards (one card per plot) and subsequently dried at 65°C and weighed. Twigs and needles were placed on ice, transported to Raleigh, and dried to a constant weight at 65°C. Foliage and wood were separated and weighed for each twig. Foliage density was calculated (foliage weight) twig length) as well as bud density (lateral buds) twig length). Results were analyzed with GLM and regression procedures (SAS Institute, Inc.). After processing the twigs, the foliage was composited within each plot, ground to pass a 40-mesh screen, and analyzed by the North Carolina Department of Agriculture, Agronomic Division. Results were analyzed with GLM and regression procedures (SAS Institute, Inc.).

Results for Twig Sampling. Because some trees were inadvertently sheared before measurement, the analysis for twig length was conducted only for plots and trees that were not sheared. The number of non-sheared trees in the 0, 2.2, 4.4, and 8.8-gallon treatments was 22, 18, 18, and 24, respectively. Only four of the measured or calculated variables for side shoots appeared to be affected by compost. There was a slight linear increase for total foliage (Figure 1) per branch (g), foliage density (g/cm), and average needle weight (mg). The relationship for lateral buds was quadratic (Figure 2), with highest values for the 2.2- and 4.4-gallon rates, and exhibited great variability. Trees that received standard fertilization (adjacent to experimental plots) yielded results similar to those for the control trees in the experimental plots.

FIGURE 1 – Total Foliage

FIGURE 2 – Lateral Buds

Results of Soil Sampling. Soil pH showed a strong in



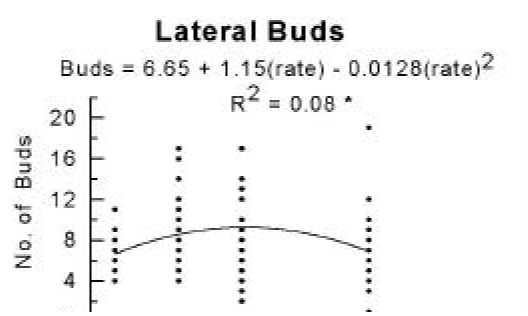
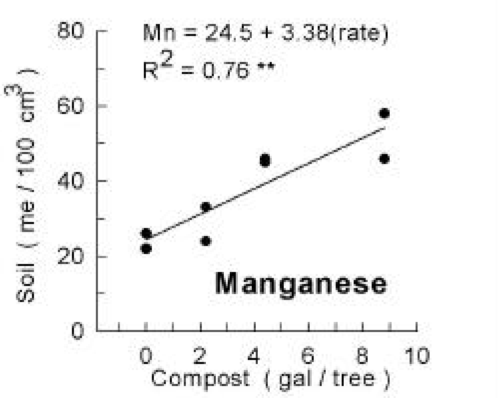


FIGURE 3 – Soil pH



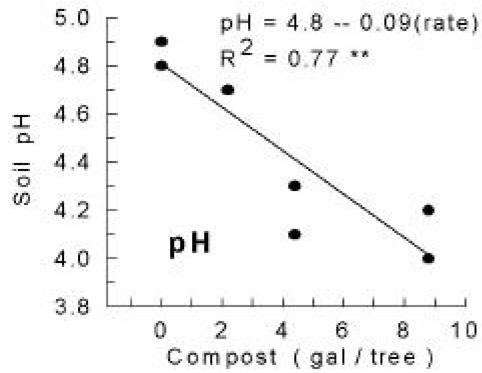


FIGURE 5 – Copper

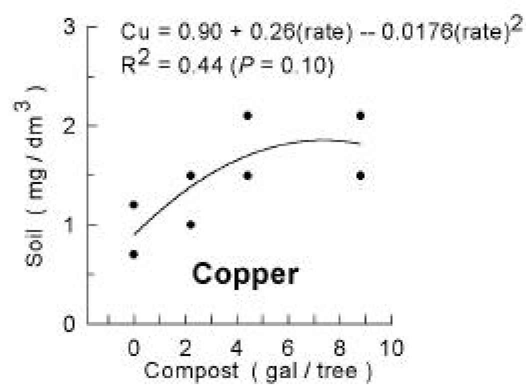


FIGURE 6 – Manganese

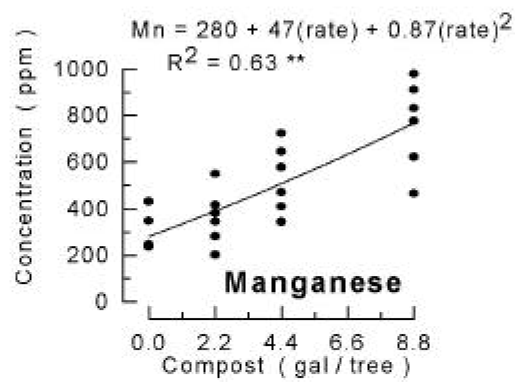
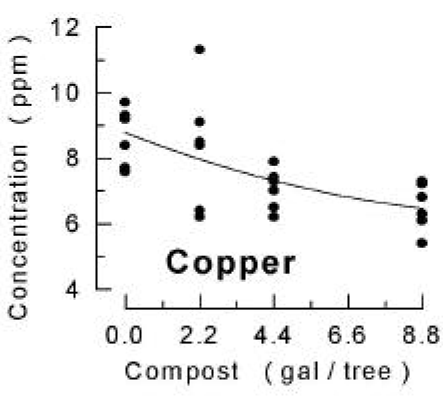


FIGURE 7 – Copper



Variables included in the soil analysis were phosphorous (mg/dm^3); potassium, calcium, magnesium, and sodium ($meq/100\ cm^3$); weight-to-volume ratio (g/cm^3); pH in water, buffer acidity at pH 6.6, sum of cations, and cation exchange capacity buffer (meq/100 cm^3); base saturation (%); manganese, zinc, and copper (mg/dm^3); and humic matter (g/100 cm^3). Regression analysis was also conducted on various soil indices to identify any effects due to compost. Five indices were significant ($P \leq 0.05$) – potassium, copper, manganese, zinc, and pH – and graphs were prepared for these indices, including regressions, R^2 values, and the level of significance.

Results of Foliar Analysis in the Field. For the foliar nutrient concentrations in the field, a regression analysis was conducted to determine if any nutrient concentrations were related to compost rates. Nutrients included in the tissue analysis were nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur (measured in %); and iron, manganese, zinc, copper, and boron (measured in ppm). For any nutrient that was significant ($P \leq 0.05$), a graph was prepared, including the regression, R^2 value, and level of significance. Four nutrients proved significant: nitrogen, phosphorous, manganese, copper, and boron. The regression for boron was significant at P=0.10.

Concentrations of several nutrients in the foliage were affected by compost treatments. Nitrogen and manganese (Figure 6) increased with application rate, whereas phosphorus and copper (Figure 7) decreased. The effect was most dramatic for manganese, which exhibited a steep linear increase with increasing application rate. The most likely explanation is that the pH of the surface soil decreased noticeably at the higher application rates, and manganese is much more soluble below pH 5.3.

The only thing that might be a "red flag" is the unusually high manganese values for the two heaviest rates of compost. Values above 500 ppm often are associated with yellowing of foliage and tend to adversely affect the calcium-to-manganese ratio.

STUDY 2 – THE EFFECT OF COMPOST ON THE VIABILITY OF PHYTOPHTHORA CINNAMOMI ROOT ROT IN TRANSPLANTED FRASER FIR SEEDLINGS

This study was designed to determine the effects of compost on suppressing *Phytophthora cinnamomi,* a plant disease that is an increasing concern in Fraser fir production. Earlier studies have shown that compost can reduce or eliminate certain plant diseases when mixed with the potting media at up to 30 percent of compost by volume.

Four levels of compost by volume (0, 10, 20, and 30 percent) were mixed with potting media. On April 9, 1999, 300 three-year-old Fraser fir seedlings were lifted and graded from a bed at Laurel Springs, North Carolina and heeled into soil in several plastic boxes and buckets. Plants were about one foot tall.

On April 12, 1999, plants were potted into one-gallon pots using a pine-bark medium. No lime or fertilizer was incorporated into the medium. The pH of the planting media was around 5.0. There were 70 pots of each treatment. After potting, plants were watered and placed beneath 50 percent shade. The plants were irrigated twice daily by overhead sprinklers. On June 2, 1999, pots were moved underneath an overhead shade structure, where they were watered three times daily for 30 minutes each time.

In each compost treatment, 30 plants were inoculated with rice grains infested with *Phytophthora cinnamomi* using three holes per pot (about one inch deep), and two grains per hole. Holes were closed and pots watered shortly thereafter. Thirty non-inoculated plants of each treatment were used as controls. Dr. Mike Benson, Department of Plant Pathology, North Carolina State University, cultured and provided the *Phytophthora cinnamomi* for this study.

The experiment was terminated on July 28, 1999. The primary treatment effect was whether the plant was alive or dead. However, early after inoculation with *Phytophthora cinnamomi,* it became clear that nearly all plants subject to the treatment would die. To determine if compost affected growth, the following measurements were made on each non-inoculated plant:

1. Total height
2. Leader elongation in 1999
3. Length of the longest lateral branch in top whorl
4. Length of a single needle from the longest lateral in the top whorl
5. Average stem diameter two centimeters above ground-line

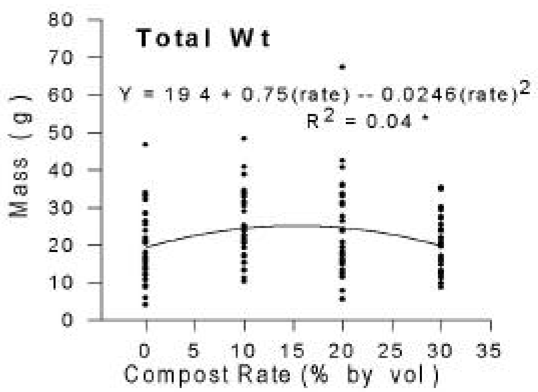
All new growth was removed from the aerial part of each plant. Roots were separated from tops and washed clean of rooting medium. These components, as well as the needle measured in #4 above, were dried at 65°C to a constant weight and weighed for each plant.

RESULTS AND DISCUSSION – STUDY 2

It was hoped that compost might reduce the mortality normally associated with Phytophthora root rot. However, this did not occur. All but a few of the inoculated plants died, with no differences evident among treatments. *Phytophthora cinnamomi* was not deterred by any level of compost.

With regard to the other measurements, results indicate that compost did have an effect on plant growth. In general, the response to compost rate was quadratic, with the maximum for each growth index at 20 to 30 percent, as evidenced in the response for total weight of seedlings (Figure 8).

FIGURE 8 – Total Weight of Seedlings



Values were normally lower for the control (no compost) and for the 30 percent rate, which was similar to the control. However, there was one exception; the average weight of individual needles decreased with increasing compost rate, with the maximum weight in the controls. This result did not carry through into the field experiment, where needle weight increased slightly with increasing levels of compost. Most regressions were statistically significant, but there was tremendous variability, causing the R^2 values to be low. No treatment was included to compare compost to standard fertilization.

The results of this study show that this particular compost did not provide protection from *Phytophthora cinnamomi.* Additional research that became available after commencing this study (DeCeuster and Hoitink, 1999) suggests that the age of the compost can make a difference on biological control. Composts that are either too immature or too mature are less likely to suppress disease. Composts that have reduced levels of free nutrients yet still have active populations of microorganisms will be most likely to provide some level of protection. This particular compost had a respiration rate of less than 2 mg CO_2-C/g, which indicates very low microbial activity.

Further studies on this topic should concentrate on the age and the stability of the compost as well as the amount of compost used in the planting mix. For example, a compost that is 0, 30, 60, 90, and 120 days old (after active composting) at various mix ratios (0, 10, 25, and 50 percent, by volume) would provide a better indication of whether compost would have an effect on *Phytophthora cinnamomi* in Fraser firs.

The additional measurements taken in this study were not a part of the original intent or design of the study, yet they do provide an indication that compost can improve the growth of Fraser firs. In the pot study, growth measurements were made only over a seven-week period, yet results were observed. Although there was tremendous variability within each treatment, the results did have some significance. A study specific to the effects on young seedlings would be easy to design, and a longer-term growth study would provide more conclusive results.

CONCLUSIONS

The studies provided mixed results. Although there are clear results in some areas, the project raised additional questions that need further investigation.

With regard to the growth issue, the strongest results are that compost will reduce soil pH, add nutrients and micronutrients to the soil, and affect some nutrient levels in the trees. Also significant, but less predictable, was the response to growth as measured in total foliage, foliage density, and needle weight. Realizing that not all effects of the compost would likely be evident in a single growing season, results over a two-year period would provide more convincing evidence as to the effects of compost.

Results for disease suppression were clear. This compost did not have any impact on the suppression of *Phytophthora cinnamomi* in any of the compost treatments. However, a recent article (DeCeuster and Hoitink, 1999) suggests that the age of compost has a bearing on whether the compost will help suppress plant diseases. The particular compost that was used in this study was very well aged, which is likely the reason that it had no impact on disease suppression in this study. An area of further investigation would be whether differently aged composts would provide different levels of protection from this disease. This issue is important to the extent that compost has been viewed by some producers and users as providing disease suppression in plants. If compost is capable of providing such disease suppression, the circumstances under which it provides protection should be better understood so that this characteristic could be marketed appropriately. This study identifies one set of conditions of compost type, stability, and application where disease suppression did not occur, and this needs to be recognized.

Although this project produced some clearly positive results in using compost on growing Fraser firs, it also uncovers a few areas of concern. The increase in manganese in the soil and in the needles is most likely a result of the lower soil pH with increasing levels of compost. The concentrations of manganese in the needles could be high enough to raise concern about yellowing of the needles, which is not a goal in raising Fraser firs. However, our comparisons of the needles did not uncover any differences in color in relation to amount of compost used. Another area of concern is the decrease in needle phosphorous with the increase in compost. The concentration of phosphorous in the needles was below desired levels in all cases, which suggests phosphorous is deficient regardless of compost use. The drop in pH may have reduced the availability of phosphorous. These areas need further investigation.

There are several changes that would have made the research more meaningful and should be considered in future research efforts. The first is that more than one type of compost could have been used. Understanding the differences between yard waste and biosolids-based compost would be helpful. A second change would be to collect and analyze data over a two-year period rather than just one year. For example, the effects of compost applied in year one on bud development would be more easily measured in shoot growth from those buds in year two. A third area of improvement would be to use compost of different ages in determining the effects of compost on suppressing *Phytophthora cinnamomi.* The compost used in this experiment was well aged, and that could have been a significant reason why the compost did not suppress the disease at any application rate.

ACKNOWLEDGMENTS

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SUBSURFACE INJECTION VERSUS SURFACE APPLICATION OF COMPOSTED MUNICIPAL SOLID WASTE IN COTTON PRODUCTION

By

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ABSTRACT

Equipment was developed and tested for injection and broadcast application of municipal solid waste (MSW) compost at selected rates to agricultural land for cotton production. Replicated tests were conducted to determine the effects of injected vs. broadcast applied compost on soil parameters (organic matter, soil compaction, and soil fertility) and plant growth.

All broadcast application rates of compost significantly reduced hardpan formation in the top 6-in. of soil compared to no compost application. In addition, all rates of injected material significantly reduced soil compaction in the E- and B-horizons (6-18 in.). Injected applications did not affect compaction in the top 6-in. of soil. Broadcast application of compost significantly increased soil organic matter content 6- and 12-weeks-after planting proportional to the compost application rate. In addition, soil nitrogen content was significantly higher in the broadcast application plots 6-weeks-after planting. Twelve-weeks-after planting, only application of 12-tons/acre compost (broadcast) statistically increased soil nitrogen content averaged over the top 8 in. of the soil.

MSW compost (broadcast or injected) significantly increased plant N, P, and K contents compared to no compost application. Increases in plant nitrogen were proportional to application rates. In addition, injected application increased plant sulfur compared to no compost application. All rates of compost (injected or broadcast applications) significantly increased cotton lint yield compared to no compost application. Yield increase was proportional to application rates. For the 12 tons/acre injected application treatment, yield increases were 23%, 24%, and 44% in 1997, 98 and 99, respectively compared to no compost application. Compost significantly increased plant height. Height increase was proportional to application rate.

Vitazyme increased plant N, P, and K contents with no effects on Ca, Mg, and S. Vitazyme increased cotton lint yield 31 lb/acre or 3%. In addition, soil nitrogen content 6-weeks-after planting in plots treated with Vitazyme was 12% higher than no-Vitazyme plots.

INTRODUCTION

Municipalities are facing a growing problem of how to safely dispose of their solid waste. Composting the organic fraction is possible solution to this problem. Biosolids are processed in composting facilities, which turn the waste by-products into a valuable resource. Industry is looking to expand towards composting the organic fraction of the municipal solid waste stream as evidenced by the development of Bedminster BioConversion Corporation in Sieverville, TN and Cobb County GA. The largest potential user of MSW compost is agriculture (Parr and Hornick, 1992; Slivka et al., 1992). Application of MSW compost usually increases yields of agronomic and horticultural crops, under both field and greenhouse conditions. Agricultural uses of composted MSW have shown promise for a variety of field crops (sorghum, maize, forage grasses) and vegetables sold for human consumption (lettuce, cabbage, beans, potatoes). Responses by plant systems have ranged from none to over twofold increases in yield (Shiralipour et al., 1992). In a replicated study in South Carolina, surface application of 15 tons/acre of MSW compost (broadcast or banded) resulted in a 30% increase in seed cotton yield (Khalilian et al., 1998).

Soil compaction limits root penetration below the plowing depth and is a significant problem in many soils in the Southeast. It reduces yields, limits productivity, and makes plants more susceptible to drought stress. Most upland sandy soils of the coastal plains have a compacted zone or hardpan about 6 to 14 in. deep and 2 to 6 in. thick. This is called the E-horizon and must be broken so that root can grow into the subsoil or B-horizon to allow optimal crop performance. Trouse (1983) has explained the benefits of and requirements for effective under-the-row subsoiling. This practice has been shown to improve yields in those soils of the coastal plain which are subject to the formation of tillage pans (Garner et al., 1986; Khalilian et al. 1991). Garner, et al. (1989) reported that in-row subsoiling in coastal plain soils increased seed cotton yield by 189 lb/acre compared to non-subsoiled plots. An additional deep tillage operation with a Paratill TM in the fall increased the seed cotton yield about 460 lb/acre. Composted MSW has the potential to increase organic matter content of sandy coastal plain soils. Organic matter acts as glue which helps keep soil structure more stable and resistant to compaction. Under laboratory conditions values of bulk density, penetration resistance and peak shear strength decreased with increasing organic matter contents in sandy loam and clay soils (Ekwue and Stone, 1995). Preventing soil compaction in coastal plain soils means fewer deep tillage operations and an $8 to $10 savings per acre.

Plant-parasitic nematodes cause over $250,000,000 in yield losses on cotton in the United States each year (Blasingame, 1996). Yield losses in individual fields may reach 30-50%. At the present, nematode management relies heavily on the use of nematicides, such as aldicarb (Temik 15G) applied in-furrow at-planting at a cost of approximately $16.00/acre. Higher organic matter content tends to increase the populations of many soil microorganisms, including those that are naturally antagonistic or parasitic to plant-parasitic nematodes. Khalilian et al. (1998) reported that application of MSW compost significantly reduced the Columbia lance nematode densities on a Faceville loamy sand soil. Compost treatments had nematode densities comparable to those found in the Temik 15G treatment.

Recently Vital Earth Resource Research Center (706 East Broadway, Gladewater, TX) has introduced a soil fertility booster called “Vitazyme” for improving the growth of plants. Many researchers have used this material for crop production. Yield increases ranging from 5 to 25% have been reported for different field crop such as cotton, corn, soybeans, etc. (Syltie, 1998).

Currently there is no equipment commercially available to inject MSW compost below the soil surface. The ability to inject solid waste material in a narrow band under the crop row is important since it optimizes plant nutrition and minimizes nuisance factors. Injection of compost will have a two-fold objective: placement of organic material in the root zone and fracturing the soil hardpan.

OBJECTIVES

The objectives of this project were a) to develop and test equipment for injection and broadcast applications of composted municipal solid waste at selected rates to agricultural lands for cotton production. b) To determine the effects of compost on soil parameters (organic matter, soil compaction, and soil fertility) and plant responses (yield, nutrition).

METHODS AND MATERIALS

Equipment

In 1997, equipment was constructed for injecting MSW compost pre plant under the seed row at sufficient depth to place it in the compacted subsoil layer at different application rates. The equipment was modified in 1998 to increase efficiency of the system. The compost injector was a 2-row configuration and consisted of subsoiler shanks, which had been modified by attaching a 4-in. x 8-in. thin-wall rectangular tubing to the back of each subsoiler shank. These extended from the lower end of the shank to a position above the soil surface. The trailing edge of the rectangular tubing was cut away from the lower end of the tubing to allow the MSW compost to be deposited into the slot created by the subsoiler shank. Compost was funneled into the top of the rectangular tubing and fell by gravity flow to the bottom. As the tool moved through the soil, the MSW compost was placed into the bottom of the trench created by the subsoiler.

For preparing the injected test plots, the MSW was carried on the subsoiler. A hopper was constructed and attached to the subsoiler frame. This hopper was fitted with a drag chain, which pulled the MSW material toward a drop point above the injection tubes. Material was dropped by gravity from the hopper floor into the top of the injection tubes with transitions constructed from sheet metal. A hydraulic motor was used to run the drag chain. Compost application rates were adjusted by changing the speed of the hydraulic motor and utilizing an adjustable gate that was added to the spreader.

A conventional flatbed, chain conveyer type manure spreader was used for broadcast application. An adjustable gate was added to the spreader to control application rates. The spreader was adjusted to uniformly broadcast composted material the width of two rows (6.33 ft). A 4-shank subsoiler-bedder was used to disrupt the hardpan and incorporate the MSW compost.

Field Test

The Bedminster BioConversion Corporation's composting facilities in Sieverville, Tennessee provided the MSW compost for this study each spring. Analysis of the composted material is shown in Table 1. Tests were conducted from 1997 to 1999 at the Edisto Research and Education Center at Blackville, SC on a Varina sandy loam soil (clayey, kaolinitic, thermic

Plinthic Paleudults). A randomized complete block design with four replications was the statistical model selected for comparing treatments. Two application methods (injection and broadcast), three application rates (4, 8, and 12 tons/acre), and a control (no compost) were used in 1997 and 98. The same treatments were used in 1999 except the test plots, after compost application, were split in half and one half received Vitazyme. Vitazyme was sprayed at 13 oz/acre over the soil surface directly behind the planter. A second application of 13 oz/acre was sprayed on the cotton leaves and soil at first bloom.

Table 1. Analytical laboratory results of composted municipal solid waste at the time of application.

Year	pH	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Moisture (%)
1997	6.8	1.42	0.72	0.33	2.28	0.23	0.49	17.8
1998	7.3	1.19	0.62	0.37	2.22	0.26	0.37	30.7

Cotton was planted with a 4-row John Deere MaxEmerge2 planter and carried to yield using recommended practices for seedbed preparations, seeding, fertilization, and insect and weed control. Plot size was 8 rows (25 ft X 80 ft). The two middle rows of each plot were machine harvested for yield determinations.

To determine the effects of compost on soil compaction, a tractor-mounted, hydraulically operated, microcomputer-based, recording penetrometer system was used to quantify soil resistance to penetration. Soil cone index values were calculated from the measured force required to push a 0.5 in.^{2} base area, 30^o cone into the soil at a constant velocity (ASAE, 1999).

Penetrometer data was taken before compost application and immediately after cotton harvest in 1999. Penetrometer readings were taken to a depth of 18 in. from two middle rows of each plot.

Table 2. Effect of compost application methods and rates on formation of hardpan under cotton rows, 1999. Edisto Research and Education Center, Blackville, SC.

Application Method	Compost (tons/acre)	Cone Index (psi)		
		0 - 6 in.	6 – 12 in.	12 – 18 in.
Broadcast	4	60 c	137 b	269 ab
	8	59 c	131 b	312 a
	12	57 c	125 bc	394 ab
Injected	4	70 a	111 dc	268 bc
	8	65 ab	105 de	263 c
	12	66 ab	91 e	248 c
None	None	70 a	154 a	300 a

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

In 1999, each plot was sampled for Columbia lance nematodes, soil organic matter, and ammonium and nitrate contents at planting, 6-weeks-after planting and 12-weeks-after planting. Twelve cores 8-in. deep and 1-in. in diameter were taken from each plot on each date. Plant tissues (35 leaves/plot) were collected and analyzed for N, P, K, Ca, Mg, and S.

RESULTS AND DISCUSSION

All rates of broadcast application of compost significantly reduced formation of the hardpan in the top 6-in. of soil for cotton rows compared to no compost application in 1999 (Table 2). In addition, all rates of injected material significantly reduced soil compaction in the E-horizon (9-12 in.) and in B-horizon (12-18 in.). Injected application did not affect the compaction in the top 6-in. of the soil.

Table 3 shows soil organic matter and nitrogen content averaged over the top 8 in. of soil for 1999. Broadcast application of MSW compost significantly increased the soil organic matter content 6- and 12-weeks-after planting proportional to compost application rate. In addition, soil nitrogen content was significantly higher in the broadcast application plots 6-weeks-after planting. 12-weeks-after planting, only application of 12-tons/acre compost (broadcast) statistically increased soil nitrogen content averaged over top 8 in. of the soil. Since the injected material was about 12 in. deep, it did not affect the soil organic mater and soil nitrogen content in the top 8 in. of the soil.

MSW compost (broadcast or injected) significantly increased plant N, P, and K compared to no compost application (Table 4). Increases in plant nitrogen were proportional to application rates. In addition, injected application increased plant sulfur compared to no compost application (Table 5). Application of compost did not affect plant Ca or Mg (Table 5).

Table 3. Effects of MSW compost on soil organic matter and nitrogen content 6- and 12-weeks-after planting, 1999.

Application Method	Compost Rate (tons/acre)	% Organic Matter		NO3-N ppm	
		6-week	12 week	6-week	12-week
Broadcast	4	1.75 c	1.69 b	11.88 c	6.90 ab
	8	2.06 b	1.95 a	13.00 b	6.51 ab
	12	2.59 a	2.01 a	15.25 a	8.94 a
Injected	4	1.10 e	1.18 c	8.75 d	4.93 bc
	8	1.33 d	1.14 c	8. 75 d	4.48 bc
	12	1.25 de	1.21 c	8.75 d	4.74 bc
None	None	1.19 de	1.06 c	8.38 d	3.54 c

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

All rates of compost (injected or broadcast applications) significantly increased cotton lint yield compared to no compost application in each year (Tables 6 and 7). Yield increase was proportional to application rates. In 1997, for 12 tons/acre injected application treatment, yield increase was 249 lb/acre lint or 23% more than compost application. In 1998 and 99, yield increases at this level of application rate were 24% and 44% higher than no compost application, respectively. There were no differences in yield between broadcast and injected application method for a given compost rate. Increased soil organic matter and nitrogen content combined with the potential increase in soil water-holding capacity and decreases in soil density associated with MSW compost, could be the contributing factors to yield increase. Compost significantly increased cotton plant heights (Table 7). Height increase was proportional to application rate.

Table 4. Effects of MSW compost on plant tissue (%N, P, and K), 1999, (Samples taken 12-weeks-after planting).

Application Method	**Compost Rate (tons/acre)**	**N (%)**	**P (%)**	**K (%)**
Broadcast	4	3.97 d	0.30 a	1.96 b
	8	4.13 c	0.29 b	1.93 b
	12	4.32 a	0.33 a	2.14 a
Injected	4	4.01 d	0.32 ab	1.94 b
	8	4.18 bc	0.30 ab	2.11 a
	12	4.28 ab	0.33 a	2.16 a
None	None	3.54 e	0.26 c	1.61 c

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 5. Effects of MSW compost on plant tissue (%Ca, Mg, and S), 1999, (Samples taken 12-weeks-after planting).

Application Method	**Compost Rate (tons/acre)**	**Ca (%)**	**Mg (%)**	**S (%)**
Broadcast	4	2.61 a	0.48 b	0.76 bc
	8	2.62 a	0.51 ab	0.66 c
	12	2.67 a	0.50 ab	0.76 bc
Injected	4	2.78 a	0.55 ab	0.83 ab
	8	2.57 a	0.52 ab	0.88 a
	12	2.78 a	0.57 a	0.89 a
None	None	2.52 a	0.57 a	0.71 c

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Vitazyme increased percent N, P, and K in plant tissue with no effects on Ca, Mg, and S (Tables 8 and 9). Vitazyme increased cotton lint yield 31 lb/acre or 3% (Table 10). In addition, soil nitrogen content 6-weeks-after planting in plots treated with Vitazyme was 12% higher than no-Vitazyme plots (Table 11).

Table 6. Effects of compost on cotton lint yield for 1997 and 1998 tests.

Trt. No.	Compost (tons/acre)	Application Method	Yield (lb/acre) 1997	1998
1	4	Broadcast	1228 b	940 c
2	8	Broadcast	1282 ab	1018 b
3	12	Broadcast	1343 a	1047 ab
4	4	Injected	1222 b	945 c
5	8	Injected	1293 ab	1013 b
6	12	Injected	1351 a	1076 a
7	None	-------	1103 c	868 d

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 7. Effects of MSW compost on cotton lint yield plant height and population at harvest, 1999.

Application Method	Compost Rate (tons/acre)	Yield lb/acre	Plant height (in)	Plant Population (Plant/ft)
Broadcast	4	1016 c	31.5 d	2.7 a
	8	1083 b	33.3 b	2.5 a
	12	1203 a	34.4 a	2.6 a
Injected	4	1030 c	32.5 c	2.7 a
	8	1078 b	33.3 b	2.6 a
	12	1217 a	34.7 a	2.4 a
None	None	844 d	30.0 e	2.6 a

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 8. Effects of Vitazyme on plant tissue (%N, P, and K), 1999, (samples taken 12 weeks after planting).

Vitazyme	N (%)	P (%)	K (%)
13 OZ at planting & 13 OZ at first bloom	4.22 a	0.31 a	2.08 a
None	3.91 b	0.29 b	1.88 b

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 9. Effects of Vitazyme on plant tissue (%Ca, Mg, and S), 1999, (samples taken 12 weeks after planting).

Vitazyme	Ca (%)	Mg (%)	S (%)
13 OZ at planting & 13 OZ at first bloom	2.71 a	0.54 a	0.77 a
None	2.60 a	0.52a	0.74 a

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 10. Effects of Vitazyme on cotton lint yield, plant height, and population at harvest, 1999.

Vitazyme	Yield lb/acre	Plant height (in)	Plant Population (Plant/ft)
13 OZ at planting & 13 OZ at first bloom	1083 a	33.1 a	2.6 a
None	1052 b	32.6 b	2.6 a

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

Table 11. Effects of Vitazyme on soil organic matter and nitrogen content 6- and 12-weeks-after planting, 1999.

Vitazyme	% Organic Matter		NO3-N ppm	
	6-week	12-week	6-week	12-week
13 OZ at planting & 13 OZ at first bloom	1.61 a	1.45 a	11.32 a	5.73 a
None	1.60 a	1.47 a	10.07 b	5.71 a

Values in a column followed with the same letter are not significantly different (LSD test, α = 0.05).

CONCLUSIONS

Equipment was developed and tested for injection and broadcast application of MSW compost at selected rates to agricultural land for cotton production. Replicated tests were conducted to determine the effects of compost on soil parameters (organic matter, soil compaction, and soil fertility) and plant growth.

All rates of broadcast application of compost significantly reduced formation of the hardpan in the top 6-in. of soil compared to no compost application. In addition, all rates of injected material significantly reduced soil compaction in the E- and B-horizons (6-18 in.). Injection application did not affect the compaction in top 6-in. of the soil.

Broadcast application of compost significantly increased the soil organic matter content 6- and 12-weeks-after planting proportional to compost application rate. In addition, soil nitrogen content was significantly higher in the broadcast application plots 6-weeks-after planting. Twelve-weeks-after planting, only application of 12-tons/acre compost (broadcast) significantly increased soil nitrogen content averaged over top 8 in. of the soil.

MSW compost (broadcast or injected) significantly increased plant N, P, and K content compared to no compost application. Increases in plant nitrogen were proportional to application rates. In addition, injected application increased plant sulfur compared to no compost application.

All rates of compost (injected or broadcast applications) significantly increased cotton lint yield compared to no compost application. Yield increase was proportional to application rates. For 12 tons/acre injected application treatment, yield increase was 23%, 24%, and 44% in 1997, 98 and 99, respectively compared to no compost application

Compost significantly increased plant height. Height increase was proportional to application rate.

Vitazyme increased plant N, P, and K contents with no effects on Ca, Mg, or S. Vitazyme increased cotton lint yield 31 lb/acre or 3%. In addition, soil nitrogen content 6-weeks-after planting in plots treated with Vitazyme was 12% higher than no-Vitazyme plots.

ACKNOWLEDGMENTS

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COMPOSTING FOOD WASTES AT THE 1999 SPECIAL OLYMPICS WORLD SUMMER GAMES

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INTRODUCTION

The 1999 Special Olympics World Summer Games were held in the Raleigh-Durham-Chapel Hill area of North Carolina from June 26 through July 4. This international event drew 7,000 athletes and 3,000 coaches from 150 countries to compete in 19 different sports. In addition, over 35,000 local area volunteers were recruited to help put the Games together and to provide a comprehensive support program for the athletes, coaches, and families.

In mid-1998, representatives of the Special Olympics Games Organizing Committee (GOC) requested a meeting with local area solid waste and recycling professionals to discuss the logistics of solid waste management at the Games. Over the course of the following year, three separate committees of professionals were assembled, one each for solid waste disposal, for recycling, and for food discards composting.

PLANNING PROCESS

The Composting Subcommittee met monthly from January 1999 until June 1999. The subcommittee prepared an operations plan for composting during the Games. The operations plan spelled out the logistical details of food discards collection, transportation, composting, and compost use. Financial support for the program was obtained from the Division of Pollution Prevention and Environmental Assistance (DPPEA) in the North Carolina Department of Environment and Natural Resources (DENR).

Project planning included detailed evaluations of the Special Olympics plans for feeding visiting athletes and coaches, selection of the collection containers to be used for food discards collection, preparation of signage for containers and obtaining Solid Waste Composting Demonstration Permits from the Division of Waste Management, NCDENR. This planning process also included developing a "flow plan" for food discards. This plan addressed the questions of what to divert, how to divert it, the roles of volunteers, the placement of the collection containers, the movement of the containers from the kitchens to the composting sites, the unloading and mixing procedures at the composting sites, and other factors.

PROJECT IMPLEMENTATION

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During the Summer Games, Olympians were housed at three area universities (North Carolina State University (NCSU) and Meredith College (in Raleigh) and University of North Carolina (UNC) at Chapel Hill). The athletes, coaches, staff, and volunteers used the universities' dining halls for their meals.

154,369 meals were served from 5 AM to Midnight from June 24 through July 5, 1999. The number of meals served daily was much greater than the normal school-year number of meals served at NCSU (10,000 per day as opposed to 4,500 per day during the school year). The number of meals served at Meredith and UNC were similar to normal servings. The Special Olympics established menus in advance, and food service was all-you-could-eat buffet style with disposable paper plates, cups, and cutlery.

A pool of 62 volunteers was assembled to accomplish this food discards diversion. Volunteers were drawn from state government, local recycling associations, and local high school environmental clubs. Volunteers were assigned to one or more of the three dining halls and were organized into 3-hour shifts, a lunch shift from 11:30 – 2:30 and a dinner shift from 5:30 – 8:30. Breakfast and late dinners were not included in the project at NCSU, due to logistical constraints with the dining halls and a lack of adequate numbers of volunteers. These other meals were captured at Meredith and UNC as the kitchen staff helped with the diversion.

FOOD WASTES COLLECTION

Separation of compostable food wastes from non-compostable items was accomplished at diversion stations established in the proximity of tray-return areas and dishwashing rooms. Volunteers and dining hall personnel staffed these stations.

Food discards were collected in 40-gal. wheeled Zarn containers (lined with 45-gal. 100% recycled black plastic bags). These containers were labeled with the Special Olympics recycling logo and a food waste-to-compost graphic illustration. The disposable products used by the dining halls contained both poly-coated and non-coated plates and bowls; the cutlery was all plastic. Some small paper plates were included in compostables (Chinette brand of non-coated paper plates); but most were not taken due to wax/poly coatings. Larger dinner plates (Chinette 9 ¼" dinner plates) were taken at first, but later not included due to their effect on compost mix C/N ratios, their effect on mix moisture content, and the potential to blow around on site. Compostables also included paper napkins.

Full containers were transported to two compost sites (one at NCSU and one near UNC-CH) in 15- ft. box trucks equipped with hydraulic lift gates. For the NCSU compost site, the truck was weighed after each meal using MD-500 portable truck scales (capacity of 20,000 lbs). For the UNC compost site, individual containers were weighed using a Pelouze heavy-duty postal scale (400 lb capacity). The total amount of food discards transported to the NCSU site was 13,888 pounds; the amount diverted to the UNC compost site was 7,736 pounds, for a total diversion of 21,624 pounds (10.8 tons). Table 1 lists the weights by day for each site.

Table 1

Date	MEALS SERVED	FOOD DISCARDS (LBS) NCSU/Meredith	COLLECTED UNC – CH	Total
6/24/99	2,340	430	389	819
6/25/99	14,405	1768	488	2256
6/26/99	16,772	815	353	1168
6/27/99	16,614	1630	549	2179
6/28/99	17,885	1768	1271	3039
6/29/99	17,147	1380	950	2330
6/30/99	17,605	1780	865	2645
7/1/99	17,504	1556	917	2473
7/2/99	17,876	1493	914	2407
7/3/99	16,221	1268	1040	2308
Totals	**154,369**	**13888**	**7736**	**21624**

COMPOSTING AT THE NCSU SITE

The site is normally used to produce mulches from campus and municipal yard waste. The compost mix at the NCSU site consisted of food discards, partially composted leaf mulch from 1997 leaf fall, and ground, screened wood waste from campus landscaping (screened to a 1" minus mesh size). Figure 1 illustrates the nature of the waste stream.

Figure 1

The bulking agent (leaf mulch and wood waste) was added to the food waste at approximately a 5:1 volumetric ratio. This ratio is larger than the typical value used in composting (3:1) because North Carolina regulators required the windrows to be recovered after each turning to conceal exposed food wastes. As finished compost was not available to cover the windrows, additional wood waste or leaf mulch was used.

Wastes from each meal were dropped off on 6” wood mulch base, debagged, spread evenly (contaminants removed), and covered with 6” layer of leaf mulch. Approximately 200 gallons of water were added after each layer (food wastes & leaf mulch). Four meals (four layers) were added to the mixing pad over two days. Materials were mixed with a Wildcat Model FX 700 PTO Turner (pulled by Ford 9030 Tractor). Mixed materials were reformed into a windrow on 6” layer of wood mulch with Ford 755A Backhoe Loader. Windrows were covered with 3-4” layer of wood mulch (1”- ground and screened wood waste).

Three windrows were constructed over the course of twelve days. As composting progressed over the next several weeks, the windrows were combined into one longer windrow. The total quantities of materials used in the compost mix are shown in Table 2:

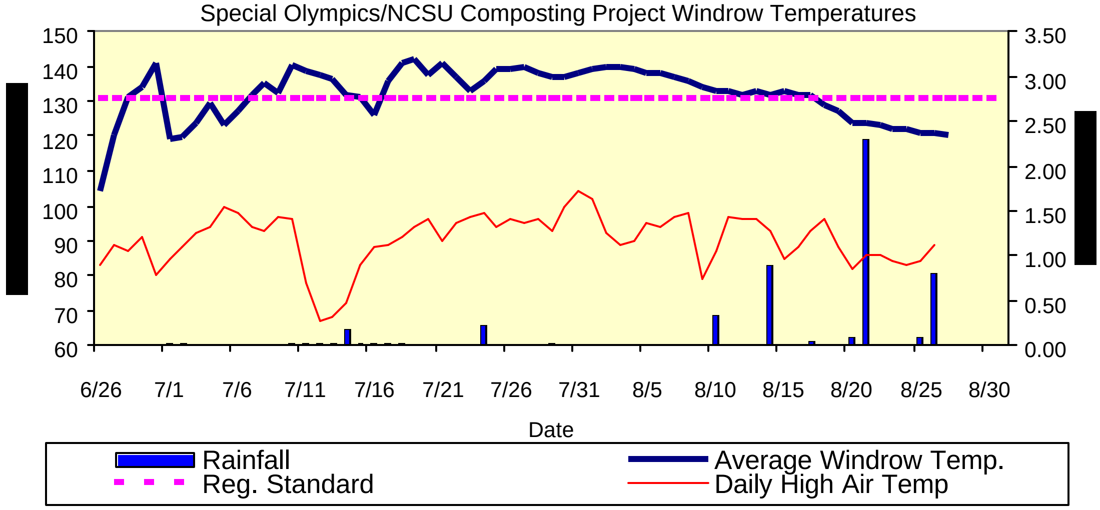
Table 2
Compost Mix Materials (cubic yards)

Ingredient	Windrow #1	Windrow #2	Windrow #3	Total
Food Wastes*	5.2	7.2	3.1	15.5
Leaf Mulch	10.5	10.5	7.5	28.5
Wood Wastes	19	20.5	9.0	48.5
Water (gallons)	1,750	2,520	1,020	5,290

*Food waste bulk density assumed to be 900 lbs/cubic yard

Windrows #1 and #2 were turned six times between June 26 and July 21 before being consolidated together. Windrow #3 was turned five times before consolidation. Consolidation was needed to more effectively utilize the windrow turner. The consolidated windrow was turned an additional five times between July 21 and August 20. Water was added periodically if the compost mix in the windrows did not pass the “squeeze test”. Composting temperatures at the NCSU site exceeded the regulatory requirement of a minimum temperature of 131^{o} F. for 15 days. Figure 2 shows the average windrow temperatures at the NCSU site as well as daily high air temperatures and rainfall recorded at a nearby weather station. Unusually cold temperatures around July 12 significantly affected compost pile temperatures; however temperatures rebounded over the next several days to ensure meeting Process To Further Reduce Pathogens (PFRP) requirements.

