COMPOST FACILITY TRAINING WORKSHOP

DESIGN ◆ OPERATIONS ◆ MARKETING

Edited by:

Jason Governo, Dr. Mark Risse, Dr. K.C. Das

7th Edition

ACKNOWLEDGMENTS

This training workshop and the guide were made possible due to the support of several people who worked together as a team. First, the speakers who provided their expertise and time in preparation of the lectures and were available to teach in the workshop. Second, Nathan Melear of the Bioconversion Laboratory, BAE Department, UGA, who developed the laboratory demonstrations and conducted the windrow composting portion of the workshop. Third, Cathy Felton of the BAE Department, UGA, who prepared the notebook and was a constant resource of workshop experience. Finally, for Dale Threadgill, BAE Department Head and Tom Adams, Director of the Faculty of Engineering Outreach Service, who provides the support for composting education and technical assistance at the University of Georgia.

Compost Facility Training Workshop
Agenda

Tuesday, October 10, 2006

8:00 am	Registration	
8:30	Course Introduction and Welcome	**Jason Governo**
9:30	Science of Composting Process	**Dr. K. C. Das**
10:15	Break	
10:30	Composting Systems	**Jason Governo**
11:00	Feedstock Preparation and Handling	**Dr. Mark Risse**
12:00 pm	Lunch (catered)	
1:00	Compost Pile Recipes Feedstocks and Software, lab data analysis	**Jason Governo**
2:15	Break	
2:30	Recipe Development	**Jason Governo**
3:00	Windrow Construction	**Nathan Melear**
5:00	Adjourn	

Wednesday, October 11, 2006

8:00 am	Microbiology of Composting	**Julia Gaskin**
9:00	Laboratory – pH, EC, O2, basic sampling	**Nathan Melear**
10:00	Break	
10:15	Managing the Composting Process	**Jason Governo**
11:00	Product Quality, Maturity and Stability	**Gaskin / Das**
12:00 pm	Lunch (catered)	
1:00	Odor	**Dr. K.C. Das**
2:00	Facility siting and Design: Contest	**Jason Governo**
4:00	Erosion control and rainfall simulator	**Dr. Mark Risse**
5:00	Adjourn	

Thursday, October 12, 2006

8:00 am	Overview – The Economics of Composting	**Jason Governo**
8:30	Filtrexx – Erosion control market	**Polly Sattler**
9:30	Poultry Compost and Marketing	**Dr. Casey Ritz**
10:15	Break	
10:30	Compost Marketing Strategies	**Gerry Harstine**
11:30	Group Project Evaluation	**Jason Governo**
12:00pm	Adjourn	

Speakers
October 10-12, 2006

Gerry Harstine, Harvest Farms Agricultural Products Harrison, TN 37341
(877) 206-3013

Gerry Harstine is the President of Harvest Farms Agricultural Products, a company specializing in compost manufacturing, market research and development.

Dr. K.C. Das, Department of Biological & & Agricultural Engineering, University of Georgia, Driftmier Engineering Center, Athens, GA 30602, (706) 542-8842

Researcher / Educator with experience with odor management/abatement and experience in the engineering aspects of composting as a waste management tool.

Julia W. Gaskin, Cooperative Extension Service, Engineering, University of Georgia, Driftmier Engineering Center, Athens, GA 30602, (706) 542-1401

Scientist with research and educational experience in land application of by-products of agricultural and industrial processes including manures and composts

Jason Governo, Engineering Outreach Service, Department of Biological & Agricultural Engineering, University of Georgia, Driftmier Engineering Center, Athens, GA 30602, (706) 542-6119

Workshop coordinator and research engineer with experience with compost facility design and composting as a waste

Dr. Nathan Melear, Department of Biological & & Agricultural Engineering, University of Georgia, Driftmier Engineering Center, Athens, GA 30602, (706) 227-7147

Research coordinator with extensive research experience in waste residual composting and laboratory data analysis.

Dr. Mark Risse, Cooperative Extension Service, Engineering, University of Georgia, Driftmier Engineering Center, Athens, GA 30602, (706) 542-9067

Pollution prevention specialist with experience in animal and agricultural waste management issues.

Evaluation
Compost Facility Training Workshop – October 2006

Rate the Program	Excellent	Good	Fair	Poor
Time allotted for the training				
Training materials				
Visual aids				
Appropriate content				
Effectiveness in meeting your needs				
Field demonstrations				
Overall Training Program				

Rate the Facilities	Excellent	Good	Fair	Poor
Learning atmosphere				
Field demonstrations				
Overall Impression				

What was the ***most beneficial*** part of the training for you?

What was the ***least beneficial*** part of the training for you?

In Case of Emergency:

Attention: Jason Governo

Compost Facility Training Workshop
The Bioconversion Research and
Education Facility
Whitehall Road
Athens, GA 30602

Call: **(706) 542-6119**
(706) 542-3086
(678) 794-6664
Fax: **(706) 583-0875**

Working Groups
October 2006

Group 1

Kent McCormick
Tim Lesko
Adam Jones
Johnny Guardiola
Charles Pitts

Group 2

Fernando Caudillo
Russell Lesko
Sean Hayes
Warner Palermo
Ryan Adolphson

Group 3

Susan Johnson
Bill Alley
Joe Briggs
Dwayne Hobbs
Buster Haddock

Group 4

Bill Twomey
Elizabeth Heffner
Brian Luzier
Matt Martin

The Science of Composting

INTRODUCTION

Composting, a technology choice for today ?

K.C. Das
The University of Georgia
Bioconversion Research and Education Center

WASTES

A byproduct of a process for which an immediate need is not known.

Two things to remember

Two things to remember

First:

No matter where we put our wastes its still

<u>in our environment</u>

Two things to remember

Second:

In nature there are no wastes

What is in our MSW waste stream ?

2000 Total Waste Generation— 232 Million Tons (before recycling)

- Paper 37.4% ⟵
- Yard Trimmings 12.0% ⟵
- Food Scraps 11.2% ⟵
- Plastics 10.7%
- Metals 7.8%
- Rubber, Leather, and Textiles 6.7%
- Glass 5.5%
- Wood 5.5% ⟵ Total Compostable 66%
- Other 3.2%

What is Composting ?

Composting is the Controlled, biological stabilization of organics

! Microbial farming !

What is Composting ?

1. Actively managed
2. Optimized
3. Desired end product

Composting is the Controlled, biological stabilization of organics

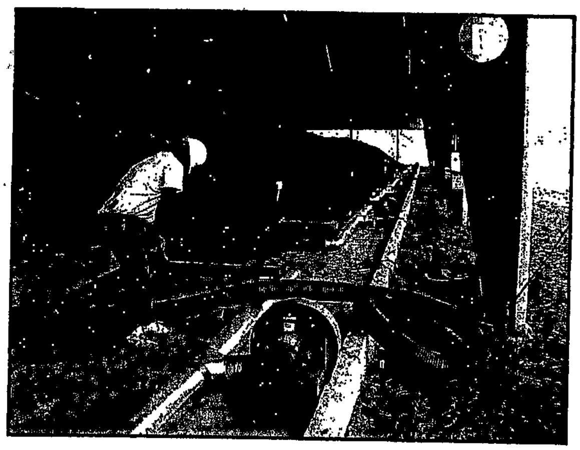
! Microbial farming !

What benefits composting offers

- Stabilizes the organic portions of wastes
  - Volume, Weight, and Moisture reduction
- Reuses the stable product – NO RESIDUES
- Can be cost effective
  - If technology choices and management are proper

What benefits composting offers

- Multiple waste streams can be handled together [Co-composting]
- When managed well, it is environmentally safe and sustainable



Developmental focus areas..

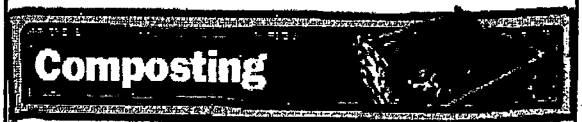
- Identify new waste streams to compost – Process development
- Develop facility design and process methods for reducing costs and improving product quality

Developmental focus areas..

- Increase process efficiency
- Reduce/Eliminate Nuisance problems
- Develop applications for compost (markets):
  - » Erosion control
  - » Bioremediation, etc.

The Composting Process

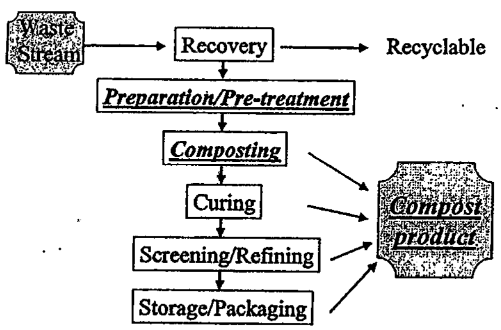
K.C. Das
The University of Georgia
Bioconversion Research and Education Center



Reference sources

- The science of composting - Epstein
- Compost facility Op. Guide. - US Comp. Council
- Winning the organics game - Tyler
- Sc. & Engr. of Composting - Hoitink and Keener
- Compost Engineering - Haug
- Biological reclamation of MSW - Golueke
- BioCycle Journal of Composting (1987-02)
- Microbial Ecology - Atlas and Bartha
- NRAES Handbooks

Composting Process Steps



Beware !

Composting is a value-adding process with increased inputs

but,

Never add more value than you can recover through the available market.

I: Recovery

Recovery of compostable

- Separation of recyclables
- Removing contaminants
- HHW
- Methods :
    - Manually
    - Trommel screen
    - Magnetic separators
    - Eddy current separators....

I: Recovery

Household hazardous wastes [HHW]

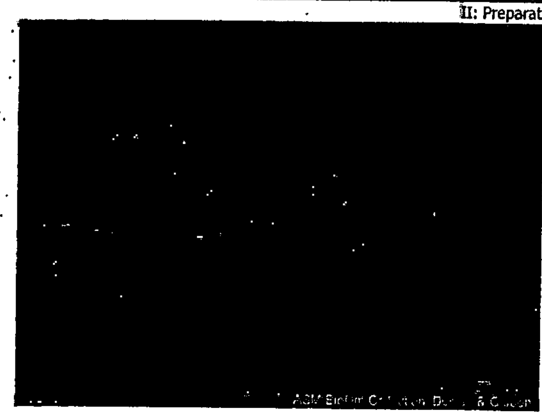
- Batteries, Cleaning products, Motor oil, Paints, Pesticides, Treated wood....

II: Preparation

Why particle size is critical...

- Microbes live/work on particle surface

II: Preparation



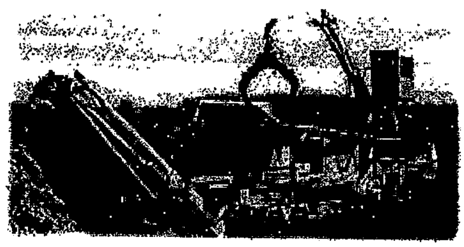
II: Preparation

Why particle size is critical...

- Microbes live/work particle surfaces
- Specific surface area increases as particle size reduces
- Limitation : Too small a particle leads to packing and aeration difficulties

II: Preparation

Grinding to reduce particles



II: Preparation

Amendments

- Amendments are for setting
  - C:N, Porosity and Moisture
- Solid materials, e.g.
  - bark, sawdust, manures, biosolids ...
- Liquid amendments, e.g.
  - fresh water, leachate ...

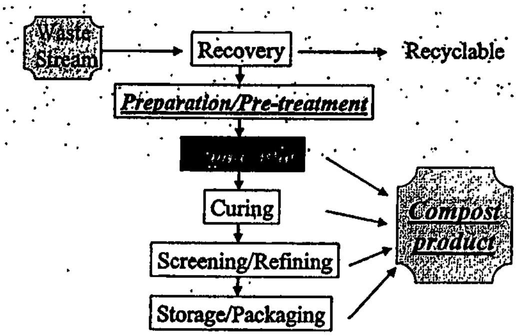
Be prepared to control the process as materials become biologically active

II: Preparation

Nutrient balance

- C:N ratio
- C:P ratio
- Micro-nutrients

Composting Process Steps



III: Composting

Composting

- Biological process - 10 to 30+ days
- Objectives :
  - Degradation/stabilization
  - Pathogen destruction
  - Weed seed destruction
  - Remove odor potential
- Process Control :
  - Porosity, Oxygen level, Moisture
  - Microbial diversity by Temperature control

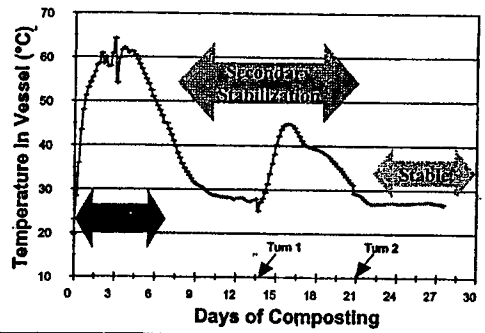
III: Composting

Composting step involves ...