Figure 2
Special Olympics/NCSU Composting Project Windrow Temperatures



COMPOSTING AT ORANGE COUNTY SITE

The Orange County composting site is located at the Orange County Regional Landfill in Chapel Hill. The site was approximately 4,000 s.f. (40x100) and fenced to prevent windblown litter from entering or leaving the site.

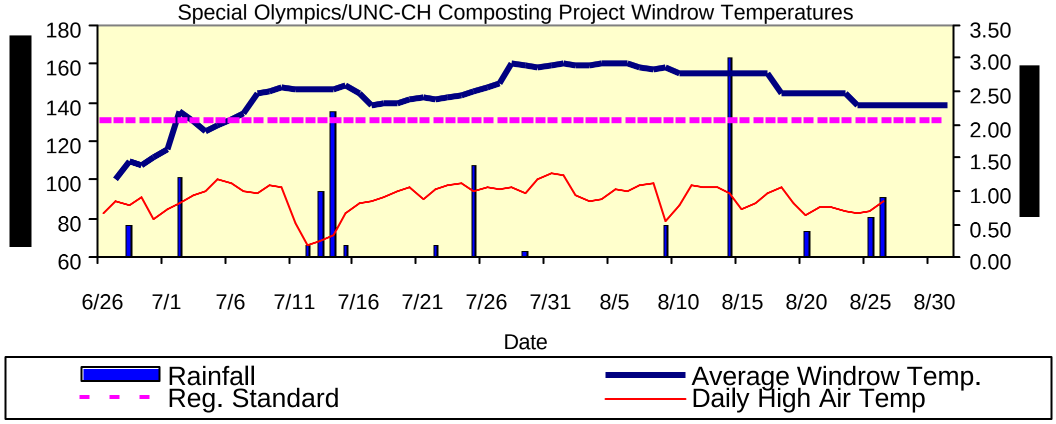
Food wastes were removed from bags, spread out on a 6" base of ground yard waste supplied by the Town of Chapel Hill, and inspected for contaminants. Because paper plates and cups used at Lenoir Dining Hall were plastic coated (hence not fully biodegradable), they were not included in the diversion program. Another significant difference in the composition of food discards from Lenoir Dining Hall is attributed to the inclusion of unserved food from the serving lines and food preparation areas.

After contaminant removal (mostly plastic cutlery), the food discards were mixed with the ground yard waste base using a Bobcat 863 bucket loader and formed into a pile. The yard waste bulking agent was added to the food discards at a volumetric ratio of approximately 2.5 to 1. A total of 3 piles were built over the course of the Summer Games. Each pile was approximately 8-9' wide, 14' long, and 3-3.5' high. Following the attainment of the regulatory requirement for minimum temperatures, the piles were combined. Figure 3 depicts the nature of the food discards collected at Lenoir.

Figure 3

Composting temperatures at the Chapel Hill site also exceeded the regulatory requirement of a minimum temperature of 131^{o} F. for 15 days. Figure 4 shows the average windrow temperatures at the Chapel Hill site as well as daily high air temperatures and rainfall recorded at a nearby weather station. The July 12 cold spell had less effect on these compost piles as they were configured as static piles, with greater insulation characteristics.

Figure 4
Special Olympics/UNC-CH Composting Project Windrow Temperatures



COMPOST ANALYSIS

The compost piles completed the active composting phase by the end of August. The composts were allowed to cure until the end of November. Composts were sampled and analyzed in accordance with the requirements of the North Carolina Solid Waste Compost Rules[3].

Testing for foreign matter content was accomplished by drying the samples (EPA Method 160.3), weighing samples, and screening samples through a 0.25 inch screen. No foreign matter was detected in either sample. Samples were partitioned and sent to three laboratories

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[3] NC Division of Waste Management, North Carolina Solid Waste Compost Rules, 15A NCAC 13B, Section .1408(a) – (d)

for analysis: North Carolina Dept. of Agriculture Agronomic Division for nutrients, heavy metals, soil testing, and Mehlich-3 Extraction for soil heavy metals; Woods End laboratory for pathogen analysis, and Soil FoodWeb, Inc. for microbiological analysis. Analytical results are shown in Tables 3 through 6.

Table 3
Waste Analysis Report

Parameter	NCSU	UNC	Reg. Criteria
Chemical Constituents			
(ppm, unless noted)			
Total Nitrogen	7484	7015	
Phosphorus	594	925	
Potassium	1356	2156	
Calcium	7299	7301	
Magnesium	866	5888	
Sulphur	550	792	
Iron	9160	22473	
Manganese	337	659	
Zinc	51.5	55.7	2800
Copper	12.0	63.4	1500
Boron	28.8	52.8	
Carbon	122385	82578	
Sodium	433	854	
Nickel	2.03	10.3	420
Cadmium	0.81	1.51	39
Lead	9.81	3.11	300
pH (units)	6.42	6.93	
Soluble salts	68.0	111.0	
C:N Ratio	16.35	11.77	
Dry Matter %	55.02	57.08	

Table 4
Soil Test Report

Parameter	NCSU	UNC
Soil Class	Mineral	Mineral
Humic Matter (%)	0.6	0.43
Weight/Volume Ratio (gm/cm^3)	0.56	0.73
Cation Exchange Capacity ($meq/100cm^3$)	16.3	18.8
Base Saturation (%)	93.0	100.0
Exchangeable Acidity ($meq/100cm^3$)	1.1	0.0
PH	6.7	7.0
Phosphorus Index	34-Medium	95- High
Potassium Index	282- Very High	111- Very High

Calcium (%)	69.0	79.0
Magnesium (%)	16.0	18.0
Manganese Index	92- High	504 -Very High
Zinc Index	317 - Very High	241 - Very High
Zinc Availability Index	317	241
Copper Index	46	164
Sulphur Index	39	211
Sodium (meq/100cm^3)	0.7	1.8

Table 5
Pathogen Analysis

Parameter	NCSU	UNC
Pathogens - Salmonella	< 1.6 MPN/100 g	< 1.4 MPN/100 g
Pathogens - Fecal Coliform	< 4 MPN/100 g	< 120 MPN/100 g

Table 6
Soil Foodweb Analyses

Parameter	NCSU	UNC	NOTES
Organism Biomass Data			
Dry weight (one gram)	0.51	0.6	
Active Bacterial Biomass (ug/g)	8.3	13.4	Desired range: 20-50
Total Bacterial Biomass (ug/g)	287	207	Desired range: 200-600
Active Fungal Biomass ug/g)	42.1	79.5	Desired range: 20-30
Total Fungal Biomass (ug/g)	107	111	Desired range: 100-300
Hyphal Diameter (micrometers)	2.5	2.5	
Protozoa (#/gm)			
Flagellates	8966	9588	Desired range: 10,000+
Amoebae	11201	46201	Desired range: 10,000+
Ciliates	271	768	Desired range: 200-500
Total Nematodes (#/gm)	33	10.9	Desired range: 20-30
Organism Ratios			
Total Fungal : Total Bacterial Biomass	0.37	0.54	*see below for
Active to Total Fungal Biomass	0.39	0.72	Interpretation of
Active to Total Bacterial Biomass	0.03	0.06	these results
Active Fungal : Active Bacterial Biomass	5.07	5.09	
Plant Available N Supply from Predators (lbs/acre)	200-250	250-300	
Root-Feeding Nematode Presence	None detected	None detected	

INTERPRETATION OF FOODWEB ANALYSIS

Samples of both composts were submitted to Soil Foodweb, Inc. for an analysis of their microbial activity. Not a required testing parameter, the foodweb analysis is an emerging technique that assesses the diversity of microorganisms in compost as an indicator of overall quality and maturity. Active bacterial and active fungal biomass indicate the activity level of these organisms present in the compost, suggesting degree of maturity. Generally, activity above 0.10 indicates immature piles, as long as heating cycle has been achieved. In these 2 composts, the bacterial activity was at the desired level for mature compost (0.03 for NCSU and 0.06 for UNC). Both composts had more active fungi than active bacteria, however, suggesting the compost was in the maturation phase but not yet stable (0.39 for NCSU and 0.72 for UNC). Both composts were more bacterial than fungal, indicating they would be most suitable for application to row crops and grasses, whereas if the composts were more fungal than bacterial, they would be more suitable for berries, shrubs, or trees. The composts both possess good nutrient cycling and lots of plant-available Nitrogen, based on the numbers and diversity of predator organisms. Although there were no root-feeding nematodes found in either compost, the numbers and diversity of other nematodes was lower than desirable.

COMPOST UTILIZATION

Finished compost from the project was used in local planting projects. In Raleigh, the NCSU compost was used at NCSU's J.C. Raulston Arboretum and around the Bell Tower on central campus. The UNC compost was used by the Town of Chapel Hill for new planting beds at its Community Center, in Durham at S.E.E.D.S. community garden, and at North Chatham Elementary School in its educational gardening curriculum.

PROJECT ANALYSIS

Implementation of this food discards diversion and composting project required coordination with a large number of people, organizations, and governments. As with any waste management project, there were several areas where implementation was successful and several areas where improvements could be made.

The 40-gal. Zarn carts with recycled-content plastic bag liners were an effective means of moving food discards through crowded dining halls during the Games. Using volunteers and training dining hall staff to control separation of food discards at diversion stations greatly reduced the contamination with non-compostables. The use of 15-foot box trucks with lift gates were an efficient means of transportation for filled food discard containers, but smaller trucks could have served the purpose as well. No incidents of spillage or leakage were reported.

At both composting sites, the composting process worked extremely well, with no problems reported with vectors or vermin, nor with odors. The composting mix recipes used, while different at the two sites, were successful in raising composting temperatures to the thermophilic range quickly, and both sites met the regulatory requirements for pathogen destruction.

PROJECT COSTS/BENEFITS

Project costs for food discards composting include costs incurred by the GOC and costs incurred by outside sponsoring and cooperating organizations. Data is only available for those costs incurred by the North Carolina Division of Pollution Prevention and Environmental Assistance:

Subcontractor services	$ 16,140.00
Food discard collection carts	2,263.73
Labels for containers, signage	4,189.12*
Container liners	396.71
Brochure color copies	742.00
Volunteer buttons	121.90
Compost testing (estimate)	500.00
Total composting project costs	$ 24,353.46

*(includes recycling bins for plastics, paper, and aluminum)

These costs also do not include the "labor costs" of the volunteer pool working on the composting project. The 62 volunteers working on the project invested about 900 person-hours of time. With sufficient lead time and planning, the costs for labeling and signage can be greatly reduced (the costs shown above reflect rush charges to meet rigid deadlines). The brochures to educate athletes, coaches, and delegation assistants could be done without incurring color photocopying charges. The above costs also do not reflect the actual cost of composting equipment, except what is included in subcontractor services for the UNC-CH site. The cost of composting equipment at the NCSU site was absorbed by the existing operation.

The costs for composting food discards at the Special Olympics were extremely high relative to normal costs for food discards composting. The major reason for this was due to the lack of a food discards composting infrastructure in North Carolina. Had there been an existing facility that could have taken these special event wastes in addition to normally-diverted food discards, the operational and capital costs would have been much lower.

In North Carolina and beyond, this project set an important environmental management precedent. Benefits of the project go beyond the successful diversion of nearly 11 tons of food discards from North Carolina landfills. Perhaps the most important benefit is the institutional knowledge of food discards composting gained by the Games Organizing Committee and the hosting universities. This acquired knowledge, including identification of barriers to composting at major international athletic events, enables Special Olympics and other organizers to pursue composting at future events with a higher level of confidence and efficiency.

THE MCPLANT MASTER COMPOSTER VOLUNTEER PROGRAM IN CHARLOTTE, NORTH CAROLINA: STOP PREACHING TO THE CHOIR, TURN THE CHOIR INTO MISSIONARIES

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ABSTRACT

Master Composters, modeled on Cooperative Extension's successful Master Gardener program, are volunteers who receive special training in exchange for community service. Charlotte, North Carolina, used an innovative approach to prepare their first group of Master Composters in Spring 2000, funded by an SWRAG grant from NCDENR. Charlotte's program combines advanced home composting education with training in grasscycling, soil stewardship, vermiculture, reducing toxic chemical use, xeriscaping, landscaping with native and environmentally appropriate plants and community organizing and presenting skills. Charlotte's curriculum for training their Master Composters - known as MCPLANT volunteers, for 'Master Composter/Piedmont Landscaping and Naturescaping Training' - is solidly based on local experience and conditions. It also draws on excellent programs throughout the US and abroad, including Alameda County, California; Seattle, Washington; and the state programs of Texas and Georgia. Charlotte's first 17 MCPLANT volunteers are now designing and implementing independent service projects to fulfill their service requirement.

INTRODUCTION

Environmentally sound resource management requires more than technological advances - it demands changes in human behavior as well. This is especially true of programs such as home composting and residential recycling that encourage individuals and families to change the ways they view and dispose of household 'garbage'. Program managers must provide communities with on-going information and support, particularly when the goal is to replace deeply entrenched patterns with beneficial alternatives.

One promising approach that requires a change in behavior is home composting. Research has demonstrated the benefits and cost effectiveness of home composting programs (EHMI, 1996; Renkow and Rubin, 1996; Sherman, 1996). However, even the best composting brochure will not suddenly enable citizens to see 'black gold' after years of seeing 'yard trash'. To bring about sustainable change, residents need education and support, even for proven and user-friendly techniques such as home composting. Paid staff can provide this type of assistance. However, the need to reach large numbers of people, along with the growing interest in home composting, can soon overwhelm even the most dedicated staff. A 'master composter' volunteer program, modeled on the Cooperative Extension 'master gardener' program, provides a creative and cost-effective way to extend the reach and effectiveness of residential waste reduction programs.

THE MASTER GARDENER PROGRAM

In 1972. Dr. David Gibby, Cooperative Extension horticulture agent for King and Pierce Counties (Seattle, Washington), was overwhelmed by requests for information about gardening. His efforts to use the media to answer questions simply seemed to increase the number of telephone calls. Gibby had an inspiration: Could he recruit experienced home gardeners to answer the public's questions as volunteers, in exchange for specialized training in horticulture? With other extension staff and help from Washington State University faculty, Gibby designed a training program. Gardeners eagerly signed up, and 120 enrolled in the first session in 1973. After graduation, the volunteers, christened 'Master Gardeners' by Gibby, began answering phone questions and offering talks, demonstrations and plant clinics. In their first year, the master gardeners served more than 7,000 clients. Today, according to Master Gardener International, forty-five states, the District of Columbia, and four Canadian provinces offer Master Gardener programs. Master Gardeners staff horticulture hotlines, coordinate environmental and planting projects, run demonstration gardens, do research, manage public and community gardens, act as docents, work with school groups and senior centers, publish newsletters, and broadcast radio and television programs.

Master Gardener programs vary widely from state to state, but the foundational idea remains the same: Experienced hobbyist gardeners receive training lasting from 30 to 120 hours, providing solid technical and scientific knowledge to supplement their practical know-how and satisfying their desire to know more about subjects they find fascinating. In exchange, they agree to apply their knowledge as volunteers, serving a set number of hours of community service. Once trained, Master Gardeners often remain active. In some cases, Master Gardener groups continue to provide sound research-based horticultural advice to communities even after budget cuts force closure of Cooperative Extension offices.

MASTER COMPOSTER PROGRAMS

The success of Master Gardeners inspired creation of other similar 'master volunteer' programs. A little over a decade after launching the first Master Gardener program, the Seattle area witnessed what may be the first Master Composter program in the mid-1980s, a cooperative effort of Cooperative Extension, County Waste Management and the Washington State environmental organization Tilth.

Dr. John VanMiert wrote the program training guide, which has provided a model for Master Composter programs since (Van Miert, 1991). Similar to the Master Gardener program, the Seattle Master Composter program required 30 hours of volunteer service in exchange for training. VanMiert's curriculum covered fundamental composting science (aerobic and anaerobic decomposition), agricultural and horticultural uses of compost, health concerns, the history of composting, compost materials composition, practical composting methodology (such as windrows, piles and pines, layering, optimum moisture and aeration, insect control, and so on), and vermicomposting.

Master Composter programs spread quickly to other parts of the US and Canada in the late 1980s and early 1990s. Some were administered at community level, like the original Master Gardener program, others at the state level. Today, scores of programs are active, and Texas Master Composter Mary Tynes has created a very useful website for North American Master Composters: www.mastercomposter.com.

According to Tynes, Master Composter programs generally require 15-24 hours of training. This training is mostly classroom-based, with some self-study. Certification requires completion of 20 to 100 hours of volunteer service. Service opportunities include maintenance of demonstration sites, speaking about or teaching composting, giving neighborhood demonstrations, creating visual teaching aids, giving puppet shows to kids, building compost bins for schools, and other activities that further composting education. Tyne's site offers an on-line Master Composter self-study curriculum for people in areas without a program, although she stresses the advantages of participating in a local program.

Why Master Composters?

Master Composter programs are popular for good reason. To succeed, residential composting programs must provide education and support to members of the community. If recruited carefully and trained conscientiously, Master Composters are ideal for this purpose. They can reach people at a grassroots level with projects designed to demonstrate successful composting. In their own neighborhoods, they can lead by example. They can provide needed staffing for bin distributions and other events, and can help create and maintain compost education and demonstration gardens at museums, schools and parks. They can assist staff in evaluating home composting strategies and techniques. Master Composters also provide an invaluable 'sounding board' for staff ideas, as well as a source of articulate public support for environmentally beneficial and sensible public policy.

Master Composter programs are not expensive, requiring investment in training and materials rather than in expensive land and equipment. If managed effectively, and with the right volunteers, such programs can generate self-sustaining groups of trained individuals who provide a pool of expertise for public and private composting and recycling initiatives. The personal contacts Master Gardeners have with private and public agencies and decision makers, through work and community activities, can be very valuable in raising awareness of the value of composting and source reduction.

Master Composter Models

Among the many excellent Master Composter programs that now exist, several stand out as models that Mecklenburg County found especially valuable in setting up its first Master Composter program. This is by no means an exclusive list: The mastercomposter.com website has links to other outstanding programs. Like Master Gardener programs, Master Composter programs vary in both objectives and structure. Since Mecklenburg County's program focuses on residential composting and environmentally beneficial yard and garden techniques, most of the programs this paper discusses share that focus. This brief overview includes a couple of interesting alternatives as well.

Alameda County, California

Alameda County, California, a large urban county in the San Francisco Bay area, offers Master Composter training annually in the spring . The class covers composting, organic gardening, and public speaking. Participants take part in classroom presentations, field trips, constructing compost bins and practice in presentation and organizing skills. Volunteers provide 50 hours of service, teaching others to compost, in exchange for the training. The program places a unique emphasis on individual projects and support for budding entrepreneurs. Alameda County’s recycling and waste reduction program runs the Master Composter program completely independently from California Cooperative Extension. The Alameda County website is an invaluable resource for home composting and Master Composter programs. Their excellent training curriculum is now available on-line, along with other documents, including the county's interesting study on home composting in Alameda County (see web resources).

Seattle's Master Composter Program

The Seattle Master Composter Program has played an important role in the city's waste reduction and recycling efforts for more than a decade. Currently, the program teaches people how to compost food waste and yard waste, and how to use green gardening techniques such as water conservation and minimal pesticide usage. After training, Seattle Master Composters ‘pay’ for their training by donating 40 hours of volunteer work to promote at-home composting through workshops and demonstrations, leading tours, and participating in local school projects and community events. Notable in Seattle's approach is the recognition that home and community composting addresses not just waste reduction, but agricultural sustainability and environmental protection as well. Seattle's program organization is a model for other regions, since Cooperative Extension, Waste Management and the environmental and agricultural organization Tilth work cooperatively on the program. This synergy may be one of the reasons Seattle's program is among the most effective in the nation, with over 60% of households reportedly participating in home composting, compared to a national average of about 16% (Sherman, 1996).

Georgia Statewide Program

In Georgia, the state's Department of Community Affairs took advantage of an Environmental Protection Agency grant in 1992 to create the first statewide Master Composter program in the US. Georgia Cooperative Extension Agents Wayne McLaurin and Gary Wade created a handbook for use with trainings. The program helped create a number of exemplary home compost display sites, including one at Fernbank Science Museum in Atlanta that continues to be an attractive and crowd-pleasing exhibit, now (September 2000) featuring native plants and habitat gardening as well as composting and vermiculture displays.

The Composting Council National Backyard Composting Program

The Composting Council designed their 1996 National Backyard Composting Program Training Manual for intensive workshops held over two or three days. The program's target audience is educators, community leaders, public works personnel, planners and recycling coordinators. The training's goal is to enable participants to plan and implement a home composting program tailored to community needs. The Composting Council is a private group that works to encourage composting. The training manual is a useful resource for Master Composter trainings, since it covers a variety of topics in a succinct format, including practical and scientific aspects of composting; project planning and organization; education and outreach; bin give-away programs; program promotion and evaluation. However, it must be adapted for Master Composters, since it focuses on paid staff work at the city or county level, rather than on neighborhood volunteers. The resources section is especially valuable, though it does not contain web-based contacts.

South Carolina: A different approach

South Carolina's Clemson University Cooperative Extension in York County chose a somewhat different approach to master volunteer service. Their program has trained 'Master Composter/Recyclers', who work to encourage recycling and paper waste reduction as well as home composting. Their training program spends only a single session on composting, concentrating instead on other aspects of waste reduction and on outreach and presentation skills. Montgomery County, Maryland, uses a similar 'Master Recycler/Composter' approach.

Maine 'macro' Master Composter training

In some cases, 'Master Composter' training focuses on large scale rather than residential composting. For example, The University of Maine, in conjunction with Germany's University of Bremen and Australia's RMIT University, has offered three day a Compost Masterclass covering skills needed to manage large scale municipal and commercial composting. The cost is $750 AUD. More information about Maine's Composting School is available at www.composting.org. John Cline of Amaranth and Associates offers a similar program in Nova Scotia, for a similar fee. In the view of the authors, this type of higher level 'Master Composter' program is highly beneficial for professionals working with large volume composting operations, though neither necessary nor appropriate for most Master Composter volunteers working in the community. Conversely, backyard-oriented programs cannot be expected to train composting professionals to manage composting on a large scale.

MECKLENBURG COUNTY, NORTH CAROLINA, PROGRAM HISTORY

The roots of Charlotte's home composting program go back to January 1990, when Martin Webster of the 'Pile-it Project', a citizen-based home composting initiative, advocated a county home composting program. Brenda Barger of County Engineering's Waste Reduction began working on the program in 1992, when Cary Saul of Solid Waste Management named her to a newly organized Mecklenburg County Backyard Composting Education Team. Cooperative Extension Agent Ted Caudell and Master Gardener volunteers joined the effort in 1993, working with Steve Elliot, 'Compost Central's' site manager, to create a 0.3 ha (3/4 acre) home composting demonstration 'Compost Garden' at Compost

Central, the county's central yard waste processing site. In 1994, Don Boekelheide, a returned Peace Corps agriculture volunteer hired as a consultant, set up 'Peace Corps-style' hands-on two hour home composting workshops for residents, with brief discussion of grasscycling, held outdoors in the Compost Garden (Boekelheide, 1998). These workshops proved very popular. Workshops cost $5, and each participant received a wire bin at the end of class. Boekelheide and County Waste Reduction partnered to write a SWRAG grant in 1997 to expand the program through a series of compost demonstration fairs and bin distributions.

Shortly afterward, in late 1997, Ann Gill joined the program as full-time coordinator for Waste Reduction. Shortly after her arrival, home composting classes moved from Compost Central's Compost Garden to environmental science centers in Mecklenburg County Parks, to provide less rustic conditions and to better serve the public by offering classes at several locations around the county. At the same time, classes expanded to 4 hours, retaining the hands-on composting component and adding information on grasscycling, soil testing, pesticide and fertilizer alternatives and safety, and landscaping with native and traditional non-invasive plants. These workshops are now called 'PLANT' classes (for 'Piedmont Landscaping and Naturescaping Training'). They have proven as popular and successful as the original workshops. Participants still receive a bin, along with a wealth of printed materials, although the registration fee is now $10.

Home composting problems and possibilities

The success of the county home composting program lead to a number of challenges. How could the county satisfy the increasing demand for home composting information, but still work within a limited budget? How could the program meet staffing needs for special events and demonstrations? How could the composting program be as sure as possible that all program instructors and presenters would give reliable, research-based and consistent information on best composting practices? And how could the program encourage effective cooperative relationships among different agencies and institutions in the public, private and non-profit sectors?

A Master Composter program seemed to offer an ideal answer to these challenges, given a number of conditions. First, the program needed to create a 'state of the art' curriculum and training tailored to local conditions and designed to support Mecklenburg County's program. Second, the first recruits for the program needed to be highly motivated community members with solid knowledge of at least one component of the PLANT program. Ideally, trainees also would reflect the cultural diversity and distinct communities, regions and organizations found within our large county and the city of Charlotte. Finally, since this program would be a first for the county, the design needed to be flexible enough to change in response to experience and new ideas, yet strong enough to provide a foundation for sustainable success.

Materials, methods and approach

The Mecklenburg County Master Composter/Piedmont Landscaping and Naturescaping Training (MCPLANT) volunteer program took shape over about 1 1/2 years of planning and implementation, beginning with research on existing Master Gardener and Master Composter program around the United States and Canada. The programs profiled in the introduction, especially the Alameda County program (for structure and overall orientation) and the Seattle program (for curriculum content), were particularly important models.

MCPLANT planners began with an inventory North Carolina Master Composter programs started by Cooperative Extension in the early 1990s. Unfortunately, around the state, all but a handful have completely disappeared at the county level, although interest remains high in many areas. Charlotte's new program, however, was able to benefit enormously from generous help and guidance provided by NC State Cooperative Extension staff in Raleigh who were instrumental in setting up the earlier statewide program. These include Rhonda Sherman, who played a key role in creating the curriculum for both the state program and for the Composting Council, and Larry Bass, principal author of North Carolina's Coop Extension home composting brochure.

Funding

Mecklenburg County Engineering Waste Reduction sought funding for the program through a $9000 Solid Waste Recycling Assistance Grant (SWRAG) from the North Carolina Department of Environment and Natural Resources (NCDENR). The SWRAG grant required matching support from the grant recipient. County Engineering provided the match, and also received valuable in-kind assistance from County Park and Recreation's Environmental Education Program, and at least an initial commitment from local Cooperative Extension (see Discussion). The SWRAG grant has a category expressly aimed at backyard composting, believing it represents 'a low cost method to increase diversion and potentially improve the public's perception of local waste reduction programs'. NCDENR's support was indispensable and highly valued by project staff.

Statement of philosophy, goals and objectives

Boekelheide served as training and curriculum designer and lead facilitator for the training. Influenced by Peace Corps and Cooperative Extension practices, he worked with Gill and, later, MCPLANT trainees to create a clear statement of philosophy, goals and measurable learning objectives (Tables 1, 2 and 3).

As the goals and objectives make clear, there is more to this approach to home composting than simply making a leaf pile in the yard. Instead, home composting is one element in an ecologically sound, waste reducing and aesthetically appealing approach to residential landscaping and yard care. MCPLANT volunteers have a broader role than simply encouraging home composting - they also work to support grasscycling, soil stewardship, and lowering the amount of potentially toxic chemicals and pollutants from non-point sources such as residential neighborhoods.

Table 1
MCPLANT PHILOSOPHY

1. The foundation of MCPLANT training is practical experience, supported by the best available research-based literature on composting and ecological gardening.

2. MCPLANT volunteers and program organizers practice what they preach, beginning by composting at home.

3. MCPLANT training is not simply to help participants acquire knowledge, but to empower them to make a positive difference through community service.

4. The most effective way to learn about composting and other gardening and environmental skills is ‘hands-on’ by doing, seeing and discussing, not by simply listening to lectures and reading articles.

5. Adults can effectively manage their own learning, and MCPLANT training must empower participants to set their own goals and objectives, independently research topics, and contribute directly to learning activities. Given this reality, and acknowledging that many potential topics possible in this class, facilitators ask participants to ‘buy into’ and focus on the learning objectives for this training. Other topics represent opportunities for future projects and learning.

6. The MCPLANT program welcomes and encourages innovations and creativity in independent projects. All projects should, however, fit with the environmental and cultural realities of Mecklenburg County and be based on an accurate understanding of composting science and ecology.

7. MCPLANT volunteers should ‘look like’ Charlotte: MCPLANT encourages diversity in age, gender, culture, income level and neighborhood location.

8. The MCPLANT program must be ‘sustainable’: The MCPLANT program must be able to keep going in the future on its own, even without further support from the county or state (though such support is very desirable).

9. No work is more important than bringing humanity back into harmony with nature: Composting and environmentally sound gardening are important tools in this deeply rewarding endeavor.

Curriculum and learning sessions

The curriculum, influenced heavily by Peace Corps 'hands-on' philosophy and by the 'project' approach used successfully in Alameda County, stressed active involvement rather than classroom lectures. Participants built and observed a number of compost piles, made and maintained (and continue to maintain) vermicomposting bins, and got out of the classroom for field trips and outdoor learning. Participants also helped to facilitate sessions in their areas of expertise. A topics list is provided in Table 4.

Gill managed the logistics of the training, arraigning meetings at Reedy Creek Environmental Center, an ideal location provided by Mecklenburg County Park and Recreation. The program provided simple box lunch dinners, so classes could begin at 6:30 PM. Learning took place over 10 weeks in the early spring, February through April, with regular 2 hour class meetings on Thursday evenings. The group also met 4 times on Saturday morning for field trips and other activities. For example, on one outing, trainees visited Charlotte's Compost Central large scale composting

Table 2

MCPLANT GOALS

1. Enable participants to develop skills and knowledge they need to encourage home composting in the Charlotte region:

    1.1 Teach participants about composting science; vermiculture; organic and environmentally sound landscaping and gardening techniques; safe management of products used in the home and garden; and about the ‘big picture’ of how home composting and related techniques fit in with larger strategies to reduce and manage waste.

    1.2 Give participants guidance and practice in effective teaching and presentation skills.

    1.3 Give participants guidance and experience in effective community organizing, publicity and project planning.

    1.4 Encourage entrepreneurially minded volunteers to explore small business possibilities involving composting, vermiculture and environmental landscaping.

    1.5 Enable teacher volunteers to create hands-on science lessons (as well as in other subject areas) using composting, vermiculture and environmental landscaping.

2. MCPLANT training and the MC program will raise awareness of home composting in Charlotte-Mecklenburg, and encourage more people to compost and adopt environmentally friendly garden techniques.

3. MCPLANT training will ‘graduate’ 17 trained volunteers in the first class, qualified to assist the county home composting program in training, outreach and publicity.

4. MCPLANT training and the MC program will be self-sustaining, and members will continue to meet and work to encourage home composting in the future.

yard; on another Saturday, volunteers helped distribute compost bins at a 'truckload sale' of Earth Machine composters organized by the county.

Recruiting

Gill handled recruiting for the program, with help from Boekelheide, using a form based on ones used in Alameda County and Seattle. Two of the participants were already serving as PLANT trainers for the county. Since the objectives set high standards, the program looked for top quality candidates. A total of 17 were chosen to become Mecklenburg County's first MCPLANT volunteers. Since this was a pioneering training, participants did not pay a fee.

Results: MCPLANT accomplishments

All 17 MCPLANT volunteers successfully completed training and graduated from the program, and are now actively working on projects and continuing to participate in MCPLANT activities.

Table 3
MCPLANT LEARNING OBJECTIVES

Graduates of the MCPLANT program will be able to:

1. Make and maintain a home compost pile, beginning with leaves and other garden debris and ending with finished compost:
   - *1.1 Present an accurate explanation of the composting process, based on scientific research*
   - *1.2 Explain the process of making a pile correctly to others*
   - *1.3 Troubleshoot common problems in piles*
   - *1.4 Demonstrate ways to compost kitchen scraps*
   - *1.5 Demonstrate and explain alternatives to composting, such as leaf mulching and ‘sheet composting’*
   - *1.6 Demonstrate how to add compost to improve garden soil (including demonstrate ‘double digging’)*
   - *1.7 Identify finished compost*

1.8 Suggest best choices for compost bins and techniques for given situations

1.9 Recommend resources, books and websites useful to home composters, especially beginners

2. Make and maintain a successful worm composting (vermiculture) bin, using an adaptation of Mary Appelhof's technique or an alternate approved by the facilitator

2.1 Make a worm bin and set it up properly

2.2 Keep a worm bin successfully, and harvest castings

2.3 Advise others on how to set up and maintain a worm bin

2.4 Troubleshoot problems with home worm bins

2.5 Recommend books and resources for home worm composting

2.6 (Optional): Design, set up and manage worm vermicomposting units for small businesses

3. Offer accurate and helpful advice about environmentally friendly landscaping and organic gardening techniques, applied to the Charlotte region, on the following topics:

3.1 Plant choice

3.2 Mulching and 'living mulches'

3.3 Organic vegetable gardening

3.4 Local soils and soil testing

3.5 Environmentally friendly lawn care and lawn alternatives, including ground covers

3.6 Water saving strategies

3.7 Putting it all together: Naturescaping, Permaculture, and other new ideas

3.8 Wildlife gardening

3.9 Working with organizations and communities to create sustainable and environmentally sound public landscapes

4. Offer helpful and accurate information on environmentally safe alternatives to garden and household chemicals, and on safe and most effective use and disposal of garden and household chemicals:

4.1 Alternative pest and disease controls-cultural and biological

4.2 Safe and appropriate use and disposal of garden and household chemicals:

4.2.1 fertilizers and lime

4.2.2 insecticides, herbicides and other pesticides

4.2.3 other hazardous materials commonly found in homes (treated wood, paints, gasoline)

5. Lead a composting workshop (or other activity approved by the teacher)
   5.1 Use presentation techniques that keep people actively interested
   5.2 Describe the experience of leading a class in a brief report

6. Create an effective community project encouraging composting and other environmentally sound options in a Mecklenburg County neighborhood, school or community group (entrepreneurial options welcome):
   6.1 Research and plan a service project, and present the plan to the MCPLANT training
   6.2 On the basis of feedback from the training group, revise and present a final plan to the facilitator
   6.3 Implement the project, and successfully see it through to completion
   6.4 Report project results in a form useful to Mecklenburg County and other MCs and MC programs

Quality instruction for the general public

Graduates of the MCPLANT training now lead all Mecklenburg County PLANT classes for residents, meaning that all instructors have participated in a carefully designed program to build technical and presenting skills. In addition, MCPLANT volunteers have actively served as resources for other community projects. By teaching home composting part of a 'package' of environmentally sound landscaping techniques, MCPLANT volunteers encourage other beneficial outcomes, such as reduced pesticide use and improved water quality.

Table 4
MECKLENBURG COUNTY MCPLANT TOPICS

Session 1 (Thursday): FIRST STEPS (INTRODUCTION)

Session 2 (Saturday): HANDS-ON COMPOST MAKING WORKSHOP

Session 3 (Thursday): COMPOST SCIENCE: WHAT, HOW AND WHY

Session 4 (Thursday): FROM THE GROUND UP: SOILS AND COMPOST USE

Session 5 (Saturday): OBSERVE AND ASSIST WITH PLANT WORKSHOP FOR THE GENERAL PUBLIC

Session 6 (Thursday): VERMICOMPOSTING WORKSHOP

Session 7 (Thursday): SOUTHERN SPRING SHOW

Session 8 (Saturday): COMPOST CENTRAL FIELD TRIP AND TOUR

Session 9 (Thursday): NATIVE PLANTS AND NATURESCAPING

Session 10 (Thursday): WATER QUALITY AND TOXICITY REDUCTIONS

Session 11 (Saturday): COMPOST BIN SALE AT MERCHANDISE MART (ASSIST)

Session 12 (Thursday): ENVIRONMENTAL AND ORGANIC GARDENING (VISIT TO LEAD FACILITATOR'S HOME GARDEN)

Session 13 (Thursday): PUTTING IT ALL TOGETHER (PROJECT PRESENTATION)

Session 14 (Saturday): NATIVE PLANTS IN CONTEXT(VISIT TO UNCC BOTANICAL GARDEN)

Outreach projects

Each volunteer created and is working on a personal outreach project to encourage composting and other environmentally beneficial waste reduction strategies. They received a commercial compost bin and made a vermicomposting unit. MCPLANT volunteers are actively vermicomposting and composting at home, helping research the most practical and effective residential system for composting kitchen scraps (Table 5).

Program sustainability

The MCPLANT program has taken promising steps toward independent sustainability, and has continued to meet following the training. In addition, the county has funded a second MC/PLANT training for winter 2001. The MCPLANT project is attracting word-of-mouth and media attention. This will continue to grow as MCPLANT volunteers began to make an impact in the community and beyond.

Table 5
MCPLANT VOLUNTEER PROJECTS

Set up worm and composting projects at schools, 4H and scout camps (in Hamlet, NC)
(Shari Beale)

Design and facilitate MCPLANT training (Don Boekelheide, facilitator/participant)

Set up community compost demonstration site (Priscilla Crawford)

Bin construction and demonstrations in schools and community (Paula Fraher)

Develop activity and exhibit on water quality, pesticides and fertilizers (Kim Garrett)

Offer seminars in composting at garden centers (Jim Gertes)

Work on 'WAIT' program, which encourages businesses to convert 'manicured' grounds to sustainable, environmentally sound alternatives (Tim Gestuicki)

Organize and manage MCPLANT program in Mecklenburg County (Ann Gill, facilitator/participant)

Begin a composting club in the community (Chris Heeley)

Assist in design and compost consulting for church horticultural therapy program (Tom Long)

Teach PLANT program: Start native plant and composting program in area schools
(George Morris)

Research and test different alternative materials for composting (Gerard Neau)

Advocate composting on citizens advisory board on residential waste reductions and recycling (Hans Plotseneder)

Teach PLANT program: Design naturescaping plan for suburban yard: Help create third grade composting curriculum (Mary Stauble)

Set up institutional food waste composting unit at university dining commons (Gail Thomas)

Set up composting display and curriculum at local school: Assist with third grade composting curriculum (Cynthia White)

Design and create native plant and wildlife naturescaping project at inner city recreation center, with teaching program (Charles Yelton)

Handouts, curriculum and materials

The program developed handouts, lesson and activity plans, and facilitator's notes. The facilitator is revising these for the 2001 MCPLANT class. When this material is edited and in a suitable form, the program plans to put the information on line as well as to make the documents and curriculum available to other state agencies.

WASTE DIVERSION

Since MCPLANT focuses on building human capacity, by training volunteers who can teach neighbors composting and encourage changes in behavior that reduce waste, a tonnage estimate is not the best way to measure impact. Although a single home composter may have only a modest impact on reducing solid waste, the cumulative impact of the MCPLANT program over time is more significant and important. Each additional composting family adds up to additional waste reduction. Such 'ripple effects' are the most valuable contribution MCPLANT makes to reducing the waste stream.

MCPLANT volunteers will use 15 commercial units and 15 worm bins at their homes or offices. A significant percentage (estimated 25%) of their composted material will be difficult-to-process kitchen scraps. The MCPLANT graduates are also essential for continued success of the PLANT program, which now reaches approximately 500 households per year. Overall, this represents a conservative estimate of 1030 cubic meters (appx. 1442 cubic yards) of diverted material, in addition to other beneficial impacts on grasscycling and lower water, fertilizer and pesticide use. While this amount is relatively small in absolute terms, it represents a very cost effective investment (>$6 per cubic yard diverted, based on the grant amount), as well as a program whose impact will continue to grow as more and more households began to compost successfully.

DISCUSSION

The MCPLANT program has proven popular and extremely successful in its early stages, and participants and facilitators gave the training a high rating. All sessions went very well, with a variety of activities and many opportunities for active learning and involvement. MC Trainees are now able to provide accurate information on composting and other strategies for reducing waste. Beyond this, PLANT resource volunteers are continuing to contribute to waste reduction, both through their projects and their informed involvement in their neighborhoods, work places and civic organizations. Beyond these positive overall results, the project was a learning experience. There were both unexpected positive developments and unanticipated challenges to program success.

Quality volunteers

The rich backgrounds of the trainees made a positive impact on training. One is a ranking member of our regional recycling board, another is head of the Wildlife Federation local office, another is a community development office with Bank of America, yet another leads recycling efforts at the University of North Carolina, Charlotte. Two are Master Gardeners. The varied backgrounds and contacts of participants opened many opportunities for networking and building institutional support from within local groups and agencies. We were very lucky to have such an extraordinary group of skilled but patient and supportive volunteers who enrolled in the program.

Participant responsibilities

The MCPLANT program changed requirements regarding participant projects between the time of the grant application and the beginning of the training. Instead of requiring participation in projects like testing home compost bins, we asked trainees to put their energy into a project of their own choosing and design. In part, this change came from discussions in Alameda County, California, where a 'project' approach has worked very well. Empowering adult volunteers to create their own project, with review by facilitators and fellow trainees, is a powerful tool for encouraging involvement and participation.

Readings

Instead of relying solely on handouts prepared by staff, or taken from other publications, MCPLANT used a number of readily available books as ‘texts’ for the class. One of the best is Sara Stein’s *Noah’s Garden: Restoring The Ecology Of Our Own Back Yards* (Stein, 1993). Other excellent texts included *Easy Composting* (Ball and Kourik, 1992), and *Worms Eat My Garbage* (Appelhof, 1997). Materials from the Brooklyn Botanical Gardens were also very useful. These well-written books provided a wonderful starting point for discussion and involved learning.

Recruiting lessons

MCPLANT may extend the application period and do more active outreach to ensure cultural diversity that reflects our community. In addition, teachers did not volunteer for the first MCPLANT training, though the program made a special effort to reach out to teachers. However, in view of experience with the first training, a specifically designed program for teachers might be a better strategy than trying to include educators in 'regular' MCPLANT trainings. Being able to concentrate on community development in the MCPLANT classes, rather than on K-12 education requirements and issues, helped the classes stay focused. Mecklenburg County Waste Reduction is now creating a specific curriculum package for elementary schools. Training selected teachers in this curriculum and supporting 'model' school programs may be a good way to put MCPLANT in the classroom in the future.

Longer duration and more hands-on training for workshops

For the next training, MCPLANT may increase the number of workshops by 2 to 4 sessions (to a total 16 to 18 sessions, or from 28 to 36 hours) to allow for more participant-lead programs and a less frantic pace. In addition, training activities focused on native plants and toxicity reduction took the form of classroom lectures. Making these more hands-on will improve future classes.

Cooperation with local Cooperative Extension

In contrast to excellent help from NC State Cooperative Extension in Raleigh, Mecklenburg County Cooperative Extension chose to neither participate in nor support the MCPLANT program. Current Mecklenburg County Master Gardeners were not encouraged to attend the training and were not allowed to receive volunteer training credits for participating in the MCPLANT training (at the time of the SWRAG grant application, Cooperative Extension had agreed to this; however, changes in Cooperative Extension personnel at the County level lead to the changed policy).

The lead MCPLANT facilitator and one of the lead trainers of the PLANT program are NC State Master Gardener volunteers, so at least a strong informal tie remains with local Coop Extension. Hopefully, the future will see expanded cooperation on the local level in Mecklenburg County, since Cooperative Extension - a publicly funded agency - is an ideal partner for waste reduction through home composting and environmentally responsible gardening programs. This is not absolutely necessary: In Texas and Alameda County, California, for example, outstanding Master Composter programs exist with no Cooperative Extension involvement at all. However, Cooperative Extension takes a leading role in Florida, Georgia and South Carolina, and is a key partner in Seattle's pace setting program. In the view of the authors, this is a better model, since interagency cooperation is a much wiser use of public dollars.

<u>Need for a physical site</u>

The Mecklenburg County home composting program is doing an excellent job, in spite of the fact that it no longer has a suitable site for classes and education programs. The original Compost Garden home composting demonstration site, set up in the early 1990s with EPA funds, is located at the Compost Central municipal composting facility far from populated areas, directly underneath the end of the runways for Charlotte’s Douglass International Airport. Although the Compost Garden is still attractive and has the advantage of being on land owned by the county, there are inadequate toilet facilities and no classroom space. Trying to give a composting demonstration for senior citizens with 747s roaring by 200 feet overhead is less than ideal.

Now that the human component of the home composting program is in place, a next logical step is to create one or more MCPLANT and home composting demonstration sites, with appropriate teaching facilities available, in convenient locations closer to the residential populations that represent the target audience for the program.

<u>Website and electronic presence</u>

In addition to a physical site, another logical step is to create a web presence. Both authors are currently working on both a web page on PLANT within county government, and a separate MCPLANT page linked to the county page and to other Master Composter sites around the country.

CONCLUSION

Charlotte's MCPLANT Master Composter program is already making an impact in Mecklenburg County. The first 17 graduates of the program are working on independent projects to encourage home composting and other beneficial practices that reduce waste while safe-guarding the environment. Their active and informed support and volunteer service gives a welcome boost to efforts to reduce waste in Mecklenburg County. Lessons learned during this first training will pay off in better MCPLANT trainings, and improved programs for the general public, in the future. Certainly, other communities in the Carolinas and throughout the Southeast might benefit from a Master Composter volunteer program of their own.

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Web-based resources:

Master Composter national site (Mary Tynes, webmaster) : http://www.mastercomposter.com
Alameda County, California: http://www.stopwaste.org/fscompost.html
Texas Natural Resource Conservation Council: http://www.tnrcc.state.tx.us
Cornell University, New York: http://www.cfe.cornell.edu/compost/Composting_homepage.html
North Carolina Department of Environment and Natural Resources: http://www.p2pays.org/
Eco-IQ (excellent reference list): http://www.ecoiq.com/onlineresources/anthologies/recycling/
Directory of invasive plants:
http://directory.google.com/Top/Science/Environment/Biodiversity/Invasive_Species/Plants/

EPA Guide to natural landscaping: http://www.epa.gov/glnpo/greenacres/toolkit/
Home composting listserv (email linked discussion group): compost@listproc.wsu.edu

ABOUT THE AUTHORS

Don Boekelheide (MS, Agriculture), Training Coordinator, helped create Mecklenburg County's home composting program in 1993, and since that time has served as lead trainer. A graduate of Peace Corps 'Training of Trainers' program, he was a Peace Corps agriculture volunteer and training coordinator in Togo, West Africa. He is a North Carolina Master Gardener volunteer. He graduated from the University of California, Santa Barbara and the California Polytechnic State University (Cal Poly), San Luis Obispo. For three decades, he has worked throughout the world as a writer and editor, most recently as community columnist for the Charlotte (NC) Observer. Contact him at dboek@aol.com.

Ann Gill, Project Manager, is Waste Reduction Specialist with Mecklenburg Solid Waste Management's Waste Reduction Department. She manages and co-teaches the PLANT program, covering backyard composting, grasscycling, xeriscaping, vermiculture, toxicity reduction, compost gardens and compost workshops, and is currently presenting on a national level about the importance and value of safeguarding and restoring native plant communities. Ann attended Georgia Military College, and received technical training with Lockheed Missiles and Space and Solid Waste Management of North America (SWANA). She has served as director of two subtitle D Landfills, a construction and demolition landfill, an inert landfill, a material recovery facility, a compost facility and numerous drop off convenience centers.

In-Vessel Food Residual Composting

Bob Broom, President
RKB Enterprises

Introduction

A study of food waste composting was conducted at Brown Creek Correctional Institution, Polkton, NC. Brown Creek Correctional Institute houses an average of 852 inmates and has 362 employees. Funding was provided, in part, through a grant from the North Carolina Division of Pollution Prevention and Environmental Assistance, Department of Environmental and Natural Resources. RKB Enterprises, Inc. of Norfolk, VA, was the selected grant recipient to provide the equipment and conduct the study, assisted by Brown Creek Correctional Institute staff. Although this was not a university-supported study, Dr. Don Cawthon of Texas A&M University-Commerce and Dr. Alan Heyworth, teg Environmental, plc, England, contributed a significant amount of their expertise and time for consultation.

The nine-month project set out to collect data testing the appropriateness of in-vessel composting, in particular, the GREENDRUM in-vessel system, for safe and efficient composting of institutional food waste. Pre-determined objectives focused on the collection of data pertaining to:

- quantity and characteristics of waste generated
- GREENDRUM operating capacity
- operating cost
- transferability of the technology
- cost savings
- analysis of resulting compost

Before beginning the trial, it was necessary to determine daily food waste from the average prisoner. Assumptions as to the size of the daily waste stream were based on existing survey figures from the EPA document, "Waste Assessment Reference Manual." Under section 4, "Conversion Charts and Figures," in cafeteria-style dining each meal produces 1 pound. of waste per person. Interpolating this figure to the prison situation where the total waste figure per inmate is assessed as 4.5 lbs. per day, it becomes evident that food residuals are more than 50% of the total waste per inmate daily. As Brown Creek food preparation conscientiously attempts to minimize food waste, we anticipated receiving between 1,000 lbs. and 3,000 lbs. of food waste residuals daily; in addition, the prison uses paper towels at a rate of about 12 pounds daily.

This daily waste prediction prompted a request to change the contract to allow RKB Enterprises to provide at larger GREENDRUM, Type 616, in order to run a pilot program with an operating capacity closer to the maximum needed to handle Brown Creek. Based on trials by Texas A&M, Type 616 is estimated to handle 900 lb. of food residuals daily, plus amendment.

General Project Description

The GREENDRUM in-vessel composter is a continuous feed system using an insulated drum. The drum is mounted on an all-steel frame and rests on all-steel rotor casters and it rotated every 20 minutes using a chain-drive unit powered by an electric motor.

The Greendrum in-vessel process ensures that the health and environmental requirements set forth by the NC Solid Waste Composting Rules are more easily satisfied. This long-term trial of food residuals composting studied the GREENDRUM in-vessel process by rigidly applying those rules to see if the Greendrum performed to those standards. Potential problems with site location are solved through system design. All waste is isolated from the environment until after the time and temperature requirements to "further reduce pathogens" (Rule 1406 para. 12C) is accomplished. That rule requires, "temperatures in the compost piles shall be maintained at a minimal temperature of 131 deg. F for at least 3 days". Analysis confirmed pathogen requirements were attained. After removal from the drum, compost is stacked for curing.

The objective was to compost a waste stream made up entirely of all food waste. This is a more complex process than adding food waste as a minor part of an existing yard waste, leaf, or other similar waste stream. The critical mix characteristics to achieve required thermophilic temperatures are all interrelated. These are pH, moisture content, porosity, and oxygen. C:N ratio is irrelevant to the process when the primary waste is institutional food waste because nitrogen is readily available and immediately released in food waste, while the carbon in wood chips and bark amendment takes longer to breakdown. Therefore the C:N ratio in a drum filled with food waste and a carbon amendment will always be effectively lower than lab analysis indicates. C:N ratio will, of course, effect the nutrient value of the end result -- compost. Locally available bark/sawdust from sawmill, and poultry litter cake was added to reduce moisture and improve porosity. Hydrated lime was added to control pH.

The Daily Process

The availability of labor at Brown Creek allowed Warden Rick Jackson to choose a manual mixing process over purchasing additional mixing equipment. Initially, a PATZ chopper was installed to chop the food prior to mixing. Use of the chopper was discontinued as it did not improve the consistency of the mix nor did it improve the process. The PATZ chopper is designed as a hay bale chopper, not a food-waste chopper. It proved to be noisy and allowed food to drop through the grid.

The Brown Creek staff devised amore effective method of mixing. A discarded 600-gallon cylindrical drum was recycled. The staff cut it longitudinally in half and welded wheels at the corners making it an efficient mobile mixing chamber. Food waste is trucked about ½ mile from the prison kitchens to the site in 35-gallon plastic bins. Additional 35-gallon bins are used to measure the amendment to achieve an accurate mix by volume. Two inmates mix the amendments and food manually with pitchforks. The mixing chamber is then wheeled next to the input screw conveyor, and the mix is transferred to the screw-conveyor hopper that loads the drum. At the other end of the drum, the three sliding-door exit ports unload pre-cured compost completing the continuous process. Residence time is 4 to 5 days. The volume of material removed is equivalent to approximately 75% of the daily intake. Allowing for volume reduction during the process, this keeps the same mass of material in the drum. Compost drops onto a belt conveyor and then into a dump truck. Curing is accomplished static piles.

Daily Operation

The original plan was to rotate the drum continuously. In doing this, however, we were not able to achieve the required temperature. As a result, we adopted an intermittent rotation routine running the drum only during loading and unloading or about 4 hours each day. This frequency of turning incorporates sufficient oxygen into the mix to achieve accelerated composting while preventing the mix from dropping in temperature. A ventilation port was added at the unloading end, which, after further trials, may allow us to discontinue use of the small blower currently in operation. The permanent solution will either be the ventilation port or a combination of the port and a blower.

Prison food waste includes a high percentage of cooked material -- much higher than other types of institutional food waste, and less food is discarded for aesthetic reasons. Fermentation starts immediately when most cooked food waste is placed in a garbage bin. A dramatic drop in pH results, often causing pH readings of less than 3. Fermentation microbes eliminate aerobic microbes in these highly acidic conditions. The addition of hydrated lime during mixing with a porous amendment prior to loading limited the drop in pH to about 5.5, as would normally be expected during the initial stages of aerobic decomposition. It is also possible that fermentation microbes, which are mostly single cell organisms, survived more easily than the more complex aerobic microbes and fungi, in a continuously rotating drum. This contributed to our decision to run the drum intermittently.

Initially the weight of food waste composted was limited to 900 lbs. per day plus amendment; the maximum daily loading rate, recommended by Texas A&M University. As the problems resulting from low drum temperatures were resolved, the daily loading rate was increased to include all of the food waste from the kitchens, plus paper towels. The full amount of waste averaged 1615 lbs. of food and 12 lbs. of towels that were mixed with amendment and loaded each day.

Laboratory analysis by Prism Laboratories, Inc. showed no evidence of pathogens. A series of analysis conducted by NCDA Agronomic Division and A&L Laboratories, Inc. of Richmond, VA characterized the waste, amendment, and compost.

Blending Materials to Desired Moisture Content

To produce compost from food waste, an amendment material is essential. This amendment adds structure (porosity) and absorbs moisture in order to reduce the moisture content to 55% plus or minus about 5%. A sawmill about 3 miles from Brown Creek was a source of suitable amendment material -- bark chips. This proved to be an excellent source for porosity, but because it was “green” the moisture content was higher than desirable for food waste, which starts out as approximately 80 percent moisture. From trials completed at two Texas prisons, we determined the best mix for composting institutional food waste, assuming an abundance of dry amendment, is as follows:

By Volume:
2 part wood chips
1 part sawdust
2 part food waste

Initial Mix Calculation:

The target moisture content for blend of food waste and amendment is 55% moisture.

Assumptions:
weight of water = total weight x moisture content
weight of dry matter = total weight – weight of water

1 pound of mixed food waste contains:

water	1 pound x 0.77	= 0.77 pounds
dry matter	1 pound – 0.77	= 0.23 pounds

1 pound of mixed amendment contains:

water	1 pound x 0.20	= 0.20 pounds
dry matter	1 pound x 0.80	= 0.80 pounds

Formulae:

$$\text{Moisture Content (MC)} = \frac{\text{weight of water in food + weight of water in amendment}}{\text{Total weight}}$$

$$55\% = MC = 0.55 = \frac{0.77 + (0.20 \times A)}{1 + A}$$

Where A is the weight of amendment required:

$$0.55\,(1 + A) = 0.77 + 0.2A$$

$$\mathbf{A = 0.63}$$

Therefore, by weight, 0.63 pounds of amendment is needed for every 1 pound of food,

BUT the mix is achieved by <u>volume</u> not by weight:

Ratio of volume to weight of food waste to amendment is:

270 : 60 = 4.5 : 1

Therefore mix ratio by volume is:

1 : 0.63 x 4.5 = 2.835

1 part food waste : 3 amendment (approximately) by volume

In reality, experience with the locally available amendment will determine the mix to achieve the correct moisture content. At this moisture percentage, leachate will not be released. If the mix is too wet, leachate can be collected in a container situated in the unloading hopper. Variations in food waste would need a waste audit to define. The greatest variable is moisture content, which can vary from very wet --- in excess of 85% moisture, to relatively dry – 65% moisture. As the staff and inmates gained experience, variations in moisture content were countered by adding amendment in the same proportion as the general mix. The practical field-test for moisture content remains the best; hand squeeze after the waste and amendment has been mixed. Experience will lead to appropriate action.

For Brown Creek, a second amendment source of poultry litter with a low moisture content and potentially good porosity properties was located. The final mix was adjusted to the following:

By Volume:
1 part food waste
1.5 parts poultry litter (used to reduce the moisture content)
1.5 parts (green) wood bark (for porosity)

Note: Also 15 lb. per cubic yard of hydrated lime to control the pH

Unanticipated Situations

A design change intended to reduce the time spent loading the drum by fitting a U-trough screw conveyor compounded difficulties producing the ideal mix. A new U-trough conveyor allowed for a reduction in the size of the access port, increasing the usable capacity of the system. This helped achieve two objectives; faster loading and greater capacity. Excellent! However, the new U-trough conveyor caused a reduction in air entering the drum, which was a more significant factor than expected producing an oxygen deficiency within the drum. This, in effect, caused the microbes to be smothered, which in hindsight, should have been detected sooner. When a smaller Type 408 GREENDRUM was used to test the mix, the extent of the oxygen deficiency became clear.

The simple solution took months of trials to uncover because there were multiple solution options. Initially, the basics of composting were addressed:

a. Moisture content
b. C:N ratio

Note: 1. Reasonable values of these two characteristics were quickly established. Since the desired temperatures were not achieved immediately, time was lost varying the moisture content in an attempt to produce higher temperatures.

2. The analyzed C:N ratio for the mix, at approx. 35:1, was reasonable but not likely to promote a highly active composting process. We believe our effective C:N ratio was lower as the nitrogen in the food waste was much more available than the carbon in our amendment. Having exhausted combinations of the above, we concentrated on the following:

c. pH
d. ammonia
e. oxygen

Daily variations in food waste complicate the problem. The key to solving the mix equation at Brown Creek was use of the portable 408 GREENDRUM. Unworkable mixes were quickly eliminated and small batches were used to refine the mix for maximum composting efficiency. The portable unit allows each site's waste to be tested quickly with the available amendment to ensure that a full-scale system will operate efficiently.

Things I would consider doing differently

The 616 GREENDRUM design has been changed to include a heavy-duty frame mount. It is now considered too heavy to be supported on a trailer. The absence of the trailer allows the drum to be lower on the pad, which makes it easier to load. Future GREENDRUM installations of type 616 or larger should be ordered without the trailer.

Productivity, working conditions, and the efficiency of the labor/system combination were examined. Actual situations should be observed. For example, when the time to mix a batch is measured, the circumstances and the labor resources should be taken into consideration. The Brown Creek project was planned as a morning activity allowing adequate time to complete each mix in 30 minutes. Several things here could alter productivity. These include a covered paved working area and paid non-inmate labor. Notwithstanding their circumstances, the inmate workers had an excellent attitude, were interested and took some pride in this project.
The PATZ chopper added time to the process without providing any tangible improvement in efficiency. The consistency of food waste delivered to the site meant it is not necessary to employ a chopper to prepare prison food waste for composting; an aesthetically pleasing product is produced without the use of a chopper. BW Organics has designed a chopper/mixer to work with this system; a low cost smaller capacity unit has not been found currently on the market. A mixer cuts preparation time before loading and would likely reduce total handling time by half.

Waste reduction impact

The following table shows the actual daily loading rates and the total tons of food waste diverted. During the first four months the daily the loading rate was limited to the expected maximum daily capacity of the GREENDRUM 616. The drum was not loaded on a regular routine as various trials were conducted. During the second half of the trial all the available food waste was loaded:

Month	Daily Loading Rate, lb./day	Monthly Total, Tons
July	896	5.8
August	955	6.7
September	954	11.0
October	973	1.9
November	1633	24.5
December	1727	25.1
January (thru 24^{th})	1486	17.8
TOTAL		92.8

Using the figures for the months when the GREENDRUM was working at full capacity, the average daily loading rate was 1615 lb., giving a projected annual diversion of 295 tons of food waste plus, 2 tons of paper napkins for a total of **297 tons annually**.

Considering only waste disposal cost, annual savings are $10,395.00. Not including the capital cost, operating costs projected over one year including lime, labor, electrical power, and amendment are $ 2,675.00 annually. The positive balance is $ 7,719.00.

Brown Creek will produce approximately 1,000 cubic yards of compost annually. In Charlotte, 50 miles to the west, this has a market value of about $ 20,000.00 when sold in bulk.

Changes at Brown Creek.

Food Preparation

The quantity of food wasted each day prompted Warden Rick Jackson and the Food Service Department to investigate. Two primary factors were uncovered. Often, more food than required is prepared. No procedure is in place to feed this excess food to inmates. The waste food becomes a disposal cost as it is currently going into the garbage bins. Also, for security reasons, there is no method for inmates to communicate with the servers, who fill the food trays in the kitchen. Currently, each tray is filled with an entire meal and then slid under the hatch. Brown Creek Enterprise Division is building a security screen through which the inmates will be able to request items be omitted from their tray, thus reducing wastage. Rick Jackson intends to further review the quantity of food prepared for each meal.

Project accomplishments

The GREENDRUM in-vessel system, with a delivered, set-up, and running price of less than $50,000 hands on average 1615 lbs. of food waste plus amendment every day seven days a week. If the prison system could market this waste stream as they do other recyclables, the combined cost savings plus income would come to about $25,000.

The Greendrum in-vessel composting process ensures that the health and environmental requirements set forth by the NC Solid Waste Composting Rules are satisfied. The system proved simple to operate and reliable technology that could easily be transferred to other institutions in NC where similar cost savings are possible.

Quality compost is available for Brown Creek's use on grounds and vegetable gardens. Surplus compost is available for use by other North Carolina State agencies.

SOIL AMENDMENTS FOR ROADSIDE VEGETATION IN VIRGINIA

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INTRODUCTION

The establishment and maintenance of roadside wildflowers and vegetative cover crops are dependent on both the inherent productivity of roadside soils and management practices. Roadside soils are almost always highly disturbed relics of the road construction process and vary significantly from soils that have formed in place. In particular, roadside soils are generally compacted, high in soil strength, acidic, and low in organic matter and plant-available nutrients.

The combined influence of adverse soil properties and soil variability in roadside soils has led to irregularities in wildflower growth and bloom display and, in certain instances, to complete stand failures in field trials (Bill Watson and Roger Dove, personal communication). Management practices such as tillage, liming, and fertilization have mitigated these problems to only a limited extent. Land reclamation studies have proven that a lack of organic matter and organically bound nutrients are the primary properties that differentiate disturbed soils such as roadside soils from their natural counterparts (Daniels and Haering, 1994; Haering et al., 2000).

Numerous studies have demonstrated that composts produced from a wide variety of organic materials such as biosolids (sewage sludge), animal manure, and yard wastes can improve soil physical, chemical, and biological properties (Shiralipour, et al., 1992; Brosius, et al., 1998). The use of organic amendments can reduce or eliminate the need for periodic conventional fertilization and is typically less costly. Finally, and perhaps most importantly, organic amendments can ameliorate local irregularities in surface soil properties. In Virginia, many potentially useful organic amendments are available in each of the Virginia Department's of Transportation (VDOT) Districts, and regulatory guidance and financial incentives promote the utilization of these amendments. The objectives of this study are to determine the effects of application of various composts on the growth and quality of roadside vegetation and soil properties that influence vegetation sustainability.

MATERIALS AND METHODS

In August 1998, two nearly level sites were selected in Culpeper and Staunton, Virginia. The Culpeper soil has a clay loam texture and is located near an exit ramp off Hwy 29 in Culpeper County in the Northern Piedmont soil physiographic region. The Staunton soil also has a clay loam texture and is located in the median of I-81 in Augusta County of the Appalachian Ridge and Valleys soil physiographic region.

Initial soil chemical properties (Table 1) were determined using established procedures for southern U.S. soils (Donohue, 1992). Soil pH, Ca and Mg were adequate for establishment of vegetation because the soils had previously been limed by VDOT staff. Soils at both sites contained lower concentrations of P than optimum for pant growth. Soil K concentration was adequate at Culpeper but lower than necessary for optimum plant growth at Staunton.

Table 1. Analysis of the soils used in the study.

Location	PH	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Soluble Salts (ppm)
Culpeper	5.8	8	101	816	120	141
Staunton	6.1	10	25	840	117	90

The study is a two-factor experiment consisting of three plant species and six soil treatments. Plant species were lanceleaf coreopsis (*Coreopsis lanceolata*), corn poppy (*Papaver rhoeas*) and tall fescue (*Festuca arundinaceae*). The soil treatments were composts from four sources, an NPK fertilizer applied according to soil test results, and an unamended control. The composts were produced from: 1) biosolids + wood chips, 2) yard waste + poultry litter, 3) paper mill sludge, and 4) cotton gin trash. The source of each amendment is listed in Table 2. Each treatment was replicated 4x. The experimental designs were a randomized complete block at Culpeper and a completely randomized block at Staunton. Individual plots were 100 ft^2.

Table 2. Sources of amendments applied in Culpeper and Staunton in August 1998.

Treatment or Amendment	Source
Biosolids compost (BC)	Harrisonburg-Rockingham Regional Sewage Authority, Mount Crawford
Yard waste compost (YWC)	Panorama Farms, Earleysville
Paper mill sludge compost (PMSC)	Greif Bros., Amherst
Cotton gin trash compost (CGTC)	Commonwealth Gin, Windsor

The existing vegetation was sprayed with glyphosate (2 gal/acre) two weeks prior to seeding. The sites were then roto-tilled six to eight inches deep. The amendments were incorporated into the top three to four inches of soil on 8/26/98 at Culpeper and 8/28/98 at Staunton. The composition of each amendment is presented in Table 3.

Table 3. Analyses of soil amendments used in the study.

Compost	Solids (%)	Org C (%)	C:N	TKN* (%)	Org N (%)	NH_4-N (%)	P (%)	K (%)	EC** (dS/m)	pH
BC	70	37.8	9.6	3.95	3.14	0.81	2.9	0.25	10.74	6.8
YWC	32	30.3	16.0	1.89	1.88	0.02	0.6	0.65	1.48	7.6
PMSC	58	37.8	22.8	1.66	1.66	0.01	0.6	0.44	1.78	7.4

CGTC	58	23.0	10.5	2.20	2.19	0.01	0.2	0.97	1.50	7.9

*TKN = Total Kjeldahl Nitrogen
** EC = Electrical Conductivity (dS/m = mmhos/cm)

Amendments were applied at rates designed to supply 45 lbs/acre of first year plant available N (PAN), which is the estimated annual N requirement of wildflowers. Tall fescue N needs are higher than wildflowers, but the same rates were applied to all plants to provide consistent compost rates. The equation used to estimate PAN from the various organic amendments was:

PAN = (X * Org-N) + (NH_4-N),
where:
PAN = lbs of plant available nitrogen per dry ton of amendment,
Org-N = lbs of organic nitrogen per dry ton of amendment, determined as TKN - NH_4-N,
NH_4-N = lbs of (ammonia + ammonium) nitrogen per dry ton of amendment, and
X = estimated availability coefficient for organic N (x=0.10 for compost).

Nutrient application rates were estimated based on the actual composition of the composts (Table 4). Phosphorus and K rates were variable because the N:P and N:K ratios in the composts were different. Wildflower P and K needs are not known, but establishment of tall fescue required 140 lbs P_2O_5/acre at both sites and 160 and 75 lbs K_2O/acre at Staunton and Culpeper, respectively.

Table 4. Applied plant available nutrients for the first year.

Treatment	Amendment Rate	Estimated Plant Available Nutrients (lbs/acre)		
		Total N	P_2O_5	K_2O
BC	3 tons/acre (fresh wt)	47	280	12
YWC	33 tons/acre (fresh wt)	44	292	164
PMSC	22 tons/acre (fresh wt)	45	352	134
CGTC	13 tons/acre (fresh wt)	34	69	175
15-30-15	300 lbs/acre	45	90	45
Control	Not amended			

The three species selected have different characteristics. Corn poppy is a biennial that is seeded each year in the fall, coreopsis is a perennial that often takes two years to become fully established, and tall fescue is a perennial grass that is most widely planted along Virginia roadsides. Corn poppy and fescue have higher N demands than coreopsis. Corn poppy and coreopsis were expected to be more sensitive to phytotoxicity produced by immature compost than fescue. Seeding rates were 20 lbs/acre of coreopsis, 18 lbs/acre of corn poppy, and 100 lbs/acre of tall fescue. The plots were rolled after seeding to increase seed-soil contact.

Weeds were controlled with periodic use of 2,4-D (1.4 gal/acre), imazapic (4 oz/acre), and pendimethalin (1 gal/acre). In June 1999, vegetation at both sites was mowed to eight inches to control weeds. At this time, the corn poppy had senesced, the tall fescue seed heads had fully expanded, and the coreopsis was not yet tall enough to be damaged by mowing. The corn poppy was replanted in early September 1999 after the plots were sprayed with glyphosate and imazapic and roto-tilled to three inches. The plots were again rolled after seeding.

The performance of the vegetation is being evaluated until at least spring, 2001 (2-1/2 years). A visual rating system that is frequently employed by turfgrass researchers is used each spring to measure living plant ground coverage density. Soil was sampled in each plot to a depth of 3-4 inches 18 months after soil amendments were applied (March 2000) for determination of pH; Bray 1 P; cation exchange capacity; exchangeable Ca, Mg, K, and acidity; and base saturation.

RESULTS AND DISCUSSION

Compost

There was considerable variation in the nitrogen concentration of the composts, with the biosolids compost (BC) containing about double the N concentration of the others (Table 3). The BC had a low C:N ratio and a high proportion (i.e., >20%) of N in the NH_4 form, indicating that the compost was not completely stabilized at the time of application. The BC also contained (not unexpectedly) a higher concentration of P and a lower of concentration of K than the other composts. The P and K concentrations in the yard waste (YWC) and cotton gin trash (CGTC) composts were typical for composts derived from such feedstocks (Brosius et al., 1998). The paper mill sludge compost (PMSC) also contained concentrations of P and K that were consistent with published values, but the total N concentration of the PMSC used in our study was considerably higher than typical values (Campbell et al., 1995; Jackson and Line, 1997). Our PMSC was produced from a combined primary and secondary sludge that had received additions of NH_4OH during the digestion process to stimulate microbial decomposition (Evanylo and Daniels, 1999). This resulted in a higher initial C:N ratio of the sludge (40:1) than is normally associated with paper mill sludge.

Corn poppy

Eight months after seeding (May 1999), the stand density of the corn poppy at Culpeper increased in the order: control#CGTC#YWC#BC=PMSC=Fertilizer (Figure 1). There were no treatment differences at Staunton at this time. There were no differences in corn poppy density with soil amendment treatments at either site by the following spring (March 2000), when ground coverage averaged 62% at Culpeper and 71% at Staunton.

Coreopsis

None of the amendments increased coreopsis density above the control at Culpeper or Staunton seven months after seeding (April 1999; Figure 2). Coreopsis density averaged 39% at Culpeper and 55% at Staunton. Coreopsis density was decreased by the BC at Culpeper 18 months after seeding (March

2000), but no differences in density among amendments were observed at Staunton, where density averaged 65% across all treatments.

Tall fescue

Only the application of the composted yard waste at Culpeper increased the density of tall fescue above the control at either site in April 1999 (Figure 3). None of the treatments increased tall

fescue density above the control at either site by March 2000, but tall fescue density in the CGTC treatment was lower than the control at Staunton.

Soil Properties

At both locations, the greatest increases in soil extractable P concentration were effected by yard waste and biosolids composts (Table 5, 6), which each supplied nearly 300 lbs P_2O_5 per acre (Table 4). Surprisingly, the paper mill sludge compost, which supplied the greatest amount of total P (352 lbs P_2O_5 per acre), did not raise soil P concentration above that of the control, fertilizer, or CGTC treatments. The P in the PMSC was apparently not readily extractable. Composts had little effect on soil pH, which were already adequate, but soil pH tended to be higher with the PMSC and YWC than with the control and/or fertilizer treatments at both locations (Table 5, 6). This was likely due to the higher base saturation and lower exchangeable acidity with PMSC and YWC than with the control and fertilizer treatments. PMSC increased the soil Ca% above the control and fertilizer treatment at both locations. At Culpeper, the YWC-amended soil also contained higher Ca% than the control and fertilizer-amended soil. No compost treatments increased K% or Mg% above the control or fertilizer treatments at either location. Only the YWC increased soil cation exchange capacity at either site. The lower C:N ratios of the BC and the CGTC than of the PMSC and YWC may have resulted in greater N mineralization and subsequent acid-creating nitrification in the BC and CGTC soils, which may have reduced the liming effectiveness of the organic matter in the BC and CGTC.

Table 5. Effects of amendments on properties of soil sampled at Culpeper in March 2000 and averaged across species. Means for all treatments followed by the same letter are not significantly different at the 5% level according to Student, Newman and Kuels test.

Treatment	P (ppm)	pH	CEC	% K	% Mg	% Ca	% EA	% Base saturation
BC	23.6b	6.0b	9.1b	5.9	16.2ab	63.0bc	14.8a	85.2b
YWC	34.0a	6.3a	11.5a	6.7	18.0a	65.6b	9.6b	90.4a
PMSC	13.8c	6.4a	9.9b	4.9	15.8b	71.2a	8.0b	91.9a
CGTC	14.5c	6.1b	9.3b	6.9	18.2a	61.0c	13.8a	86.1b
Fertilizer	15.6c	6.0b	9.0b	6.1	16.9ab	61.4c	15.4a	84.5b
Control	11.4c	6.0b	9.1b	5.8	17.1ab	62.0c	14.5a	85.2b

Table 6. Effects of amendments on properties of soil sampled at Staunton in March 2000 and averaged across species. Means for all treatments followed by the same letter are not significantly different at the 5% level according to Student, Newman and Kuels test.

Treatment	P (ppm)	pH	CEC	% K	% Mg	% Ca	% H	% Base Saturation
BC	40.2ab	6.1ab	9.7b	1.8	14.8	70.4b	12.9ab	87.1
YWC	46.0a	6.3ab	11.5a	5.4	16.1	70.0b	11.2ab	91.6
PMSC	21.8c	6.4a	9.9b	1.8	14.4	75.1a	8.7b	91.3
CGTC	27.1bc	6.1ab	9.5b	2.7	15.2	68.9b	13.0ab	86.9
Fertilizer	27.8bc	6.1b	8.7b	2.6	14.	67.9b	14.6a	85.4
Control	21.1c	6.2ab	9.3b	1.9	15.4	70.4b	12.3ab	87.7

CONCLUSIONS

Compost is valuable for restoring productivity of disturbed soils because it improves nutrient availability, water-holding capacity, and soil structure. Plant density data obtained during the initial 1-1/2 years of this study was affected by drought, which may have masked specific effects of the various composts. Each plant species performed poorly with the CGTC relative to other compost treatments at some location and sampling time. The most noticeable difference in chemical composition between the CGTC and other composts was the lower rate of P supplied. Conversely, the YWC always resulted in plant densities that were among the best at each location and time of sampling. Composts are created by similar biological processes, but the characteristics of each will be greatly dependent on the feedstocks employed and the degree to which the finished material is allowed to mature. The concept of matching compost type to individual plant species should be considered further.

ACKNOWLEDGEMENTS

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Figure 1 - Corn Poppy Density in Culpeper and Staunton

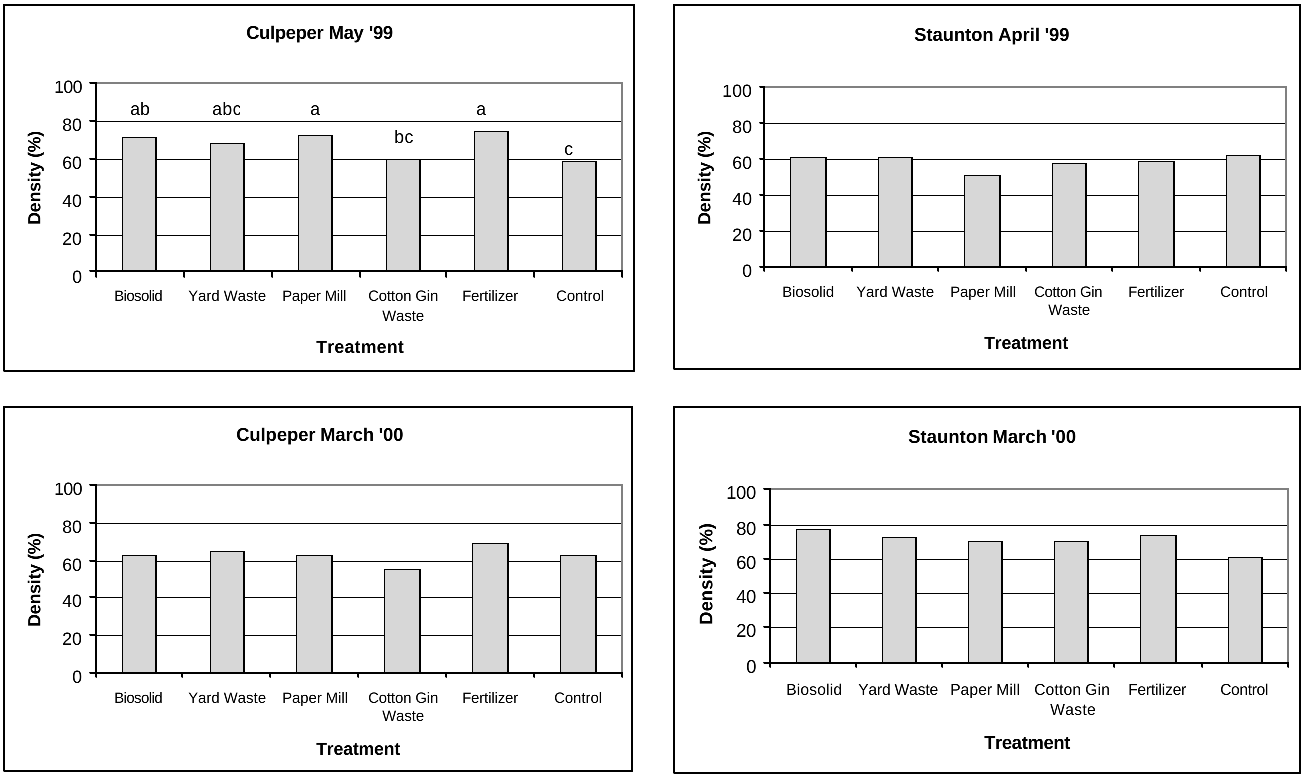


Figure 2. Coreposis Density in Culpeper and Staunton

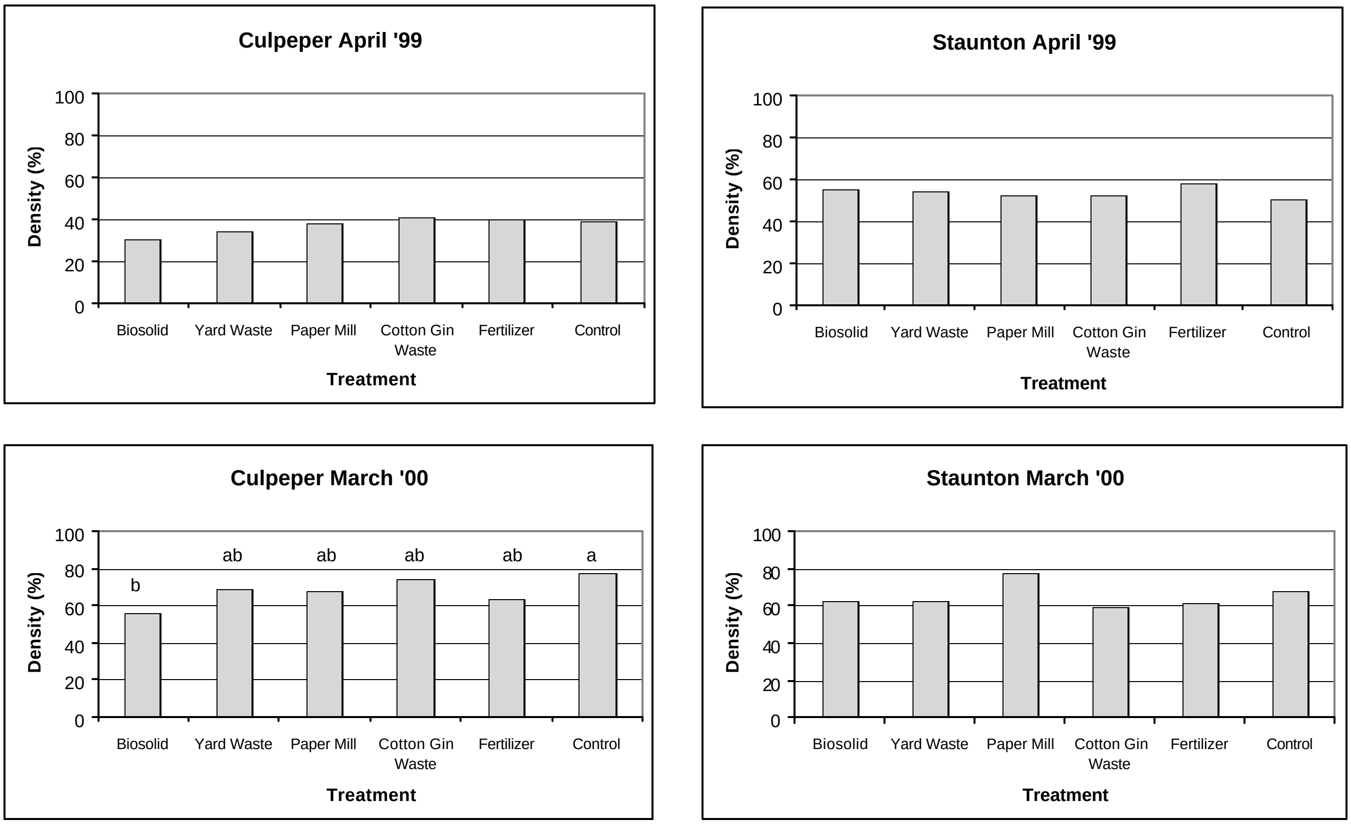
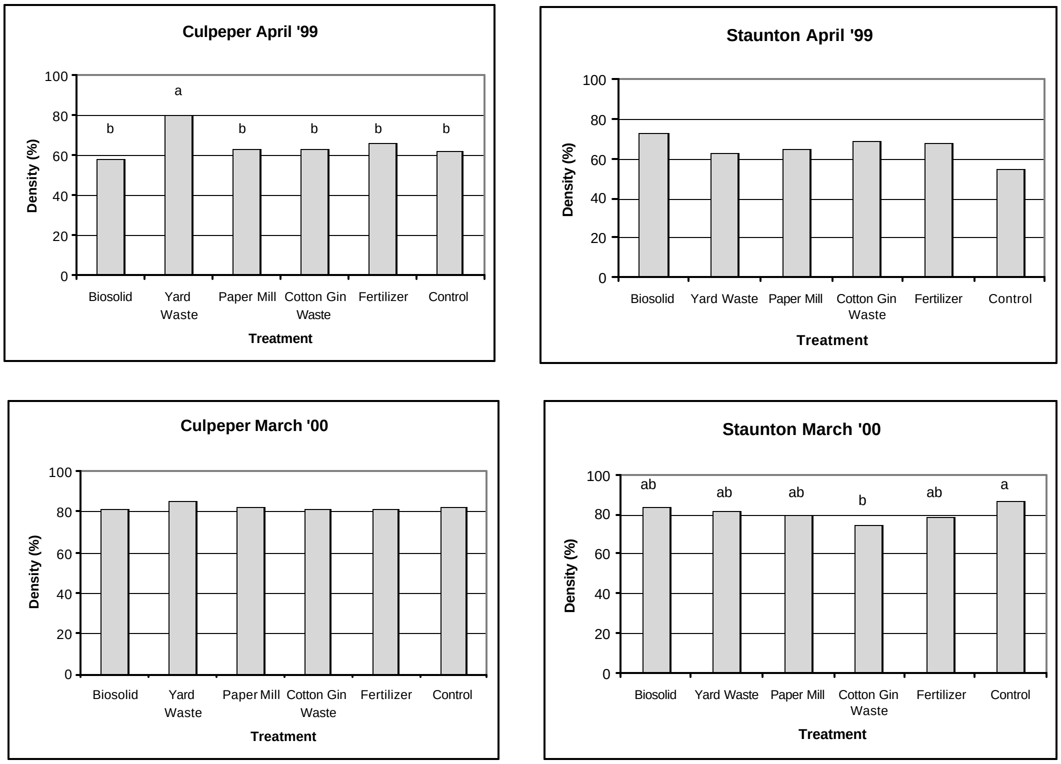


Figure 3. Tall Fescue Density in Culpeper and Staunton



Erosion Control and Environmental Uses For Compost

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INTRODUCTION

For the last ten years, the use of compost in environmental applications and markets has been increasing at a steady rate. Although environmental uses for compost appear to be an absolutely huge market, there are limited numbers of successful programs that have tapped this great market potential. Still, it is clear that with the invention of pneumatic application equipment, i.e., 'blower trucks', the future use of compost in some of these environmental applications will only increase.