- **HIGH RATE COMPOSTING**
  - Initial Thermophilic Stage
- **STABILIZATION**
  - Secondary Mesophilic Stage
  - Maximum degradation

III: Composting

Typical Temperature Profile



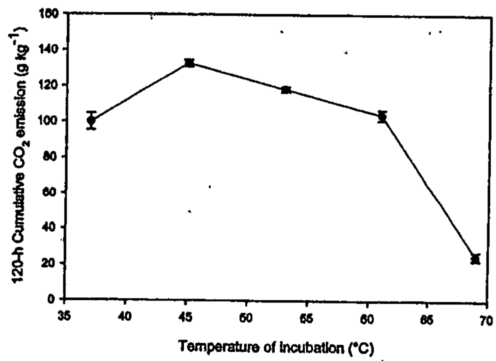
III: Composting

Note - Microbial diversity

- Temperature 45 - 55 C
  - Maximum degradation rates
  - Maximum microbial diversity
- Temperature 65 + C
  - Only thermophiles

Opt. Temperature
Species diversity/Transp.

Effect of temperature on microbial activity



IV CURING

Stability

Stage in decomposition - function of biological activity
[Hopefully achieved during the composting step]

- Methods :
  - O_2/CO_2 Respirometry
  - Re-heat potential [Dewar flask]

The science of composting - Epstein (1997)

IV CURING

Maturity

Biochemical state of the compost
Indicates phyto-toxicity
[To be achieved during curing]

- Methods :
  - Germination Index / Cress seed
  - Humification Indices
  - Acetic acid assay

The science of composting - Epstein (1997)

IV CURING

Issues to consider ...

- Manage Porosity [35-65]%
  - Retain bulking agent
- Manage O_2 as in Composting > 16%
- Manage Moisture [40-50]%

Screening & Refining

V REFINING

Screening and Refining

- Only after complete STABILIZATION - Bulking agents required for curing process
- Remove inerts > 4mm
  Refining
  Glass, plastic, film, sharps ...
- Refine based on product value requirement

V REFINING

Typical equipment - requirements

- Trommel,
  Shaker screens

- Remove and reuse bulking agents
- Moisture control required :
  - 40-45% = Good for screening [Check Eq. Specs]
  - Too wet = Screen clogging
  - < 30% = Dust production

Composting Systems

Composting Systems

Brief Overview

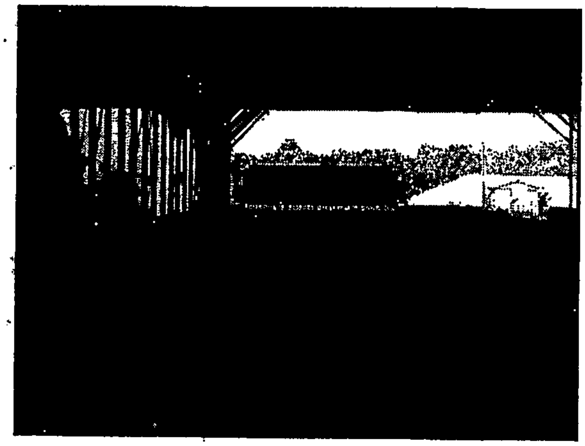
Jason Governo

Engineering Outreach Service

Composting systems

- In vessel
  - Agitated bay – Page 37 in On-Farm Book
  - Rotary drum
- Static Pile
- Aerated Static Pile
- Windrows
- Other sources of composting systems

http://www.ciwmb.ca.gov/FoodWaste/Compost/InVessel.htm



Bedminster System

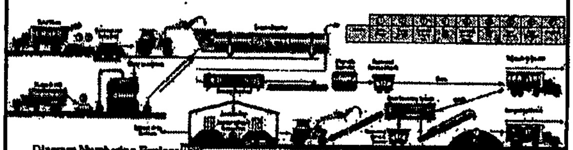
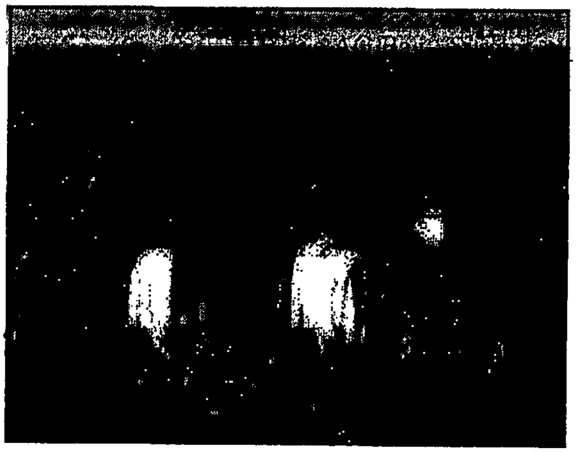


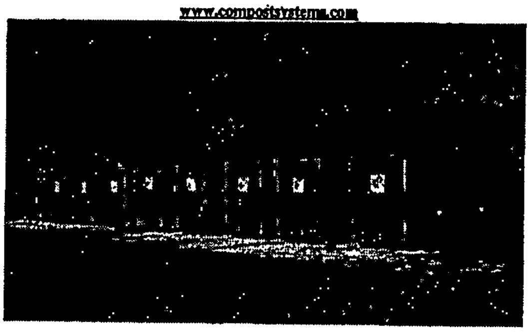
Diagram Numbering Explanation:

1. Bulk feedstocks delivered to the Facility's pre-processing floor
2. Semi-solid feedstocks delivered to the Facility's pre-processing floor
3. Feedstocks pre-processed, mixed and placed in digesters
4. Composting inside the digesters.
5. Screening of inert materials.
6. Aeration floor where compost is agitated and cured for approximately 30 days
7. Compost is again screened to desired particle size and remaining inert materials
8. Cured compost ready to leave the site for additional curing or market
9. Any residuals will be taken to the transfer station for disposal in Landfill

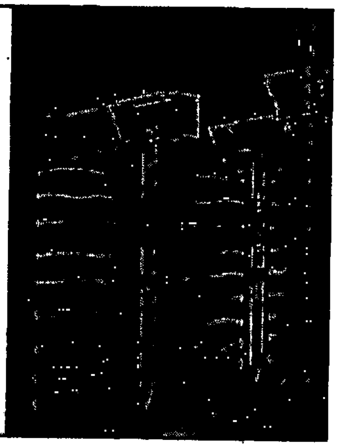


Engineered Compost System

www.compostsystems.com



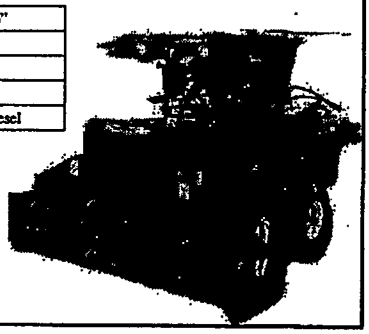
Air Lance
Composting
System



Windrows - Biosolids

Hen In-House – Compost Cat

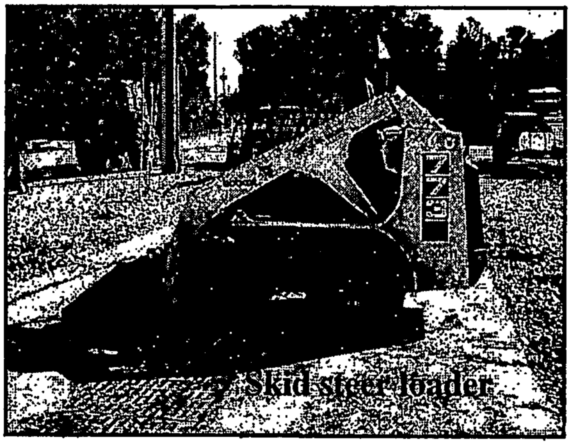
Auger Width	72" – 96"
Overall Length	110"
Overall Height	80"
Weight	3775 lbs
Power	45 hp diesel



Equipment Considerations

- Equipment is the most costly line item for a composting facility.
- Equipment is your control of the process.
- Equipment can make or break your facility.

- KNOW WHAT YOU NEED and
  DON'T BE CHEAP!

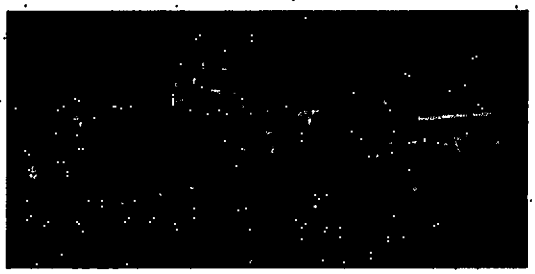


Windrow Turners

- Front End Loader
  - cheap, multipurpose, time vs. capital, use large capacity bucket with high lift
- Pull behind Turner
  - one or two pass, speed, fluff or beat, produces higher quality
- Self Propelled Turner
  - only economical on large, will require better pad.

Wildcat TS616-260

Windrow size	6'x16' one pass
Capacity	3,000 ton/hr
Horsepower	60 hp tractor

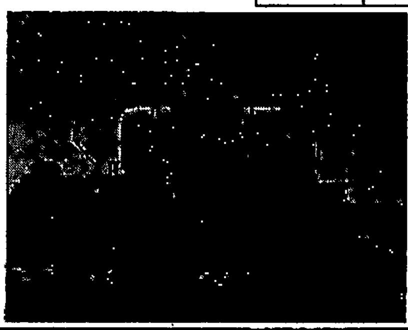


Self Propelled Turners

- Used predominantly at large operations
- High capacity allows for larger windrows
- Reduces land foot print
- High capital cost
- Reduces operating time

Aeromaster SP 155

Windrow size	one pass
Capacity	3,000 yd/hr
Horsepower	



Scarab

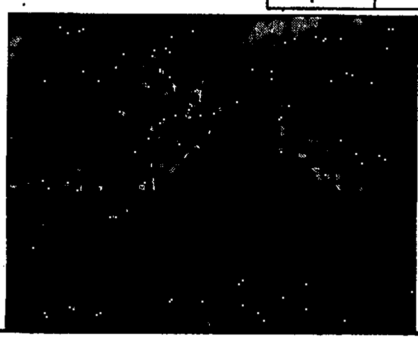
Windrow size	8'x20' one pass
Capacity	
Horsepower	370-600

Scat 4833

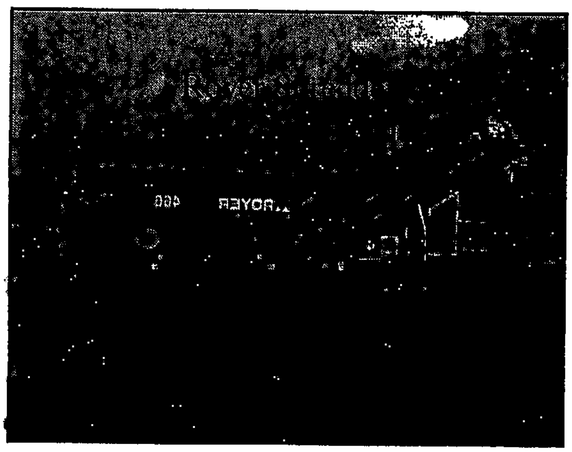
Windrow size	10'x20'two pass
Capacity	4,000 yd/hr
Horsepower	155