Environmental applications include slope stabilization and erosion control, stormwater filtration, vegetation establishment, and replacement of silt fence with compost filter berms. Filter berms will be the focus of this paper, however we want to briefly point out the advantages of using compost in these other applications.

SLOPE STABILIZATION

In many slope situations, there is no real need to establish vegetation if a layer of mulch is effective in preventing erosion. But how long will the compost or composted mulch last? Will annual applications be required? The norm is to try and establish vegetation, regardless of the severity of the slope. As a result, using compost for slope stabilization and erosion control has met some barriers in the field in that it may not be readily accepted unless seeding is performed on top of the compost layer.

Using both seed and compost applications may or may not be more cost effective than current practices. Certainly, in severe cases where vegetation has not been able to established, compost may be the ONLY option left to try. In these cases, the state, county or local governing body will gladly try anything to keep from repairing the drastically eroding slope every single year. Our experience has shown the local officials will be glad to try any newfangled erosion control materials on their worst possible sites. This truly offers the composting industry a unique chance to quickly show how effective erosion control is with compost. In fact, our marketing motto for erosion control products has now become… "Give us your worst nightmare".

STORMWATER FILTRATION

Stormwater filtration is a relatively new use for compost. Although only a few commercial systems exist, the promise of using compost in filter systems lies in the effectiveness of capture rates compost offers compared to other filter systems. The added benefit is that compost can normally be purchased locally, is annually renewable, and there are good long term odds that this use will also become more mainstream in the next

10 years. This will be further enhanced by recent focuses on water quality and quantity issues in most of our growing communities.

VEGETATION ESTABLISHMENT

For vegetation establishment, compost is perhaps the number one soil amendment when used for turf. For other vegetation establishment, hydroseeding is still king. However, recent comparisons of costs for hydroseeding vs. vegetation establishment with compost and seed applied via a blower truck have proven favorable. In fact, if this combination proves to be as successful in the field as on paper, it will eventually replace part of the hydroseeding market. After all, what would you rather have – a hydroseeded lawn or a lawn seeded with ¼" of compost? For other environmental applications, like the slopes mentioned earlier, seeding is even more tedious than turf, so the likelihood of compost use increasing in these applications is nearly 100%.

FILTER BERMS REPLACE SILT FENCES

Silt fence has been used for erosion control on slopes and around the edges of construction sites for years. It is obviously the accepted standard. (By the way, who invented this stuff and is she now retired in a warm ocean climate somewhere?) Silt fence is used on nearly 100% of construction projects in the US, but there are some inherent problems with it's use. First, it just does not work as well as we originally thought it did. In fact, most officials at the state level will agree that it really does not work at all. Yet it continues to be used and is considered the standard for our environmental containment of silt and sediment.

Silt fence, by the way, is also a product made from petroleum resources, is hard to install properly, and is quite often left abandoned on job sites. Further, it prevents natural migration of aquatic animals like turtles and salamanders from area to area as they are disturbed during the construction process. In developing communities that are sensitive to endangered species or aquatic life, this has recently become a bigger issue of concern. Last but not least, silt fence, if it is picked up after construction is completed, needs to be properly disposed of in a landfill. What a waste.

HISTORICAL PERSPECTIVE

Compost, when properly installed in long filter berms, actually works better than silt fence in the function both were intended to perform: Keep both suspended and settlable solids out of our water sources when moving on the surface. Perhaps a historical review may help at this point.

In 1993, Bill Stewart conducted research which showed surprising results in a number of erosion applications on a local roadway that had extremely steep slopes. The research (regarded as one of the first major sources of info on this topic) also showed how ineffective silt fence was. In 1994, the Maine Waste Management Agency tested compost in Kennebec County to determine if the results were predictable. This followed with Clyde Walton from Maine DOT to be one of the first to specify compost filter berms on DOT projects in 1996. In 1997, USEPA recognized the use of compost for erosion control and specifically the use of filter berms as important methods to reduce environmental problems associated with erosion. CalTrans has been working on many projects for the last ten years and now has a very progressive program.

So why are we still using silt fence? Until the advent of the blower trucks, accessibility and efficient application of compost or composted mulch was hard to achieve. Manual application on 2:1 slopes would be nearly impossible. Application of filter berms around construction sites would require a bobcat, loader or other equipment and would simply be less efficient. However, the blower trucks are now becoming popular in nearly every major city in the US and with them comes the possible services relating to efficient applications of organic materials.

Reasons to use filter berms:

The compost amends native soil, assisting in vegetation establishment
The berms can be easily be incorporated into native soil when the job is completed, which means less hassles at the end of long projects
Incorporated material left on site provides better organic matter levels for seeding/planting
Filter berms are less expensive than silt fence
Filter berms are more effective in removing sediment and clearing up our waterways
Filter berms are more effective at removing chemical compounds from runoff
Compost is an annually renewable resource, all organic, and 100% natural

Reasons NOT to use silt fence:

Silt fence is ineffective in removing sediment and chemicals from runoff
Silt fence is hard to keep up during construction projects
Silt fence is often left on site after construction and is unsightly
Silt fence is a non-recycled material and needs to be landfilled
Silt fence allows a certain level of environmental damage on every project it is used on

How Organic Materials prevent erosion

What is so special about compost or composted mulch that allows it to perform the filtering function? Most experts in the field have noted they are surprised that filter berms hold up under heavy rains. When filter berms are used in combination with slope protection via a layer of compost or composted mulch, you can expect minimal erosion.

Filter berm at the top of a slope with compost

There are two main reasons these two applications assist in reducing erosion. First, filter berms reduce the speed of water flowing on a given slope. By preventing speed of water, which reduces also the speed of soil particles tumbling down the slope, overall displacement of other soil particles is reduced. Many applications have tried a series of filter berms down the slope which has worked well to slow the water down long enough to reduce erosion of the slope.

A layer of compost or composted mulch applied to the slope acts like a 'wet blanket' or a 'wet deck of cards' scattered randomly over the surface. Remember, soil particles are normally round and roll easily once displaced by water. As they gain speed and momentum, they displace other soil particles which channel together in faster moving water and this creates small rills. Rills lead to channels and channels lead to gullies. The rounder the soil, steeper the slope and greater quantity of water, the more erosion.

Compost and composted mulch prevents the soil from rolling or gaining this momentum and therefore covers it like a blanket. A secret of success in the field is making sure that water is not able to 'get under the blanket' at the top of the slope. If water is allowed to get under the layer of compost, and if the slope is steep, you can expect erosion and the compost or composted mulch will float away. However, if you have a filter berm at the

top of the slope and keep the compost layer continuous over the 'shoulder' of the slope, the water will hit the slope and ride all the way to the bottom on top of the blanket of organic materials.

Organic materials are more flexible, lighter, and absorb more water than soils in general, so they also aid in helping water infiltrate into the soil underneath. For vegetation establishment, this is crucial to new seedling germination.

ECONOMICS

All the experts reviewing Bill Stewart's research have had the same comments. What about the cost? Until a mechanism of delivery was possible and predictably available via blower trucks, the use of compost and composted mulch for filter berms has been limited. Depending on the charge for installation and the cost of local compost or composted mulch products, filter berms can be significantly less expensive than silt fence. In other words, cost is not a real barrier to the use of filter berms.

In a study conducted in South Carolina with one of the very largest builders, we determined that silt fence would cost about $1.50 per linear foot of installed silt fence. This cost did not include the cost to remove the silt fence and disposal costs. However, it appears that many people in the field ignore these costs or simply consider the costs of retrieving silt fence as zero. When comparing the installation of a 1 foot high by 2 foot wide filter berm of compost, we found we could be very cost competitive (see cost spreadsheet at the end of this paper).

It is important to note that the costs we experienced in the project in South Carolina were perhaps the lowest we have found in the country. In general, the larger the contractor, the better price they have for silt fence installation. In other meetings with smaller contractors, we discovered that they were paying up to $4.50 per linear foot of silt fence, with an earmarked $2.00 per linear foot included for the removal and disposal of used silt fence.

In many markets, the cost of application matches the cost of the product. For instance, a $16 per cubic yard compost would cost $16 per yard for application. Many blower truck operators simply double costs of materials to arrive at an installed cost for organic materials. This is a good rule of thumb to use and when calculating the amount of compost or composted mulch required, we determined that one cubic yard will provide 20 linear feet of filter berm 1 foot high and 2 feet wide. This sized berm is adequate for the majority of silt fence replacements, which are actually demarcations of the work zone itself. Much of the silt fence installation, when performed on flat ground, is simply to show the perimeter of the active work zone.

Remember that on state jobs, where silt fences are used, that the monies to pay for installation and removal has to come from some tax base or government fund. It stands to reason for all of these agencies to band together and support compost use for filter berms because it can save the state money and it will most likely be a locally produced product. In every single case study we have done, the officials at the state level agreed that silt fence did not work to achieve the runoff and erosion reduction goals. Also, they pointed out that silt fence is not actually specified n many projects. Rather, the contractor has to submit an erosion control plan or water discharge plan that calls for some recognized method to reduce erosion.

Silt fence, because it is so common, is the leading tool used to respond. In other words, if local contractors put compost filter berms into their plan, the local officials would have to determine if this tool would be acceptable. Several agents confessed they could not shut a project down if we submitted filter berms as the chosen method, but if it failed, we would be forced to utilize another method.

Real world benefits of using filter berms are during projects that are very dynamic. A day in the life of field construction is unpredictable and often times weather plays a spoiling role in the best laid plans of good contractors. When berms are disturbed at the top of slopes, as is shown in the photo below, we violate the cardinal rule not to let water under the berm or compost blanket. Without repair, erosion will set in and gullies will form. However, the new option with compost filter berms and blower trucks is to provide a 'Band-Aid' to these real world un-preventable construction scars. Trucks can quickly and efficiently return to sites and cover initial erosion that starts as a result of late completion of guard rail installation or other surface disturbances. This makes local officials very comfortable with the use of compost because it allows a faster remedy than waiting until the slope is eroded, getting a dozer to level it back out and reseeding. Remember, those are your tax dollars on state projects!

FIELD REPORTS

Two field projects have been completed recently which focus on the principle objectives outlined earlier: reducing erosion on slopes using compost blankets and replacement of filter berms using filter berms.

Richmond, Virginia

A project was coordinated in Richmond with the Virginia Department of Transportation to determine the effectiveness of compost for mulch and as filter berms. Due to the nature of the slopes, we did not gather much data on filter berms. The berms installed at the top of the slope were eliminated during the final phase of the project, which allowed us to examine the use of compost for repair in these types of situations. The 'construction scar' shown below is indicative of real life projects that have soil disturbances during their final phase and this can cause significant disturbance to the berm or allow water to get under the compost blanket. The photo on the right shows the 'Band-Aid' we used to fix the problem. This is clearly a low cost method compared to other options.

Construction Scar

Band-Aid for construction scar

Four other compost materials were used in two different applications (2" and 4" application depths). The slope was covered with these composts and eight treatment areas resulted. All of the composts were applied with a blower truck which allowed even, efficient application. One of the benefits we discovered by using a blower truck was that there is ample hose (500 ft) to reach most areas needing application. The materials used were a 2" minus compost, a ½" minus product, leaf compost ½" minus and recycled 'overs', a product common after screening ½" minus products. The overs were rather punky and a little on the larger side, but seemed to work adequately in the blower trucks.

The treatment areas ran the entire length of the slope for all eight treatments. We used the other side of the road, which had matching slope and soil type, as the control. The photos below show the erosion associated with the control area. This area had been a problem in the past for VDOT, so the project served a good purpose in showing how compost can impact even the worst erosion situations.

Treated slopes with compost

Untreated controls

The results of the project were similar for all four treatment areas – there was minimal erosion on all of the slopes except where the berms had been disturbed late into the process, allowing water to get under the mulch layer. Besides these areas, there was no noticeable erosion of soil from anywhere on any of the applications. Since we repaired the damaged areas with our 'Band-Aid' application, erosion has been minimal or non-existent.

The VDOT offices were tremendously cooperative in this effort and it is important for readers to understand that these projects take a lot of time and energy and a commitment from both parties to see it through to the final phase. VDOT has since hydroseeded the areas in an effort to understand how the treatment areas would respond. VDOT has concluded that there may be combinations of compost, filter berms and hydroseeding for the toughest erosion projects.

The final determination for the four materials used on the slopes was that the 2" application rates provided enough protection for the slopes to reduce erosion to acceptable levels. Obviously, a 4" application offers for protection, but there is concern that the costs for these materials and their application would be too high. The 2" application rates, however, are cost competitive with the repair costs experienced on these severe slopes and problem areas.

Sun City, South Carolina

DelWebb, a large developer in Sun City, South Carolina, ran several tests using compost for erosion control and filter berm replacement. This project provided much of the data and field results that we missed in the VDOT trial - mainly information about filter berms and the replacement of silt fences.

As a large developer, DelWebb is faced with constant environmental concerns. In the current project, they build up to 500 houses per year, with a total of 6,000 houses targeted in the local area. This requires a large disturbance on local soils, like any construction project. The state requires silt fence be properly installed around each new construction phase. DelWebb became interested in compost because of their environmental concern and their desire to use recycled products, where possible. DelWebb also has a strong commitment to local environmental issues, as well as being good stewards of the land as they develop large areas.

The photos below show the application of filter berms to replace silt fence on DelWebb property. We used the one foot high by two foot wide berm and they seemed to hold up well in most areas. In a few cases, where the berm became damaged from traffic or equipment, we simply asked DelWebb to fix the berm by adding a small amount of compost with a bobcat. This allows minimal maintenance to be performed with equipment normally already on most construction sites.

The final analysis of the filter berms at DelWebb is that they work well enough to consider using in all future construction. The company is currently analyzing costs and has asked to move to the next stage, which will be to use filter berms for an entire new development phase, or neighborhood. As these filter berms are placed, it will be an excellent test to determine how the berms hold up through an entire project rather than just for a couple of months. It is obvious that if the filter berms are more cost effective and perform better than silt fence that they will eventually be adopted as the norm for all construction projects with large developers like DelWebb.

ISSUES FOR THE FUTURE

We need to be conscious of the possible damage to the environment that our accepted practices are now causing. Is the use of silt fence causing more harm than good? Since we never have calculated the amount of materials which escape silt fence, there is a good chance that the amount of environmental damages are larger than we originally thought. We should be conscious of this as we support the new uses of compost and composted mulch in the applications outlined above.

Training and education is certainly a huge need in every state. Even though many states have reportedly worked with some type of compost, all of the state agents we worked with were hungry for information and eager to learn. All of them agreed to field trials during the first meeting, mostly out of frustrations with silt fence failures. As an industry, we need to develop easy to access data, project reviews, specifications, and architect drawings of filter berms and compost applications which satisfy our environmental goals.

In states which have annual printing of spec books for DOT or other agencies, compost use needs to be automatically included with the appropriate drawings. The US

Composting Council already has a good set of specifications to use for erosion control and due to the amount of requests, our offices recently developed CAD drawings to accompany a modified set of specs we make available to all interested parties. This information needs to be at every state office which can use these products.

Finally, nothing substitutes for field projects demonstrating the value of what has been discussed above. The three projects we coordinated helped us learn first hand about the issues, roadblocks and politics that are present in every single project you encounter. We would like to thank those involved for accepting our challenges to use compost and allowing us to demonstrate what others have found to be true. Compost is a versatile, useful product which reduces erosion when used as a filter berm or erosion control blanket.

There are several case studies that have been conducted including Texas, California, Ohio, and other states which have shown that compost has outperformed hydromulch and has reduced erosion by other standard methods used. It is clear we are just at the tip of the iceberg for market development in this area.

Tyler, King and Stinson are founders of Matrixx Organics Company, based in Richmond, VA. Specifications and drawings for filter berms can be obtained via email at rodndon@gte.net.

EPI - Grind-All SE			Del Webb Project				4/5/2000
Cost comparisons of various soil and mulch applications in the Landscape							
Application	Product cost/ft	Product cost/A	Installation cost/ft	Installation cost/A	Total cost/ft	Total cost/A	Comments
Sodding	$ 0.16	$ 6,970	$ 0.10	$ 4,356	$ 0.26	$ 11,326	Sod may not take first time
(per square foot)							
Compost & Seed Application		$ 3,200		$ 4,000		$ 7,600	$400 per acre for good seed
Features	One inch application with seed will smooth over rough spots, reduce final grading required.						
Benefits	Less prep costs, more control over window of time needed to complete job, lower costs						
(1.5 inches compost applied is $16.00/c.y. for material and $20.00/c.y. for installation = $36/c.y.total seed cost figured at $400/acre)							
				Total Savings per Acre:		$ 3,726	
Installation of Silt Fence	$ 0.60	n/a	$ 0.90	n/a	$ 1.50	n/a	Does not work - ineffective
(per linear foot of installation)							
Filter Berm Application (flats)	$ 0.80		$ 1.00		$ 1.80		
($16/yd product + $20/yd install at 20 linear ft. per cubic yard)							
Filter Berm Application (slopes)	$ 2.37		$ 2.96		$ 5.33		
($16/yd product + $20/yd install at 6.75 linear ft. per cubic yard)							
Features	Aquatic animals able to effectively navigate over berms, no cleanup needed, recycled product, living filter						
Benefits	Preservation of local environment, less cost, more aesthetically appealing, more effective at removing sediment						
				Total Savings per Year:			(need total ft. of silt fence)
Slope Stabilization/Naturalization							
($16 per yard for product and $20 for installation)							
Mulch applications - seed extra	$ 0.10	$ 4,320	$ 0.12	$ 5,400	$ 0.22	$ 9,720	
(2" application)							
Features	Not necessary to seed slopes, soil stays in place, less repair required, aesthetically appealing						
Benefits	Lower overall land mgt. Cost, more environmentally appealing, less erosion of valuable soil						
Installation of Landscape mulch	$ 15.00		$ 25.00		$ 40.00	(all mulch costs per cubic yard)	
(per cubic yard - manual application)							
Custom Mulch Application	$ 15.00		$ 20.00		$ 35.00		
Features	More even application, use 25% less materials, utilize less labor during peak times						
Benefits	More aesthetically appealing, employees do other tasks, less expensive overall						

EFFECTS OF COMPOSTED ORGANIC MATERIALS ON THE GROWTH FACTORS FOR HARDWOOD AND SOFTWOOD TREE SEEDLINGS

Joseph D. Bonnette, Cheogh Ranger District, Robbinsville, N.C.
Dr. Rosalie Green, NCBA Grant Participant with USEPA
Terry Grist, Office of Solid Waste, USEPA

INTRODUCTION

This project was a demonstration of the effects of compost on the growth of hardwood and softwood tree seedlings. There is intense interest in identifying cost-effective means to improve the revegetation of severely disturbed sites. The standard method of revegetating these types of sites generally involves seeding and/or planting, fertilizing, and mulching. For erosion control and revegetation, grass seed, pine seedlings, chemical fertilizers, straw and machine-blown pulp mulches are commonly used.

This report was a cooperative effort by the U.S. Forest Service, U.S. Department of Interior Bureau of Indian Affairs' Cherokee Forest Branch and the Office of Solid Waste, Environmental Protection Agency (EPA). Two mountainous sites were used on the Cheogh Ranger District of the Nantahala National Forest and one in the adjoining Qualla Cherokee Reservation in western North Carolina with permission of the Cherokee Tribal Council. This effort was funded under Interagency Agreement No. DW12936577-01-0.

STUDY DESIGN

This study tested the hypothesis that the use of composted products from organic materials has practical uses in forestry related applications and has the potential to improve the growth of tree seedlings in severely degraded soils. During December 1994, a group of tests were initiated on three damaged (i.e. compacted or severely eroded) sites to compare a standard straw mulch to three different composts used as mulches (i.e. biosolids, yard, and municipal solid waste). Although pines have been developed for consistent characteristics, both softwood and hardwood seedlings were used to provide a greater variety of tree seedling responses. White pine, chestnut oak and Chinese chestnut seedlings were planted. The conifer seedlings were 8-10 inches high and the hardwood seedlings (both oak and chestnut) were 24-30 inches high in 1994. Seedling growth and response of natural vegetation were monitored from December 1994 to the summer of 1998. Comparisons of ground cover, soil erosion, growth and survival data, and soil nutrient values showed distinct differences in the four treatments.

Mulch materials were generally applied two-inches thick. Yard compost was shredded leaves, grass, tree trimmings, etc. donated from Compost Central of Charlotte, N.C. The commercial cost in 1994 was $10/cubic yard. Biosolids compost was wastewater sludge donated from the City of Lexington, N.C. The commercial cost in 1994 was $21/cubic yard. Municipal solid waste (MSW) was mixed municipal solid waste donated from Bedminster Corporation of Sevierville, Tenn. The commercial cost in 1994 was $10/ton or $5/cubic yard. Straw was standard baled straw from Robbinsville, N.C. with a cost $4/bale, which equates roughly to $12/cubic yard.

DESCRIPTION OF TEST PLOTS

Cheogh Clearcut Site #1: A yellow pine/upland hardwood site had been clearcut by the sale to a commercial timber company. All residual vegetation was cut near ground level with chainsaws following the logging. The logging slash and debris were pushed off the test site with a bulldozer. Most of the topsoil and some of the organic duff (i.e. partially decomposed twigs, leaves, etc.) were retained. The ridgetop site had eight test plots 12 feet wide by 32 feet long on the southeast face, and eight identical plots on the northwest face. The 50 Year Site Index (i.e. the average height growth of trees in 50 years of a site) was 75 feet for shortleaf pine and 68 feet for upland oaks. Slopes averaged 30-35%. Soil samples were taken at 4-5 inches depth prior to the test applications for nutrient assessment. All four mulching materials were used as a 2-inch mulch on the sixteen test plots. Thirty white pine seedlings were planted in four tests with different mulches on each site of the ridge making a total of eight plots. Each of the 480 hardwood seedlings were planted in holes approximately 6 inches in diameter and 12 inches deep made by a hand-held power auger. Each tree was marked with a color-coded wire flag (Figure 1).

Cheogh Landing Site #2: The second test site was a log landing devoid of all topsoil and the remaining soil compacted by the trucks and tractors used in previous log harvesting. Site #2 was located on top of a ridge about a mile north of Ridge #1 and was surrounded by a yellow pine/upland hardwood stand on an old road where logs had been loaded on trucks (Figure 2). On all eight plots, two inches of mulching materials were turned into the hard-packed soil by use of a disk harrow pulled by a farm tractor. Additionally, on four test plots, a 2-inch surface mulch was applied. Chinese chestnut seedlings were planted into 12-inch holes made by a 6-inch gas-powered auger bit in each of the eight 30 tree seedling test plots. Each of the 240 seedlings were marked with a color-coded wire flag.

Cherokee Old Field Site #3: The third test site was located within the Cherokee Reservation on a rocky north slope that had a marked loss of topsoil. At the bottom of the slope was s small stream. In an old field cleared of brush, Chinese chestnut seedlings were planted into 12-inch holes made by a 6-inch gas-powered auger bit. The four test materials were added as a 2-inch layer to each test plot and turned into the soil with a disk harrow pulled by a farm tractor. An additional 2-inch layer of mulch was added to each of the plots. More intensive data was

collected on Sites #1 and #2 because Site #3 was compromised when a third 2-inch layer of MSW compost was inadvertently spread over the entire test sites including the control site. Although Site #3 could not be used for valid statistical comparisons, it was quite impressive to observe the average of about 3 feet of growth per year in those seedlings that received both turned-under and surface-applied compost, about 3-inches total around each tree.

FINDINGS

Tree Growth – Site #1 and Site #2: White pine: Height and diameter values after three years for all of the composted materials were significantly higher than the values for straw, with the highest in the yard compost. Chestnut oak: Height and diameter after three years were significantly higher in all of the compost plots compared to the straw plots (Figure 3) with the highest in the MSW compost. Chinese chestnut: At the log landing, similar to chestnut oak, the height and diameter of the Chinese chestnut tree seedlings were significantly greater in the MSW compost (Figure 4).

Survival – Site #1 and Site #2: The survival rates after three years of growth exhibited certain mixed results. There was a good survival rate for tree seedlings after planting, regardless of treatment. Among white pine seedlings, the 3 types of compost-treated plots averaged 93% survival and the straw-treated plots averaged 92%. All of the hardwood seedlings survived the first year very well but declined rapidly in the second and third years. However, this survival pattern is typical of most hardwood species. The survival rates of hardwoods among the composts averaged 69% and the survival rate in the straw plots were 77%. The survival rates of the Chinese chestnut seedlings were impeded by chestnut blight infection and the damage due to a tree-fall across the yard compost plots. Even with the disease and physical damage, the survival in the straw plots and in the compost plots both averaged 63%. Among the three composts, the highest rate of Chinese chestnut survival was 75% in the biosolids compost plots and the lowest was in the yard compost plots due to damage by the wind-thrown tree. Before the storm damage, the straw plots showed the lowest survival.

Herbaceous Ground Cover – Site #1 and Site #2: Herbaceous volunteer cover was estimated by the percent of ground surface area covered for each plot six months after the initial planting. The average cover for each type of mulch was: biosolids compost at 95%, yard compost at 80%, MSW compost at 60%, straw at 50% and an untreated control on Site #1 at 45%. The natural vegetation by herbaceous plants on the biosolids compost was remarkable in the first growing season with many plants well over five feet in height. The negative height growth of tree seedlings in the biosolids plot in Site #1 measured after the first growing season could have been due to that dense herbaceous cover shading the seedlings (Figure 5). In all of the composted plots, the vegetation showed a deeper green color with few yellow hues compared to the straw plots (Figures 6 and 7). There was no visible soil erosion in any of the compost or straw plots

during the first year after planting. However, erosion was apparent during the first year in the untreated areas. In the second and third years, similar trends were noted except that the erosion was visible in the straw plots as well as the untreated areas. None of the three compost plots showed any signs of erosion over the three years of observation. Serially dated photographs of each test site showed heavier vegetation cover on all of the compost sites compared to the straw plots.

Soil Nutrient Values – Site #1 and Site #2: Soil samples were again taken from the center of each of the 24 treated plots in November 1996, nearly two years after the tests were initiated. Control samples were taken at Sites #1 and #2 from an adjacent area within 12 feet of the test plots that were site-prepared, but not treated with compost or straw. Organic component (Hm %): The soil organic component (mean values) in the straw treated plots was 63% greater than the untreated control but the compost-treated plots were 140% greater than the untreated control. In Site #1, the MSW compost showed the highest values, and in Site #2 the yard compost showed the highest values. However, in damaged mountain ridges, variations in soils could occur within the 1200-square-foot test area.

Soil pH: For the control samples, the mean soil pH was 4.65; for the straw plots the mean pH was 4.75; and for the composts, the mean soil pH was 5.1. The greatest gains in soil pH were in Site #2 where the compost was plowed into the soil and additional compost was surface-applied. On Site #2, the straw plot pH was 4.9; the untreated control was 4.7; and the composts averaged a pH of 5.5. A soil pH of 5.5 is considered to be minimum desirable level for growing hardwood trees on these areas, indicating that soil pH was borderline for compost-treated chestnut oak and Chinese chestnut in these mountainous soils.

Soil nutrient values: Phosphorus (P) was not detectable in any of the control samples or in any of the samples taken from the straw-treated plots. The P mean values for all of the compost -treated plots was 23.1, and the highest levels in this group were in the biosolids compost-treated plots. The potassium (K) and calcium(Ca) values for the control and straw samples were virtually the same for all areas and the mean values for the compost-treated plots were approximately twice as high as the control or straw plots. The secondary and micro-nutrient values for magnesium (Mg), manganese (Mn), zinc (Zn), and copper (Cu) were significantly higher in the compost-treated plots. The greatest difference of all the nutrients was in the Zn values where the compost samples showed more than nine times the values of the control and straw plots. It is important to note that the levels of most of the nutrients found in all soil samples were described by the soil scientists as below the desirable levels for nursery and field tree crops. The low P values were labeled as the most critical. None of the nutrient values in any of the plots were raised to the highest acceptable values (see Table 1).

TABLE 1. THE NUTRIENT VALUES OF SOIL*

Value	**Straw**	**Compost**	**Control**
Hm (organics)	0.44	0.65	0.27
pH	4.75	5.1	4.65
P-1	0	23.1	0
K-1	33.0	64.4	29.0
Ca %	12.8	37.7	13.0
Mg %	6.2	10.4	6.0
Mn-1	84.0	90.4	53.5
Zn-1	20.2	182.7	21.0
Cu-1	40.1	100.5	32.0
S-1	146.2	141.1	169.5

* North Carolina Agronomic Division reported as standardized index or percentage of the cation exchange capacity (CEC).

Cherokee Site #3: Each of these plots inadvertently received additional MSW compost over most of the area plots after a severe storm washed the original 2-inch layer of compost downhill in a few areas. The wash-down may have been attributable to the fact that the compost was newly applied and had been screened to 1/4-inch or less rather than the conventional ½-3/4-inch screening size. Although the additional unplanned MSW mulching eliminated the Site #3 data from any valid data comparisons, the results were unexpectedly significant. The median height growth of all of the surviving seedlings after 22 months was 48.1 inches. The average diameter of all the seedlings was 0.81 inches. The overall survival rate was over 76%. The growth in Site #3 was much greater than in the plot at Site #2 originally turned under and surface-mulched with yard compost (Figures 8 and 9). The average tree in the yard-compost plus MSW compost plot was slightly over 100 inches in height and was 0.89 inches in diameter; however, some measured over 180 inches in height and about 1.4 inches in diameter. The height growth across all of the compost test plots was slightly greater than the test plot originally treated with straw only. The straw test plot was accidentally "treated" with a 2-inch layer of MSW compost over the straw. These trees appeared to be sustaining their exceptional growth through the end of the third year, including an average height of 15 feet in the yard/MSW compost plot. In the biosolids test plot (Figure 10), herbaceous volunteer growth continued to be robust after three years, compared to

the control and straw-treated plots, which is consistent with the use of biosolids compost to establish permanent turf.

CONCLUSIONS

Natural vegetation and soil stabilization response were visibly superior in the compost-treated sites. Compost-treated test plots had much more visible natural vegetation response and clearly had no soil erosion and higher soil nutrient values in each of the following three-and-half years after treatment. During the first year after treatment, the biosolid compost plot showed the highest density of natural revegetation of grasses and leafy plants and provided the best protection against soil erosion. After almost four years, all of the compost treatments were shown to be revegetated to a much greater degree than the straw treatments. Soil erosion was non-detectable in all of the compost plots in Sites #1 and #2. Minor soil erosion was visible in the 2-inch straw-treated plots and vegetation recovery was slower and less dense. Soil nutrient values and pH had recovered far better in the compost-treated plots compared to the untreated control and straw-treated plots. The hardwood seedling tests showed mixed results between the four treatments early in the test period, but most of the compost plots resulted in better growth and higher survival rates throughout the three-year test period. All tree seedlings clearly grew larger in height and diameter in the compost plots than in the straw plots. Survival of pine seedlings was also greater in each of the composted plots than in the straw plots.

The results of this project after three-and-a-half years of monitoring show that compost mulching is consistently superior to straw mulching for revegetating severely disturbed sites. Furthermore, results of the combination of disked-under compost plus compost mulching showed both superior survival and growth potential of hardwood and softwood tree seedlings even in soil of borderline nutrient value. In this particular study, the height and diameter growth of white pine trees was greatest in plots treated with yard compost, while the height and diameter of chestnut oak and Chinese chestnut trees was greatest in plots treated with MSW compost. Forestry application benefits were: gained soil rehabilitation, growth of planted seedlings, natural revegetation and in the prevention of soil erosion.

RECOMMENDATIONS

The data produced by this three-year demonstration show that the application of mature compost contributed to a significant accelerated growth of hardwood and softwood tree seedlings when compared with straw and no treatment. The enhanced growth by all three composts could have positive economic implications for public and private tree growers, the lumber industry, the furniture and building construction industries, the biomass/utility/energy industries and the environmental entities dealing with clean air and global warming even though the initial costs of using compost may be greater than straw.

The reproducibility of this study, however, remains to be tested due to the nature of types of composts used in the study. First of all, the mature yard compost used was kept thermophilic (120-140 degrees) for about five months instead of the usual 3-8 days. This process is standard for the company making this compost and was used for the purpose of this study. In addition, the mature MSW compost used was made from mixed municipal solid waste from residential and commercial generators (i.e. compost made from municipal solid waste that has not had recyclables removed). This means that the MSW compost contained a greater diversity of organic materials such as food scraps, paper and other organics. These feedstocks are not usually found in combination in most commercial MSW composts currently being made. It is uncertain what beneficial effects, if any, these factors may have had on the quality and composition of the MSW compost. In addition, the composts used in ths study were analyzed by three laboratories for different compositional characteristics, making comparative analyses of results impractical.

In this study, all three composts (yard, MSW, and biosolids) had a 2% nitrogen (N) level which is more than twice that generally found in most commercial yard waste composts. We recommend that future demonstrations compare these composts to those more commonly found in the marketplace. Additionally, future studies should consider substituting a commercially-valuable hardwood, such as white oak, for the chestnut oak; and that a commercial variety of fruit or nut tree be substituted for the Chinese chestnut. All tree seedling planting and measurements should continue to be under the supervision of experienced forest service personnel. Compost analyses should be done by a single laboratory and that the laboratory meet the standards defined by the U.S. Composting Council.

Figures and color photographs can be seen on the U.S. EPA website: http://www.epa.gov/epaoswer/non-hw/compost/trees.pdf

COMPOSTING BIOSOLIDS IN VIRGINIA: CASE STUDIES OF THREE FACILITIES

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ABSTRACT

Composting of biosolids generated from wastewater treatment plants (WWTPs) has continued to increase over the past 16 years. There are approximately 280 biosolids composting facilities currently operating in the United States. The production of an "Exceptional Quality" (EQ) product as outlined in the United States Environmental Protection Agency (USEPA) Part 503 Regulations, system flexibility, and economics are key factors that have led to the continuous increase in the number of operating facilities. This paper will present information on three operating biosolids composting facilities in the Commonwealth of Virginia. The three facilities are the Town of Abingdon facility, the Harrisonburg-Rockingham Regional Sewer Authority (HRRSA) facility in Mt. Crawford, and the Rivanna Water and Sewer Authority (RWSA) in Charlottesville. For each facility, information such as facility design, equipment, capital cost, operating costs, operational experiences, and product marketing programs will be provided.

The Town of Abingdon had been disposing dewatered biosolids in a landfill. Based on a demonstration project and cost analysis, the Town decided to compost and produce an EQ, marketable product. The facility utilizes yard waste collected by the Town as a bulking agent, and composting occurs on an open pad adjacent to the WWTP. The facility composts approximately one dry ton of biosolids per day. The facility markets the finished compost under the name Wolf Creek.

The HRRSA facility was designed to compost 5.5 dry tons of 25 percent solids digested biosolids per day. The facility has been operating since January 1996 and currently composts approximately 2.5 dry tons of biosolids per day, with the remaining 3 dry tons utilized in a liquid land application program. The facility utilizes wood chips as a bulking agent. All materials

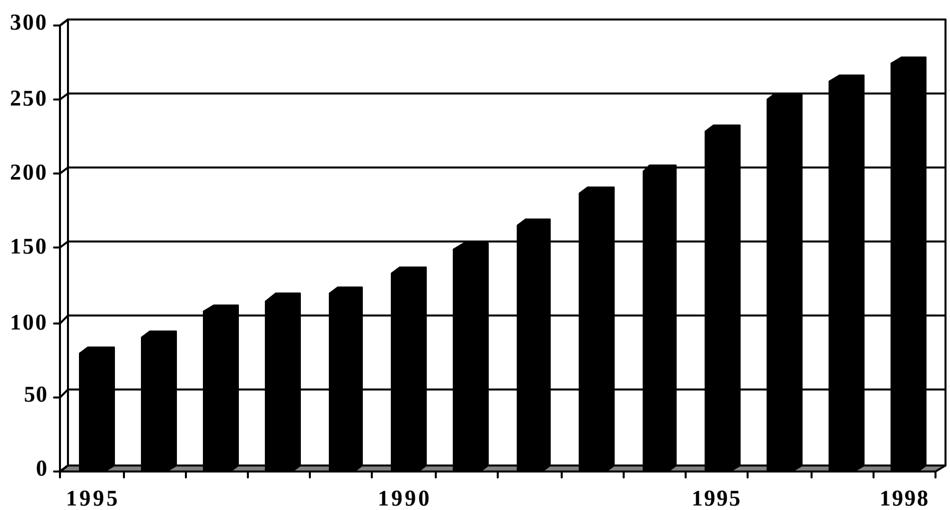
handling processes are conducted on a concrete pad, and curing occurs on asphalt pads. The materials handling, composting, and curing areas are covered. The compost is principally sold to local landscapers and the Virginia Department of Transportation for highway landscaping and wildflower production.

The RWSA facility currently composts approximately 7.7 dry tons of biosolids per day. The facility began operating in 1984 and consists of a covered asphalt composting area and mobile materials handling equipment. The facility utilizes wood chips and shredded pallets as a bulking agent. Based on a recent biosolids management study, RWSA decided to cease landfilling and divert all of the biosolids generated at the WWTP to the composting facility. As such, the facility is currently going through an expansion to 13.5 dry tons of biosolids per day. In the expansion, the composting area and the bulking agent storage area will be increased, and all materials handling will be conducted under cover. The finished compost is sold to local residents and landscapers.

INTRODUCTION

Composting of biosolids generated from WWTPs has continued to increase over the past 20 years. Figure 1 shows the growth of biosolids composting in the United States since 1985.

FIGURE 1
Number of Biosolids Composting Facilities
Operating in the United States



There are several factors that contributed to this continual growth:

- Federal Regulations – The USEPA encourages beneficial use and production of Class A, EQ products.
- Economics – Composting, after direct land application, is the most economical biosolids management option.
- System Flexibility – Numerous options in system design are available to suit local conditions.
- Product Marketability – The compost produced is widely marketed and accepted.

The growth of biosolids composting should continue and will probably increase as a result of public apprehension over land application of Class B biosolids. Currently, there are local land application bans in areas of California, Virginia, New Hampshire, and Maine.

Biosolids composting produces a Class A product, which has numerous applications in agriculture and horticulture. Income from the sale of the product has often significantly reduced operating costs.

This paper will describe three operating facilities in the Commonwealth of Virginia. The three facilities are the Town of Abingdon facility, the HRRSA facility in Mt. Crawford, and the RWSA facility in Charlottesville.

ABINGDON, VIRGINIA

The Town of Abingdon dewaters anaerobically digested biosolids using a centrifuge to a total solids content of between 16 and 21 percent. As part of a previous WWTP expansion, the facility included a 34,000 square foot asphalt pad for use as a composting area. Due to low tip fees, the Town determined that landfilling biosolids was more cost effective. With tip fees rising and the hauling distance to the nearest landfill increasing, along with a desire to beneficially reuse the biosolids, the Town began to investigate co-composting the biosolids with yard waste and wood waste. Based on their initial investigation, they decided to evaluate a full-scale composting facility. A composting demonstration project was initiated in October 1998. Based on the demonstration study, a conceptual design and economic analysis was conducted. This resulted in implementing the current facility.

Site and System Design

The site is located at the Town's WWTP. The overall site contains the composting area and the yard materials storage area. In addition, a finished compost storage building was located away from the activities of the WWTP. This allows for public access and sales. The composting area is paved and sloped so that run-off is drained and returned to the WWTP. The facility consists of the following elements:

- Three-sided concrete biosolids receiving bin
- Mixing area with batch mixer that discharges mix into two-sided concrete bunker
- Composting pad containing five 5-horsepower blower stations and control building (pad is designed for 28 calendar days of composting)
- Bulking agent storage area

- Screening area located between bulking agent storage area and mixer to minimize materials handling
- Covered aerated curing area with four blowers
- Finished compost storage area

Economics

The capital costs are shown in Table 1. An estimated cost for the composting pad that was previously constructed is approximately $156,000.

TABLE 1 – Capital Costs for the Abingdon Facility

Category	Cost
Curing Building	$60,000
Site Work	$0
Asphalt Pad	$0
Control Building	$2,500
Mixer	$40,000
Compost Blowers	[a]$1,500
Curing Blowers	$500
Miscellaneous Piping	$500
Mobile Equipment	
Front-end Loader	[b]$41,000
Screen	$135,000
Electrical Service	$0
Electrical Connections	$2,000
Temperature Probes & Misc. Equipment	$1,000
Subtotal	$284,000
Engineering, Start-up, Marketing Assistance	$30,000
Total	$314,000

[a]Three 5-horsepower blowers were already on the site.
[b]The front-end loader costs were shared with other public works activities.

Operating costs are shown in Table 2. These costs are based on 293 dry tons per year of 18 percent solids.

TABLE 2 – Operation and Maintenance (O&M) Costs for the Abingdon Facility

Category	Cost
Labor[a]	$0
Maintenance[b]	$9,100
Fuel[c]	$1,500
Electricity[d]	$800
Yard Waste Grinding	$10,000
Monitoring[e]	$2,400
Miscellaneous[f]	$2,500
Total O&M Costs	$26,300

O&M Costs Per Dry Ton of Biosolids[g]	$90

[a]No additional labor was hired.

[b]Based on annual maintenance cost of 3 percent of screen capital, 5 percent of mixer capital, 5 percent of front-end loader capital, purchasing new aeration pipe, and $1,000 maintenance for the asphalt pad.

[c]Based on 3 gallons/hour and 12 hours/week for the front-end loader, 3 gallons/hour and 7 hours/week for the screen, and $0.60/gallon for diesel fuel.

[d]Based on mixer and blower estimated usage rates and $0.05/Kwh.

[e]Based on 12 samples monitored for nutrients and metals.

[f]Miscellaneous includes insurance and licensing fees.

[g]Based on 293 dry tons per year.

Table 3 shows the estimated first year annual costs. These costs include revenue from compost sales and revenue from leaf compost sales. A separate leaf compost is produced in an area adjacent to the biosolids composting area. The leaf composting is part of the overall composting activities of the facility. In the second and following years, additional revenue is expected from biosolids delivered from other communities. In addition, tip fees from yard waste/wood waste are currently $0.

TABLE 3 – Annual Costs for the Abingdon Facility (based on processing 293 dry tons of biosolids)

Category	Cost
Annualized Capital	$38,000
Annual O&M	$26,300
Total Annual Costs	$64,300
Total Annual Cost/Dry Ton of Biosolids	$219
Revenue from Leaf Compost Sales	$9,600
Revenue from Compost Sales	$16,400
Total Annual Costs Minus Revenues	$38,300
Total Annual Costs Minus Revenues/Wet Ton Biosolids	$131

Product Marketing

The product is of excellent quality. It meets USEPA Exceptional Quality criteria. There is a high demand for compost in the Town of Abingdon and the Tri-Cities of Bristol, Johnson City, and Kingsport, Tennessee, which are nearby. The principal markets are nurseries, greenhouses, landscapers, and topsoil blenders. Two different products are being sold. The screened leaf humus is priced at $13 for quantities of 1 to 24 cubic yards. Discounts are provided for larger quantities. One-cubic-foot bags and three-cubic-foot bins are sold at $3 and $5, respectively. Biosolids compost is sold for $15 per cubic yard for quantities up to 24 yards and $11 per cubic yard for quantities of 24 to 100 cubic yards. Bags and bins are sold at $3.50 and $6, respectively.

HRRSA

The HRRSA operates a 16 million gallons per day secondary treatment plant that serves approximately 40,000 persons and accepts a significant amount of industrial wastes from four area poultry processors. The North River Wastewater Plant was recently expanded from 8 to 16 million gallons per day and is currently treating 9.1 million gallons per day of wastewater. Thickened sludge from the treatment plant is anaerobically digested prior to being dewatered with a new high-solids belt filter press. A covered Aerated Static Pile (ASP) composting facility was constructed in 1995 and began operations in 1996.

Site and System Design

Although the design and construction of these facilities included dewatering and composting, this paper will discuss the composting portion of the facility only. The composting facility is designed to process 5.5 dry tons per day of 25 percent total solids digested biosolids cake on a five-day-per-week operating basis. A description of the process flow and equipment features at this facility follows:

- Site Characteristics – The composting facility is located on a two-acre parcel of land immediately adjacent to the existing digesters and dewatering building at the North River Wastewater Plant. Minimal site grading and other preparation activities were required for the construction of the composting facility. All biosolids receiving, mixing, composting, drying, screening, curing, and compost storage activities occur under a 40,000-square-foot pre-engineered metal building.

- Materials Delivery and Processing – Dewatered biosolids are conveyed from the belt filter press to a concrete storage bunker in the composting facility. Wood chips are delivered in dump or live-bottom trailers for use as the primary bulking agent. A portion of the wood chips (up to three operating days' worth) can be stored under cover, with the balance stored outside on an asphalt pad.

- Bulking Agents – Papermill-quality wood chips are used as the primary bulking agent and are supplemented with a limited amount of yard waste available from the Rockingham County Landfill. An asphalt storage pad is provided for storage of new bulking agent as well as recycled bulking agent.

- Mixing – Mixing of the bulking agents with biosolids occurs in an electrically driven 18-cubic-yard batch mixer. The batch mixer is equipped with weigh scales to determine exact quantities of each of the bulking agents as well as the biosolids used in any given mix. A front-end loader is used to load the batch mixer with the biosolids and the bulking agent. After thoroughly mixing these materials, the initial mix is discharged into a 60-cubic-yard three-sided concrete storage bunker, which is also under cover in the composting building.

- Composting – Composting of the biosolids occurs under cover in a 15,000-square-foot area. A front-end loader picks up the mixture from the initial mix discharge bunker and places it in the static piles in the composting area. The facility is designed to allow a one-foot base of wood chips to be placed over aeration piping, followed by eight feet of mix and a one-foot insulative cover of recycled compost. Compost piles are approximately 90 feet long. Polyethylene pipe is used to supply aeration to the compost piles. Sixteen aeration stations, each capable of providing 630 cubic feet of air per minute at eight inches of water column, service two polyethylene headers spaced approximately four feet apart. Each blower station is capable of operating in the induced draft (negative) or forced (positive) aeration mode, depending on operator preference and the stage of the composting process. Negative aeration allows capture of the odorous exhaust and treatment through a biofilter system. To date, the facility has experienced no odor problems and only practices positive aeration. The aeration rate delivered to the static piles is controlled based on operator adjustments through a central programmable logic controller system. Allowance for up to five days of aerated drying is also provided in the composting building for times when additional drying is necessary.

- Screening – After composting, the material is screened through a deck-type screen. The screening system has a capacity of 40 cubic yards per hour and produces a 3/8-inch minus compost product for curing and use.

- Curing – Aerated curing is provided under cover using portable blower stations and perforated polyethylene pipe. This area is located adjacent to the composting area and is sized to handle 30 days of screened compost production. Six portable aeration stations are provided in the curing area for positive aeration. Cycling timers control aeration rates as necessary in this stage of the process. Upon completion of the curing period, the compost is stored under cover or moved outside to the storage area for marketing. The paved storage area provides up to two months' capacity for the finished compost product.

- Odor Control – Odor control at this composting facility consists of treating process offgas from the most odorous composting process and treatment through a biofilter system. Initial modeling at the facility indicated that the nearest receptors, approximately 1,000 feet from the facility, would not be adversely affected with this type of odor control approach. A 3,150-cubic-feet-per-minute biofilter has been provided to allow a 60-second residence time of odorous gases in the open bed biofilter system for treatment. Moisture control is provided through in-line humidification and surface irrigation. To date, use of the biofilter system has not been required.

Two part-time operators are utilized to operate the composting facility two to three days per week. These operators also perform other plant operations, such as dewatering, land application of liquid biosolids, and other duties within the wastewater plant operation.

Economics

The capital costs for the covered composting facility are shown in Table 4, and the operating costs are shown in Table 5.

TABLE 4 – Capital Costs for the HRRSA Facility[a]

Category	Cost
Total Capital Cost[b]	$1,510,000
Cost per Dry Ton per Day of Capacity	$274,500
Cost per Wet Ton per Day of Capacity	$68,600

[a]HRRSA costs based on 5.5 dry tons per day, 5 days per week, and 25 percent total solids cake.
[b]Includes all facilities, equipment, site work, engineering, permitting, and construction management. Land costs and dewatering costs are not included.

TABLE 5 – Annual O&M Costs for the HRRSA Facility

Category	Cost ($)	% of Total
Labor	$39,500	55
Utilities	$3,600	5
Maintenance	$2,100	3
Bulking Agent	$13,300	19
Fuel	$1,800	2
Miscellaneous	$11,400	16
Total	$71,700	100
Compost Revenue[a]	$16,800	--
Net O&M Costs[a]	$54,900	--
Net O&M Costs/Dry Tons[a]	$120	--

[a]Based on the facility processing 458 dry tons during fiscal year 1999.

Product Marketing

A compost marketing assessment was performed in mid-1994 to determine potential demand for a compost product. Currently, the HRRSA is initiating a program to market the compost using in-house personnel. The product is sold for $15 per cubic yard. One of the biggest users of the product in the past has been the Virginia Department of Transportation. They use a considerable amount on intermediate highway strips for wildflower vegetation.

RIVANNA WATER AND SEWER AUTHORITY

The Rivanna Water and Sewer Authority (the RWSA) currently operates a 7.7 dry ton per day composting facility to handle most of the biosolids produced by the Moores Creek Wastewater Treatment Plant. The WWTP is designed to handle 15 million gallons per day (MGD) and is currently treating an average of 11 MGD. The existing composting facility processes about 78 percent of the biosolids currently produced at the WWTP. The RWSA is currently constructing an expansion to the existing composting facility that will increase the capacity to 13.5 dry ton per day. This will provide sufficient capacity to process all the biosolids produced at the WWTP at the full design flow of 15 MGD.

Site and System Design

The facility is an aerated static pile composting operation located at the site of the WWTP. The existing facility consists of a 90 X 293 foot roof only structure and an asphalt pad for final product storage. The expansion will include an additional 70 X 293 foot roof only building and a new asphalt pad to provide delivery access to the expanded facility. The existing building will house the aerated static piles. Capacity for 18 days of composting will be available. The new structure will house the mixing, biosolids, and bulking agent receiving and storage areas. The facility will consist of the following elements:

- Three-sided concrete bunker that will provide two operating days storage of biosolids.
- Stationary batch mixer that will discharge to a three-sided concrete bunker.
- Two two-sided concrete bunkers that will provide up to 17 operating days storage of recycled bulking agent and four days storage of new bulking agent.
- Screening area located under the roof adjacent to the recycled bulking agent storage bunker.
- 22 computer-controlled blowers will provide aeration to the compost based on a temperature and an adjustable time cycle. The composting piles are designed for a seven foot mix height. This allows future increases in capacity by increasing the mix height of the piles.
- All of the new floor space will be asphalt with no concrete floors.
- No odor control system is provided.

Economics

The total capital cost for the composting expansion is estimated at $1,000,000. Table 6 outlines the capital cost.

Table 6 – Capital Costs for the Rivanna Composting Facility

Category	
Site Work	$58,300
Pads & Walls	$117,200
Structures	$468,900
Blowers & Mixer	$150,000
Electrical & Controls	$55,600
Engineering & Contingency	$150,000
Total	$1,000,000

Table 7 – Estimated O&M Cost for Expanded Facility Handling 13.5 DTPD

Category	Cost
Labor	$113,670
Bulking Agent	$65,000
Equipment Maintenance	$37,650
Site Maintenance	$8,091
Fuel	$34,632
Electricity	$16,500
Product Monitoring	$2,000

License Fees	$900
Miscellaneous	$1,460
Total O&M Cost	$279,903
Compost Revenue (@ $13 per cubic yard)	$212,900
Net O&M Cost	$67,003
Net O&M Cost Per Dry Ton	$19.08

Table 7 Total Annualized Cost Based on a 7% Discount Rate

Category	Cost
Amortized Capital (Existing Facility)[1]	$70,600
Amortized Capital (Expansion)	$101,600
O&M	$279,900
Total Annual Cost	$452,100
Compost Revenue	$212,900
Net Annual Cost	$239,200
Net Annual Cost per Dry Ton	$68.15

[1] From the RWSA Records

PRODUCT MARKETING

The compost product is of excellent quality and meets US EPA Exceptional Quality criteria. Demand is good for the product and the RWSA currently charges $13 per cubic yard for the finished compost. Since a detailed marketing study has not been performed it is not known if the increased compost production will effect the cost given the current market.

MEDIUM-TO-LAGE-SCALE VERMICOMPOSTING SYSTEMS

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Institution and business managers are looking for new ways to divert waste from their disposal systems. Food waste and other organic materials are of particular concern because they can be as much as 90 percent of a facility's total waste stream. However, businesses and institutions often do not have enough space to compost their organic materials on-site or there are no composting operations within a reasonable distance. Therefore, many facilities managers are investigating the possibility of vermicomposting their organics.

This presentation will provide an overview of the types of vermicomposting systems used at 13 institutions and businesses located throughout the United States and Canada. Slides will depict a variety of systems that were either commercially produced or designed and built on-site. The following types of facilities will be highlighted:

* Elementary school in Pennsylvania
* Air force base in Nova Scotia
* Hospital in New York
* 28-story downtown office building in Ontario
* Processor of grocery chain food scraps and municipal organic materials in Oregon
* Correctional facilities in North and South Carolina, California, and Florida
* Athletic arena in Washington
* College in Washington
* Federal building in North Carolina

Four correctional facilities in the Carolinas--Caledonia, Brown Creek, and Sampson in North Carolina, and Broad River in South Carolina--are expanding projects with on-site composting and vermicomposting of organic residuals as they examine ways to reduce the amount of garbage they send to landfills. Several other North Carolina prisons are considering adopting these methods of waste reduction in the future in response to Governor Jim Hunt's call upon state agency managers to implement more environmentally-sustainable practices. The governor has asked state agencies to "look for ways to reduce the use of natural resources, eliminate waste and limit environmental impact, and serve as models of environmental stewardship." Furthermore, state officials are

considering expanding executive policy to specifically address food waste recycling by requiring state agencies that operate food service establishments, such as snack bars, cafeterias, dining halls, etc., to implement programs to recover and recycle edible and inedible food when feasible and practicable. Reducing waste will also save taxpayers money; during FY 1997-98, 83 correctional facilities statewide disposed of a total of 31,710 tons of solid waste at a cost of $791,205.00 (average disposal fee of $24.98 per ton).

CALEDONIA CORRECTIONAL INSTITUTION

In 1995, Caledonia Correctional Institution in Halifax County was the first prison in North Carolina to implement on-site composting. Located on 7,600 acres near the Virginia border, Caledonia has always diverted kitchen scraps from their waste disposal system, initially by giving them to a nearby hog farmer who collected them two or three times a week. When hog prices plummeted in 1997, the hog farmer severely cut back on food scrap collection, and prison managers scrambled to find another method for keeping the materials out of the landfill. They obtained a one-year pilot permit from the state which allowed them to implement windrow composting. In the meantime, Caledonia began the lengthy process of applying for a permanent facility composting permit while designing and constructing a bin system. As soon as the permit was approved in May 1998, they began composting in aerated bins.

The $40,000 forced-air static composting system was designed by the prison's maintenance supervisor and carpenter. The system consists of 12 bins, divided into two rows of six, and each bin is 7 feet long by 7 feet wide by 5 feet tall. The front of each bin has six 2 by 8's that can be removed two at a time by a person on each end. The capacity of each bin is 36, 30-gallon barrels, or over 9,700 pounds of food scraps. The floor of each bin has 16 BioPlates for aeration and leachate. The BioPlates, constructed of fiberglass and concrete at a cost of $89 apiece, are strong enough to withstand the weight of a skid loader. The top of each BioPlate is flat with cones underneath that rest on a concrete pad, thus raising the plate several inches off the floor so leachate and air can move through the numerous holes in the plate. A 980 cubic feet-per-minute fan for each bin is operated on a timer to aerate the pile by forcing air through the center of the system and up through the BioPlates in the floor. When aeration is needed, usually for moisture reduction, the blowers run for 10 minutes every hour on the hour. Moisture is usually added at a rate of 25 gallons at a time by placing a portable irrigation sprayer on top of the compost pile that uses a 3 gallon-per-minute electronic water meter. They presently use the "dig and squeeze" method of moisture testing, but plan to obtain an electronic moisture reader. An overhead irrigation system was considered but rejected due to the prohibitive cost of purchasing an electric water meter for each bin ($113 for each meter) to meet the requirement of keeping daily records for their permit. Leachate runs to a trough between the two rows of bins and into a 1,500-gallon septic tank.

The collected leachate is handled by three alternative methods: either added to bins to increase moisture levels or land-applied as allowed by their permit or processed at their wastewater treatment plant.

Caledonia is composting food scraps, paper products from the kitchen, 100% cotton t-shirts, and

bones. T-shirts are only occasionally added to the bins. About 12 barrels (30-gallons each) a day are generated of food preparation waste, leftovers, and scrapings from inmates' plates. When all of the bins are operating, they plan to compost cannery waste plus kitchen scraps from two smaller correctional facilities next door. Because the maximum security inmates housed at Caledonia are ineligible to work at the composting facility, a team of three inmates from the minimum-security facility next door use a front-end loader attached to a tractor to fill and empty the bins. Wood chips, obtained at no cost from a nearby paper company, are used as a bulking agent. They initially tried using wheat straw and poultry litter separately as bulking agents, but both compacted so much that the forced-air system didn't work and inmates had to hand-turn the piles. Inmates apply a 4-inch layer of wood chips (two Bobcat scoops or 420 pounds) on the bottom of the bin, then add 4- to 8-inches of food scraps (12 drums; 190 pounds), then 10 pounds (5 scoops) of 46 percent nitrogen urea from a fertilizer company (to increase pile temperature). This procedure is repeated three more times until the bin is almost full and then capped with a 4-inch layer of wood chips. The materials remain in these layers during the next two weeks; no agitation or mixing takes place since the bins are aerated with forced air. From May 1998 through March 1999, Caledonia composted 131 tons of organic materials.

Organic materials are composted for about two weeks, and then the bins are emptied into windrows for at least two months of curing. So far, Caledonia has been using most of the compost as a bulking agent in the bins because the wood chips and compost can be reused three times for this use. Eventually the compost will be screened and used to grow day lilies or spread on fields for crops.

One prison official and three inmates maintain the composting operation. They spend about an hour a day checking the bins, and twenty minutes taking temperature readings of the five bins currently in use. It takes two to four hours to empty and refill the bins and mow grass around the site when needed. A separate crew consisting of a corrections officer and two inmates delivers about 40 barrels of food scraps once a week to the composting site. Approximately 8 to 12 barrels of kitchen scraps are generated daily and stored in a fenced area near the kitchen. The crew spends about an hour per week hauling the barrels of food scraps over to the composting site.

Caledonia is still trying to get the kinks out of the their composting system. The biggest challenge occurred the first winter when bin temperatures would not rise enough to meet their permit requirements. This problem was attributed to the BioPlates lying on a concrete pad that did not allow the bins to hold heat. The bin contents were emptied into windrows during the coldest months of winter. A couple of other "lessons learned" are also associated with the BioPlates. To dump the organic materials into each bin, they were driving a skid loader right onto the BioPlates. They didn't realize until several months later that the Bobcat tires were pushing the organic materials into the holes of the plates and plugging them up. Now they use a front-end loader attached to a tractor so that the tires only roll onto the first three inches of the plates. Another problem was that a lot of grease was being added to the bins, and the spaces between the concrete pad and the BioPlate cones were getting clogged with grease and impeding the flow of air and

leachate through the holes.

The bin system would also be improved by adding more overhang to the roof and curtains on the sides of the bins to keep out rain. They also could use asphalt around the bins to prevent the skid loader from getting hung up where the gravel doesn't come up to the sides of the bins.

Thus far, Caledonia has no cost savings associated with their composting operation. There are no disposal savings because food scraps were never sent to a landfill or wastewater treatment facility. And since they haven't used the compost yet, Caledonia has no documented savings on its use as a fertilizer or soil amendment.

BROWN CREEK CORRECTIONAL INSTITUTION

Near the South Carolina border in Anson County (NC), Brown Creek Correctional Institution (BCCI) implemented a comprehensive waste reduction program that includes composting and vermicomposting. BCCI reduced their solid waste disposal by 67 percent, from 333 tons (28 tons per month average) in 1996-97 to 73 tons (9 tons per month) in 1998-99, saving the state more than $4,000 in disposal fees. During 1997-98, BCCI recycled 62 tons (reaping revenues over $5,000), composted 43 tons, and recovered 8,488 articles of clothing (worth $17,848) by hand sorting all of their garbage.

In August of 1997, BCCI began their experimental vermicomposting project. First, they built a 24-inch by 48-inch wooden box and added five pounds of redworms and food waste to the shredded paper bedding. A few months later, two additional worm bins measuring 24-inches by 28-inches were set up after converting them from a used wooden shipping crate. Worms were taken from the original worm bin to stock the new bins. All three bins are located inside a greenhouse used for a therapeutic planting program for chronically-mentally ill inmates who mix the worm castings with soil to grow vegetables and flowers. Built of salvaged steel bridge beams, the 20 foot by 24 foot worm bin is divided into three sections by recovered concrete blocks. They stocked small sections of this vermicomposting unit with worms harvested from the greenhouse bins. Since the project began, they have not purchased additional worms; they continue to expand their vermicomposting program with worms raised in the original greenhouse box.

The vermicomposting project is staffed by one correctional officer and one inmate who spend approximately 15 to 30 minutes each week checking on the worm bins, and 30 to 45 minutes twice per month adding food residuals to the bins. They discovered that lettuce leaves and other food scraps that decompose rapidly are more suitable for the worms than whole potatoes or broccoli stalks, so only certain organic residuals from the waste stream are fed to the worms. Plate scrapings, which could have grease or meat mixed in, are not added to the worm bins. The following types and amounts of food are added to worm bins per feeding: 60 to 80 pounds of lettuce, 5 to 10 pounds of coffee grounds, 3 to 7 pounds of paper and paper egg crates, and 10 to 15 pounds of banana peels. Through April 1999, the total amount of food added to the worm bins was 915 pounds of paper, 640 pounds of lettuce, 170 pounds of coffee, and 200 pounds of banana peels.

BCCI's first composting bin was fairly small, constructed of wire and concrete. They soon realized that a larger system was needed to compost pre- and post-consumer food scraps, dryer lint, and hair clippings from their barber shop. So, inmates constructed a three-compartment composting bin from wood and wire measuring 4 feet by 12 feet by 5 feet high. The bin system worked fine, so Superintendent Rick Jackson planned to have more bins built, until he heard about Organic Wastes Recycling Grants available from the state Division of Pollution Prevention and Environmental Assistance. Jackson applied for and was awarded a grant for a demonstration project of food waste source-separation and in-vessel composting. In early June 1999, BCCI set up a Greendrum In-Vessel Composter, distributed by RKB Enterprises of Norfolk, Virginia. The $39,000 rotary-drum composter, measuring 6 feet in diameter and 16 feet long, has a 900 pound per day capacity. The unit takes one part food to two or three parts amendment for bulking and moisture reduction. Organic wastes are loaded at one end, passed through a grinder, and moved through the drum by gravity (it's on a two-degree angle). Retention time inside the chamber is one week, followed by one month of curing. Jackson also purchased an identical composter so the two units can handle the 1,400 pounds per day of food scraps generated at BCCI and 400 pounds of food scraps produced daily at a smaller prison next door.

BROAD RIVER CORRECTIONAL INSTITUTION

In 1990, a composting system was implemented at the Broad River Correctional Institution (BRCI) in Columbia, South Carolina to divert food waste from disposal and build up soil for their vegetable garden and flower beds. Kitchen scraps generated from preparing meals for 1,000 inmates ranges from 1,000 to 3,000 pounds per week, depending on menus. Food scraps are mixed with yard waste and pine straw in windrows for composting. Cow manure is added periodically to increase the pile temperature. Two inmates are in charge of hauling the materials, grinding them and aerating the pile using a rototiller and pitchforks. Plans call for expanding the program to plate scrapings and they anticipate having six 100-foot windrows to compost most of the organics.

Although prison officials were satisfied with the windrow composting system, when they were approached by a state official interested in setting up a vermicomposting demonstration project, she readily agreed to try it. Beginning in June 1998, BRCI started vermicomposting about 10 percent of their food scraps. Every two to three weeks, about 800 to 1,000 pounds of kitchen scraps that have been shredded and allowed to cool in a pile for a few days are added in 4 to 6-inch layers to worm bins. Mostly leafy food scraps are added to the bins because the worms are able to process them faster. The vermicomposting bins were manufactured and installed by Vermitechnology Unlimited at a cost of $2,000, which included 120 pounds of worms (90 pounds of worms were added to this system, and 30 pounds of worms were used for another project). The Insulated Ground Vermicomposting System is constructed of wood and insulated panels, measuring 34 feet long by 7 feet wide by 18 inches high with a center divider for ease of feeding and harvesting. It has a capacity of 100 to 150 pounds of food waste per day. A screen is installed beneath the unit to keep out moles and other pests. Inmates added a greenhouse mesh suspended by metal poles for shading, at a cost of $120.

So far, the worm bins have only been harvested once. From May to September 1998, thirteen 55-gallon barrels of worm castings were produced and harvested. The state was interested in seeing how the vermicompost would sell at retail outlets, so they developed labels to stick on paper bags containing 5 pounds of castings in plastic bags, to be sold for $7.50 per bag. The bags are being offered for sale at an herb farm, a flower shop, and a nursery, however they have not been selling well. The prison is splitting sales of the vermicompost with the retail outlets.

Table 1. Summary of systems used at three prisons and tonnages diverted

Prison Name	**Type of Composting System**	**Tonnage Diverted/Month**
Caledonia	Forced-air static bins	13
Brown Creek	Greendrum Rotary-Drum Composter	19
Brown Creek	Hand-made vermicomposting bins	2
Broad River	Vermitechnology Unlimited	4

COMPOSTING OPERATIONS AT CHEROKEE TRIBAL FACILITIES

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INTRODUCTION

The Eastern Band of the Cherokee Indians (EBCI) live on the Qualla Boundary in North Carolina, a land area comprised of 56,572 acres directly adjacent to the Great Smoky Mountains National Park. The 12,000 members of the Eastern Band are descendants of those Cherokee who, in the late 1830s, remained in the mountains of North Carolina rather than be forced to march along the infamous "Trail of Tears" to Oklahoma.

Today, the Eastern Band of the Cherokee is the only tribe of North Carolina's six recognized tribes which possesses both state and federal recognition, lives on a reservation and is served by the Bureau of Indian Affairs in the US Department of the Interior, the Indian Health Service and the federal departments of Labor, Commerce, and Health and Human Services. The North Carolina Commission of Indian Affairs subcontracts Community Action Partnership Program (CAPP) funding to the Eastern Band of the Cherokee each year.

The EBCI have developed several composting operations at their facilities in Cherokee, including biosolids composting, food waste composting and backyard home composting programs.

BIOSOLIDS COMPOSTING

Composting biosolids at Tribal Utilities evolved because the sludge was formerly classified as a “special waste” which required the EBCI to send the sludge to a special landfill at a great cost. Composting was determined to be a way to save significant money.

Biosolids from the EBCI wastewater treatment plant are dewatered with belt filter presses and trucked to the composting site adjacent to the solid waste transfer station. There, biosolids are amended with ground wood produced by the EBCI’s yard trimmings tub grinder. Mixing is accomplished by a Volvo L50C Front End Loader working against a reinforced concrete push wall. The facility handles about 30 tons per day of biosolids.

The biosolids-yard trimmings mixed is composted in a roofed, partially-walled building using the Aerated Static Pile method of composting (see Figure 1). The mix is composted for approximately 21 days in the building and then moved to curing for at least 30 days. Following curing, the compost is screened with a vibrating deck screen (1/2" screen size) and sold to area landscapers and a lily farm.

Figure 1
Aerated Static Pile Biosolids Composting

FOOD WASTE COMPOSTING

In 1997, the EBCI were successful in obtaining funding from EPA's Office of Solid Waste to undertake a pilot project involving the composting of food wastes. This was a first of its kind project to be implemented upon Indian Country within the whole United States. As with biosolids, the special food wastes from the in-house restaurants of the Tribal Casino operations required a means of proper disposal. The primary objective of this project is to develop an operation designed to demonstrate the effectiveness of a windrow composting process and particle screening process.

Primary feed stock for this project is source-separated food waste generated at the three restaurants located at the Harrah's Cherokee Casino. To date, the project has been very successful. On average, nearly 30 tons per month of food waste from the casino restaurants are being processed into the Food Waste Composting Project, with the amounts steadily increasing.

Incoming food waste is mixed with ground yard trimmings and shredded office paper using the front end loader (using a different bucket than is used with biosolids, to prevent cross-contamination of the food waste compost). The compost mix is then taken to a graded area on the other side of the solid waste transfer station and formed into windrows (see Figure 2). The material is composted in windrows for about four weeks and then moved to curing for another four-to-six weeks.

The finished compost is in great demand by area landscapers and farmers. The EBCI are also considering developing an organic herb farm using the food waste compost generated by the Tribe.

Figure 2
Food Waste Composting Windrows

BACKYARD COMPOSTING

The EBCI have a very active Tribal Recycling Program that has been expanded to include backyard composting programs. This project has met with huge participation and has accomplished a large success rate within this project. This program consists of giving backyard composting demonstrations and techniques to individual homeowners, school classrooms, civic organizations, and area businesses. This program will also supply these individuals with a personal backyard composter unit at no charge to them.

Planning, Design, and Operational Factors that Affect Odor Control at Composting Facilities

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Odors are often the greatest source of public complaints with which a composting facility must contend. As residential and commercial developments begin to encroach on once remotely located facilities, off-site odor impacts become an issue of concern. To further exacerbate the situation, the encroachment is often a result of increased populations; more people produce more waste, and facilities must therefore deal with expansion pressures while working to improve odor control.

This paper will address several key issues related to odor control. First, it will outline the sources of odor on site and operational parameters which can be monitored to minimize odor generation. Second, it will discuss the development of an odor balance which can be used to compare the relative generation of odor from different sources. Odor control measures to eliminate primary sources will then be described. Finally, odor modeling, a tool which can be used to evaluate odor control, operational, and siting parameter and their impacts on odor dispersion, will be presented.

ODOR SOURCES

There are many potential odor sources at a composting facility. The most obvious sources of odor include the delivery and mixing of raw feedstock materials, active composting, and curing. There are many other potential odor sources including the movement of compost and raw materials around the site, leachate puddles, screening and storage of final product. In addition to general housekeeping issues such as maintaining a clean site, optimization of the composting process can help minimize odor generation. Key issues to consider are feedstock handling, mix ratios, aeration rates, and temperature control.

Feedstock Handling

Different feedstocks have different odor potential. For example, raw sewage sludge has more odor potential than digested sludge or treated biosolids. Grass is typically a significant source of odor at yard waste facilities. Fish wastes and certain vegetable wastes are more odorous than food processing wastes. Facilities should be prepared to handle incoming waste appropriately and to mix putrescible materials with bulking agents such as woodchips or leaves immediately after they arrive.

Mix Ratios

The ratio of materials combined to form the compost feedstock is significant because it determines the moisture content, the pore space, and the carbon to nitrogen (C:N) ratio of the mix. For most composting systems, the initial solids content of the compost mix should be at least 40 percent (less than 60 percent moisture). Excess moisture reduces pore space and impedes the even flow of air through the composting material resulting in anaerobic pockets. Insufficient moisture inhibits the microbial composting activity, slowing degradation. The C:N ratio of a composting mix should be approximately 30:1. A lower ratio (excess nitrogen) results in the loss of ammonia which may lead to odor problems. A mix with a higher C:N ratio may have insufficient nitrogen for optimum microbial degradation of carbon, and composting will be slowed.

Aeration Rates

Aeration is one of the most important elements of a composting system because oxygen is essential to microbial activity. Although both aerobic and anaerobic degradation can result in odors, more odorous compounds are generated under anaerobic conditions than aerobic conditions. Compost piles are aerated by agitation, in the case of windrow systems, forced aeration operated by mechanical blowers, in the case of aerated static piles, and by both forced aeration and agitation in many in-vessel systems. The aeration system must be carefully sized to provide enough air to composting microbes without excessively removing heat and moisture from the pile. Moisture content and pore size are important elements to a proper aeration system; excess moisture or overly dense material will impede aeration and increases the potential for odor generation.

Temperature

Temperature control of composting piles through the adjustment of aeration rates is also an important operational parameter. There is conflicting data regarding the effect of high temperatures on odor generation. Higher temperatures typically result in increased odor generation; odor character and strength of compounds formed at higher temperatures is quite discernable even at large distances. However, if material composts at higher temperatures, less air is used to cool the pile, and therefore, the volume of emissions is lower. Total odor generation is a function of both odor concentration and the volume of emissions from a pile; the overall effect of higher pile temperatures is not clear. However, it is certain that maintaining uniform temperatures throughout piles and optimizing the rate of composting will help to minimize odor generation.

DEVELOPING AN ODOR BALANCE

Although operational changes can help to minimize odors, many well-run facilities encounter odor problems because of the proximity of their neighbors. Before odor control work is undertaken, an odor balance should be developed to determine what the primary odor sources are. An odor balance is tally of the total number of odor units generated by specific odor sources. The total number of odor units is a function of the concentration of odor, expressed in dilutions to threshold or odor units per cubic meter, the total emissions rate from a source, and the duration of odor generation. The odor balance can help to prioritize odor control actions by determining which sources contribute the largest percentage of odor units.

Odor Sampling and Measurement

Odor sampling methodology is similar to sampling for any air contaminants. Samples are captured from pile or biofilter surfaces, or from plumes generated from volume or point sources and sealed in Tedlar bags. Bags are then shipped to laboratories for odor analysis.

Odor concentration is determined by odor panel analysis. An odor panel is a group of eight or more trained individuals who are presented with an odor at decreasing levels of dilution (increasing concentration). The panelists are concurrently presented with non-odorous air at additional sniff ports and asked to identify the sample which contains the odorous air. The point at which one-half of the panel members can detect which sample contains the odorous air is considered the dilution threshold, or the number of volumes of fresh air needed to dilute a volume of odorous air in order to render it undetectable.

The dilution threshold, expressed as dilutions to threshold (D/T) or ED_{50}, is also expressed in terms of odor units per unit volume of air. Since the number of odor units generated by a particular source is a function both of the odor concentration (odor units per volume air) and the volume of air generated by a source, flow rates from piles, biofilters, or other odor sources are also measured. These measurements are used to formulate an odor balance.

Odor panels also analyze odor for intensity. Odor intensity measures the sharpness or the potential to cause odor impacts of a particular odor. A high intensity odor would create odor impacts even at low concentration while a low intensity odor could be present in relatively high concentrations before causing nuisance conditions. Odor intensity is measured by comparing an odor sample at different concentrations to a standard scale of intensity. A dose-response curve is thereby created which can be used to determine the concentration at which a particular odor will cause odor impacts.

Table 1 is an example of an odor balance that was constructed for a windrow composting facility. The second column shows the concentration of odor emissions from specific sources. The third column shows the number of hours each day that each source is active. The flux rate, or the volume of odorous air generated per square meter of surface area per unit time is not listed in the table but is used to calculate the total number of odor units generated per day, listed in the fourth column.

As shown, 27 percent of the odors were generated by composting windrows and 62 percent of odors were generated by curing piles. Although turning was generating the strongest concentration of odors, the short duration of turning, as compared with the constant surface area source of large curing piles, actually resulted in fewer odor units overall. An odor balance is a good preliminary indication of what the primary odor sources on a site are; odor mitigation measures can therefore be designed for maximum effectiveness. It should be noted however that odor dispersion from a site is not simply a matter of the number of odor units generated; there are many parameters to consider including source dimensions, topography, and the hours of emissions. Odor balances also do not take odor intensity into account; for example, while new compost piles may not produce the highest number of odor units, the intensity of the odor generated may be higher because of the types of compounds formed during the early stages of composting. Higher intensity odors are detectable at lower concentration and therefore have a relatively higher potential to cause odor impacts.

Table 1 – Odor Balance – Windrow Composting Facility

Source	***Odor Concentration***	***Duration (hours/day)***	***Total Emissions (10^3 odor units/day)***	***Percentage***
Feedstock Delivery and Storage				1.0
Feedstock delivery	200	8	77	
Feedstock storage	386	24	14,895	
Feedstock transfer	82	8	26	
Feedstock Mixing				1.0
Mixing	1500	8	468	
Mix pile storage	386	24	14,895	
Mix pile transfer	82	8	26	
Composting				27.1
Pile construction	82	8	26	
Surface (1-5 days)	1370	24	169,174	
Turning (1-5 days)	5460	0.8	10,319	
Surface (6-10 days)	1500	24	185,227	
Turning (6-10 days)	7080	0.8	13,381	
Surface (11-20 days)	23	24	2,840	
Turning (11-20 days)	5000	0.8	12,600	
Surface (21-28 days)	89	24	10,990	
Turning (21-28 days)	3000	0.8	7,560	
Pile tear down	82	8	26	
Curing				61.6
Surface (1-7 days)	7080	24	455,350	
Surface (8-28 days)	7080	24	455,350	
Surface (29-70 days)	177	24	22,767	
Pile tear down	7080	8	2,209	
Post-Processing				7.7
Screening	1000	8	312	
Storage	1000	24	115,767	
Transfer	1000	8	312	
Standing Water				1.7
Compost runoff	149	24	3,833	
Curing runoff	149	24	17,249	
Agitated curing runoff	12800	24	3,994	
Total			1,519,672	

ODOR MITIGATION

There are several means to mitigate site odor. These include counteractants and masking agents which are sprayed over a site or specific odor sources, chemical scrubbers which adsorb or oxidize odorous gases by passing emissions through scrubbant solutions, and biofilters which utilize natural microbial activity to break down odorous compounds.

Counteractants and Masking Agents

Both counteractants and masking agents are typically applied through a fine-mist spray system. The mist can be sprayed directly over odor sources, or mist may be sprayed from points along the perimeter to prevent odor from moving off-site. Masking agents are designed to cover up odors while counteractants are meant to react with odorous compounds and alter their character and intensity. In both cases, the effectiveness depends in large part on ensuring contact between odorous compounds and the spray particles. In general, they have not been very successful at composting facilities.

Chemical Scrubbers

Chemical scrubber systems pass scrubbant solutions through the emissions air stream to remove odorous gases by adsorption or oxidation. Scrubbers are typically best suited to low-volume, high-concentration odorous exhaust air, so they are not always appropriate for composting facilities which generate a large volume of exhaust. In addition, since compost exhaust typically contains multiple odor-causing compounds, multi-stage scrubber systems are often required for effective odor control. The use of scrubbers requires chemical handling and storage, and scrubbers can be expensive to maintain because of the cost of the chemical agents.

Biofilters

Biofilters use the naturally occurring microbial populations within a solid media matrix to adsorb and biologically degrade odorous air pollutants. Biofilter media typically consists of compost, bark, woodchips, soil, sand, or a mixture of these and other materials. Biofilter design often includes a humidification system which moistens exhaust air as it moves from the composting process to the biofilter plenum. The stone plenum and a system of aeration piping distribute the exhaust air evenly throughout the biofilter media which removes a wide range of odorous compounds as they pass through. The advantage of biofiltration is that the biological system can remove multiple compounds at low operating cost. The primary disadvantage of biofilters is that they require a relatively large area.

The success of any odor control system depends on the ability of the system to capture a high percentage of odorous emissions generated and the effectiveness of odor treatment. However, the potential for off-site odor impacts also depends on the dispersion patterns from an odor source. Dispersion is dependent on source parameters such as height and velocity, local topography, and meteorology. Odor models can be used to determine the direction of dispersion and the potential for off-site odor impacts.

ODOR MODELING

Air dispersion modeling can be used to evaluate the movement of odor from a source and determine the extent and frequency of odor impacts on a surrounding community. Models are often used as part of the permitting process to determine if a proposed facility will create odor nuisance conditions. Models are also used by existing facilities to evaluate proposed expansions or operational modifications. For example, a model can be used to compare different odor control scenarios so that the most cost-effective solution can be identified.