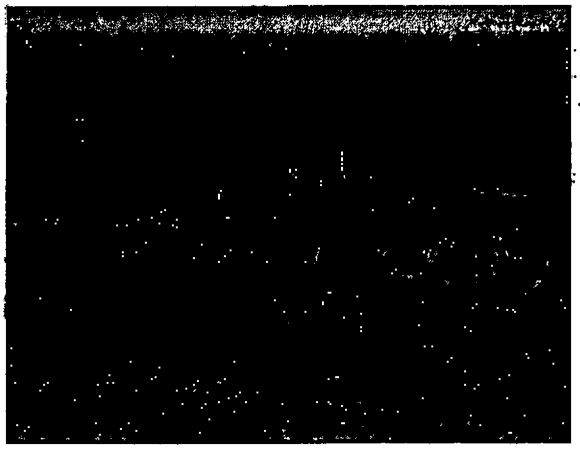
Wildcat SPB822

Windrow size	8'x22'onepass
Capacity	
Horsepower	425



Windrow Turner	Size of windrow	Number of Passes	Capacity (yd/hr)	Horsepower
Self Propelled				
Aeromaster SP155		One	3,000	
Allu 38	10' x 26'	One	7,840	458
Frontier F-20	8' x 20'	One	5,500	550
King Windrow 818	8' x 18'	One	3,000	550
Scarab	8' x 20'	One		370-600
Wildcat SPB 822	8' x 22'	One		425
Tractor Pulled PTO				
Aeromaster PT 130	5.5'x 10'	One		100 tractor
Wildcat PS 100A	5' x 17'	Two	2,000	100 tractor
Tractor Towed Turners				
Wildcat TS616-260	6' x 16'	One	3,000	60 tractor
Front End Loader Mount				
Wildcat LH325A	6' x 18'	Two	4,250 t/hr	4yr loader
Brown Bear SC 4912		Two	1,800	4yr loader





Economic evaluation

<u>Operational Costs</u> – Reoccurring expenses

- Insurance – Employee, equipment, site
- Utilities – fuel cost, electricity
- Supplies – office supplies, analytics, advertising
- Maintenance – replacement costs
- Salaries – employees, contract work

<u>Cash Flow</u>

- Feedstock costs
- Tipping fees
- Sales
- Interest rate, loan life
- Cost avoidance

Anaerobic Digestion: Systems And Components

ADI Systems, Inc.
Arrow Ecology
Bac Tee Systems, Inc.
Bion Environmental Technologies, Inc.
Bioscan A/S
Biothane Corp.
BSI Environmental, Inc.
Canada Composting Inc./ BTA Process
Citec International Ltd.
EcoCorp, Inc.
Ecovation
Entec Environment Technology
Entek BioSystems, L.C.
EnviroControl Ltd.
Envirologics International
Environmental Products & Technologies Corp. (EPTC)
Environomics
Ecovation
Framatome ANP
IR Energy Systems
Kompogas AG
Kruger A/S
LINDE BRV BiowasteTech AG
Lotepro
Microgy Cogeneration Systems, Inc.
MWH Energy Solutions
NIRAS
O.W.S. Inc. (Organic Waste Systems)
Onsite Systems
Pinnacle Biotechnologies
Resource Conservation Management
Resource Development Associates
Roediger Pittsburgh, Inc.
Steinmuller-Valorga/Waste Recovery Systems
STM Power, Inc.
UTI Jaeger GmbH
WETCO

Anaerobic Digestion: Microturbines And Engine-Generators

Alliant Energy
Capstone Turbine Corp.
Ingersoll-Rand Energy Systems
STM Power, Inc.
Waukesha Engine

Backyard Composting Bins

Covered Bridge Organic, Inc.
Fibrex, Inc.
Greenline Products
Norseman Plastics
Plastopan North America, Inc.
SCL Plastics, Inc.
Smith & Hawken
Triformis Corp.

Bagging

Amadas Industries
Bouldin & Lawson Inc.
Creative Concepts of Georgia, Inc.
Creative Packaging
Fecon, Inc.
F.M.I. Bagging Equipment
Hamer LLC
Morbark Inc.
Premier Tech Packaging
Rotochopper Inc.
Sandbagger Corp.
Southtech Industries, Inc.
Verville Machinery

Biofuels: Biodiesel And Ethanol

Biodiesel Industries
Biothane Corp.
Iogen Corp.
Masada Resource Group
Pacific Biodiesel
Resource Development Associates

Biosolids Management

Agronomic Management Corp.
Bio Spread Inc.
Carylon Corporation
GRRO (Global Resource Recovery Organization)
McGill Environmental Services
MSD Environmental Services, Inc.
N-Viro International
Synagro
Trimax Residuals Management, Inc.
Wessuc, Inc.
White Mountain Resource Management

Compost Covers

Autrusa/Imants USA
DuPont de Nemours Sarl
Midwest Bio-Systems
Texel, Inc.

Compost Tea Equipment

EPM Inc.
EarthWorks
Growing Solutions, Inc.
Keep It Simple, Inc.
SoilSoup, Inc.

Composting Systems: Aerated Containers

Double T Equipment
Engineered Compost Systems
Green Mountain Technologies
Herhof Umwelttechnik GmbH
HotRot Composting Systems Ltd.
Nature's Soil, Inc.
NaturTech Composting Systems, Inc.
Reciorganica Ltd.
Stinnes Enerco
Wright Environmental Management

Composting Systems: Enclosed Aerated Static Piles

Ag-Bag Environmental
DuPont de Nemours Sarl
SEC Technologies, Inc./W.L. Gore, Inc.

Composting Systems: Horizontal Agitated Beds

Fairfield Service Co.
Farmer Automatic
Global Earth Products
Heil Engineered Systems
Longwood Manufacturing
Miller Waste Systems/Ebara
Resource Optimization Technologies
Sorain Cecchini Techno
Transform Compost Systems Ltd.
U.S. Filter/IPS

Composting Systems: Open Windrows, Aerated Piles

C:N Composting Systems
EarthCare Technologies
Express Composting Systems
Norton Environmental Equipment

Composting Systems: Rotating Drums

A-C Equipment Services
Augspurger Komm Engineering, Inc.
Bedminster AB
BW Organics
Conporec, Inc.
EnviroGro Solutions, Inc.
Envirologics International

Materials Collection: Carts

Ameri-Kart Corp.
Otto Industries, Inc.
Plastopan North America, Inc.
Rehrig Pacific
SSI Schaefer Systems International, Ltd.
Toter, Inc.
Zarn, Inc.

Materials Collection: Vacuums
ODB Co.
Shred-Vac Systems

Mixers

Detcon
Jaylor Fabricating, Inc.
Kuhn Knight Inc.
McLanahan Corp.
New Direction Equipment
Patz Sales, Inc.
Roto-Mix
SSI Sludge Systems
Transform Compost Systems Ltd.
Vaughan Co., Inc.

Monitoring And Measuring: Instrumentation

Columbus Instruments
Demista Instruments
Pike Lab Supplies, Inc.
Reotemp Instrument
Spectrum Technologies

Monitoring And Measuring: Laboratory Testing

A & L Canada Labs East Inc.
A & L Great Lakes Labs
Agri Energy Resources
BBC Laboratories, Inc.
Edge Analytical
Microbial Matrix Systems, Inc.
Soil and Plant Laboratory, Inc.
Soil Control Lab
Soil Foodweb, Inc.
Woods End Research Laboratory

Mulch Colorization

Amerimulch
Becker Underwood, Inc.
EarthSaver Equipment Inc.
Fecon, Inc.
Morbark Sales Corp.
Rotochopper Inc.
T.H. Glennon Co.

Odor Control

Alltech, Inc.
Biorem Technologies, Inc.
Bohn Biofilter Corp.
CH2M Hill
D.F. Brandt, Inc.
Desert King International
Duall Division/Metpro Corp.
Envirogen
Global Odor Control Technologies
Hinsilblon
Monsanto Enviro-Chem Systems, Inc.
Nature Plus, Inc.
NuTech Environmental Corp.
Odor Management, Inc.
Purafil, Inc.
Spencer Turbine Co.
St. Croix Sensory, Inc.

Screens

Action Equipment Co.
Aggregates Equipment, Inc.
Allu Group
Amadas Industries
Bulk Handling Systems, Inc.
CBT Wear Parts, Inc.
CMI Corp.
Construction Equipment Co.
Continental BioMass Industries
Doppstadt US
Duratech Industries International, Inc.
EarthSaver Equipment Inc.
Erin Systems
Excel Recycling & Manufacturing
Extec, Inc.
EZ Screen/ Argus Industrial Co.
Farmer Automatic
Fecon, Inc.
Finlay Hydrascreen U.S.A.
Kuhn Knight, Inc.
Lubo USA
McCloskey Bros. Mfg.
McLanahan Corp.
Multitek, Inc.
Nordberg-Read Corp.
Norton Environmental Equipment
Orbit Screens
Peterson Corp.
Powerscreen International
Rawson Mfg., Inc.
Re-Tech, A Terex Co.
Royer Industries, Inc., A Terex Co.
The Screen Machine
Screen USA
Triple/S Dynamics, Inc.
United Rotary Brush Corp.
West Salem Machinery Co.
Wildcat Manufacturing
Willibald GmbH

Size Reduction: Chippers, Shredders And Grinders

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Amadas Industries
Ameri-Shred Industrial Corp.
American Pulverizer
American Rubber Technologies, Inc.
Auburn Machinery, Inc.
Bandit Industries, Inc.
Bouldin & Lawson Inc.
Burrows Enterprises, Inc.
CBT Wear Parts, Inc.
CMI Corp.
Columbus McKinnon Corp.
Continental Biomass Industries
C.S. Bell Co.
CW Manufacturing, Inc.
Diamond Z Mfg.
Doppstadt US
Duratech Industries International, Inc.
EarthSaver Equipment Inc.
Excel Recycling & Manufacturing
Fecon, Inc.
Granutech-Saturn Systems Corp.
W.J. Heinrichs, Inc.
Industrial Paper Shredders, Inc.
Jeffrey Specialty Equipment Corp.
Jones Manufacturing Co.
La Bounty Manufacturing
Lane Forest Products
Metso Minerals
Morbark Sales Corp.
Multitek, Inc.
Norton Environmental
ODB Co.
Patz Sales, Inc.
Peterson Corp.
PlanA, Inc.
Powerscreen International
Precision Husky Corp.
Recycling and Processing Equipment
Re-Tech, A Terex Co.
Rotochopper, Inc.
The Screen Machine
Shred-Tech
Shred-Vac Systems
Simplicity Engineering/ Gruendler Crusher
SSI Shredding Systems
Sundance
Terex Recycling
Triple/S Dynamics, Inc.
Tryco/Untha
U.S. Manufacturing Co.

A

A1 Organics
16350 WCR 76, Eaton, CO 80615
970-454-3492
www.a1organics.com

A & L Canada Labs East Inc.
2136 Jetstream Rd.
London, ON Canada N5V 3P5
888-605-6054

A & L Great Lakes Labs
3505 Conestoga Dr.
Ft. Wayne, IN 46808
260-483-4759

A and A Magnetics
P.O. Box 1427, Woodstock, IL 60098
815-338-6054
www.aamag.com

A-C Equipment Systems
6623 W. Washington St.
Milwaukee, WI 53214
414-475-2554
www.a-cequipment.com

Action Equipment Co.
P.O. Box 3100, 1000 Industrial Pkwy.,
Newberg, OR 97132
503-537-1111
www.actionconveyors.com

ADI Systems, Inc.
182 Main St., Unit 6,
Salem, NH 03079
603-893-2134
www.adisystems.ca

Advanced Biotechnology, Inc.
P.O. Box 3637, #2 East Lake Way
Airdrie, AB Canada T4B 2B8
403-912-7424

AGCO/Ag-Chem Equipment Co.
13625 Geyser Path
Apple Valley, MN 55343
952-891-4567
www.agchem.com

Ag-Bag Environmental
2320 S.E. Ag-Bag Ln.
Warrenton, OR 97146
800-334-7432
www.ag-bag.com

Ag-Gressor One
24915 Page St., Kewanee, IL 61443
309-853-1644
www.ag-gressorone.com

Aggregates Equipment, Inc.
9 Horseshoe Rd., Leola, PA 17540
717-656-2131
www.aggregatesequipment.com

Agresource, Inc.
100 Main St., Amesbury, MA 01913
978-388-5110

Agri Energy Resources
21417 1950 E St.,
Princeton, IL 61356
815-872-1190
www.agrienergy.com

Agronomic Management Group
P.O. Box 120306,
Arlington, TX 76012
817-571-9391

Alfa Laval Separation Inc.
955 Mearns Rd.,
Warminster, PA 18974
215-443-4019

Allgro
P.O. Box 247, Columbus, NJ 08022
800-662-2440

Alliant Energy
4902 N. Biltmore Ln., P.O. Box 77007
Madison, WI 53707-1007
608-458-5049
www.alliantenergy.com

Alltech, Inc.
3031 Catnip Hill Pike
Nicholasville, KY 40356
606-885-9613

Allu Group
861 Main St., Hackensack, NJ 07601
800-939-2558
www.allugroup.com

Amadas Industries
1100 Holland Rd., Suffolk, VA 23434
757-539-0231

Ameri-Kart Corp.
433 Industrial Rd.,
Goddard, KS 67052
800-533-2475
www.ameri-kart.com

Ameri-Shred Industrial Corp.
P.O. Box 205, Alpena, MI 49707
517-356-1593

American Bio Tech
280 Business Park Circle
St. Augustine, FL 32095
904-940-5140
www.abt-compost.com

Amerimulch
6409 Granger Rd.
Independence, OH 44131
888-556-3304
www.amerimulch.com

American Pulverizer
5540 W. Park Ave., St. Louis, MO 63110
314-781-6100
www.ampulverizer.com

American Rubber Technologies, Inc.
302 N. Ln. Ave.,
Jacksonville, FL 32254
800-741-5201
www.americanrubber.com

Arrow Ecology
105 Carmel Rd., Wheeling, WV 26003
304-242-0341
www.arrowecology.com

Ashbrook Corp.
11600 E. Hardy, Houston, TX 77093
800-362-9041

Auburn Machinery, Inc.
P.O. Box 3065
Auburn, ME 04212
800-888-4244
www.auburnmachinery.com

Augspurger Komm Engineering, Inc.
15455 N. Greenway-Hayden Loop
Ste. C14, Scottsdale, AZ 85260
480-483-5966
www.aeincaz.com

Autrusa/Imants USA
941 Perkiomenville Rd.
Perkiomenville, PA 18074
610-754-1110
www.sandberger.com or
www.imants.com

B

Backhus Kompost-Technologie
Wischenstr. 26
D-26188 Edewecht-Jedde, Germany
044-86-928418
P.O. Box 193, Allamuchy, NJ 07820
908-850-3899
www.backhus.com

Bac Tee Systems, Inc.
P.O. Box 5192, 830 South 48th St.
Grand Forks, ND 58206
701-775-8775
www.bactee.com

Baler Equipment Co.
6002 S.W. Texas Ct.
Portland, OR 97219
800-426-1723
www.baler-eqpt.com

Bandit Industries, Inc.
6750 Millbrook Rd., Remus, MI 49340
517-561-2270
www.banditchippers.com

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41 Kelfield St.
Rexdale, ON Canada M9W 5A3
416-247-7875

Barnes Nursery
3511 W. Cleveland Rd.
Huron, OH 44839
419-433-5525

BASF Corporation
3000 Continental Dr., N.
Mount Olive, NJ 07828
973-426-4206
www.basf.com

BBC Laboratories, Inc.
1217 N. Stadem Dr.,
Tempe, AZ 85281
480-967-5931
www.bbclabs.com

Cortec Corporation
4119 White Bear Parkway
St. Paul, MN 55110
800-426-7832
www.cortecvci.com

Cover-All Building Systems
2201 Speers Ave.
Saskatoon, SK Canada
S7L 5X6
877-615-4776
www.coverall.net

Covered Bridge Organic
P.O. Box 91, Jefferson, OH 44047
440-576-5515

Creative Concepts of Georgia, Inc.
P.O. Box 425, Varnell, GA 30756
706-694-2517

Creative Packaging
820 Scenic Hwy., #500
Lookout Mtn., TN 37350
423-825-5311
www.forestindustry.com/creativepackaging

C.S. Bell Co.
170 W. Davis St., Tiffin, OH 44883
419-448-0791
www.csbellco.com

CW Manufacturing, Inc.
P.O. Box 246, 14 Commerce Dr., Sabetha, KS 66534
785-284-3454

D

Darling Industries
2501 O'Connor Ridge Blvd., #300, Irving, TX 75038
972-281-4460

Demista Instruments
316 E. Foster St.
Alrington Heights, IL 60056
847-439-6857

Desert King International
3802 Main St., Chula Vista, CA 92011
800-982-2235
www.desertking.com

Detcon
P.O. Box 2249,
Farmingdale, NJ 07727
732-938-2211

D.F. Brandt Inc.
8152 Kirkville Rd.,
Kirkville, NY 13082
315-656-3884
www.dfbrandt.com

Diamond Z Mfg.
11299 Bass Ln., Caldwell, ID 83605
208-585-2929
www.diamondz.com

Dings Co., Magnetic Group
4740 W. Electric Ave.
Milwaukee, WI 53219
414-672-7830

Doppstadt
PO Box 307, Haslett, MI 48840
517-881-9980

Doran Mfg.
P.O. Box 147, Harlan, IA 51537
712-755-7980

Double T Equipment
P.O. Box 3637, #2 E. Lake Way
Airdrie, AB Canada T4B 2B8
403-948-5618
www.doubletequipment.com

Dry Vac Co.
101 N. Front St.
Rio Vista, CA 94571-1838
707-374-7500
www.dryvac.com

Duall Division-Metpro Corp.
1550 Industrial Dr.,
Owosso, MI 48867
989-725-8184
www.met-pro.com

Dupont de Nemours Sarl
Rue du General Patton
L-2984 Contern,
Luxembourg
www.dupont.com
352-3666-5677

Duratech Industries International, Inc.
P.O. Box 1940
Jamestown, ND 58402-1940
701-252-4601
www.dura-ind.com

Duro Bag Mfg., Co.
Davies & Oak Sts., Ludlow, KY 41016
800-879-3876

Duske Engineering
10700 W. Venture Dr.
Franklin, WI 53132
414-529-0240

E

EarthCare Technologies
820 Industrial Dr., P.O. Box 998, Lincoln, AR 72744
501-824-5511
www.ecticompost.com

EarthSaver Equipment, Inc.
P.O. Box 7325, Kalispell, MT 59904
866-227-2244
www.earthsaverequipment.com

Earth Shell Corporation
1301 York Rd., Suite 200
Lutherville, MD 21093
410-847-9420
www.earthshell.com

EarthWorks
P.O. Box 278K, Martins Creek, PA 18063
800-732-8873

East Manufacturing Co.
P.O. Box 277, Randolph, OH 44265
330-325-9921
www.eastmfg.com

Eastman Chemical Co.
P.O. Box 431, 200 S. Wilcox Dr., Kingsport, TN 37662
423-229-2067
www.eastman.com

EcoCorp
1211 S. Eads St., Ste 803
Arlington, VA 22202
626-405-1463
www.ecocorp.com

Ecovation
Eastgate Square, Ste. 200
50 Square Drive
Victor, NY 14653
585-421-3500
www.anaerobics.com

Edge Analytical
11525 Knudson Rd.
Burlington, WA 98233
800-755-9295

Engineered Compost Systems
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Seattle, WA 98199
206-634-2625
www.compostsystems.com

Entec-Environment Technology
A-6972 Fussach
Schilfweg, Austria RSB-HAUS
435-578-7946
www.biogas.at

Entek BioSystems, LC
P.O. Box 372, Smithfield, VA 23431
757-357-6500

EnviroControl Ltd.
26 Forsythia Dr.,
Greenways
Cardiff UK CF23 7MP
029-205-49909

Enviro-Ganics
4505 Baker Rd., R.R. #3
Niagara Falls, ON Canada
L2E 6S6
905-382-0330

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P.O. Box 90, Pewaukee, WI 53072-0090
414-549-6898

EnviroGro Solutions, Inc.
P.O. Box 10761
Lancaster, PA 17605-0761
717-295-9515
www.envirogro.com

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Hallco Manufacturing Co., Inc.
P.O. Box 505, Tillamook, OR 97141-0505
800-542-5526
www.hallco-mfg.com

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Plymouth, MN 55447
800-927-4674
www.hamerinc.com

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559-738-9301
www.happydranch.com

HCL Machine Works
15142 Merrill Ave., Dos Palos, CA 93620
209-392-6103
www.hclmachineworks.com

Heil Engineered Systems
205 Bishops Way, #201
Brookfield, WI 53005
707-894-7724

Herhof Umwelttechnik GmbH
Riemannstrasse 1
35606 Solms, Germany
49 6442 207 111
www.herhof.de

W.J. Heinrichs, Inc.
21013 E. Dinuba Ave.
Reedley, CA 93654
209-638-3627

Hinsilblon
820 N.E. 24th Ln., Cape Coral, FL 33909
800-833-4777
www.hinsilblon.com

Hi-Way/Highway Equipment Co.
616 D Ave. N.W., Cedar Rapids, IA 52405
800-363-1771
www.highwayequipment.com

Hobart Corp.
401 West Market St., Troy, WI 45374
937-332-3000
www.hobartcorp.com

HotRot Composting Systems Ltd.
Private Bag 4749
Christchurch, New Zealand
64-332-56685
www.hotrotsystems.com

Hydropress LLC
59 Dwight St., Hatfield, MA 01038
413-247-9656
www.hydropress.net

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Indaco
3391 McNicoll Ave.
Scarborough, ON Canada K1B 3G6
416-332-0422

Industrial Magnetics, Inc.
1240 M-75 South, Boyne City, MI 49712
231-582-3100
www.magnetics.com

Industrial Paper Shredders, Inc.
P.O. Box 180, Salem, OH 44460
888-637-4733
www.industrialshredders.com

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800-D Beaty St.
Davidson, NC 28036-9000
704-896-5349
www.irenergysystems.com

Insta-Pro
10104 Douglas Ave.
Des Moines, IA 50322
515-254-1200
www.insta-pro.com

International Paper Co.
Two Manhattanville Rd.
Purchase, NY 10577
800-223-1268

Iogen Corp.
300 Hunt Club Rd., East Ottawa, ON Canada K1V 1C1
613-733-9830
www.iogen.com

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J&J Truck Bodies & Trailers
10558 Somerset Pike
Somerset, PA 15501
800-777-2671
www.jjbodies.com

Jacobs Corp.
P.O. Box 727, Harlan, IA 51537-0727
800-831-2005
www.jacobscorp.com

Jaylor Fabricating Inc.
R.R. #2, Orton, ON
Canada L0N 1N0
519-787-9353
www.jaylor.com

Jeffrey Specialty Equipment Corp.
398 Willis Rd., Woodruff, SC 29388
864-476-7526
www.jeffreycompany.com

Jones Manufacturing
P.O. Box 38, 1486 12th Rd.
Beemer, NE 68716-0038
402-528-3861
www.mightygiant.com

K

Keep It Simple, Inc.
12323 180th Ave. NE
Redmond, WA 98052
866-558-0990
www.simplici-tea.com

Keith Manufacturing
P.O. Box 1, Madras, OR 97741
541-475-3802

Kellogg Supply Co.
350 W. Sepulveda Blvd.
Carson, CA 90745
310-830-2200

Kennametal, Inc.
P.O. Box 231, Latrobe, PA 15650
800-222-9327
www.kennametal.com

Komline-Sanderson Engineering Corp.
12 Holland Ave., Peapack, NJ 07977
908-234-1000

Kompogas AG.
Rohrstrasse 36
8152 Glattbrugg, Switzerland
014-180-97137

Kruger A/S
Klamshgervej 2-4
8230 Aabyhoj, Denmark
458-746-3300
www.kruger.dk

Kuhn Knight Industrial Div.
1501 W. Seventh Ave.
Brodhead, WI 53520
608-897-2131
www.knightmfg.com

Kurtz Brothers
P.O. Box 31179
Independence, OH 44131
800-223-7645

L

La Bounty Manufacturing
100 State Rd. 2, Two Harbors, MN 55616
218-834-2123

Lane Forest Products
P.O. Box 1431, Eugene, OR 97440
541-345-9085

LINDE BRV BiowasteTech AG
Rue de Verger 11, Case Postale 112
CH 2014 Bole, Switzerland
41-0328-430-450

Littleford Day, Inc.
7451 Empire Dr., Florence, KY 41042
606-525-7600

Longwood Manufacturing
816 E. Baltimore Pike
Kennett Square, PA 19348
610-444-4200
www.lmconline.com

Lotepro
9 Parsons Ln., Redding, CT 06896
203-938-3527

Lubo USA
78 Halloween Blvd.
Stamford, CT 06902-5120
203-967-1140
www.lubo.nl

O.S. Walker Co., Inc.
Rockdale St., Worcester, MA 01606
800-962-4638

Otto Industries, Inc.
P.O. Box 410251
Charlotte, NC 28241-0251
704-588-9191

O.W.S., Inc. (Organic Waste Systems)
3155 Research Blvd., Ste. 104
Dayton, OH 45420
937-253-6888