The model that is typically used for composting facilities is the EPA-recommended ISCST3 model. This model takes local topographical and meteorological data into account and combines this information with emissions concentrations, site layout, operational parameters, and source dimensions to determine the movement of odors from the source. The results are expressed as a series of isopleths, concentric circles which are drawn based on the maximum odor concentration projected to occur at points surrounding the facility. An example of modeling results is shown in Figure 1.

As shown, the source of odors is an open biofilter in the southwest corner of a facility. Odor dispersion isopleths show that off-site odor concentrations will range from 5-8 D/T along Highway 101 to 3-5 D/T in the residential development to the west. Points along the border of the site are projected to experience concentrations in the range of 5-13 D/T.

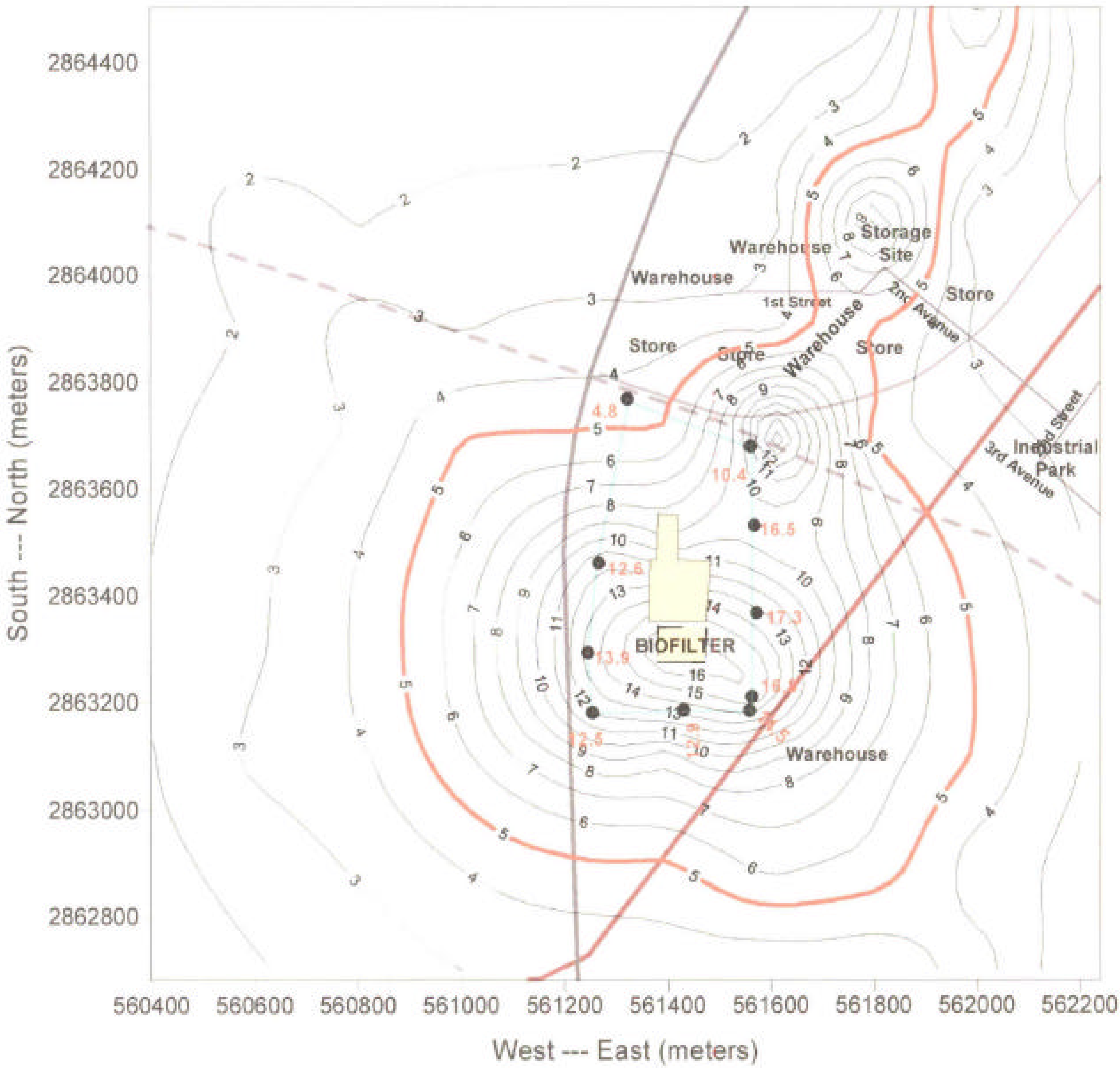
As discussed above, the concentration at which a particular odor creates nuisance conditions depends on the intensity of that specific odor. Odor analysis data from various composting operations has shown that compost odors typically constitute a nuisance condition at 5 D/T. Based on this nuisance threshold of 5 D/T, all points on Figure 1 which fall within the 5 D/T isopleth are projected to experience at least one 10-minute odor nuisance condition under the meteorological conditions modeled (typically 1-5 years of meteorological data are used). The results of this model were unacceptable to the residents of the community as many of their homes, the school, and the local state park were projected to experience odor impacts.

The model was therefore run with an enclosed biofilter with two roof vents. Although in this scenario, the same number of odor units were still being emitted from the biofilter surface, enclosing the biofilter improved odor dispersion by several means. First, since an enclosed biofilter must be sufficiently tall to allow a front-end loader access to the media, the roof vents were at a much higher height than the open biofilter. The vents also released air at a higher velocity than the open biofilter. Both added velocity and height increase the rate at which exhaust air will mix with ambient air, increasing dispersion. In addition, make-up air added to the biofilter exhaust to boost biofilter emissions through the vents diluted the emissions before they were released.

The resulting model output is shown in Figure 2. As shown, enclosing the biofilter greatly reduced the range of odor impacts, but there were still some off-site impacts projected. The biofilter scenario was therefore run a third time; for the third scenario, an additional 10 percent make-up air was added to the exhaust, and the number of roof vents was increased to four. As shown in Figure 3, the result for this scenario was a complete elimination of off-site odor impacts.

The model can be used to project the number of odor impacts at a particular receptor point and to determine the conditions under which impacts are likely to take place. A facility can then use this information to select the best odor control option. For example, in the case of Scenario 2, if odor impacts were found to occur off-site only during late night hours, or only during winter weather conditions, a community might be satisfied with this odor control option. Other communities might have a zero-tolerance policy and would not accept any odor impacts, regardless of the cost of mitigation. The model allows a facility to examine options and their effectiveness before investing in site equipment or construction.

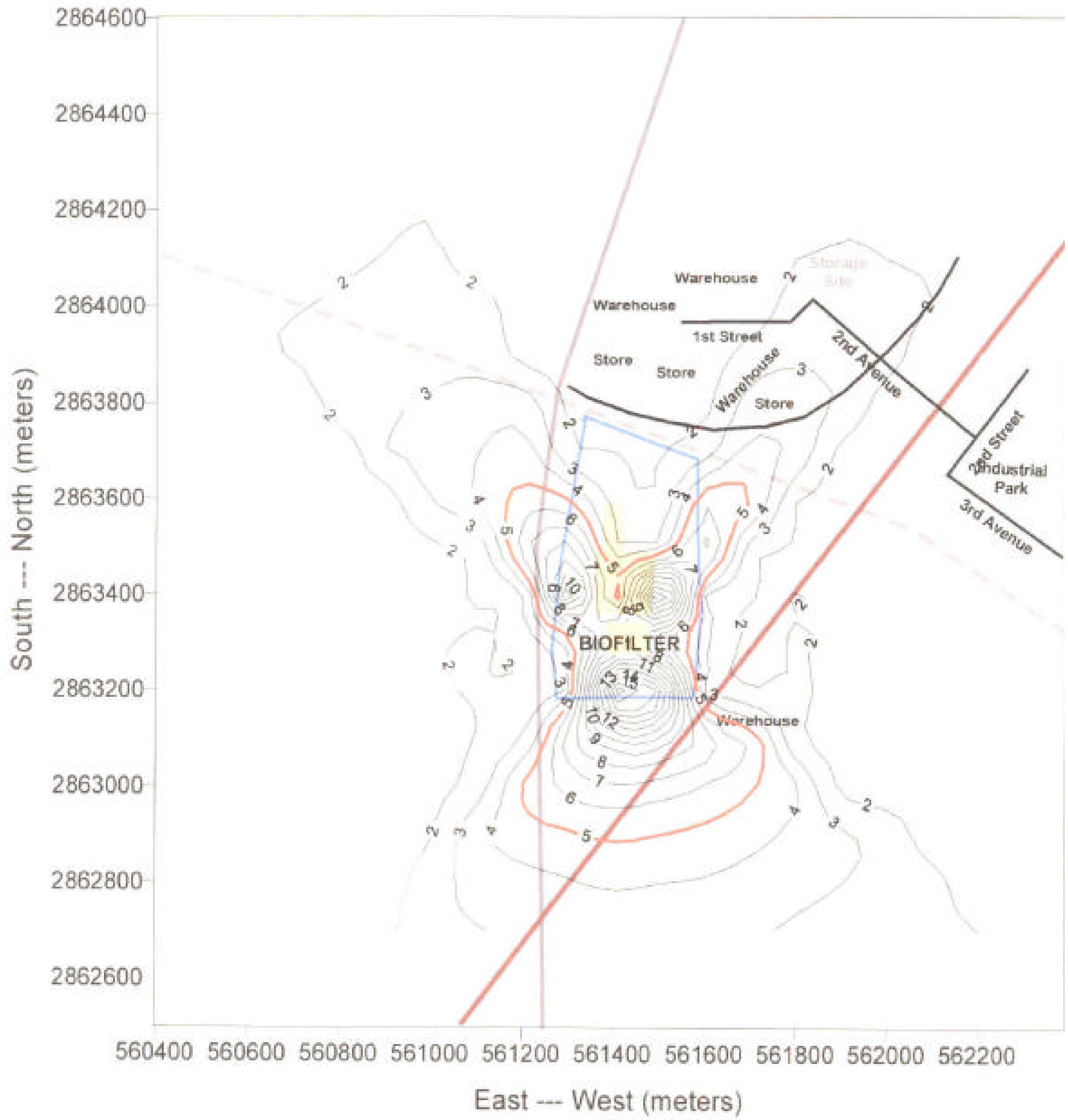
FIGURE 1 - OPEN BIOFILTER



Isopleths represent the highest odor concentration (D/T) projected to occur during a five-year period. Receptors located along the property line are also labeled with the maximum odor concentration projected to occur at that point.

Figure 1 - NC Odor Paper
June 27, 2000

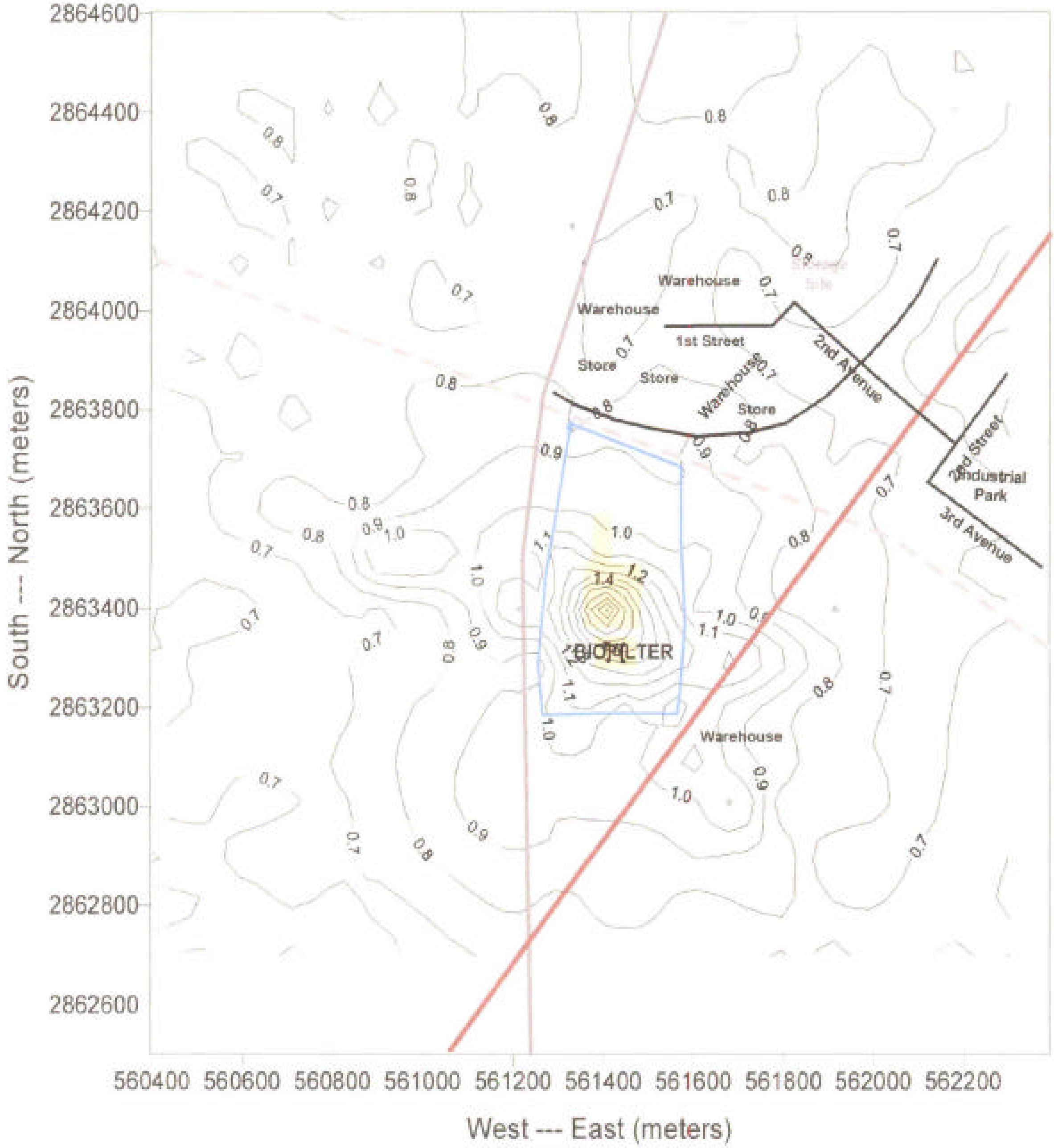
FIGURE 2
ENCLOSED BIOFILTER - 2 ROOF VENTS



Isopleths represent the highest odor concentration (D/T) projected to occur during a five-year period.

Figure 2 - NC Odor Paper
June 27, 2000

FIGURE 3
ENCLOSED BIOFILTER - 4 ROOF VENTS AND 10% MAKEUP AIR



Isopleths represent the highest odor concentration (D/T) projected to occur during a five-year period. As shown, no off-site odor impacts are projected.

Figure 3 - NC Odor Paper
June 27, 2000

RECYCLING AND BIOMASS ENERGY

Dr. George A. Garland and Dr. Rosalie Green
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Material which is now going to landfill or a waste to energy facility could be used differently in several ways. It could be recycled as material, composted, used as feedstock for chemicals, or burned for energy. This paper explores the factors which may interest the Department of Energy as it explores the possibilities of using biomass in furtherance of Executive Order 13134.

POSSIBLE OPPORTUNITY

The MSW Characterization Report for 1997 (data for 1996) showed about 47 million tons of paper still disposed of in landfills or waste to energy facilities. Corrugated, office paper, and newspaper are about 19 million tons and the rest is about 28 million tons.

Table 1: Waste Paper Generation Recovery and Disposal
(Thousands of Tons, 1996)

Waste Stream and Material	Generated	Recovered	Disposed
Corrugated, Office Paper, and Newspaper	47,970	29,180	18,790
All other Paper included in MSW	31,960	3,430	28,530
Total	79,930	32,610	47,320

Tellus makes the point that, unlike corrugated, office paper, and newspaper which fetch $50 per ton and up, other paper, for example mixed residential as reported in Waste News, frequently costs as much as $30 per ton for disposal.

Wood in construction and demolition waste is another source which now costs money for disposal. Over 25 million tons could be used to replace coal.

Table 2: C&D Wood Waste
(Thousands of Tons, 1996)

	Generated	Recovered Or Unavailable	Available
Construction	4,207	474	3,733
Renovation	23,142	9,417	13,725
Demolition	16,506	9,496	7,010
Total	43,854	19,386	24,468

Land clearing debris is another source of wood. About 16 million tons may be available for replacing coal.

Table 3: Waste in Urban Wood Waste
(Thousands of Tons, 1996)

	Generated	Recovered	Available
Commercial Tree Care	9,628	2,449	7,179
Utilities	1,232	313	919
Land Clearance Contractors	735	187	548
Lawn/Garden Landscapers	9,871	2,510	7,361
Total	21,465	5,459	16,006

POTENTIAL IMPACT ON ELECTRIC GENERATION

Paper and wood currently going to disposal from MSW, C&D, and land clearing waste is shown in

Table 4 along with millions of kilowatt hours it could produce. 125 billion kWh is 6.7 percent of the electricity generated using coal in 1996.

Table 4: Electric Generation Possible by Co-firing Available Paper and Wood with Coal

Waste Stream and Material	Available Waste (Thousands of Tons)	Electricity (Millions of kWh)
MSW		
Paper	40,340	51,340
Wood	10,350	15,060
Wood from C&D Waste	24,470	35,590
Wood from Land Clearing Debris	16,010	23,280
Total	91,170	125,270

AT WHAT PRICE?

Relative to the Btu value of paper and wood, coal fired utilities could be expected to pay **between $8 and $16** per ton of wood or paper delivered to their utility. That compares with a fee at a landfill. In essence, one can offset processing and delivery costs by $8. Utilities can replace up to 2 percent of coal with paper or wood without major retrofitting.

WHAT ABOUT YARD TRIMMINGS AND FOOD WASTE?

Yard trimmings and food waste have about a third the Btu value of wood and paper. They are

Table 5: Properties of Waste Materials

Waste Material	Heating Values (Btu/lb)	Moisture Content (%)
Paper	7,000	6

Wood	8,000	20
Food Waste	2,000	70
Yard Trimmings	2,800	60

unlikely to be used as long as paper and wood are available.

WHAT'S IN IT FOR RECYCLING?

Suppose a MRF or a transfer station could be assured of a floor price for paper or wood of 8$ compared to a penalty of $30 for "unmarketables". A MRF could then add a shift to process mixed residential paper and, for material with a better price, sell it, while being assured of a floor price for everything else. A transfer station could accept wood or paper loads from commercial customers knowing that the worst they would do was a sale at $8 a ton. In essence, encouraging coal fired utilities to burn paper and wood would create a low risk environment for expanded recycling opportunities.

ENVIRONMENTAL IMPACT OF REPLACING COAL WITH PAPER OR WOOD

Emissions of carbon dioxide and sulfur would be reduced. Nitrogen oxides would also be reduced but particulates would increase. Organics would be reduced in landfills and indirect effects of mining coal would decrease. An initiative to replace 1 percent of coal usage with paper and wood would

Table 6: Emissions Reductions Due to Co-firing

	Carbon Dioxide (MMTCE)	Sulfur Dioxide (Gg)
Emissions Reduction Due to Co-firing	30.7	725
Total U.S. Emissions	1,471.1	17,339
Reduction as a Percent of U.S. Emissions	2.1%	4.2%

result in global warming savings of 4.6 million metric tons of carbon equivalent.

UNINTENDED CONSEQUENCES

Executive Order 13134 promotes use of biomass as alternate fuel. It might cost $80 per ton to replace coal with switchgrass. Subsidies of $80 per ton could make it attractive to burn materials currently recycled. This discussion assumes no subsidies.

LIME-STABILIZED SOIL FOR USE AS A COMPOST PAD

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Designing a successful compost facility requires consideration of several site and environmental constraints. The site must be far enough from area housing so that risks of dust and odor complaints are minimized. It must be close enough to necessary raw materials and a source of water so that its operation is economically feasible. Finally, the site must possess suitable characteristics(e. g. , slope, drainage, distance) to avoid pollution of local streams, groundwater and wetlands. The On Farm Composting Handbook (1992) states that a compost site should transport leachate and runoff from the site surface so that muddy conditions and odorous pools of standing liquid do not develop. One possibility is to place the compost site on a well-drained soil where distance to groundwater is greater than 5 ft. However, due to the long-term nature of a compost facility and the volumes of material processed yearly, an impervious surface that directs leachate to a treatment area would be more environmentally suitable than a well-drained soil.

Although an impervious pad is considered a luxury, there may be certain situations where regulations demand an impervious pad for which several options are now available. Besides concrete or asphalt, soil stabilization methods are available that produce a hardened, nearly impervious layer capable of supporting all the equipment normally located at a compost facility.

Although not a new concept, soil stabilization has been practiced more frequently in road construction due to excessive costs of aggregate. Depending upon the type of soil, stabilization can be accomplished with lime, lime-fly ash, Portland cement, asphalt or combinations of all. Experience at the Beltsville Agricultural Research Center showed that soil stabilization with quicklime produced a hardened surface that supported wheeled composting equipment 12 months a year (Fig. 1). An average of 10,000 yds^3 of organic by-products were composted annually for the last 3-and- half years at the Beltsville Agricultural Research Center Research Composting facility. The following is a description of the site preparation.

Figure 1. Beltsville Agricultural Research Center. Windrows cover the compost pad and an orchard grass buffer area is seen in the foreground.

SOIL STABILIZATION

Soil stabilization with lime achieves the dual goals of producing an impervious layer so water does not penetrate and a tough all-weather surface that allows vehicular traffic under all conditions. Lime-stabilized soil has a hydraulic conductivity similar to clays, i.e. 10^{-7} cm/sec., preventing leaching of soluble nutrients from composting mixtures through the soil profile. The lime stabilized soils which go through a 'curing' phase do not swell or shrink with changes in water availability and have a strong load-bearing capacity. Although most soils can be lime-stabilized, some soils are more easily stabilized than others.

Stabilization of Clay Soils

In soil stabilization with lime, clay soils (clay content greater than 10%) are chemically changed into a natural cement structure of calcium silicates/aluminates. When lime products are added to raise the pH of the soil above 11.5, clays become a gel. This silicate/aluminate gel reacts with calcium in the presence of water to form a calcium- silicate/aluminate glue (natural cement). This is a pozzolonic or cementing reaction (Fig. 2). The pH decreases from around 11 over several days as the mixture adsorbs atmospheric carbon dioxide and particles bind together into crystals forming a natural cement.

Figure 2. Transition of pad from the ripped soil with lime amendment (right), tilled soil to mix in lime and water (center) and rolled soil to form smooth pad surface (left)

Raising the pH of soils to above 11.5 requires a highly reactive lime product such as quicklime (Calcium Oxide -CaO) or hydrated lime [Calcium Hydroxide- $Ca(OH)_2$]. Ordinary agricultural limestone(Calcium Carbonate- $CaCO_3$) is not sufficiently reactive to raise the pH to 11.5, and thus is not a suitable substitute. Other industrial lime-containing products such as fly ash and carbide sludge may be suitable if the available Calcium Oxide Index (CAO) level is sufficiently high and availability, transportation and manipulation costs are economical. Even when these materials are free, their transportation costs and the additional soil manipulation required to achieve stabilization often makes them uneconomical.

Stabilization of Sandy - Silty soils

Soils containing less than 10% clay will need a source of silicates and aluminates to build the 'bridges' between soil particles for the natural cement to form. A source for these "pozzolons " is fly ash, a by-product of the coal burning power industry. Some fly ash has more reactive material than others and the source would have to be checked for suitable cementing characteristics. Sufficient fly ash to bring the pozzolon (clay) content above 10 % is needed.

CURING OF LIME-STABILIZED SOILS

Curing during soil stabilization is relatively slow in comparison to the quick setting time of Portland cement. The compacted mass must be kept damp so that the cementing processes and products are formed. Lime soil stabilization takes approximately one week under mild weather conditions after which the site can be used by vehicles. Stabilization and strength gain continue slowly with time called 'curing'. Because the process is slow, the natural cement formed is not as brittle as Portland cement-treated soils. It does, however, provide sufficient strength to meet load requirements. Ideally, one would work lime/soil mixtures at temperatures above 40 degrees F (2 degrees C) to assure that the natural cementing chemical reactions proceed. The site can be reworked within a few days or weeks using the same techniques if unforeseen problems like freezing weather occur during the construction process. Freezing weather affected the curing of the Beltsville pad, which was left uncovered. After two weeks when it was noted that curing was unsuccessful, the pad was tilled again, wetted, packed and rolled. The pad was covered with hay for insulation and allowed to cure for two weeks after which the first windrows were made (Fig. 3).

Figure 3. Photo of rototilling and roller equipment working in tandem to form lime stabilized pad. Steam is formed when quick lime and water come into contact.

POTENTIAL PROBLEM AREAS

A. Soil organic matter does affect the amount of lime needed to stabilize the soil, but in most cases it is not a factor. In most soils in the US, organic matter normally does not exceed 5 % and where organic matter is high, clay content will generally be low. Ideally, soils with less than 1 % organic matter stabilize the easiest. Similarly with more than 10 % clay, soils stabilize without fly ash amendments.

B. Soils with excess sulfate can also pose a problem, creating heaving of the compacted soil as it cures. However, if the soil/lime mixture is manipulated and compacted at about 5% above optimum moisture, the sulfates in the soil react during mixing, and form non-expansive, stable compounds, with no potential for heaving. If heaving occurs, the site can be re-mixed and compacted without further damage. Attention to these potential problems will insure a satisfactory project.

C. Soils with significant sodium or potassium carbonate content will react with the lime, forming sodium and potassium hydroxides in solution. The level of these salts may compromise the formation of natural cements. As a general rule, when encountering these soils, lime is added until the pH rise stabilizes. Then the soil-lime mixture is cured and formed into cylinders for un-confined compression testing. An increase in strength of 50 pounds per square inch (psi) over the untreated soil sample indicates that the soil is reactive with lime and stabilization is possible.

DETERMINING THE AMOUNT OF LIME NEEDED

Simple tests are available to determine the amount of quick lime or hydrated lime needed to form the stabilized soil natural cement. ASTM (American Society of Testing and Materials) Method C-977, addendum, outlines the Eades-Grimm pH test method, giving a simple method for determining the amount of lime needed to achieve stabilization of a particular soil. Briefly, it tests the amount of lime required to raise the pH of the soil mixture to pH 12.4 after a one-hour contact.

An extra test that may be of interest is the load bearing capacity - unconfined compressive strength - of the final mixture. This test determines the maximum weight of equipment that the site will bear. Specific engineering test equipment is required for this test which can be performed by geo-technical consulting companies. Alternatively, a small test pad can be constructed, cured and driven over with the equipment expected to be used. This is called a “pumping" test and is used by contractors to determine if the soil strength is satisfactory. This test assures that cementing products are formed.

SAFETY

Caution must be exercised when working with quicklime (CaO) because it generates very high temperatures when it comes in contact with water, and can cause burns on the skin and the eyes. The reaction with water is an exothermic (heat producing) chemical reaction process - forming Calcium hydroxide (hydrated lime) which is generally complete within about 30 minutes.

Alternatively, calcium hydroxide can be purchased to mix with the soil, but calcium hydroxide is less reactive than quicklime, requiring about 25% more material. However, it is safer to handle from the heat-generating aspect, but it is a dry powder and dusty and requires masks during the application. Though hydrated lime is safer to use, it is very dusty if used as a dry powder. The dry powder hydrated lime can be made into a slurry using water prior to application. A 30% solids slurry is made by mixing one ton of hydrated lime mixed with 500 gallons of water. The slurry needs to be kept in suspension while applying it to the soil. When using quicklime or hydrated lime, goggles, gloves, and a simple dust mask should be utilized for personal safety. A sufficient supply of clean water should be available for washing the skin and eyes, if necessary.

ECONOMICS

Soil stabilization is generally more economical than the cost of concrete built to bear the same weight. The minimal equipment needed to stabilize soils for a compost pad include a front-end loader to apply the lime amendments, a roto-tiller to mix the ingredients, a means of applying water to begin the reaction, and a roller to pack the surface. The cost of lime stabilizing the 77,000 sq. ft site for composting at Beltsville was approximately $0.50 per sq ft. This cost was based on a commercial company using road equipment to stabilize the pad. An estimate for a reinforced concrete pad six inches thick was approximately $1.80 sq. ft. Economies of scale reduce the cost of both methods. In 1994, The Kentucky Department of Transportation estimated a cost of $0.25 square ft for lime stabilization of 500,000 sq yds.

SINGULARITIES TO BELTSVILLE PAD

The initial mixture added to the soil at the Beltsville site contained fly ash. In retrospect, this fly ash was not needed. It was added as part of the effort at Beltsville to promote sustainable systems by using recycled by-products. Portland cement was donated to the Research Center and also put into the mixture, but it also was not a necessary ingredient for lime stabilization of the site which was located on a Christiana clay soil. It is difficult to determine what effects fly ash and Portland cement had on the final characteristics of the pad. However, an addition was made to the circumference of the pad in 1998 using just quick lime and the performance of the addition is no different than that of the original pad.

RECENT EXPERIENCES

The University of Maryland farm at Clarksville, MD enlarged their compost pad area made from concrete (actually an old barn floor) with a lime-stabilized pad. Our compost pad was enlarged about 15% to accommodate new research projects. The same technique as the original construction was used except that only quicklime was used. As mentioned earlier, the performance of the new and old pads are similar. Repair of a ‘sink’ holes was done by excavating the area to a depth of around 12 inches, mixing the excavated soil plus additional clay brought in from an outside source with quicklime, adding water, mixing the ingredients on the pad and placing the mixture into the hole. The tractor tires leveled the lime-clay mixture into place. After a few weeks of curing, the repaired area was ready for use.

CONCLUSION

Soil stabilization techniques are a suitable, affordable alternative to asphalt or concrete pads. Testing of soil to determine its suitability for lime stabilization and locating the necessary materials and equipment for stabilization are requirements for investigating the use of soil stabilization at a location. The benefits of soil stabilization is cost, endurance and repair ability.

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Footnote: Mr Francis served as Technical Manager for the National Lime Association from 1989 to 1997.

IMPROVING COMPOSTING BY CONTROL OF THE SOLID MATRIX STRUCTURE

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INTRODUCTION

Food processing is a major industry that is rapidly growing because of a demand for packaged foods in urban areas. In Atlanta, Georgia, several food processors are in the business of packaging fresh salads for grocery stores. These companies have large processing facilities where vegetables, such as lettuce, cabbage, carrots, onions etc. are cleaned, chopped, mixed and packaged. In a typical operation, the amount of wastes generated equal in quantity (by weight) to the amount of product shipped. Presently, these wastes are land disposed or landfilled. Vegetable wastes do not provide any known concerns relating to pathogens or human health issues, however, they are prone to potential odors during decomposition and are expensive to dispose because of of their high moisture content leading to high landfill tip fee and transportation cost. Composting vegetable wastes, McGuckin et al. (1999) reported that the sulfur content of lettuce and onion wastes were 0.2 and 0.7 %, respectively. Discarded components of lettuce and onions have an effective carbon to sulfur ratio of 215 and 63, moisture contents of 96.2 and 91.1% and carbon to nitrogen ratios of 10.3 and 11.5, respectively. The low C/S ratio of onions indicates that mixes with high fractions of onions can result in release of odorous sulfur compounds. High water content, most of which is bound within the vegetable fiber, results in significant leachate formation during composting and collapse of the composting matrix from initial height of e.g. 1.5 m to a lower value of e.g. 0.5 m resulting in reduction in air space and oxygen availability within the pile. Each of the phenomena discussed above potentially result in increasing the amount of odors released and therefore negatively affecting the composting process.

The physical properties of food wastes and the factors that affect their performance in composting require us to identify reliable methods to compost them. The standard method of composting with an organic amendment such as sawdust and an organic bulking agent such as bark may not be the most appropriate. In this project, we evaluated the use of synthetic (plastic) bulking agents while composting these food wastes. The presence of plastic bulking agents is expected to maintain the structure of the composting matrix, thereby preventing large reduction in porosity during composting. This is expected to provide a more rapid composting with relatively lower production of odors. In addition the synthetic bulking agents could be recovered and reused for subsequent composting trials thereby reducing the cost of bulking agents.

The objective of this work was to compare use of a plastic bulking agent with pine bark nuggets using three criteria: (1) Environment of composting, i.e. Oxygen level and temperature inside the compost pile; (2) Quality of final product and (3) Odor reduction.

MATERIALS AND METHODS

Food wastes were obtained from a commercial salad packing company. The salad packing wastes were previously characterized at the University of Georgia Bioconversion Research and Education Center (McGuckin et al., 1999) and some information on properties and behavior were known. Two bulking agents were evaluated, namely, (1)Pine bark with average size of 4.5 cm, void volume of 78% and bulk density of 136 kg/m^3 and (2)Synthetic packing media with the following characteristics, 5-cm saddles, void volume of 94% and bulk density of 50.5 kg/m^3.

Compost feedstock was brought to the research center, weighed and placed on a large concrete floor. Sawdust, obtained from a neighboring sawmill, and the two bulking agents were also weighed and placed on the concrete floor. Three samples of 3 L each were obtained from each of the feedstocks for analysis. Then, a portion of food waste was weighed and placed on a separate pile, followed by addition of sawdust and the bulking agent (Table 1). Once a pile was constructed, the materials were homogenized using a bucket loader for a period of 15 minutes and three samples of 3 L each were obtained from each mix. Thereafter a pile of homogenized materials was constructed such that it had a height of approximately 1.2 m (4 ft) and was covered using a Compostex® compost cover. The compost cover was used to prevent infiltration of the piles by rainwater. In this manner each of the piles were created. Two trials were conducted, trial 1 began on Jan 1999 and ended in April 1999 and trial 2 started and ended in April and July 1999. After the end of each trial, samples were obtained for analysis of physical and chemical properties of the product.

During the composting trial, temperature of the pile was measured weekly using a 1.2 m long stainless steel cased thermometer (Reotemp® Inc.). Temperature was measured at a point that was visually located to be the center of the pile at a depth of 0.6 m from the surface. After the measurement of temperatures, a 1.2 m stainless steel gas-sampling probe was inserted to the same location and the oxygen concentrations of the gas within the pile were measured. The sampling probe was removed and reinserted to approximately the same location and a sample gas was extracted to measure the concentration of odorous gases, namely, ammonia, dimethyl sulfide, hydrogen sulfide and total mercaptans. Each of the gas measurements was conducted one after the other without removal of the probe. Measurements were performed using the field gas detection tubes manufactured by Drager Inc. After temperature, oxygen and gases were measured in the piles, the piles were homogenized using a bucket loader. After sufficient mixing, three samples 3-L each were removed from the center of the pile and placed in a plastic sealable bag. The samples were taken to the laboratory within a period of 4 hours.

Moisture content was evaluated by drying in a forced draft oven at 75°C until constant weight. After complete drying approximately 500 g was sampled and finely ground to an approximate diameter of 0.5 mm. A 50-g sub-sample from the ground dry sample was used for total carbon and nitrogen analysis using a Leco® Carbon-Nitrogen-Sulfur analyzer. The pH and soluble salt content (measured as electrical conductivity, EC) of the sample were measured using a 1:2 (v/v) sample to deionized water extract. The ground sample (20 ml) was mixed with 40 ml of deionized water, allowed to equilibrate for 30 minutes with occasional stirring with a glass rod. The resulting solution was filtered through a Whatman No 4 filter paper and used for direct measurement using an Acumet 50 pH/EC meter (U.S. Composting Council, 1997).

The stability index (SI) of the compost product was measured using the procedure described by Iannotti et al (1993). A sample of material was obtained and standardized for particle size (<9.5 mm) and moisture content (50%), and incubated (37°C) for 16 hours under aerobic conditions to build the microbial populations to an active standard level. A 60-g sample of the incubated material was placed in an aerated respirometric flask at constant temperature in a water bath (37°C) for one hour. The aeration source was removed and oxygen concentration inside the flask was monitored every five minutes for a period of one hour. The change in oxygen concentration in the flask was used to calculate a consumption rate in mg(O_2)/g(volatile solids)/hr. This rate of oxygen consumption under standard conditions of particle size, moisture, temperature, aeration and incubation depends only on the amount of substrate availability. Greater substrate availability results in higher oxygen demand indicating that the sample is biological unstable, i.e. the sample is continuing to degrade. Organic compost with a SI less than 1.0 mg/g/hr is considered stable and 1.0-1.5 mg/g/hr moderately stable. Unstable composts typically exhibit SI greater than 2.0 mg/g/hr (Epstein, 1997).

Two treatments were evaluated in trial-1, namely, vegetable waste, sawdust and bark as bulking agent in a mix of 28.5-27.2-44.3% (dry basis) and vegetable waste, sawdust and synthetic bulking agent in a mix of 40.4-39.1-20.5% (dry basis). Initially each treatment was replicated three times to provide six total windrows for monitoring. However, because of significant volume reductions resulting in very small size windrows, the three windrows of each treatment were combined to form one windrow per treatment toward the end of the trial (March 17). Trail 2 utilized similar treatments to Trial 1, with the amount of bulking agent reduced. The two treatments evaluated were vegetable waste, sawdust and bark as bulking agent in a mix of 36.7-44.3-19.0%(dry basis) and vegetable waste, sawdust and synthetic bulking agent in a mix of 41.9-50.7-7.4%(dry basis). Specific weight fractions in windrows are shown in Table 1.

RESULTS AND DISCUSSIONS

Initial moisture contents in the mixes in trial 1 were 84.1 and 88.2 %. These levels are higher than typically encountered in composting (60-70%), however it would require a large amount of amendment (sawdust) to reduce this moisture and the physical structure of the windrow did not require this. As a result of leachate release and moisture reduction by drying, the final moisture contents were 65.2 and 56.3 % for bark and synthetic bulking mixes, respectively. Final compost had a stability index of 0.215 and 0.248 mg/g/hr (Table 2). These results suggest that end product at the 78th day of composting show no significant difference between the two treatments. After this period both the composts have reached the same level of stability and quality. The final nitrogen and phosphorus contents of the two products were also very comparable at approximately 1 and 0.2% (Table 2), respectively. The germination index, a measure of how well plants would grow in this compost indicates that the final compost product demonstrated very good plant growth characteristics.

The process of composting, however, followed a different path, especially in the first 30 days. The temperature (Figure 1-A) of the bark amended mix increased rapidly to over 45°C, whereas the synthetic amended mix only reached a maximum of 25°C. Moisture was not a limiting factor (data not shown) as both treatments had very similar moisture levels that decreased at similar rates. The lower temperatures in the synthetic amended mix were likely a result of addition of excessive bulking agent. In the month of January, the ambient outside temperature were typically in the 2-8°C range and having a pile with excess air space resulted in an inability to maintain a critical thermal mass. The rate of heat generation was almost equal to that being removed from the synthetic amended pile. The extremely high oxygen levels (over 18%) in synthetic amended piles also confirm this possibility during trial 1 (Figure 1-C).

Ammonia release from the two treatments was very comparable, with slightly higher levels seen in the synthetic amended windrows (Figure 2-A and B). Ammonia release was highest at about the 15th day, before which there was negligible release and after the 15th day the release steadily decreased till about the 45th day. In contrast, the release of dimethyl sulfide was clearly higher in the bark-amended mix. There appears to be an initial release in the first 15 days and a second release around the 35-40 day of composting in the bark treatment. In the synthetic treatment the concentrations were about three fold lower and was present only in the first 15 days. Only trace amount of hydrogen sulfide and mercaptans were measured. Possibly due to the sampling frequency adopted in this study being too sparse (once a week or less).

From the results of trial 1, it was concluded that the rate of bulking agent would have to be reduced to obtain more self-heating and better decomposition. Therefore trial 2 consisted of different ratios of mixing the vegetable waste-sawdust-amendment (Table 1). Initial moisture contents in the mixes (Table 2) were 81.5 and 84.6 % for bark amended and synthetic amended mixes, respectively. Over the period of composting, because of leachate release and moisture reduction by drying, the final moisture contents were 56.8 and 58.1 % for the two treatments, respectively. Final compost had a stability index of 0.175 and 0.172 mg/g/hr, indicating that better stabilization was achieved in approximately the same time (86 days vs. 78 days). As in trial-1, these results show that end product at the 86th day of composting show no significant variation between the two treatments. The final nitrogen and phosphorus contents of the two products were lower than in trail-1 at approximately 0.5 and 0.1%. The lower nitrogen levels were possibly a result of more nitrogen volatilizing because of higher temperatures in this trial compared to the previous.

Temperatures observed in trial 2 (Figure 1-B) were in the range expected for good composting (60-70°C). Both mixes followed a similar pattern with peak temperatures reached in the 10-20 day range. As earlier, the synthetic amended mix had a lower temperature because of higher porosity and better aeration. However, the temperature of 60°C reached can be considered acceptable and this amount of bulking agent addition can be recommended. Moisture content in both treatments were very similar and decreased at similar rates from initial values over 80% to final values around 60% at the 80th day. The temperature profile showing no significant change after the 30th day indicates that in this system of composting, most of the biological activity was completed in the first 30 days. The small increase of approximately 5°C (from 30 to 35°C) over the 40 to 60 day period is not significant to indicate that the material is unstable. Oxygen levels inside the windrows dropped to below 6% in the bark-amended mixes, indicating potential anaerobic conditions (Figure 1-D). In contrast, the synthetic amended mixes had a lowest measured oxygen level of over 12%. This indicates that the rate of bulking agent addition is within the range to achieve our goal of maintaining a solid matrix that remains porous while supporting good composting. The steady level of windrow oxygen levels (15-18%) after the 30th day also shows that biological oxygen demand has reduced suggesting stability. As in trial 1, almost no hydrogen sulfide or mercaptans were detected in this trial (Figure 2-C and D). The only measurable gas readings were ammonia and dimethyl sulfide. Ammonia release from the two treatments was very comparable, with bark amended mixes releasing ammonia at higher rates initially (10-20 days) and rapidly decreasing thereafter, whereas the synthetic amended mixes releasing maximum ammonia at the 10^{th} day and then gradually decreasing till the 40^{th} day. Following the 40^{th} day there was almost no measurable ammonia. Peak levels of ammonia measured inside the pile were 450 ppm in the bark mixes and 320 ppm in the synthetic amended mixes. These are very high levels of ammonia and support the reason for the lower nitrogen content of these treatments compared to trial-1. The release of dimethyl sulfide was clearly higher in the bark-amended mix compared to the synthetic amended mixes. As in trial 1, there appears to be a bimodal release, with an initial release in the first 10-15 days and a second release around the 40^{th} day of composting in the bark treatment. Although this phenomenon was observed in both trials, at this time we have no explanation for this. In the synthetic treatment the concentrations of dimethyl sulfide measured were about three to four fold lower than in the bark amended mixes.