P

Pacific Biodiesel
285 Hukilike St., B105
Kahului, Maui, HI 96732
814-349-9820
www.biodiesel.com

Pacific Garden Co.
HCR 1, Box 150, Millheim, PA 16854
814-349-9820
www.livingsoil.com

Packer Industries
5800 Riverview Rd.
Marbleton, GA 30126
800-818-2899
www.packer2000.com

Pannell Mfg. Corp.
1780 Baltimore Pike, Avondale, PA 19311
610-268-2012

Patz Sales, Inc.
P.O. Box 7, Pound, WI 54161-0007
920-897-2251
www.patzsales.com

Peterson Corp.
P.O. Box 40490, Eugene, OR 97404
541-689-6520
www.petersoncorp.com

Pike Lab Supplies, Inc.
R.R. #2, Box 92, Strong, ME 04983
207-684-5131
www.pikeagri.com

Pinnacle Biotechnologies
1667 Cole Blvd., Ste. 400
Golden, CO 80401
303-674-3236
www.pinnaclebiotech.com

PlanA, Inc.
P.O. Box 10656
San Bernardino, CA 92423
888-932-7668
www.planainc.com

Plastics Solutions, Inc.
761 Cardero St., 2nd Fl.
Vancouver, BC Canada V6G 2G3
604-597-7063
www.degradableplastics.com

Plastopan North America, Inc.
812 E. 59th St.
Los Angeles, CA 90001-1006
323-231-2225

Powerscreen International
11001 Electron Dr.,
Louisville, KY 40299
502-736-5200
www.terex.com

Precision Husky Corp.
P.O. Box 507, Leeds, AL 35094-0507
205-640-5181
www.precisionhusky.com

Preferred Solutions Inc.
7819 Broadview Rd.
Cleveland, OH 44131
216-642-1200
www.stayflex.com

Premier Tech Packaging
1 Ave. Premier
Riviere-du-Loup, PQ
Canada G5R 4C9
418-867-8883
www.premiertech.com

Prescott Paper Products USA
P.O. Box 1235, Main PO
Kingston, ON Canada K7L 4Y8
613-384-9604
www.ppaper.com

Processall Inc.
10596 Springfield Pike
Cincinnati, OH 45215
513-771-2266

PRSM
200 Gilbertsville Rd., Bldg. E, Gilbertsville, PA 19525
800-432-3966

Purafil, Inc.
2654 Weaverway,
Doraville, GA 30340
800-222-6367

R

Rawson Mfg., Inc.
99 Canal St., Putnam, CT 06260
860-928-4458

Re-Tech, A Terex Co.
212 S. Oak St., Durand, MI 48429
989-288-9224
www.re-tech.com

Reclorganica Ltd.
Diagonal 108 A, No. 6-24,
Santafe de Bogata
Columbia, South America
571-256-2515

Recycling and Processing Equipment
R.R. 4, Box 317, Peru, IN 46970
800-472-3202

Rehrig Pacific Co.
4010 East 26th St.
Los Angeles, CA 90023-4601
800-421-6244
www.rehrigpacific.com

Reotemp Instrument
11568 Sorrento Valley Rd., #10
San Diego, CA 92121
800-648-7737
www.reotemp.com

Resource Conservation Management
P.O. Box 4715, Berkeley, CA 94704
510-658-4466

Resource Development Associates
200 E. Spring Creek Dr., Unit 4
Pierre, SD 57501-6240
605-224-4334
www.biogasworks.com

Resource Optimization Technologies
R.R. #2, Box 495, Cornish, NH 03745
603-542-5291

Resource Recovery Systems of Nebraska/KW Composter
Route 4, 511 Pawnee Dr.
Sterling, CO 80751
970-522-0663
www.rrskw.com

Rexius, Inc.
750 Chambers St., Eugene, OR 97402
800-285-7227
www.rexius.com

Roediger Pittsburgh, Inc.
3812 Route 8, Allison Park, PA 15101
412-487-6010

Rotochopper, Inc.
Route 1, Coon Valley, WI 54623
320-548-3586
www.rotochopper.com

Roto-Mix
P.O. Box 1724, Dodge City, KS 67801
316-225-1142
www.rotomix.com

Royer Industries, Inc., A Terex Co.
212 S. Oak St., Durand, MI 48429
989-288-9224
www.royerind.com

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Sandbagger Corp.
P.O. Box 626, Wauconda, IL 60084
815-363-1400
www.thesandbagger.com

Sandberger Co.
941 Perkiomenville Rd.
Perkiomenville, PA 18074
610-754-1110

T.H. Glennon Co.
26 Fanaras Dr., P.O. Box 5311, Salisbury, MA 01952
978-465-7222
www.mulchcolorject.com

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2361 Durham-Dayton Hwy.
Durham, CA 95938
800-824-4163

Toter, Inc.
841 Meacham, Statesville, NC 28687
704-872-8171

Trail King Industries
P.O. Box 7064, 300 E. Norway
Mitchell, SD 57301
605-995-3604
www.trailking.com

Transform Compost Systems Ltd.
#201, 33230 Old Yale Rd.
Abbotsford, BC Canada V2S 2J5
604-504-5660
www.transformcompost.com

Triformis Corp.
222 N. Sepulveda Blvd., Ste. 2000
El Segundo, CA 90245
310-364-5262
www.triformis.com

Trimax Residuals Management Inc.
9440 60th Ave.
Edmonton, AB Canada T6E 0C1
780-433-7373
www.trimaxenv.com

Trinity Trailer Mfg., Inc.
8200 Eisenman Rd., Boise, ID 83716
208-336-3666
www.trinitytrailer.com

Triple/S Dynamics, Inc.
1031 S. Haskell, Dallas, TX 75223
214-828-8600
www.sssdynamic.com

Tryco/Untha
P.O. Box 1277, Decatur, IL 62525
217-864-4541
www.tryco.com

U

U.S. Filter/IPS
2650 Tallevast Rd.,
Sarasota, FL 34243
508-347-4560
www.water.usfilter.com

U.S. Manufacturing, Inc.
104 N. Main, New Providence, IA 50206
800-800-1812
www.usmexpress.com

United Rotary Brush Corp.
20078 State Rt. 4,
Marysville, OH 43040
937-644-3515
www.united-rotary.com

Universal Fabric Structures
2200 Kumry Rd.,
Quakertown, PA 18951
215-529-9921

Universal Refiner Corp.
P.O. Box 151, Montesano, WA 98563
800-277-8068

UTI Jaeger GmbH
Am Muehlberg 1,
Starnberg, Germany
4981512536
www.uti-jaeger.com

V

Vaughan Co., Inc.
364 Monte Elma Rd.
Montesano, WA 98563
360-249-4042
www.chopperpumps.com

Vecoplan, LLC
P.O. Box 2284, High Point, NC 27261
336-886-6070

Vermeer Manufacturing Co.
P.O. Box 200, Pella, IA 50219
641-628-3141
www.vermeer.com

VermiCo
P.O. Box 1134, Merlin, OR 97532
541-476-9626
www.vermico.com

Vermitechnology Unlimited, Inc.
P.O. Box 130, Orange Lake, FL 32681
352-591-1111
www.vermitechnology.com

Verville Machinery
1835 Power
Drummondville, PQ
Canada, J2C 5X4
819-477-3135
www.machinery.verville.com

W

Waukesha Engine
1000 West St. Paul Ave.
Waukesha, WI 53188
www.waukeshaengine.dresser.com

Wessuc, Inc.
973 Alberton Rd., S.
Jerseryville, ON Canada L0R 1R0
519-752-0837

West Salem Machinery Co.
P.O. Box 5288, Salem, OR 97304
503-364-2213
www.westsalem.com

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6701 Business Way
Boise, Idaho 83716
888-344-2539
www.westerntrailer.com

WETCO
3701 Faulkner Dr., #306
Lincoln, NE 68516
402-420-2874

White Mountain Resource Management
P.O. Box 1081, Ashland, NH 03217
603-536-8900
www.rmi-recycles.com

W.H.O. Manufacturing Co.
P.O. Box 1153, Lamar, CO 81052
719-336-7433
www.who-mfg.com

Wildcat Manufacturing
Hwy. 81, Box 523,
Freeman, SD 57029
800-627-3954
www.wildcatmfg.com

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Bahnhofstr 6
Sentenhart, D-88639
Germany
497-578-189131
www.willibald-gmbh.de

W.L. Gore, Inc.
c/o SEC Technologies, Inc.
774D Meadowlark Road
Lynden, WA 98264
360-354-2250
www.compost-technologies.com

Wood-Mizer
8180 W. 10th St.,
Indianapolis, IN 46214
317-271-1542

Woods End Research Laboratory
20 Old Rome Rd., P.O. Box 297
Mt. Vernon, ME 04352
207-293-2457
www.woodsend.org

Worm World, Inc.
12425 N.W. CR 231
Gainesville, FL 32609
352-485-1235

Wright Environmental Management
9050 Yonge St., Ste. 300
Richmond Hill, ON Canada L4C 9S6
905-881-3950
www.wrightenvironmental.com

Y

Z

Zarn, Inc.
1001 Northeast Market St.
Reidsville, NC 27320
910-342-8842
www.zarn.com

Appendix B. Equipment

The following information describes some of the most common pieces of equipment used for large-scale composting facilities and yard waste management in general. Each type of equipment is explained, followed by cost information on selected models. Listing of product brand names is provided as a means of giving examples and does not constitute Ohio EPA endorsement of the equipment or the manufacturing company. In addition, omission of a particular product should not be interpreted negatively.

Front-End Loader

A front-end loader is the single, essential piece of equipment for yard waste composting and the only equipment used by the majority of communities. For leaf composting, the loader needs to be available continuously for windrow-building between mid-October and mid-December, and thereafter, primarily for turning on a frequent basis. (A windrow is a long, triangular-shaped pile of material. In yard waste composting, a typical windrow size is 10 to 12 feet wide at the bottom of the pile, 6 to 12 feet in height, and sometimes hundreds of feet long.) Both track loaders and wheel loaders may be used in composting operations. The track loader functions better in loose and muddy soils, is useful in rough site grading, and can move piles of dense materials. However, the wheel loader, shown in Figure B-1, is more versatile, more easily maneuvered, and causes less damage to road and ground surfaces.

Track and wheel front-end loaders come in various sizes with standard and optional accessories. They usually are equipped with diesel engines and are hydraulically-powered, although models using gasoline and other fuels are also available. Bucket sizes range from 3/4 to four cubic yards and are dictated by engine size and intended use. Because compost is much less dense than gravel or soil, often a larger bucket can be used than is normal for a particular machine. A two-part drop bucket may be useful in building very large wind-

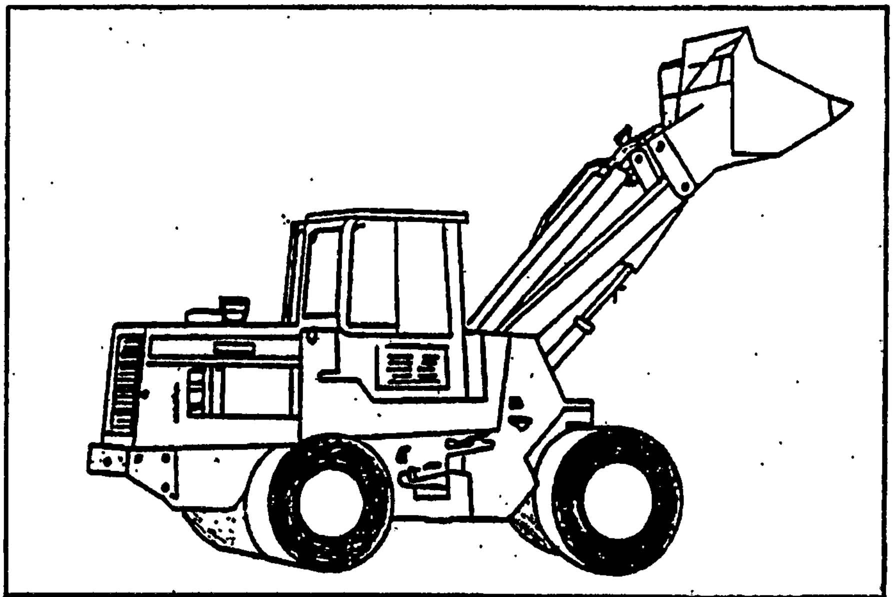


Figure B-1. Front-End Loader

The large, self-contained turners can process about 2,000 to 4,000 cubic yards per hour and cost ranges from $100,000 to $200,000. Tractor and loader-propelled units typically cost from $10,000 to $100,000 and are designed to turn smaller windrows. A major maintenance requirement of turners is replacement of the flails or teeth, which cost from $375 to $500 per set. If a compost turner is to be used, community officials may prefer to lease a turner or share the cost with one or more other composting projects. (The Cities of Westlake and Bay Village in Cuyahoga County, Ohio cooperated to purchase a Scarab windrow-turning machine for use at their facility.)