EFFECT OF RATE OF BULKING AGENT ADDITION

In trial 1, we used a high rate of bulking agent addition, namely, 44.3% bark and 20.5% synthetic bulking agent in the corresponding treatments. This rate of bulking was found to be excessively high as the temperature profiles of the two treatments were significantly lower than that in trial 2 (Figure 1). In order to achieve good composting structure, a critical mass of material is required that will provide enough porosity that air will enter the pile through natural convection at a rate sufficient to replenish oxygen. In the case of trial 1, too much air entered the pile resulting in excessive cooling.

The addition of a lower amount of bulking agent in trial 2, namely 19% bark and 7.4% synthetic bulking agent resulted in a more favorable environment indicated by the higher temperatures. In both amounts of bulking agent addition, the bark amended mix reached oxygen levels of below 6%. This level is considered in the potentially anaerobic region, as pore space concentration of 6% oxygen results in a low gradient to provide sufficient mass transfer from the gas phase to the biofilm. Therefore a greater portion of the windrow would be under anaerobic conditions. The synthetic amended mix at the lower rate of addition (Figure 1-D) maintained over 12% oxygen levels in the pile at all times. This leads us to conclude that the rates of bulking in trial 2 can be recommended for these type mixes. Also, the use of synthetic amendment achieved its goal of maintaining an aerobic structure.

With regard to gases released during composting (Figures 2) there was an indication that the release of dimethyl sulfide and ammonia were higher in the bark amended treatment. The lower bulking agent rate (Trial 2) resulted in greater amounts to odor release, probably due to the higher levels of activity seen. The data also suggests that ammonia release was higher in the synthetic amended treatment and dimethyl sulfide release was higher in the bark amended treatment, however, this would have to be confirmed with more controlled testing.

KEY CONCLUSIONS

The following are a set of conclusions from this study. These can be used as recommendations or cautionary notes to persons who are designing food waste composting facilities in the future.

1. A bulking agent rate of 6-7% by dry weight of synthetic bulking agent (or 17-19% bark) in the mix is sufficient for maintaining an aerobic solid matrix.
2. Addition of bulking agent in excess of rate noted in (1) results in reduction of biological activity. A lower rate (e.g. 5% by dry weight of synthetic bulking agent) may be acceptable as this rate provides for processing of larger amount of the composting feed stock.
3. Most of the biological activity (based on temperature) was completed in the first 40 days. Thereafter, the compost was cured to reach a high level of stability and maturity at the 78^{th}-96^{th} days. These time frames are recommendations that can be used in facility sizing.
4. In salad waste composting, moisture control was not an issue. The initial moisture was higher than desirable, however this did not retard the composting process. At the end of composting the moistures were in the acceptable ranges of 50-60% for a good product. No addition of water was required.
5. The final compost from the salad waste had C-N-P concentrations of 45-1-0.2 %(dry basis). The product can be considered biological stable (Respiration Index 0.175-0.2 mg/g/hr) and having no phytotoxic properties (Germination Index 87-100%).
6. Final soluble salt content and pH from all trial ranged was 1.7-2.9 dS/m and 7.4-8.5; these are within limits considered acceptable for use as a soil amendment.

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4. Jaeger Product, Inc., Houston TX, for assistance with acquiring synthetic bulking agents for the study.

Table 1. Initial feedstock and mix properties during composting.

	Food waste	Sawdust	Bark	Synthetic
		Trial 1[1]		
Wet weight of each component, lbs	2691.7	270 .0	288.3	
Initial Moisture content, %	94.0	43.1	13.0	
Percentage in mix (wet basis)	82.8	8.3	8.9	
Percentage in mix (dry basis)	**28.5**	**27.2**	**44.3**	
Wet weight of each component, lbs	2578.3	263.3		78.3
Initial Moisture content, %	94.0	43.1		0.0
Percentage in mix (wet basis)	88.3	9.0		2.7
Percentage in mix (dry basis)	**40.4**	**39.1**		**20.5**
		Trial 2[2]		
Wet weight of each component, lbs	6613.3	995 .0	235 .0	
Initial Moisture content, %	94.1	53.0	14.6	
Percentage in mix (wet basis)	84.3	12.7	3.0	
Percentage in mix (dry basis)	**36.7**	**44.3**	**19.0**	
Wet weight of each component, lbs	6191.7	935.0		63.8
Initial Moisture content, %	94.1	53.0		0.0
Percentage in mix (wet basis)	86.1	13.0		0.9
Percentage in mix (dry basis)	**41.9**	**50.7**		**7.4**

[1] Trial 1 – Bulking amount = 214.2 lbs(pine bark)/ton(vegetable waste); 60.7 lbs(synthetic bulking)/ton(vegetable waste); Sawdust = 0.10 lbs(sawdust)/lbs(vegetable waste)
[2] Trial 2 – Bulking amount = Pine bark bulking agent rate = 71.1 lbs(pine bark)/ton(vegetable waste); 20.6 lbs(synthetic bulking)/ton(vegetable waste); 0.15 lbs(sawdust)/lbs(vegetable waste)
[3] Each treatment was replicated in three windrows of approximately similar sizes. All data reported in the table are averages of measurements from three different windrows.

Table 2. Changes observed during composting.

Initial properties (Day 0):	**Trial 1**		**Trial 2**	
	Bark	**Synthetic**	**Bark**	**Synthetic**
Moisture content, %	84.1	88.2	81.5	84.6
Carbon content, %	44.9	43.9	46.1	46.8
Nitrogen content, %	1.92	2.21	0.86	0.98
C/N ratio	23.4	19.9	54.3	48.6
Final properties	**(Day 78)**		**(Day 86)**	
Moisture content, %	65.2	56.3	56.8	58.1
Nitrogen content, %	0.98	1.07	0.51	0.51
Phosphorus content, %	0.18	0.22	0.13	0.16
Respiration Index, mg/g-VS/hr	0.215	0.248	0.175	0.172
Germination Index, %	100	100	87.4	90.7
pH	7.4	7.9	7.9	8.5
Soluble salts (EC), dS/m	1.8	2.3	1.7	2.9

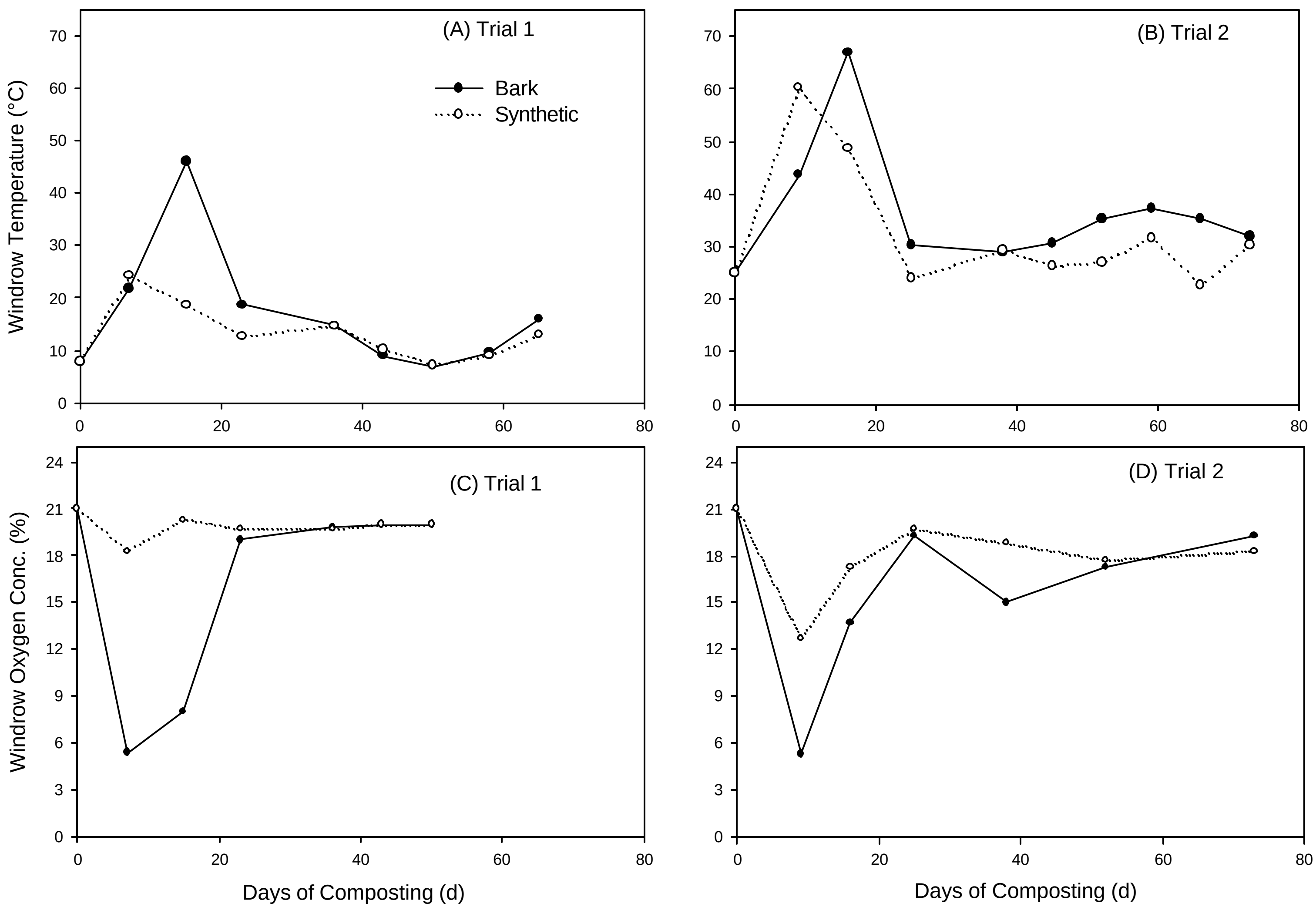

Figure 1. Comparision of composting performance when using bark and synthetic bulking agents. Response based on temperature (A, B) and oxygen concentration (C, D).

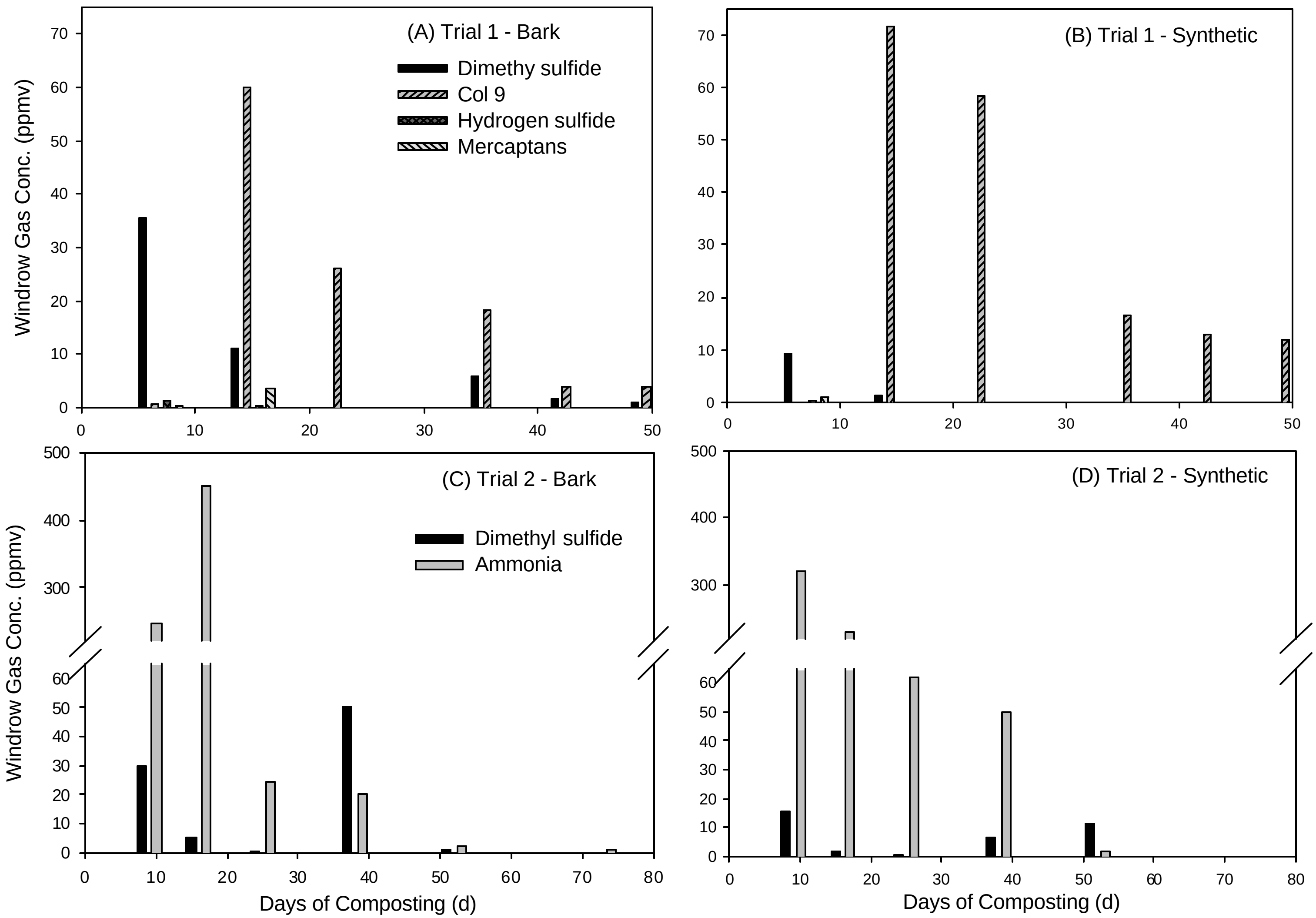

Figure 2. Comparison of composting performance when using bark and synthetic bulking agents. Response based on odorous gases. All data are averages of three readings in each of three windrows.

Evaluation of Aerated Container Composting of University Preconsumer and Postconsumer Food Waste

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ABSTRACT

Composting of food waste generated from the University of Georgia's cafeterias was evaluated using an agitated aerated composting system. The goal of the project was to determine if all of the University's food waste could be recycled using six Earth Tubs. Secondary evaluations investigated the amount of leachate produced, odor generated, speed of composting, quality of compost, cost savings to the University, and amount of waste diverted from the Clarke County Landfill. Three mixes of food waste and yard waste were evaluated, namely 1:2 (food waste to yard waste) 1:1 and 2:1. Temperature, percent oxygen, moisture content, compaction rates, and aeration rates were monitored in order to compare composting strategies. Temperatures exceeded 55 degrees C for more than 72 hours to ensure pathogen reduction. Total contaminants and human-made inerts averaged 0.5%. A ratio of 2:1 was determined to work best under experimental conditions. Ammonia (NH_3) concentrations peaked at 560 ppm. Leachate production was highest in the 2:1 mixture generating 117 liters for the duration of the study.

INTRODUCTION

In 1990, 13.2 million tons (11.88 billion kg.) of food waste amounting to nearly 7% of the municipal solid waste stream was landfilled in the United States (US-EPA, 1993). As demands on landfills increase, tipping fees continue to climb, and valuable resources are wasted, the University of Georgia's Engineering Outreach Program of the Department of Biological and Agricultural Engineering is experimenting with ways to reduce waste and prevent pollution. At the Bioconversion Research and Education Center on the University of Georgia (UGA) campus a pilot study was initiated in the fall of 1999 to begin recycling pre and postconsumer food wastes. The study involved all four of the university cafeterias which produce 19,000 meals a day. The paper reports on a pilot study of all food waste (preconsumer and postconsumer) produced from the University of Georgia's cafeterias for four days.

The objectives of this study were: 1) to determine if the agitated aerated composting system can be used to recycle all the universities food waste; 2) evaluate the speed and function of the agitated aerated system; 3) evaluation of mixing ratios to asses their impact on the composting process; 4) determine the amount of leachate produced per unit volume of food waste; 5) evaluate odor levels based on ammonia and hydrogen sulfide concentrations; 6) to determine if the system meets the US-EPA temperature requirement to eliminate plant and human pathogens; and 7) to determine air flow rates based on amount of food waste in an in-vessel system. The paper reports on a pilot study of all food waste (preconsumer and postconsumer) produced from the University of Georgia's cafeterias for four days

In 1998 the total throughput of composted food residuals totaled 230,000 tons (Goldstein, Glenn, Gray, 1998). This included 250 food waste composting projects nationwide, with 187 in full scale operation, 37 pilot projects, and 26 in development (Goldstein, Glenn, Gray, 1998). Of the 250 projects, 115 were on-site institutional projects, 10 were university pilot projects, 7 were full scale university operations, and 1 was located in the state of Georgia (Goldstein, Glenn, Gray, 1998). On site composting systems at universities may be the fastest growing area of food service composting (Kunzler, Roe, 1995). A University of Maine study demonstrated that an in-vessel compost system can reach required temperatures faster than open windrow systems, as well as decrease the likelihood of vectors including odors (Donahue, Chalmers, Storey, 1998). In addition, growing numbers of cafeterias and restaurants are installing pulpers for volume reduction and to create a feedstock for composting (Kunzler, Roe, 1995). A 10% decrease in initial food waste moisture content can result in nearly half as much compost, which may be of greater importance to groups who are more interested in waste reduction rather than marketing the final product (Lowe and Bockmaster, 1995). A recent study at a midwestern university found the total cost in disposal fees for service waste at one cafeteria including water, energy, and sewer (excluding tipping fees) was $3,582 a year. If local landfill tipping fees ($35) are included with the estimated total weight of food waste generated by a university the size of UGA (1,122 tons), annual tipping fees would be $39, 287.

MATERIALS AND METHODS

System Description

The aerated composting containers are designed to hold 3.5 cubic yards of compost (Green Mountain Technologies, 1998). The design of the Earth Tubs includes a 2 horsepower auger for mixing feedstocks and a blower for forced aeration. The container is a circular tapered fully enclosed tub that is four feet deep. The base of the tub is 64 inches and the lid is 89 inches in diameter. It is made of durable double walled plastic with polyurethane foam insulation. Feedstock is loaded through a hatch on the lid as the vertically mounted auger mixes the incoming material. While the auger itself is motorized, it is manually rotated around the tub and from center to outer edge. Compost is removed manually through two trap doors on opposite sides of the tub. The aeration system pulls air through the compost from the top and is discharged from the tub after passing through a perforated floor chamber. The floor chamber also collects leachate and discharges it through the same aperature as the blower. Two temperature thermisters per tub were connected to a central computer that monitored temperature in the middle of the pile and outer portion of the pile.

Feedstocks

The university food waste was a mixture of preconsumer and postconsumer food waste at the time of collection. University Food Services pulps the food waste at the cafeteria before it is discarded into a separate dumpster. The pulping process removes between 10% and 20% of the moisture content from the food waste. The University Physical Plant collected the food waste and transported it to the University of Georgia Bioconversion Research and Education Center. The food waste was dumped on a concrete pad and immediately weighed and loaded into the three compost containers.

Yard waste from the university was used as the bulking agent. The yard waste consisted mainly of chipped stems and leaves. The three containers were partially loaded with yard waste prior to delivery of the food waste.

Mixing Ratios

Initially, three recipes were selected for investigation. These included volumetric mixing ratios of 1:1 (food waste : yard waste), 2:1, and 1:2. Table 1 provides analytical information on the raw substrates prior to mixing. Each of these ratios were expected to maintain appropriate C:N ratios (30:1) and moisture contents (60%) (Lowe and Buckmaster, 1995). Incoming food waste was loaded in the aerated containers over four days. Table 2 shows the mixture ratios and actual composition of each container.

Table 1: Selected Properties of Food Waste and Yard Waste

Material	Food waste	Yard waste
Carbon, %	51.3	50.2
Nitrogen, %	5.7	1.1
Sulfur, %	0.4	0.1
C:N	10:1	50:1
Moisture, %	70.9	52.8
Bulk Density (wet) kg/m^3	760	358

*Moisture content of un-pulped food waste is 80-90%

Table 2: Target and Actual Mixing Ratios (food waste: yard waste), and Initial Contents of Aerated Containers

	Container 1	Container 2	Container 3
Target Ratio	2:1	1:2	1:1
Actual Ratio by weight (kg)	1:1.3	1:4.3	1:2.3
Actual Ratio by volume (L)	2:1.1	1:1.8	1:1

C/N Ratio	24.3	35.7	30.0
Moisture content, %	61.83	59.24	64.43
Total weight (kg)	1623.5	1361.6	1530.2
Total volume (L)	2611.3	2736.4	2668.2
Total food waste (kg)	1286.9	758.3	1074.5

Process and Procedures

Once the containers were filled to capacity based on individual mixing ratios the raw ingredients were mixed using the auger. The containers were kept inside a building to limit extreme ambient temperature fluctuations. Each aerated container had two thermisters that were inserted into the compost pile. One was placed in the center of each pile, the other was placed in the outer portion of the pile. The thermisters measured temperature readings every 5 minutes and were connected to a Central InterfaceUnit that logged and graphed the readings. Each container had a 10 watt blower that provided forced aeration to the compost. The blowers were continually run at maximum power unless the compost seemed to dry too quickly at which point the blowers were turned off until moisture and temperature levels returned to optimum levels. The aeration rate was based on recommendations provided by the manufacturers of the containers. A 2 inch PVC pipe was attached to the blower to monitor air flow rates and air velocity rates. A 5 gallon (18.95 L) bucket was attached to the PVC pipe to collect and measure leachate quantities.

Each container was mixed twice a week. Leachate quantities were measured using a graduated cylinder (leachate was measured daily for the first two weeks and less frequently thereafter). Compaction rates were monitored by measuring the height of each pile in three locations before each agitation and after each agitation. Percent oxygen inside the compost matrix was measured prior to agitation by using a portable O_2 analyzer with a stainless steel probe. Readings were taken from the center of the pile and from the blower discharge pipe. Air velocity and air flow rates were measured from the center of the PVC pipe attached to the blower using a hot-wire anemometer. Following this, each pile was turned using the motorized auger. After agitation Drager tubes were used to measure ammonia (NH_3) and hydrogen sulfide (H_2S). Gas readings were taken from the discharge pipe of the blower. Finally, a sample from each pile was obtained and oven dried to estimate moisture content. If moisture content fell below 40% water was added to the pile while agitating. Enough water was added to increase the moisture content to 60%.

Once temperatures decreased to ambient levels composite samples were taken for physical, chemical, and agronomic analysis. The compost was removed from the containers, weighed, and screened to remove contaminants like plastic film. Finally, the compost was put outdoors and covered for stabilization. The finished compost will be land applied in demonstration plots at UGA's Bioconversion Research and Education Center.

RESULTS AND DISCUSSION

Temperatures and Pathogen Reduction

All three mixes reached temperatures in excess of 55 degrees C (Figure 1) for three days to ensure reduction of human pathogens (EPA, 40 CFR Part 503). Temperatures fluctuated with moisture content and aeration. When moisture contents fell below 35%, temperature levels decreased significantly. Forced aeration was continual for the first 16 days and then ceased because of excessive drying. Moisture contents stabilized and temperatures increased immediately after blowers were turned off. All three mixes maintained ambient temperature levels after 73 days. The 2:1 treatment experienced temperatures at or above 55 degrees C, more frequently than the others, for 29 days in total. The 1:1 maintained temperatures at or above 55 degrees C for 21 days. Temperatures fluctuated quite drastically between the center and outer edges of the piles. The center heated faster, however the outer portions of the pile maintained heat longer. This may be due to drying effects occurring more rapidly at the center of the pile. Figure 1 shows the average daily temperatures for container 1 (all three containers were similar).

Weight and Volume Reduction

All three experiments exhibited 75 to 80% wet weight reduction from beginning to end with container 1 demonstrating the greatest weight reduction (Table 3). Container 3 showed the greatest volumetric reduction at 61%. All three experiments had volumetric reductions between 55 and 61%. Container 1 had the heaviest mixture but produced the lightest compost.

Table 3: Total Weight and Volume Changes After Composting

	Container 1	Container 2	Container 3
Initial (wet)	1623.5 kg/ 2611.3 L	1361.6 kg/ 2736.4 L	1530.2 kg/ 2668.2 L
(dry)	487.1 kg/ 783.4 L	544.6 kg/ 1094.6 L	535.6 kg/ 933.9 L
Final (wet)	321.9 kg/ 1114.3 L	344.5 kg/ 1224.2 L	373.5 kg/ 1034.7 L
(dry)	231.8 kg/ 780.0 L	244.6 kg/ 869.2 L	190.5 kg/ 527.7 L
% Reduction (wet)	**80.0% / 57.4%**	**74.7% / 55.3%**	**75.6% / 61.2%**
(dry)	**52.4% / 0.1%**	**55.1% / 20.6%**	**64.4% / 43.5%**

Water Additions

Water was added to a container if the moisture content fell below 40%. Container 1 only required one moisture amendment, while the other two containers required three (Table 4). This was probably due to the higher initial moisture content due to the use of a greater amount of food waste in the treatment. Container 3 required the most water over the duration of the study at 1363.95 kg compared to 815 kg and 664 kg for containers 2 and 1 respectively. Figure 2 indicates the moisture content fluctuation of each reactor.

Table 4: Water Added to Containers during Composting

Date	Container	*Amount (Kg.)	% Increase
12/16/99	2	271.8	**21%**
1/3/00	3	600.8	**39%**
1/5/00	2	241.6	**20%**
1/13/00	3	457.2	**32%**
1/24/00	2	271.8	**18%**
1/27/00	1	664.2	**45%**
2/10/00	3	306.0	**18%**

*Water additions are based on faucet hose dispensing 16.65 kg/min.

Leachate Production

All three experiments produced leachate ranging from 35 liters in container 2 to 117 liters in container 3 (Table 5). Most leachate was produced in the first week with virtually none produced after two weeks (Figure 3).

Table 5: Leachate Production Totals from Food waste

Container	Food Waste	Leachate Produced	kg (food waste)/L (leachate)
1	1286.9 kg./ 1625.9 L	**117.43 L**	**13.85: 1**
2	758.3 kg./ 970.2 L	**35.69 L**	**27.18: 1**
3	1074.5 kg./ 1334.1 L	**73.82 L**	**18.07: 1**

Odor Production

Odor problems were persistent on all reactors. Hydrogen sulfide (H_2S) monitoring stopped after 21 days because of no detectable concentrations. Container 1 produced the most ammonia and was often difficult to work with (Figure 4). This was probably caused by the higher moisture content. Ammonia levels decreased over time. After the first month odor levels decreased dramatically but increased with moisture additions.

Oxygen, Air flow rates, and Compaction

Percent oxygen in the exhaust air remained near ambient concentrations (21%) throughout the study with occasional low readings near 18% oxygen. Air flow rates through the containers decreased over time as the feedstocks broke down decreasing pore space (Figure 5). Air flow rates stabilized after the first month of composting. Compaction rates were fairly uniform between the three treatments with all decreasing in height of pile by nearly 15 inches from start to finish.

Selected Physical, Chemical, Agronomic, and Human-made Inerts Analysis

Table 6 shows a detailed comparison between the feedstocks and the cured compost. Human made inerts levels were measured according to U.S. Composting Council recommendations using a 4mm sieve. Inerts were lowest in Container 2 at 0.4%. All three compost mixtures met the recommendation of total human-made inerts under 1.5% of the total dry weight of the compost (U.S. Composting Council, 1996). Identified inerts included straws, condiments packaging, candy wrappers, gum wrappers, glass shards, and plastic shards. Table 6 also compares bulk densities, moisture contents, nutrient levels, pH, and C:N ratios for the feedstocks and the cured compost.

The nutrient content of the 2:1 mixture was greater than the other two treatments especially with plant available nitrogen and calcium. Soluble salts are also significantly higher in the 2:1 mixture, probably due to the high salt content of processed foods. All three mixtures exceeded the Georgia Department of Agriculture's soluble salt standards for horticultural grade compost. The C:N ratio for the 1:2 mixture is also above recommended levels for quality compost.

Table 6: Analysis of Feed stocks vs. Compost

	FOOD WASTE	YARD WASTE	COMPOST (cured)		
			C1	C2	C3
Moisture, %	70.91	52.75	17.08	15.40	26.40
Carbon, %	51.26	50.19	37.00	41.70	37.80
Nitrogen, %	5.68	1.09	1.58	1.23	1.64
C:N ratio	10:1	50:1	23:1	34:1	23:1
Ammonium N, ppm	-	-	404.0	139.0	184.0
Nitrate N, ppm	-	-	42.0	8.0	7.0
Total N, ppm	-	-	15,800	12,300	16,400
Plant Available N, ppm	-	-	446	147	191
Sulfur, %	0.41	0.09	0.32	0.24	0.30
Bulk density, g/ml	0.76	0.36	0.58	0.58	0.71
Phosphorous, ppm	-	-	203.4	147.8	103.0
Potassium, ppm	-	-	588.6	574.8	504.4
Calcium, ppm	-	-	172.8	83.7	93.4
Soluble Salts, mmhos	-	-	8.2	4.9	5.1
Magnesium, ppm	-	-	45.5	25.5	23.1
pH	-	-	7.1	6.7	7.4
Contaminants and Total human-made Inerts, %	-	-	0.64	0.42	0.47

CONCLUSIONS

The University of Georgia would need 58 containers to compost all of its food waste on a continual basis. Stable compost was achieved in all three treatments after 73 days. Wet volume reductions averaged near 60%. Mixture ratios proved beneficial for varying situations. All used pulped food waste which had 10 to 20% less moisture than food waste that has not been pulped. A mixture of 2:1 was optimum for composting the most food waste in the same amount of time, however ammonia and leachate problems were a concern. At times ammonia levels were so high as to make working with the compost uncomfortable, particularly with the 2:1 mixture. Leachate production averaged 1 liter per 20 kg of food waste. A mixture of 1:2 may be suitable if there is an abundance of yard waste, however moisture contents must be monitored closely as this mixture tends to dry out quickly.

All treatments attained U.S. EPA temperature recommendations of 55 degrees C for 72 hours. All three mixtures contained less than 1.5% total human-made inerts according to U.S. Composting Council recommendations. The compost ranged from 0.4% to 0.6% contaminants and inerts. Generally, the more food waste in the initial mixture the higher the nutrient content was in the finished compost. However, the soluble salt content was higher which may restrict its use for commercial horticultural purposes.

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FIGURE 1: CONTAINER 1: AVERAGE DAILY TEMPERATURES

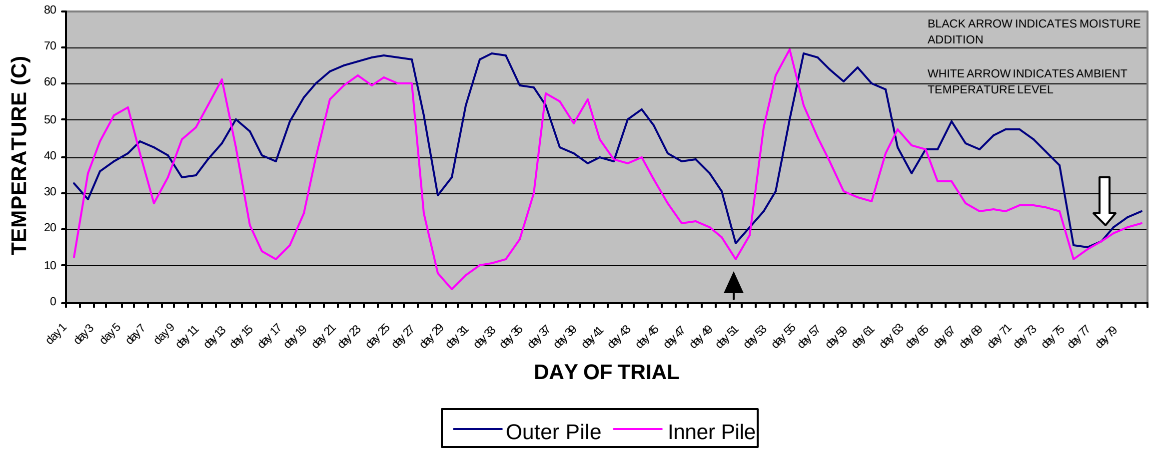


FIGURE 2: MOISTURE CONTENT BY CONTAINER

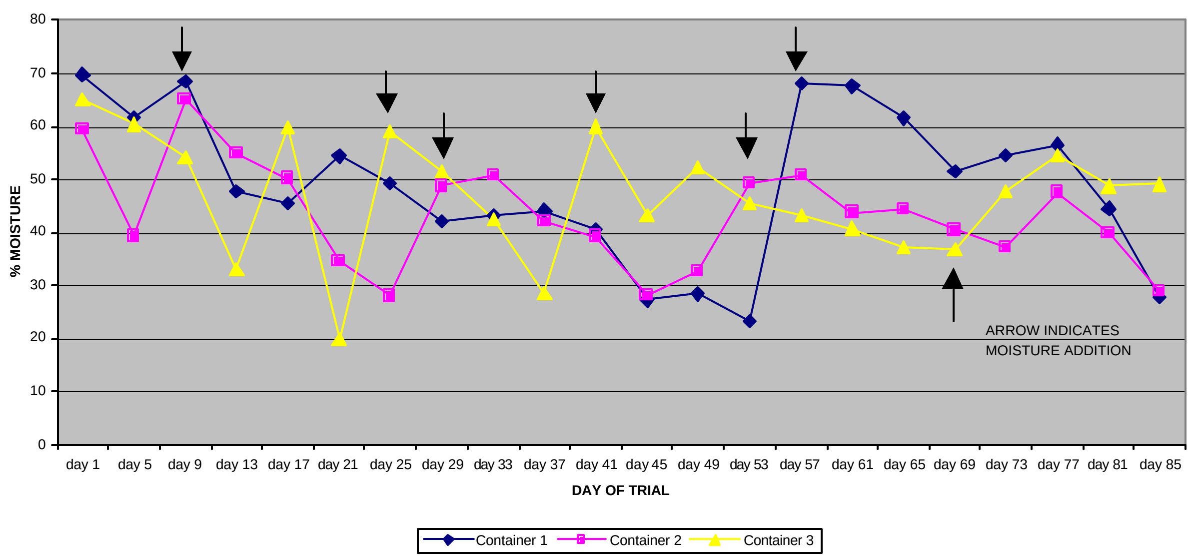


FIGURE 3: LEACHATE PRODUCTION BY CONTAINER

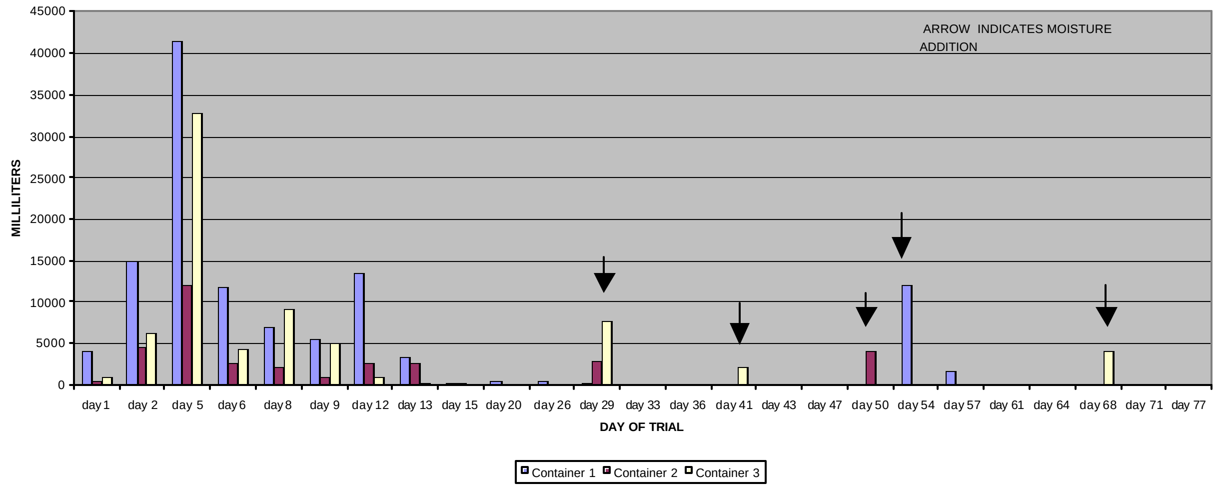


FIGURE 4: ODOR ANALYSIS OF AMMONIA (NH3) BY CONTAINER

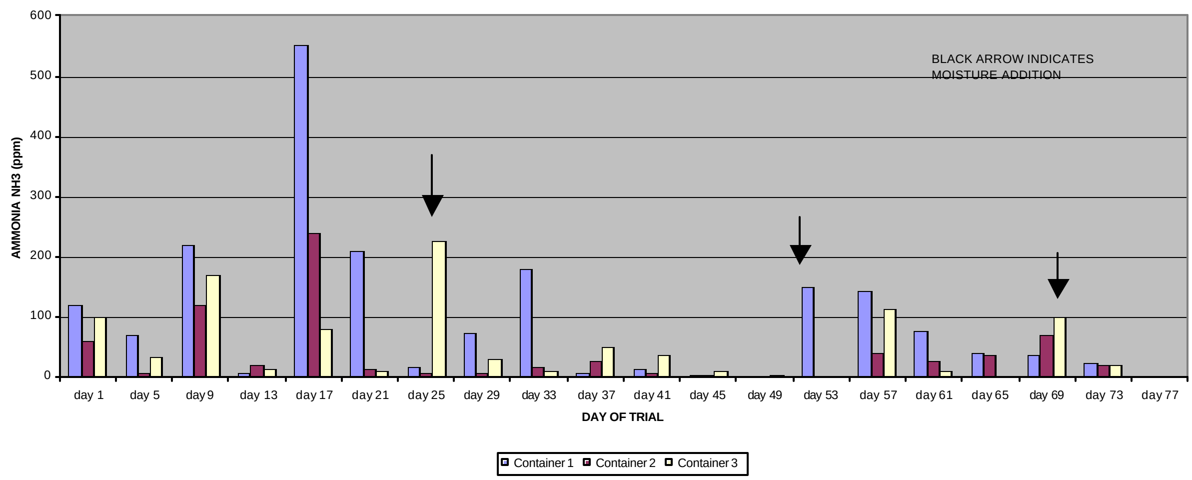
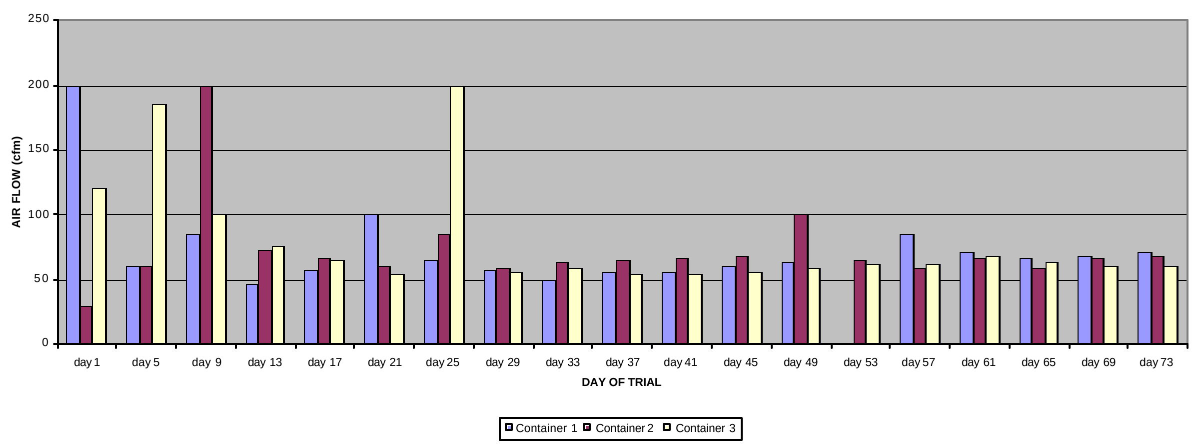


FIGURE 5: AIR FLOW RATE OF CONTAINERS



CUSTOM APPLICATION OF BIOFERTILIZERS FROM RECYCLED ORGANIC WASTE

Mark O'Farrell/Hungry Mother Organics

PROJECT ACCOMPLISHMENTS:

This project accomplished several goals in increasing the marketability of compost from recycled organic waste. In particular, it demonstrated several value- added markets and applications for local poultry litter compost that could be accessed by area landscape or farming enterprises.

The primary purpose of the project was to evaluate new distribution technology to better access existing markets. It became increasingly clear that there is tremendous potential to use existing technology in a system that accesses lucrative new markets.

In an area like Chatham County, North Carolina there is a huge natural resource in the form of several types of poultry waste. As current environmental concerns make way for new waste management regulations, this resource is often thought of in terms of liability. With the application of fairly simple technology and astute marketing strategy, this resource could provide significant additional revenue to farmers and allied operations.