Plastic bags can be a problem in many compost operations. These bags can be manually removed from the teeth of the windrow turner at the end of the windrow, although it is preferrable to remove them prior to placement in windrows, or eliminate plastic bags altogether as a collection option.

Shredders and Grinders

Shredders are frequently used to reduce the size of yard waste material and/or compost. A shear shredder is a stationary or trail-mounted machine that reduces the size of material through the action of knives travelling in opposite directions. After the material is loaded into a receiving hopper it is carried to the top of a conveyor. After the conveyor drops the material onto a belt, and it passes a system of adjustable, variable sweep fingers, the material undergoes a continuous raking action to shred and aerate the load. Oversized pieces are forced back for further shredding while items such as sticks, stones, metal and glass are rejected and discharged through a trash chute.

Depending upon the size of the hopper opening, shredders can process almost any size of material. However, most shredders are designed to process waste in pieces less than six inches in size. The processing rates can range from one to fifty tons of material shredded per hour.

A shredder may be operated by one or two individuals, depending upon the quantity of material which must be shredded. The cost of shredders ranges from $30,000 to almost $500,000 depending on size and options selected.

Hammermills reduce the size of waste by free-swinging metal hammers mounted on a spinning shaft, which pulverize material until small enough to drop through discharge openings. Tub grinders are perhaps the best example of equipment which utilizes hammermills. (See Figure B-3.) These machines are characterized by a rotating tub-like intake system. The rotation of the tub moves materials across a fixed floor containing the hammermills. As material is pulverized, it is forced through a screen and then conveyed into piles or a transfer vehicle. Tub grinders normally include a conveyor belt or a knuckleboom loader. (A knuckleboom loader is a hydraulically-operated arm with a grapple on the end which is used to pick up loads of waste material and then drop it into the tub-portion of the machine.)

capable of processing from 25 to 50 cubic yards per hour range in price from $35,000 to $170,000, including screens, feed hoppers, and conveyors.

Bag Breaking Equipment

As the size of projects grow, the need for a system other than the manual opening of bags increases. Today there are several manufacturers producing bag breaking or ripping units to separate the yard waste from the bags. In one of the two bag breaker designs, widely-spaced flails slice the bag followed by a trommel screen that actually separates the yard waste from the bag. In the other system, only a trommel is used, but the trommel contains hooks or barbs that cut the bags as they pass through it. The capacity of bag breaking systems ranges from 10 to 50 tons per hour with the systems costing from $60,000 to $180,000.

Monitoring Equipment

Thermometers are important instruments for monitoring composting operations. A thermometer with a three to four foot stem and a range of 0 to 200 degrees Fahrenheit or 0 to 100 degrees Centigrade is an essential item. These instruments cost from $50 to $100 each. Temperature readings allow operators to determine the most appropriate time to turn the material.

A thermometer with a digital readout may be needed for automated aerated static pile composting. (See Chapter Two for a discussion of aerated, static

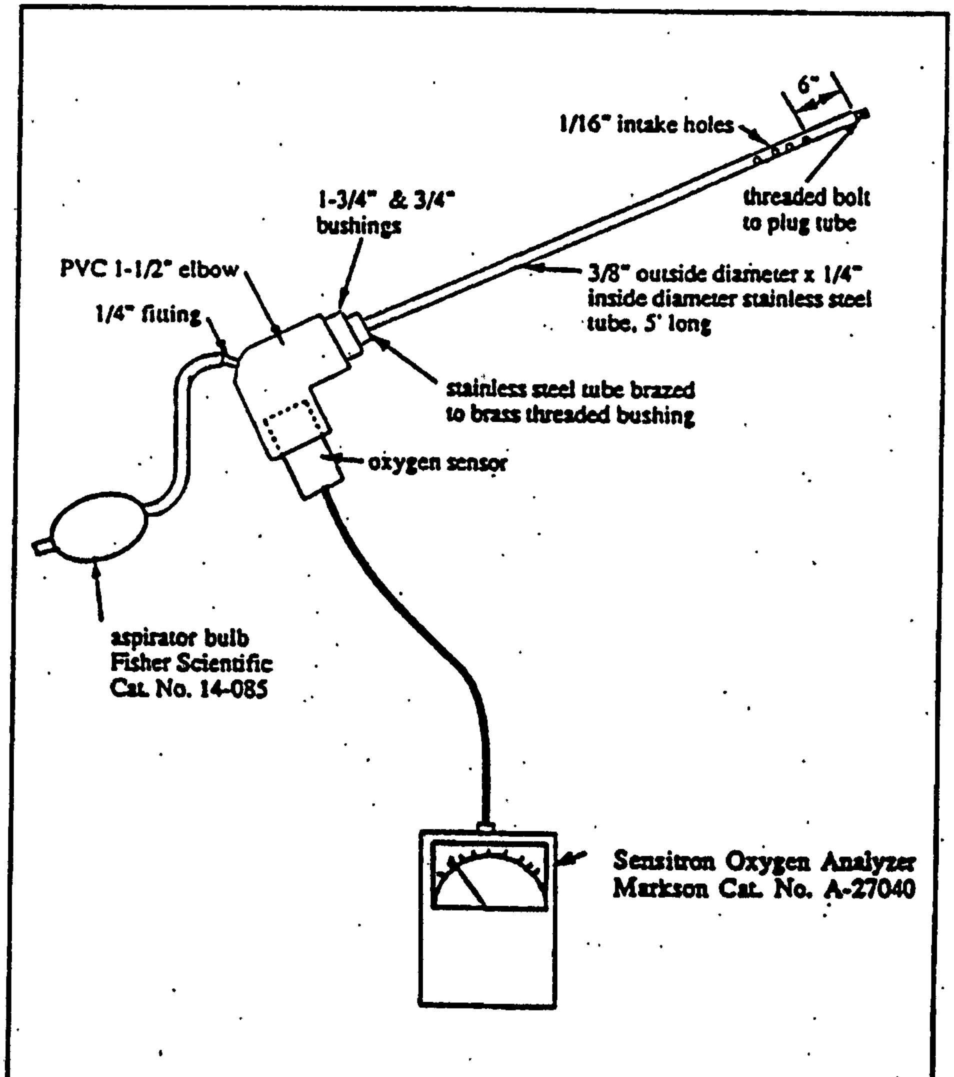


Figure B-4: Oxygen Analyzer

Table B-1. Selected Composting Equipment Costs

Manufacturer	Equipment Type	Size/Capacity	Cost	Comments
Windrow Turners				
Brown Bear P.O. Box 148 Lenox, IA 50851 (515) 333-4551	Model 200	115 HP 1,500 cu.yd./hour 10'x 31" aerator head	$124,300	Auger moves compost to the windrow turner
	Model 300	177 HP 3,000 cu.yd./hour 10'x 3' aerator head	$147,100	
	Model 400	225 HP 3,000 cu.yd./hour 14'x 39" aerator head	$175,800	
	Model 500	290 HP 4,000 cu.yd./hour 12'x 4' aerator head	$207,900	
Cobey Composting (Eagle Crusher Company) 4250 S.R. 309 Galion, OH 44833 (419) 468-2288	Model 12A	225 HP 1000-2000 tons/hour 14'x 6' windrow	$105,000 to $185,000	Straddles windrow, and drum lifts and turns compost
Resource Recovery Systems Route 4 Sterling, CO 80751 (303) 522-0663	K-W 614	300 HP 5,000 cu.yd./hour 2000 tons/hour 14'x 6' windrow	$102,500	Straddles windrow, and drum lifts and turns compost
Scarab Route 2 Box 40 White Deer, Texas 79097 (806) 883-7621	Scarab 14	234 HP 2,000 tons/hour 14'x 6' windrow V-belt drive	$122,000	Straddles windrow, and drum lifts and turns compost

Manufacturer	Equipment Type	Size/Capacity	Cost	Comments
Window Turners (cont.)				
	CX750ME	177 HP 14'x 5' windrow 1,100 tons/hour	$70,000	Self-powered; mounted on 3 cu.yd. capacity front-end loader.
	M700B Special	325 HP 2,600 tons/hour	$100,000	Self-powered; mounted on 4 cu.yd. capacity front-end loader.
Shredders/Grinders				
Amadas Pulverizer 1100 Holland Road Suffolk, VA (804) 539-0231	421	75 HP 40 cu.yd./hour	$11,000*	Hammermill
	430	150 HP 60 cu.yd./hour	$14,000*	Hammermill
		350 HP	$34,000*	Hammermill
Farmhand 6421 Hazeltine Blvd. Excelsior, MN 55331 (612) 474-1941	6650	100 cu.yd./hour	$26,400*	Large tubgrinder with hammermill; single axis PTO driven from tractors with 100 to 200 HP.
Finn Corporation 9281 LeSaint Dr. Fairfield, OH 45014 (800) 543-7166	Willibald MZA 1500	165 HP 25 to 50 cu.yd./hour	$140,000 to $150,000	Hammermill, best for brush, grass, and leaves; also shreds logs.
	Willibald MZA 2500	245 HP 50 to 100 cu.yd./hour	$180,000 to $200,000	Hammermill, best for brush, grass, and leaves; also shreds logs.

Manufacturer	Equipment Type	Size/Capacity	Cost	Comments
Shredders/Grinders (cont.)				
Recycling Systems, Inc. P.O. Box 364 Winn, WI 48896 (517) 866-2800	Industrial Tub Grinder	400 to 525 HP Up to 30 tons per hour	$130,000 to $175,000	Tub grinder with hammermill (loader optional)
Mitts & Merrill (Carthage Machine Co.) 571 W. End Carthage, NY 13619 (315) 493-2380	MS-1714 MS-2817 MS-2833 MS-4220 MS-4256 MS-5028 MS-5040	10 HP 20 HP 30 HP 50 HP 75 HP 125 to 150 HP 200 HP	$17,500* $35,000* $55,000* $70,000* $110,000* $180,000* $320,000*	Low speed, high torque hook/shear shredders
Royer P.O. Box 1232 Kingston, PA 18704 (717) 287-9624	182	25 cu.yd./hour	$20,000*	Two stage mixing of material; cleated belt shredders; separates non-shreddable material from end-product.
	300	75 cu.yd./hour	$48,000*	
	365	125 cu.yd./hour	$65,000	
	401	250 cu.yd./hour	$105,000	
Shred Tech P.O. Box 1508 Cambridge, Ontario Canada N1R 7G8 (519) 621-3560	ST-10L	10 HP	$14,000*	High torque, 0.5 ton/hour low energy shredders. Counter-rotating shafts with hooked cutter blades.
	ST-20	15 to 20 HP 1.5 tons/hour	$28,300*	
	ST-36	30 HP	$43,500*	

Manufacturer	Equipment Type	Size/Capacity	Cost	Comments
Screens				
Ohio Central Steel Company 7001 Americana Parkway Reynoldsburg, Ohio 43068 (800) 837-3344	Pulverize II	60 to 80 cu.yd./hour	$44,900	Oscillating screen stacking conveyor
	Screen Machine	120 to 180 cu.yd./hour	$60,000	Oscillating screen stacking conveyor
	Blender	120 to 180 cu.yd./hour	$99,500	Double hoppers, blender, oscillating screen and stacking conveyor
Powerscreen of America 11300 Electron Drive Louisville, KY 40299 (502) 267-2316				
Resource Recovery Systems, Inc. P.O. Box 32965 Detroit, MI 48232 (519) 736-5481				
Royer Industries P.O. Box 1232 Kingston, PA 18704 (717) 287-9624				
Temperature Probes				
Atkins 3401 Southwest Fortiers Drive Gainesville, FL 32608 (904) 378-5555				
Camx Scientific P.O. Box 747 Rochester, NY 14603-0747 (716) 482-1300	Item no. 5224 x 36		$82.00	

Manufacturer	Equipment Type	Size/Capacity	Cost	Comments
Front-End Loaders (cont.)				
Elliot & Frantz, Inc. 450 East Church Road King of Prussia, PA 19406 (215) 279-5200				
Foley Machinery Company Caterpillar 855 Centennial Avenue Piscataway, NJ 08854 (201) 885-3030				
Ford New Holland, Inc. 500 Diller Avenue New Holland, PA 17557 (717) 354-1121				
J.I. Case 700 State Street Racine, WI 53404 (414) 636-6011				
Kubota Tractor Corp. 550 West Artesia Blvd. P.O. Box 7020 Compton, CA 90224 (213) 357-2531				
Long Manufacturing N.C., Inc. 111 Fairview Street Tarboro, NC 27886 (800) 344-5622				

Note: All cost information is based on 1991 prices except those marked with an asterisk (*) which are 1990 prices.

The tub itself serves two purposes. It is first a containment vessel, holding material in place until it reaches the hammermill. Secondly, the tub functions as a feeding mechanism, with the operator using the rotation of the tub to carry material around until it passes over the mill. The feeding action is also assisted by gravity.

Once the processed material passes through the sizing grates, it must be quickly carried away from the area beneath the hammermill before plugging occurs. Finally, processed material is carried away from the machine and stacked with a folding belt conveyor.

Tub grinders are in use around the world in a number of material reduction and recycling operations. Depending on the size and power of the unit, tub grinders are capable of handling all forms of woody debris to pallets and municipal yard waste. End products vary, but strong markets have been developed for hog fuel, landscape mulch, ground cover, animal bedding and compost.

Purchasing Decisions

Recycling professionals contemplating the purchase of a tub grinder are faced with a myriad of choices. First they must decide whether to go with a conventional tub grinder or a horizontal grinder, which is a hammermill that is force-fed from the side. Horizontal grinders have a slight advantage in populated areas because they contain material a little better than a tub. However, horizontal machines often have lower production rates than tub grinders.

Next, a decision must be made on what size grinder is needed. Tubs range in size from nine feet up to 15 feet in diameter, with wide ranging production capabilities and price tags that start at around $50,000 and can reach as high as $500,000. This decision should be driven by the volume and type of material to be processed. If your budget allows it, it often makes sense to purchase a slightly larger tub than is presently needed to allow for future growth.

Some other important features and options to consider are:

How will you load the tub? Most major manufacturers offer tubs with a self contained operator's cab and knuckleboom loader, or you may opt for a window without a loader. If you choose the latter option, you must have an excavator, front-end loader or other auxiliary equipment to put material in the tub.

Hammers and tips. Hammers are available in many different configurations depending on the application. Fixed hammers are usually equipped with replaceable, hard surfaced tips that can easily be reversed and replaced as they wear. Make sure you have a reliable source for these important wear parts.

Hydraulic tub tilt. Most manufacturers offer full tub tilt, which allows access to the hammermill for service, changing hammers and grates, and other maintenance.

Preparing for the Daily Grind

As recyclable materials become more diverse, the choise of the most efficient cutting tools and screen combinations gets complicated.

For example, a contractor that chooses a block hammer set-up which works well in grass and leaves, may assume it to be the best choice for grinding bundled paper. Here, conical (coned or pointed) teeth should be used.

Block-type hammers have difficulty grinding tightly packed, bundled material, causing irregular feeding. With the conical tooth, product is partially shredded in the tub and fed more consistently through the grinding chamber.

Screen choices are important, as well. With conventional screens, hammermills beat material until it's small enough to pass through the sizing holes. A knife screen, on the other hand, sheers vines, brush and construction debris, such as sheet rock and papers, by forcing material through evenly-spaced cutter knives. Wear also is reduced because in one motion, product is drawn from the tub, forced through the system and fed onto the discharge belt, resulting in little or no re-circulating.

Grinding tips:

- Nothing can save you money more than removing dirt from material prior to grinding.
- Plugged screens will drastically accelerate hammer and tooth wear.
- Reducing product size more than necessary results in accelerated hammer and tooth wear and decreased production.

In addition, contractors should consult their dealer or manufacturer when choosing hammers, teeth/cutter blocks and screens.

The bottom line is that higher productivity and less wear on these items results in increased profitability.

--Duane DeBoef, Vermeer Manufacturing, Pella, Iowa. As printed in *World Wastes*.

Feedstock Preparation and Handling

Compost Feedstock Sources: Making the Decision

Dr. Mark Risse
Extension Agricultural Pollution Prevention Specialist
The University of Georgia

Waste Management

- National MSW Generation
  - 2.7 lbs/capita/day in 1960
  - 7.2 lbs/day/capita 2002
- National Average Tip Fee
  - $10.00/ton in 1986
  - $13.63/ton (CA) to $72.60/ton (MA) in 2002
- National Number of Landfills
  - 5,345 in 1992
  - 2,142 in 2001
  - 1,765 in 2002
- EPA states that 61% of MSW stream is organic

Waste Management cont.

- In 1990, The Georgia General Assembly passed Georgia Comprehensive Solid Waste Management Act
  - Reduce solid waste 25% by 1996
  - Ban yard trimmings from landfill
  - Solid waste reporting
  - Activities to promote reduction of waste going to landfill
- State funded programs
  - Department of Community Affairs - education
  - The Georgia Environmental Partnership (GEP) – tech assist

EPA 503 Regulations

- Biosolids regulated by 40 CFR 503
- Based on over ten years of research
- For land application 503 sets limits on:
  - metals content
  - disease organisms
  - requires treatments to minimize attractiveness to flies, rodents, etc. (vectors)

Metals

- Regulated chemical elements

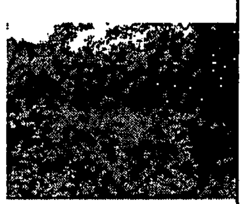
Arsenic (As)	Lead (Pb)	Selenium (Se)
Cadmium (Cd)	Mercury (Hg)	Zinc (Zn)
Chromium (Cr)	Molybdenum (Mo)	
Copper (Cu)	Nickel (Ni)	

Compost industry adopted Code Part 40 CFR 503 rules

- Ceiling concentrations and pollutant concentrations
- Single application, annual, and life limits

Metals

- Management of soil pH critical
  - Maintain pH close to 6.5
    - Metals not available
  - Don't overlime
    - Some metals more available over pH 7.0 to7.5
      - molybdenu m, arsenic,selenium



2. Safe & Marketable

- Issues of concern:
  - Household hazardous waste
  - Treated wood
    - Wood treated with the preservative CCA (Chromated Copper Arsenate) and PCP prevents microbial activity in the wood, in piles and the soil
    - Treated wood should not be included in feedstocks for composting
  - Most pesticides and herbicides are taken care of in the composting process
  - Clopyralid – Broad leaf herbicide can't be composted

3. Processed by technology

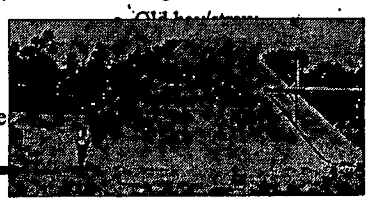
- Issues of concern:
  - Compatibility with your composting technology
  - Compatibility with your handling equipment
    - Trucks, loaders
    - Mixers, shreaders, turners, tankage etc
  - Impact on odor generation
    - Neighbors
    - Capital to contain and/or treat odors

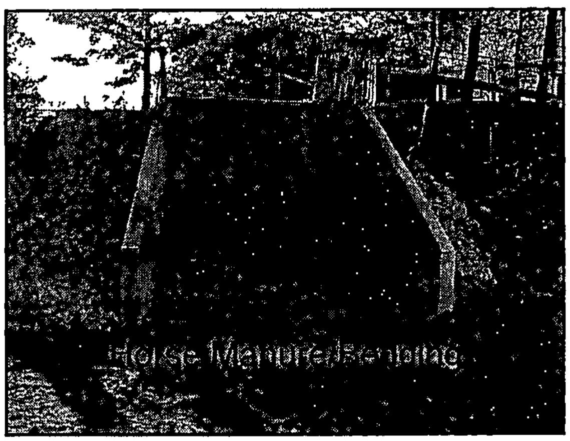
4. Economics & contracts

- Issues of concern:
  - Delivered cost – biggest cost item
  - What is available near by
  - Location of facility dependent upon feedstocks
  - Availability and source of supply
  - Duration and reliability of supply
  - Contract – secures business plan, work out ahead of time
  - Materials are sometimes dealt to you, make the most of it

Agricultural Feedstocks

- Animal manures
  - Dairy
  - Broiler
  - Layer
  - Horse
- Cotton waste
- Peanut hulls
- Row crop waste
- Vegetable culls

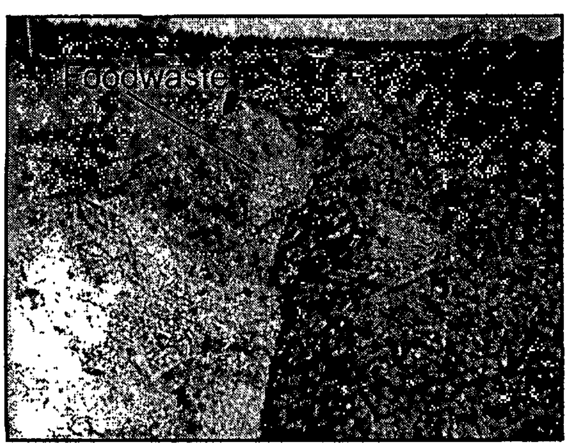




Municipal Feedstocks

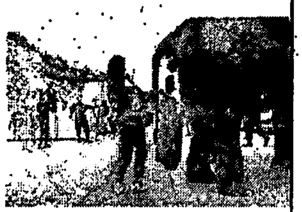
- Residential yardwaste/yard trimmings
- Woodwaste
- Municipal solid waste (MSW)
- Water Treatment Plant residuals
- Biosolids


MSW & Tobacco


Foodwaste

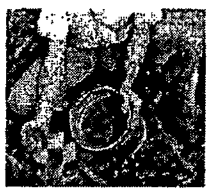
"Creative" Feedstocks

- Waste liquids
- Fats, oils, and grease (FOG)
- Ice cream
- Stamps
- Shredded paper/documents
- McDonald's batter waste
- Many more.....



By-product considerations:

- Tests to be run:
  - Nutrient content
  - Liming ability
  - Metal content
  - Tox-screen or growth analysis
- Must insure that there are no growth inhibiting substances or pathogens



Other Considerations

- Impurities: glass, plastics, sharps
- pH
- Salinity
- Organic matter
- Spreadability
- Transport and application costs
- Odor and public perception

Permitting

- Dependent on feedstock choices
- Time frame may be extensive
- Some permits may require high initial expenses
- Public perception
- May not qualify for the permit – Plan B

Composting Permits

- Yardwaste Exempt
  - Yardwaste, grass clippings, clearing debris
- Agricultural Exempt
  - Agricultural wastes, animal manures
- Permit by Rule
  - 75% of waste generated on-site
- Solid Waste Handling
  - Compost any type of waste, same permit as landfills
- NPDES Permit Amendment
  - Biosolids composted on POTW property

Site (Pad) Requirements

- Bulk densities, daily volumes/tonnage
- Agricultural and animal manures
  - No site requirements
- Foodwaste may require site modifications depending upon the size
- Biosolids and industrial wastes will require:
  - Impermeable surface,
  - Collection pond
  - Leachate disposal system (POTW or land app)

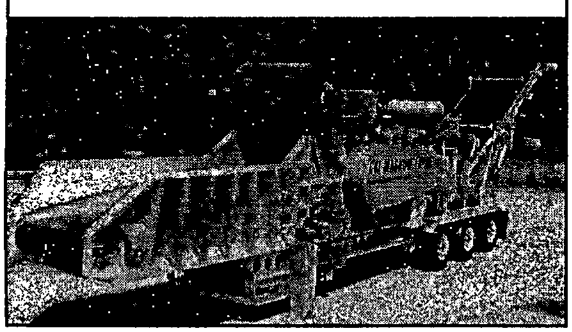
Think about....

- Costs, up front and financing
- features, do you need them?
- Performance, talk to other owners
- service and O&M costs and time
- Warranty
- Cost of contracting
- Can you buy used materials?