Individually, the three areas of evaluation for the project provided significant successes, as well as some frustrating setbacks. The greenhouse component was by far the most successful in economic terms. The hydroseeding and dry material delivery components, however, each yielded information indicating that they could be profitable enterprises. A combination of the two technologies in a total soil management operation offers even more potential.

GREENHOUSE TRANSPLANT PRODUCTION

- Evaluated numerous potting mixtures, arriving at an excellent media containing over 50% local poultry litter compost.
- Marketed over 10,000 wholesale organic vegetable transplants in the Triangle area through conventional nurseries and specialty retailers.
- Produced a wide variety of bedding plants, both edible and ornamental, including hanging baskets, all under certified organic conditions.
- Introduced local producers and consumers to the value of composted waste as a plant growing media and soil amendment.

HYDROSEEDING

- Used public and private trials to evaluate numerous composted materials for suitability in hydroseeding turf and other potential crops.
- Determined application ratios and limitations on using compost to amend or replace conventional wood and cellulose hydromulches.
- Discovered two interesting new materials to enhance the performance of compost based

hydromulches.

- Promoted the use of compost by successful seeding of turf at public school and private sites in the area using poultry litter as a primary fertilizer and soil conditioner.
- Successfully produced specialty crops (lettuce, spinach, various organic greens) in an innovative system that provides an excellent economic return..

DRY MATERIAL APPLICATION

- Evaluated several components that could be included in the handling, transport and application of dry compost material
- Completed time study and cost comparison of different methods of application.
- Demonstrated how compost applied at agronomic rates can improve soil quality under different cropping systems, including turf.

ORGANIC TRANSPLANT PRODUCTION

As a result of this project, a readily expandable niche market exists for a similarly produced vegetable transplant in the Triangle area. Our transplants were marketed under the name Hungry Mother Organic Transplants, with labels and signage indicating the use of 50% recycled poultry litter. (See attached documents.) A similarly produced product could likely capture the same market, even if produced without the benefit of organic certification.

LOWER COST OF PRODUCTION

Commercial potting media (peat, perlite, vermiculite, fertilizer) can be reduced by at least 50%. We achieved our best results using a 4:4:1, Peat/Compost/Worm Castings Mixture. This comparison based on actual project costs.

Example: Using 1801 flats (3" biodegradable peat pots)
Commercial Mix -$72.00 cu.yd. yields 108 flats @ $0.66 per flat.
Compost Mix -$37.00 cu.yd. yields 108 flats @ $0.34/flat
Result: $.32 net savings per flat on production cost.
Net per year based on 3000 flats = $960.00

INCREASED RETURN

This is where the most significant economic gain is made by selling value-added compost in the form of bigger transplants. We discovered early in our spring season that the retail market preferred a larger transplant. One of the major regional growers, Bonnie Pant Farm, markets all of their vegetable transplants in single cups, and has started to market a larger transplant called their "Miracle Grow Select**".** We found that by potting up our smaller 1204s (48 cells per tray) to an 1801 (18 individual 3" peat pots), we could greatly increase profitability.

Example: 1204 Wholesale Price - $8.50 -2.80 (cost) = $6.70 Net Return/flat
1801 Wholesale Price - $22.50 - 2.80 (cost) = $19.70 Net return/flat
* Additional cost of media in larger pot was offset by reduction in labor and # of seed or plug per flat.

Production time was increased by 7 to 10 days, but the other benefits of “potting up” more than compensated us for the extra time. Benefits included:

- Larger, healthier looking transplants.
- Ability to grow transplants organically without fertilizer.
- Enhanced shelf life and resulting marketability.*

*** Table 1.**
All of the transplant mixes in the following table were combination of commercial growing media (peat, perlite and vermiculite), mixed with poultry litter compost and worm casings, in various ratios. The numerical designations represent ratios of each ingredient in the order of commercial mix, compost and orm castings, respectively. For example, the 101002 represents 10 parts commercial mix, 10 parts compost and 02 parts worm casintgs.

Average Shelf Life of Transplants								
Treatment	wk 2	wk3	wk 4	wk 5	wk 6	wk 7	wk 10	wk 12
Control	2	2	3	3	2	1	1	1
21800	2	2	2	3	3	3	2	1
61402	2	2	4	5	5	5	3	3
101002	2	3	5	5	5	5	4	3
101000	2	2	4	5	5	5	3	3
180002	2	3	4	4	4	4	3	2

This table shows the average quality scores of six plants in each treatment Quality Scale:
5 - Excellent 4- Above Average 3 - Market Ready 2 - Marginal 1- Unmarketable

In order to determine the amount of greenhouse time to market transplants, we set up this trial using tomato plugs (v. Better Boy) planted in six different potting mixes. The control was our commercial peat based mix, 200000, and 180002 was the same mix with two parts worm castings added. The other treatments had different ratios of peat/compost with worm castings added

At 14 days, all six plants in each treatment were given a supplemental dose of 3/4 tsp.of organic fertilizer (4-2-2) for three consecutive weeks. The trial was initially scheduled to go through week 6, at which point fertilizer application had been stopped. Observation continued through week 12, with many of the plants still in saleable condition after 5 to 6 weeks of watering only. The control group, having no slow release nutrients in the form of compost, declined in quality within 3 to 4 days of being taken off of supplemental fertilizer.

The increased shelf life of our transplants was a major marketing advantage. It meant fewer flats returned or written off by the retailer. The high quality of our plants was also evident to consumers, as our product was placed in close proximity to the conventionally grown transplants, which rapidly declined in quality.

CUSTOM COMPOST APPLICATIONS

Numerous seeding operations were performed on several sites in the area using a variety of custom applications. The following information summarizes some of the more useful information generated from these trials.

SOIL IMPROVEMENT THROUGH APPLICATION OF COMPOST

The project initially focused on two types of compost application, comparing the advantages and disadvantages of both. It was assumed that one or the other would prove more feasible, or at least more profitable. In reality, it was found that bulk application of compost could be combined with an ongoing system of hydroseeder applications to improve and maintain soil fertility and structure.

BULK APPLICATION

Two major challenges in promoting the use of compost are demonstrating that:
1. an appropriate rate of compost application can substitute for the use of chemical fertilizers in lawn or landscape establishment..
2. Composts will not adversely affect the soil when used at agronomic rates. (In particular, copper and zinc levels have been a concern with the use of animal manure compost.)

A seeding demonstration was conducted at Central Carolina Community College in Pittsboro, to demonstrate the benefits of applying compost at agronomic rates. Officials in the Sustainable Agriculture Program there were interested in establishing a cereal rye cover crop on a half acre plot. The following tables include NCDA Waste Analysis for composts used, and a table showing the difference in soil analysis before and after crop was grown.

Table 2.
NCDA Waste Analysis of Composts Used in Greenhouse and Seeding Production

Nutrient Availability		lbs/ton							
Sample	**pH**	**SS**	**C:N**	**N**	**P2O5**	**K2O**	**Ca**	**Mg**	**Zn**	**Cu**
Steer	**7.07**	**170**	**10.7**	**12.1**	**7.2**	**10.6**	**40**	**4.3**	**0.12**	**.09.**
Breeder Hen	**7.3**	**305**	**17.6**	**4.6**	**20.2**	**9.9**	**44.6**	**3.7**	**0.23**	**.05.**
Broiler	**6.3**	**695**	**12**	**8.6**	**24**	**12.6**	**22**	**4.2**	**0.51**	**.05.**
Turkey	**6.11**	**117**	**21.9**	**5.3**	**10.8**	**4.2**	**18.3**	**1.5**	**0.19**	**.07.**
VO Worm	**5.23**	**210**	**13**	**5.9**	**31.2**	**0.76**	**36.9**	**1**	**0.4**	**0.2**
Cult Worm	**6.07**	**75**	**17.2**	**6.9**	**9.6**	**1**	**22.5**	**6**	**0.31**	**.06.**
Eggshell	**6.79**	**113**	**13.6**	**5.5**	**6.8**	**3.5**	**166**	**2.7**	**.04.**	**.03.**

All of the composts, except for the two worm casting products were made outdoors in windrows, using a front end loader for turning. Had they all been subject to controlled conditions and made at the same time, it would be possible to do a more accurate comparison of quality.

The turkey litter product was used for the bulk of our transplant production, primarily because of the relative N-P-K balance, which was roughly 5-10-4, combined with a low soluable salts level of 117. The broiler litter was very similar, except that it was very high in soluable salts, which could be harmful to young transplants. The reason for such a pronounced difference in salts levels could be that the broiler litter had nearly as long a curing time as the trukey litter.

For field application, we chose the three products that were readily available at trial time. Soluable salts are not so much of a concern, as they will be subject to leaching in the soil. In most situations, a farmer or landscaper would choose the product that provided the most nitrogen for plant growth, in this case, the steer manure compost.

RESULTS

The following chart shows a comparison of soil analysis from demonstration plots at Central Carolina Community College in Pittsboro, NC. The top number is an indication of soil fertility tested before any treatment was applied in October 1999. The lower line is from an NCDA soil analysis 6 months after applying 3 different compost treatments at the rate of 15 tons per acre and seeding with cereal rye.

Physical indices, including pH and CEC, are significantly improved on all plots. This indicates an increased capacity in the soil to hold and exchange nutrients with plant populations. This is a benefit, even if chemical fertilizer was applied, as it would be used more efficiently by the soil and plants. Slight improvements, even on the control plots, could be associated with the plow down of plant residue on the plots prior to treatment and planting.

Another significant result of compost application is in the increase of indices for Phosphorous and Potassium. At the beginning of experiment, the indices for all plots except for #2 fell in the low to moderately low range. Post-treatment indices, except for the control plot, are all in the moderately high to high range. This indicates that residual potassium and phosphorous are adequate to supply the following crop.

One of the potential problems associated with this bulk application is the high index for phosphorus on the Turkey Litter Compost treatment. Under pending NRCS rule changes pertaining to phosphorous, such an index would more than likely limit further applications of manure, at least in the short term. There are two possible management solutions, depending on the cropping system. One would be to decrease the initial application of compost in order to maintain a lower phosphorous level in the soil. With the increased biological activity assumed from the addition of organic matter, the following crop would help to lower the P-Index. An alternative strategy, especially where one encounters a potential problem, would be to apply smaller amounts of compost over several seasons, as is possible with the hydroseeding method of soil amendment.

Copper and zinc levels, while slightly higher after compost treatment, should not be a concern. It would require repeated applications over several years before these two metals would reach a level of toxicity in the soil.

Table 3.

Treatment	CEC	pH	P-I	K-I	CA	MG	Zn-1	Cu-I
1. Pre-treatment	8.3	6.4	5	42	60	30	105	66
1. After Eggshell	21.6	7.2	69	86	84	14	213	82
2. Pre-treatment	9.2	6.3	65	70	58	29	163	73
2. After Turkey	14.6	6.6	124	114	67	25	332	80
3. Pre-treatment	8.5	6.2	28	46	56	30	82	63
3. After Steer	17.1	6.9	72	178	66	27	179	97
4. Control	9.1	6.3	34	47	59	29	122	64
4. No Compost	13.2	6.6	20	69	57	32	162	67

DRY MATERIALS APPLICATION METHODS

One of the major objectives of this project was to develop a blower assisted application method for applying bulk compost. Various applications afforded the opportunity to trial several pieces of equipment, including:

1. A chipper/shredder with 9 hp engine, retrofitted with a custom hopper and delivery hose.
2. A 14 hp bale chopper/straw blower.
3. A 24 hp brush chipper, retrofitted with 30 ft. of delivery hose.

Table 4.

Component	Flow Rate (cu. ft./minute)	Delivery Distance from machine	Material Density W/V Ratio
Straw Blower	18 to 27	80 -100 ft	<.75 @ 30% Moisture
24 hp Chipper	15 to 20	40 - 50 ft	<.75 @ 30%Moisture
9 hp Chipper	4 to 6	15 - 20 ft	<.6 at 30% Moisture

There were several unexpected difficulties in utilizing this type of application, which may explain the high cost of mulch blowing units currently on the market. The following summarizes problems encountered on this project.

1. Moisture content - All the machines used operated much more effectively with moisture content below 30%. At higher moisture levels, material would clog machine at intake, or in the hose line just past machine outlet.

2. Dust and Debris - At moisture levels low enough to facilitate good flow, there was a constant problem with small particles escaping both from the hopper and through joints in machinery sheet metal. Low moisture also resulted in significant reduction in particle size resulting in excessive wind borne particles at hose end.

3. Labor intensity- Trying to convey materials from spreader body to machine and then to the end of the hose required three workers. It wasn't possible for one person to regulate flow from the truck/trailer and keep the blower unit operational at the same time.

SUCCESSES

One discovery made in the process of evaluating machinery was the increased efficiency brought to all applications by the use of a spreader body. Two types were used on the project, a conventional litter spreader truck, and a PTO-driven Farmhand trailer (originally a grain trailer).

The following are some of the advantages realized:

- Elimination of all hand labor where vehicle access allowed mechanical spreading
- Controlling flow from the unit, so that material could be loaded directly in to wheelbarrows, cutting manual labor in half.
- Elimination of mess associated with dumping loads of material on driveways, sidewalks, turf, etc; savings in clean-up cost.
- Used as a mobile hopper, it facilitated other operations, such as processing material through grinder or screens for use in hydroseeding and greenhouse operation.
- More precise placement than a dumptruck for bulk compost deliveries.

Table 5.
Time Study of Compost Application Methods assumes a manual labor rate of $10.00/hr x two persons and equipment rate of $40.00/hr. Calculations based on 6 cubic yard application, which was the standard capacity of equipment used.

Application Method	Total Time to Apply (From arrival)	Labor/Equipment Charge per Appl.	Additional Cost per Yard of Compost
Dumped/Hand Spread	3.5 hrs @ $20.00	$70.00	$12.00
Skid/Front End Loader Assisted	1.5 hrs @ $40 1.5 hrs @ $10	$75.00	$12.50
Spreader Assisted w/Hand Labor	1.0 hrs @ $40 1.0 hrs @ $20	$60.00	$10.00
Direct from Spreader	0.25 hrs @ $40	$10.00	$1.70
Mulch Blower	0.15 hrs @ $40	$6.00	$1.00

HYDROSEEDING APPLICATIONS

The most promising aspect of this technology is the feasibility of using recycled material combined with numerous other fertilizer and or soil amendments in one procedure. Custom slurries can be mixed to provide whatever nutrients needed for a given situation. This means that after initial bulk application of compost, the hydroseeder can be used to deliver a slurry or solution that is custom blended to supply whatever macro or micronutrient needed, along with supplying a carbon rich organic matter source in one step.

We determined that it is possible to apply almost any composted material through this slurry method with proper processing and handling. Both wet and dry materials will work, but amount of material that can be used varies depending on moisture content, weight, and volume.

All of the compost materials used had the tendency to separate in the water, with larger bark pieces staying afloat, heavy finer material concentrating on bottom. The result was a thin slurry that did not form a film on ground. This problem can be eliminated by first making a thin slurry with the commercial paper mulch, then suspending the other materials in the slurry.

This technology makes it feasible to use recycled material combined with numerous other fertilizer and or soil amendments in one procedure. Custom Slurries can be mixed to provide whatever nutrients needed for a given situation.

Specialty crop trials demonstrated the ability to use hydroseeding technology to produce difficult to manage crops such as carrots, salad mix, spinach and various greens, eliminating the need to cultivate growing beds.

Completed preliminary investigation of new materials for hydroseeding, including plantago for suspension and bonding enhancement, and corn gluten for natural weed suppression.

ALTERNATIVE MATERIALS FOR HYDROSEEDING

It is important to note that all materials were tested using a 300 gal. jet-agitated hydroseeder. Paddle-agitated machines are much heavier duty and could handle the heavier materials at higher rates with fewer suspension problems. Paddle agitation provides the agitation needed to lift heavier particles off of the bottom of tank and pull lighter weight materials floating on the top into the slurry.

There are three major factors to consider in the selection of materials for hydro seeding.

1. Weight/Volume Ratio   < .60 g/ml

Another way to express this ratio is bulk density. The density of material has a direct effect on how well it will suspend in the slurry. Materials with a W/V greater than .60 tend to be too heavy to stay in suspension. Compare to commercial cellulose fiber mulches which weigh in at less than .10 W/V. In certain circumstances where the material is very absorptive, it may be possible to go higher, but it will require a lower volume of heavy material, with the addition of more light weight cellulose fiber.

Sample W/V for composts used in project slurry:

Poultry Litter Compost	.25 to .45 g/ml
Worm Castings	.42 to .53 g/ml
Hen Manure Compost	.56 g/ml

2. Particle size   <.125 “ (recommended)   <.25"(maximum)

Perhaps the most important factor because it determines both how well material will suspend in the tank, as well as how it will flow through orifices. We found that any material not screened through 1/8" mesh had a high portion of floating material and greatly increased the risk of clogging.

3. C:N Ratio   Depends on Application

This ratio determines how fast or slow the material will break down on the soil surface, as well as how quickly nitrogen will be released for plant absorption or possible leaching. Paper and wood fiber have a C:N ratio greater than 200:1, whereas all composts used on the project were less than 40:1. High C:N materials persist on the soil surface for long periods (several weeks) in the absence of supplemental Nitrogen. Low C:N materials have a tendency to break down quickly (several days). Ratio of materials added to slurry can be adjusted depending on intended use, as very high and very low ratio materials can balance the overall C:N ratio of slurry.

4. Nutrient Analysis

One major benefit hydroseeder applications is the ability to adjust nutrient levels in the solution. Almost any source of fertilizer can be used, from pelletized to liquid, organic or chemical. We frequently used a dehydrated poultry manure product with a 4-2-2 analysis in order to put out more nitrogen, as most of the composts were very high in Potassium and Phosphorus, with a fairly high C:N ratio after mixing with cellulose mulch.

Table 6.
Examples of Slurry Formulations
Mixed in 300 g. Water

Application	Materials	Coverage/Tank	Comments
General Turf Seeding	40 # Cellulose Fiber Mulch 160# Poultry Compost	3000 sf	good all purpose hydroseeding blend
Erosion Control	50-60# Cellulose Fiber Mulch 150 # Poultry Compost 10# Plantago	2000 - 3000 sf	Very tacky, good persistence on soil, resistant to water
Weed Barrier	250 # Poultry Compost 35# Plantago 25# Corn Gluten	1000 - 1500 sf	Very tacky, resists water, acts as weed barrier if applied heavily

WASTE DIVERSION

A total of 380 cubic yards of compost were applied throughout the project. Of that amount, approximately 250 yards were made from local waste sources here in the county during the project. The plan was to buy ready made compost, but compost of consistent high quality proved difficult to find.

We had an estimated demand from local consumers for approximately twice the amount we actually applied. We were not set-up to do a large volume of bulk compost, so at times we either didn't have equipment scheduled or didn't have enough compost on hand to accommodate all of the requests.

AN OVERVIEW OF COMPOSTING FACILITY PERMITTING IN REGION 4 AND CURRENT ISSUES BEING ADDRESSED BY THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY THAT AFFECT COMPOSTING FACILITY OWNERS AND OPERATORS

Davy Simonson, Environmental Scientist, U.S. EPA Region 4, Atlanta, Georgia

In late 1998, a workgroup within the United States Environmental Protection Agency (EPA) was created for the purpose of providing an internal forum for sharing information and ideas regarding sensible and appropriate management of organic materials. This includes many different types of organic materials that currently exist in America's solid waste stream. This workgroup, which includes members from all ten EPA Regional offices and from EPA's Office of Solid Waste (OSW) in Washington, D.C., is referred to as the Organic Materials Management (OMM) Workgroup. The degree of direct involvement with specific composting issues by individual EPA Regional staff and Headquarters (EPA HQ) staff on the OMM Workgroup is quite varied and is dependent upon a number of factors. It is clear however, that since composting is an obvious and significant component for establishing fully successful integrated solid waste management systems, there exists great untapped potential for the future expansion of compost markets across the country. From this viewpoint, primary keys to successful market expansion (and particularly to the potential rate of expansion) include elevated levels of public awareness and education, wide-open communications, and the ability of different groups to work together to achieve mutual goals in solid waste management initiatives. Also, improved information sharing among the many different entities that are involved with the various aspects of composting will be very important. All of these things are integral parts of the equation for accelerating the development of new markets, for enhancing the markets that currently exist and for identifying potential future markets for compost use.

EPA provides technical assistance toward the design, development, improvement and enhancement of composting projects and initiatives around the country, and to a lesser degree to foreign countries. In addition to offering technical assistance, EPA has also provided financial support to various composting initiatives. For example, EPA HQ provided funding to the U.S. Composting Council (USCC) to establish and implement the "Seal of Testing Assurance" (STA) program. This year, the USCC has been provided funds for a program that will promote the use of compost for roadside landscaping nationwide on a state and local level. Moreover, a priority of EPA HQ is promoting the use of compost by various federal agencies under Executive Order 13148. This includes roadside projects by the U.S. Department of Transportation.

Other EPA HQ initiatives involve studying compost's role in global warming, bioremediation, carbon sequestration and nutrient management issues to name a few. New concepts and applications are being examined to include:

· the potential use of compost landfill covers to oxidize methane gas;
· the economic benefits of source-separated composting compared to landfill bioreactors;
· the role of organics in the federal government's push for increased development of bio-based products and energy, per Executive Order 13134.

Region 4's Solid Waste Management Program has provided financial assistance and management of Cooperative Assistance Agreements for a variety of compost-related projects. These have included:

· development of composting educational materials including videos, slide presentations and training manuals;
· a three-year project demonstrating the effectiveness of a food waste windrow composting operation and particle screening process;
· a study on improving efficiency of composting by control of the solid matrix structure;
· a compost evaluation study to determine effects of alternative processing modifications;
· an evaluation of the effect of blending various organic wastes (e.g., biosolids, poultry, cattle and food wastes) with the separated organic fraction of municipal solid wastes on performance and product quality from composting;
· development of a vermicomposting teacher training guide and video;
· assistance with the promotion of backyard composting efforts.

Other involvement in compost-related activities by Region 4 include: assisting American Indian Tribes with development of successful composting operations; assisting with the organization of composting conferences and workshops; promoting and participating in meetings and other events that involve state and local composting organizations; disseminating EPA documents and literature to persons interested in OMM and composting; and, speaking with school children about composting and other OMM topics.

A primary objective of Region 4's OMM strategy is to develop an infrastructure of all entities in the Region that are involved with the management of organic materials. This effort will lend itself to the promotion of open communications and to the sharing of valuable information with regard to all types of OMM, including composting activities. It should also result in less trial and error on the part of those wishing to successfully start and maintain OMM projects or businesses. Included within this infrastructure will be representatives of various federal, state, tribal, county and municipal governments (including both regulatory and non-regulatory aspects), researchers, businesses, non-profit organizations and any other interested groups or individuals. Members of this infrastructure have the ultimate common objective of diverting organic materials from the solid waste stream and subsequently utilizing those materials in a more practical, sensible and economically feasible manner.

As an important part of developing the Region 4 OMM infrastructure, a review of the permitting processes of individual Region 4 state environmental programs (i.e., those in Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina and Tennessee) has revealed quite some diversity in the ways and in the types of permits that are issued to composting facilities. Likewise, the relationship between Region 4 and each of the states with regard to the

permitting of composting facilities that utilize biosolids is also somewhat different from state to state. Specifics of the individual state permitting programs and their permitting processes for composting facilities in the eight Region 4 states will be presented and open for discussion at EPA's poster session during the Y2K Composting in the Southeast Conference & Exposition.

UNIVERSITY OF GEORGIA BIOCONVERSION CENTER

Ernest W. Tollner and K. C. Das[1]

ABSTRACT

The University of Georgia began development of a comprehensive Composting and Bioconversion Center in 1995. Salient guiding principles in the development of the laboratory were 1) adequate space for processing samples and for doing pilot scale demonstrations which can be easily cleaned and is well ventilated; 2) suitable environment for sophisticated analyses equipment; 3) balance needs for proximity to main office coupled with reality that some processes must be secluded due to odor and further waste handling. The center has evolved to include a 1200 square ft building on the UGA campus equally divided between sample prep and analyses for bench scale studies (Phase 1). Additionally, a Phase 2, 12 acre site 7 miles from campus has developed into a 3-acre windrow pad, 7000 square ft classroom/demonstration building with intermediate scale bins and sample prep area, a 3500 square ft building for new products/value-added research was recently completed. A 4 acre land application system for site runoff is nearing final permitting and completion. The paper will address how the guiding principles were applied to develop the facility. Some specific shortcomings in the design and resulting "work arounds" are discussed.

DESIGN PRINCIPLES

The UGA Bioconversion center was developed in four phases through the Georgia Environmental Technologies Consortium. The UGA bioconversion center was envisioned to facilitate aerobic composting process design for municipalities and industries, facilitate the study of innovative approaches such as anaerobic composting and pyrolysis, enable investigation of pre/post processing operations associated with composting, enable investigation of air quality issues associated with solid and liquid waste and serve as an education and demonstration center. The following design principles were applied:

1. Facilities should have convenient access to the UGA campus.

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2. Sample preparation areas are as important from a size point-of-view as is clean analyses grade space.

3. Composting can be odiforus due to input stream storage and process itself. Only bonafide composters smell “green” around compost.

4. All facets of the bioconversion operation must be done within the local, state and federal regulatory framework.

5. Adequate space for preprocessing and value added postprocessing is important.

6. Educational outreach is a significant portion of the UGA bioconversion mission.

PHASE 1

Phase 1 consisted of renovating an existing 1200 ft^2 butler style building shown in Figure 1. This building is on the UGA main campus. The sample prep area, approximately 600 ft^2, is heated and ventilated but not air conditioned. It provides space for ovens and furnaces. Bench scale compost bins shown in Figure 2 are also located in the sample prep area. The phase 1 facility is very convenient for researchers doing bench scale recipe development and other process development. Prototype bioreactors for air quality control approach evaluation are examples of other prototype equipment which are located in this facility.

The clean analyses area provides space for gas analyses, and other analyses basic to compost research such as density, maturity, stability and related determinations. Figure 3 shows the gas chromatograph and other gas analyses equipment.

The Phase 1 building essentially satisfied design criteria 1 and 2. Criterion 3 was satisfied in that the bench scale produced relatively few odors (mainly associated with the furnaces) which were isolated from other campus activities. The Phase 1 bench-scale testing and evaluation facility operates with environmental constraints similar to those of ordinary campus chemistry/biology laboratories.

PHASE 2

The University of Georgia Phase 2 bioconversion facility was envisioned to provide additional research, demonstration and education capability. Composting recipes developed in the Phase 1 facility are scaled up to prototype levels, requiring substantial amounts of materials. The Phase 2 facility is permitted as a solid waste handling facility under the Georgia Environmental Protection Division (Ga EPD). The solid waste permit is a permit by rule, requiring that 75% of the material on site originated from the University of Georgia. The center piece of the permit application is the design and development report. The requirements for this report are given in Appendix A. Appendix A provides the format for the design and development report needed in Georgia for composting operations.

Phase 2 complied with the solid waste permit requirement by partnering with the University of Georgia Grounds Department, who have an extensive campus yard waste composting operation. The UGA grounds department had moved their composting operation twice in the last five years due to campus expansion.

Under Ga DNR rules, any facility which handles food waste, biosolids or animal manure (in a commercial nonfarm environment) must dispose of runoff in an acceptable manner. This necessitated collection of the runoff and disposal in an approved land application system (LAS). The Ga EPD water division oversees LAS operations. Thus, Phase 2 was required to be in compliance with solid waste and water permits.

An overview of the Phase 2 facility is shown in Figure 4. The general location was 1 mile from housing developments and was surrounded by forests on two sides. Adequate water and power were available. Excavation requirements were minimal. The site was easily accessible. The main road was somewhat of a disadvantage in that many UGA administrators and USEPA Region IV personnel pass by the facility on a daily basis. Thus, all on-site irrigation and other water management activities must be done “by the book.” Since the photograph in Figure 4 was taken, additional vegetation has been planted to serve as a site buffer. Many existing trees which were to have served as buffer vegetation were removed by the contractor in spite of extensive precautions to the contrary.

A research facility with a clean analysis area of approximately 1500 ft^2, a sample prep/bin composting area of approximately 4000 ft^2, a class room of 1000 ft^2 and 200 ft^2 office space serves as the Phase 2 headquarters. The bin scale composting area consists of 4 bins which enable compost systems research. Each bin (see Figure 5) is underlain by a drain. Bins may also be aerated. Studies have been completed wherein fans were temperature controlled. The bins are isolated from other parts of the prep area by a plastic curtain which gives some odor control. A ventilation system which removes air from the bin area to an adjacent biofilter is in place. The sample prep area has enough room for small front end loaders to maneuver when removing material from the bins, mixing it and returning material to respective bins. There are adequate floor drains and ventilation. Doors are equipped with air curtains. The space has heating and air-conditioning capability. Small windrow pads represent the logical scale up for many projects of interest to municipalities. The UGA facility has 6 concrete lined and drained pads such as shown in Figure 6. These pads are located adjacent to the research facility and may be aerated with small blowers.

The clean analyses component of the research facility serves the same purpose for the prototype scale up research as did the corresponding space in Phase 1. It is envisioned that activities in Phase 1 may be moved to Phase 2 due to campus expansion in the future.

The class room is equipped with tables for 25 students. The class room windows are

equipped with drapes for light exclusion, needed for slide presentations. Flourescent lighting is provided for the classroom. However, the lights are "all or nothing." In retrospect a variable intensity light source enabling some lighting during presentations for note taking would have been helpful.

The University grounds department uses a 3.5 acre windrow pad (see Figure 7) for campus yard waste composting operations. The pad is a packed clay with crusher run rock liner. Grounds department personnel cooperate with researchers in finding ways to accelerate the composting process. A yard waste windrow requires as much as 9 months to compost when left unattended. Introduction of some animal manure for C/N ratio adjustment, moisture adjustments and introduction of air using static pile approaches have been jointly investigated with promising results.

Because food wastes, animal manures and biosolids were contemplated as amendments to the yard waste on the 3.5 acre pad, site runoff had to be disposed of in an acceptable way. The site was not sewered nor was there a nearby waste treatment plant. Therefore the only option was to land apply the runoff in the adjacent forest.

Land application system design and approval requires a length process involving preliminary inspection by Ga EPD regulators, preparation of a detailed irrigation system and land application design development report requiring extensive site physical and chemical characterization, development of an approved operation and maintenance manual with scheduled water and soil sampling. The process includes a public comment period. The catchment pond is shown in Figure 8 and a photograph of the land application system is shown in Figure 9. The LAS is a 4 acre solid set system with distribution laterals lying on the soil surface. The entire 4 acres may be irrigated or one may divide the system into two 2 acre sites. The system includes a warning horn which sounds for 2 minutes enabling anyone in the area to leave before water application begins. The operator of record of any LAS facility in Georgia must have a Class III biological treatment plant operators license.

The University grounds department purchased a small hose-towed irrigation system for irrigating the windrow pad area shown in Figure 4. Experience has shown that significant portions of the runoff may be reapplied to the compost windrows during dry weather. Reapplication has little effect on the design size of the catchment pond because the pond must hold surplus water falling in wet months (typically winter).

A second 3500 ft^2 building, the value added processing facility, is shown in Figure 4. Foundations and required utilities for a pelletizer, twin screw extruder, thermal press and vacuum drier were included. This mission is currently under development and the equipment is being ordered.

DESIGN SHORTFALLS

The primary goals and design principles are well satisfied with the UGA design. In retrospect, the system should be somewhat more secluded than it is. Excellent natural buffers were removed during the construction period.

The sample prep/bin composting area in the primary facility is too small. There is not room to turn the bins and maintain stockpiled materials. Conduits for data loggers have been added. Drainage from the external concrete windrow pads and from the interior bins was originally pumped directly to the irrigation pump well, turning it into a septic tank. This line was subsequently diverted directly to the runoff catchment pond. In systems where there was no surface water catchment, one should anticipate an additional septic tank with debris traps.

In retrospect, partnering with a municipal treatment plant would have been highly desirable. In our case the research mission precluded such partnering. The water permit is expensive to manage due to the sampling and record keeping required. The irrigation system requires frequent maintenance due to broken and clogged sprinklers. Falling limbs and debris are problems. Proper winterization is essential. The catchment pond was not originally designed with a liner and had to be retrofitted after failing a seepage test. The LAS system cost about 20% of the entire project cost. The LAS system accounts for most of the ongoing sampling and monitoring expenses.

Figure 1. Phase One Bioconversion Facility located on the UGA Campus

Figure 2. Bench scale compost barrels located Facility located on the UGA Campus in Phase One sample preparation area

Figure 3. Analysis area photograph showing a gas chromatograph for analyzing off gases from the bench scale composting apparatus

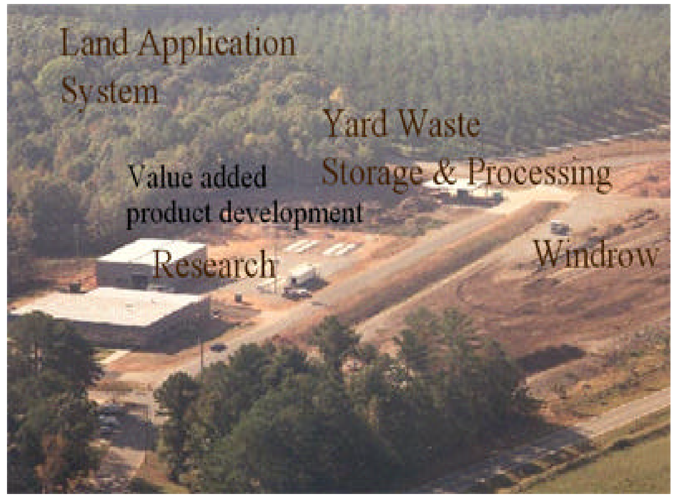

Figure 4. Aerial view of the University of Georgia Phase 2 Bioconversion Laboratory

Figure 5. Photograph of two of four compost bins showing the drainage/aeration system. A mixture of wool waste and cotton gin trash is shown in the bin on the right.

Figure 6. Concrete lined prototype windrow Pads adjacent to the research facility. The drain empties into the leachate pond (see Figure 4).

Figure 7. Windrow of yard waste compost with a windrow turner in the background.

Figure 8. Photograph showing the runoff catchment. The structure in the front is the water intake.

Figure 9. Photograph of land application System showing control valves and warning horn.

Appendix A

Georgia EPD SOLID WASTE PROCESSING DESIGN AND OPERATION PLAN

Supplemental Data for Solid Waste Handling Permit

The Design and Operation Plan should be developed only after EPD has received written zoning approval from the applicable governing authority. The approval letter should specifically reference the process. EPD staff will make an on-site investigation as part of the design review procedure. The following format is to be followed. The information and data listed below are minimum requirements for inclusion in the plans. Additional information and data may be required depending upon the specific facility and waste received.

General

Sheet dimensions of the location map, site design sheet, and detail plan of the facility should be 24" X 36". Sheet size is not to exceed 30" X 36" nor be less than 24" X 30". Each of these sheets in the plan are to be the same size using a title block.

Plans are to be prepared by a professional engineer registered in Georgia. The engineer's stamp must be placed on each sheet of the plan.

Submit two (2) copies of the Design and Operation Plan for initial review. Six 6) copies of the Design and Operation Plan are required when the plan is approved.

Format

I. Title Sheet

- A. Location Map
  1. Minimum 5 mile radius from site
  2. DOT County Map or equivalent: Map should be updated through local reconnaissance. Show north arrow.
  3. Direction of stream flow
- B. Official name of processing operation
- C. Table of contents
- D. Responsible official: Title, address and telephone number
- E. Property owner: Name, address and telephone number.
- F. Consultant: Name, address and telephone number

II. Site Design Sheets

A. General/plan criteria

1. Scale: 1 inch = 100 feet
2. Include a scale line

B. Indicate north arrow

C. Property lines: Show bearings, lengths and include a written property description.

D. Existing site topography: Must extend at least 50 feet beyond property lines

1. Identify all existing physical/land features
2. Contour interval: Two (2) feet unless another interval is approved by EPD

E. Facility layout

F. Limited access to facility

III. Detail plan of the facility (Detail drawings for shop fabrication and field construction are not necessary)

A. Facility Layout

1. Receiving area;
2. Pre-processing storage area;
3. Location of processing equipment;
4. Residue storage area and containers;
5. Drainage system discharge for wastewater, surface run-on and run-off - include profiles, if necessary;
6. Location of fire control equipment; and
7. Vehicle and equipment cleaning area.

B. Schematic drawing of equipment showing the flow of waste through the processing equipment. Label each part of the process.

IV. Narrative

A. Description of incoming wastestream(s)

1. Sources, types, and the weight or volume of each wastestream to be processed.
2. Compositional estimates - % of liquid/waste constituents, inerts, etc.
3. Special environmental pollution or handling problems associated with

wastestream.

4. Verification that incoming waste is not hazardous, if necessary.
5. For special solid waste (waste accepted for processing from facilities located outside of Georgia), waste analysis plan as required by Section 391-3-4-.10(c) of the Solid Waste Management Rules.

B. Storage and containment

1. Storage capacity of facility (cubic yards)
   a. Receiving area;
   b. Pre-processing storage; and
   c. Residue storage area and containers.
2. Containment of waste

C. Transportation of waste to facility- Chain of custody procedures for special solid waste.

D. Processing of waste Operating parameters, end use of processed material, design and construction of processing equipment.

E. Disposal of waste residue

1. Containment, handling and removal of residue from facility.
2. Treatment and disposal of wastewater.
3. Method for ensuring solid wastes pass the Paint Filter Test.
4. Transport of waste residue to disposal facility
5. Name, location and permit number of facility disposing of waste residue.
6. Disposal of rinsate from vehicles and storage tanks.

F. Contingency plan and emergency procedures

1. Procedures in response to fires, spills, explosion or equipment failure at facility.
2. Listing of all emergency equipment and spill containment equipment.
3. Include a statement to the effect that type and quantity of fire suppression equipment will be installed per directions of the local fire marshal, and letter of coordination with appropriate emergency response personnel.
4. Arrangements f or handling waste if storage capacity is exceeded due to equipment failure, fire, explosion, etc.

a. General; and
b. Special solid waste.

G. Supervision and manpower requirements

1.Supervision of facility; and
2.Education and training of supervisor(s) and employees.

H. Closure plan

1.Removal of all containerized waste residue, etc.
2.Removal of contaminated wastewater from sumps and floor drains.
3.Estimated cost of closure utilizing third party and facility not operating with seven (7) days of waste on-site.

I. Other permits

1. Air Quality (EPD);
2. Water Quality (EPD); and
3. Local.

J. Financial responsibility

1. Provide proof of adequate financial responsibility for closure by one or a combination of the following mechanisms: surety bond, trust fund, letter of credit, insurance, financial test (See EPD "Wording of Financial Responsibility" packet).
2. Closure cost
   a. Provide a detailed written estimate, in current dollars, for cost of closing facility. Estimate must be equal maximum cost for final closure at any time during the active life of the facility.
   b.Name, address and telephone number of the person or office to contact about the facility during closure.
   c.Discuss closure cost adjustment for inflation each year facility is in operation or increases in cost associated with permit modifications.

K. Other provisions for special solid waste.

1.Procedure for manifesting special solid waste; and
2.Procedure f or recordkeeping and payment of trust fund fee.

L. Post Closure

1.Include a statement to the effect that upon the decommission of the facility no further monitoring or maintenance will be required.

HOME COMPOSTING IN CONTEXT: NUTRIENT FLOWS AND USE EFFICIENCY IN AN AMERICAN RESIDENTIAL HOME ECOSYSTEM

Don Boekelheide
Mecklenburg County MCPLANT Program

Home composting is more than a cost-effective method for reducing residential waste. Compost also enriches garden soil by adding nutrients that would otherwise be lost to the landfill. These nutrients, including fixed carbon in the form of organic matter and 'humus', nitrogen and phosphorus, are key factors in determining soil fertility and the productivity of natural and agricultural ecosystems. Analysis of nutrient cycles can reveal much about natural ecosystems, as shown by the work of Odom and others. In agricultural ecosystems, studies of nutrient use efficiency have helped demonstrate that routine applications of large amounts of fertilizer may not increase yields, but may well increase pollution.

What can these complementary approaches teach us about American homes and yards? Using modeling techniques from systems theory (especially those suggesed by Waddington), ecology and agroecology, this poster presents a prelinary model for nutrient cycling within the boundaries of a suburban home and garden, focusing on the fate of nitrogen, phosphorus and fixed carbon. In contrast to a natural ecosystem, or even a farm, 'conventional' American patterns of suburban life lead to a very low level of nutrient use efficiency. The high level of nutrient 'throughput' and habitual patterns of handling 'garbage' combine to concentrate nutrient losses, generating 'bursts' of extremely high nutrient load that convert desirable nutrients into damaging pollutants. Using the model as a point of departure, this poster examines the effect various behaviors, including 'conventional' lawn and garden design, home composting and centralized composting, on nutrient use efficiency within the home system's boundaries. This approach raises questions about the sustainability of widespread and deeply entrenched behaviors in American culture.

Don Boekelheide (MS, Agriculture), graduated from the University of California, Santa Barbara and the California Polytechnic State University (Cal Poly), San Luis Obispo. His thesis research at Cal Poly was a systems study of nitrogen use efficiency over six years in a California agricultural ecosystem. He is a returned Peace Corps agriculture volunteer who served in Togo, West Africa. He is now working as a consultant for Charlotte-Mecklenburg, North Carolina's, home composting and PLANT program. Contact him at dboek@aol.com.