Preprocessing Equipment

- Obtain desired size reduction and porosity.
- Chippers, cheap, single material
- Tub Grinders, $150-200, 10-25 T/hr
  - Safety concerns, OM expense, can handle dirt
- Hor. Feed Grinders, $150-200, 15-30 T/hr
  - mobile, faster
- Shredders, $300+, 25-40 T/hr., dependable
- See buyers guides, maintenance and preprocessing saves $

Horizontal Grinder

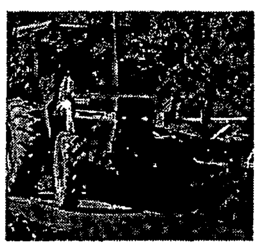


Where to get help?

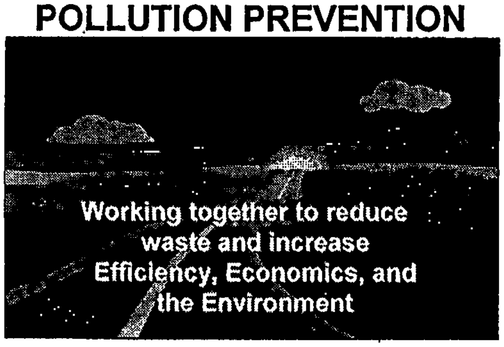
- **Locating sources**
  - **Recycling directory, Landfill, Extension agents; Industry, Local government.**
- **Extension Projects**
  - **By-product utilization at Redbud**
  - **Composting project in Douglas**
  - **Crisp Co. Recycling Center**
  - **Wallboard grinding opportunity**

Other UGA Support

- Bioconversion Research and Demonstration Center
- Mill Residue and Byproduct Utilization Project
- Soil Test Lab
- BAE outreach



AGRICULTURAL POLLUTION PREVENTION



Introduction to Compost Pile Recipes

Introduction to Compost Pile Recipes

Jason Governo
Engineering Outreach Service

Initial Process Parameters

- Three parameters should be met in initial feedstock mixes for optimal microbiological activity
  1. Moisture (50 - 60%)
  2. C : N Ratio (30 - 40:1)
  3. Free air space (50 - 65%)

Moisture

- Estimates can be made using:
  - Squeeze test
  - Exact measurements (more accurate)
    - Drying oven
    - Microwave
    - Moisture probes (usually based on electrical conductivity and do not work well on compost if high in salts)

C:N Example

- What is the C:N Ratio given the data from a lab report?
- Conversion from mg/kg to % = (mg/kg ÷ 10,000)

Parameter	Result
pH	6.2
Phosphorus	2,780 mg/kg
Nitrogen	7,120 mg/kg
Aluminum	2,550 mg/kg
Carbon	178,000 mg/kg
Potassium	6,940 mg/kg
Sodium	1,600 mg/kg

Calculating Mixture C:N

General C:N ratio equation for feedstock mixes

$$R = \frac{Q_1(C_1 \times (100 - M_1)) + Q_2(C_2 \times (100 - M_2)) + Q_3(C_3 \times (100 - M_3)) + \ldots}{Q_1(N_1 \times (100 - M_1)) + Q_2(N_2 \times (100 - M_2)) + Q_3(N_3 \times (100 - M_3)) + \ldots}$$

Q_1, Q_2 and Q_3 = total wet weight of feedstocks 1, 2 and 3 respectively (any mass units (lbs, kg, tons) must be consistent)

M_1, M_2 and M_3 = moisture of feedstocks 1, 2, and 3 respectively (% total weight or wet basis, w.b.)

C_1, C_2 and C_3 = carbon content of feedstocks 1, 2, and 3 respectively (% dry basis, d.b.)

N_1, N_2 and N_3 = nitrogen content of feedstocks 1, 2, and 3 respectively (% dry basis, d.b.)

Potential Problems

	Too High	Too Low
C:N	Slower composting Reduces potential for odors	Slower composting, higher potential for odors, Ammonia odors, potential for leachate
Moisture Content	Slower composting, Anaerobic conditions may occur causing odors, potential for leachate	Slow composting, poor conditions for bacteria generation

Field - Free Air Space & Bulk Density

- Determine weight (record the weight) and volume (hopefully 5 gallons) of the 5 gallon bucket to be used
- Compact feedstocks in bucket at 1/3 increments (1 ft drop 10 times)
  - Fill 1/3, drop 10 times, fill 2/3 drop…
- Weigh and record compacted materials and bucket (Bucket + Field moist material)
- Flood feedstocks in bucket, weigh and record (Bucket + flooded material)

Bulk Density Calculations

$A = (B - C) \div D$

Where:

A = bulk density estimate, lb/yd³
B = mass of the compost filled bucket (lb)
C = mass of the empty bucket (lb)
D = volume of the bucket (yd³)

1 gallon = 0.004951132 yd³ so 5 gallons = 0.02475566 yrd³

Free Air Space (FAS) Calculations

$A = [(B - C) \div (B - D)] \times 100$

Where:

A = free air space, %
B = mass of the water/compost filled bucket (lb)
C = mass of compost filled bucket (lb)
D = mass of the empty bucket (lb)

Feedstock basic information

Feedstock	N (%)	C (%)	C:N
Yardwaste	0.6	24	40.0
Woodchips	0.1	43	430.0
Animal Bedding	0.4	25.6	64.0
Hen Manure	5.3	53	10.0
Poultry Litter	2.7	37.8	14.0
Dairy Manure	3	54	18.0
Biosolids	1.7	7.65	4.5

Additional Information

	Moisture	Bulk Density	Free Air Space	pH	O_2	Odor	EC
Yardwaste							
Woodchips							
Animal Bedding							
Hen Manure							
Poultry Litter							
Dairy Manure							
Biosolids							

Determine Moisture Content

Feedstock Name = ____________________

A = Pan Weight: ____________________

B = Pan + Moist Material: ____________________

C= Pan + Dried Material: ____________________

Calculation:

[(B - C)÷(B - A)] x 100 = ____________________

Determine Free Air Space

Feedstock Name = ______________________

A = Empty Bucket Weight: ______________________

B = Bucket + Moist Material: ______________________

C= Bucket + Flooded Material: ______________________

Calculation:

[(C - B)÷(C - A)] x 100 = ______________________

Determine Bulk Density

Feedstock Name = ______________________

B = Bucket + Moist Material: ______________________

C = Empty Bucket Weight: ______________________

D=Volume of Bucket: ______________________

Calculation:
Bulk Density = (B - C) ÷ D = ______________________

Microbiology of Composting

The Microbiology of Composting

Julia Gaskin
Agricultural Pollution Prevention Program
Sponsored by the Pollution Prevention Assistance Division
Biological and Agricultural Engineering
Cooperative Extension Service
University of Georgia

Composting 101


Microorganisms transform raw material into a stable soil conditioner


The Microorganism World

Soil Biology Primer, NRCS

Microorganisms in Composting

Three important groups:

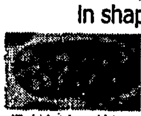
Bacteria

Actinomycetes


Fungi

Bacteria

- Single-celled organism
- Reproduces by cell division
- Protoplasm C:N ratio 5:1
- Round, rod, spiral, corkscrew, filamentous in shape

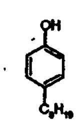


Nitrobacter winogradskyi

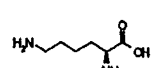
Pyrococcus furiosus

Nitrosomas sp.

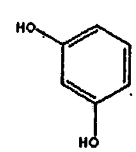
Bacteria



- Very diverse metabolic capacity
- Not always expressed
- Respond to environment to produce new enzymes and use new substrates *



lys k Lysin



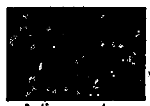
Temperature Stages of Composting

Mesophilic (< 104 °F)

E. coli

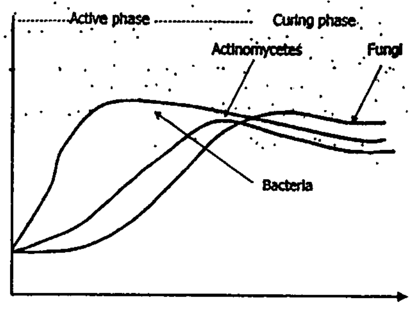
Thermophilic (104 to 158 °F)
kills pathogens and weed seeds

Curing (ambient to 86 °F)

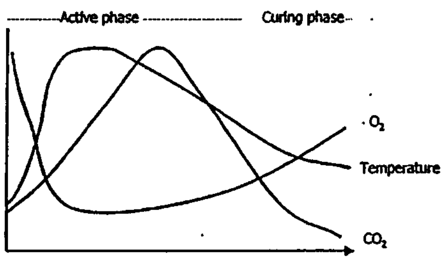


Actinomycetes

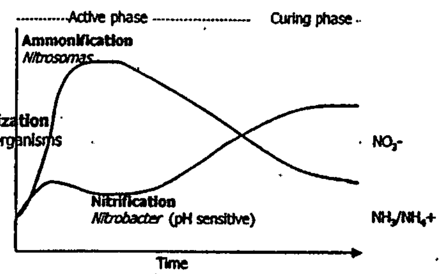
Hypothetical Population Change over Time



Changes during Composting Process



Changes during Composting Process



Early decomposition by bacteria
provides N for other groups

Carbon Processed

Group	Carbon Assimilated
Bacteria	5 – 10%
Actinomycetes	15 – 30%
Fungi	30 – 40%

From Miller in *Soil Microbial Ecology* 1993

Plants contain:

- 5-30% lignin
- 15-60% cellulose
- 10-30% hemicellulose
- 2-15% protein
- 10% amino acids, sugars, organic acids

Paul and Clark 1989

Relationship to Soil Quality and Uses

Need more research for cause and effect but:

- Many different types of compost
- Many different production systems
- Sampling problems

What We Do Know

Tillage and chemical fertilizers deplete soil organic matter

Compost can help restore this

Soil organic matter necessary for diverse microorganism community

Diverse community helps keeps diseases in check

What We Do Know

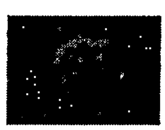
Soil organic matter stores plant nutrients and micronutrients

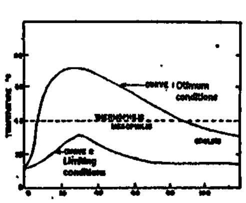
Microorganisms recycle these nutrients do plants can use them

From Soil Biology Primer, NRCS

Summary

Think small! You're farming microorganisms

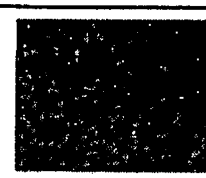




Supply their needs:

Water
Carbon
Air
Nutrients

Summary



Give time for all stages to occur:

Mesophilic, Thermophilic → Active

Curing

Examples of Microorganisms Found in Composts
(Taken from Soil Microbiology Ecology, Metting 1993)

Table 3 Bacteria Identified in Composting Materials

Species	Ref.
Bacillus	
B. brevis	Strom (1985a,b)
B. circulans complex	Strom (1985a,b)
B. coagulans type A	Strom (1985a,b)
B. coagulans type B	Rothbaum (1961); Strom (1985a,b); Fermor et al. (1979)
B. licheniformis	Gregory et al. (1963); Okafor (1966); Strom (1985a,b)
B. spharicus	Rothbaum (1961); Strom (1985a,b)
B. stearothermophilus	Niese (1959); Rothbaum (1961); Hayes (1968); Fermor et al. (1979); Strom (1985a,b)
B. subtilis	Hayes (1968); Niese (1959); Fermor et al. (1979)
Clostridium	
C. thermocellum	Henssen (1957)
Clostridium sp.	Waksman et al. (1939a)
Pseudomonas	
Pseudomonas sp.	Hayes (1968); Stanek (1971); Fermor et al. (1979)

Table 4 Actinomycetes Identified in Composting Materials

Species	Ref.
Actinobifida chromogena	Fergus (1964); Lacey (1973)
Microbispora bispora	Henssen (1957)
Micropolyspora faeni	Fergus (1964); Gregory et al. (1963); Lacey (1973)
Nocardia sp.	Lacey (1973)
Pseudonocardia thermophilia	Henssen (1957); Fergus (1964)
Streptomyces	
S. rectus	Henssen (1957); Fergus (1964); Hayes (1968) Stanek (1971)
S. thermofuscus	Makawi (1980)
S. thermoviolaceus	Fergus (1964); Stanek (1971)
S. thermovulgaris	Fergus (1964); Hayes (1968); Stanek (1971); Fermor et al. (1979)
S. violaceus-ruber	Fergus (1964)
Streptomyces sp.	Norman (1930); Waksman et al. (1939b); Tendler and Burkholder (1961); Lacey (1973)
Thermoactinomyces	
T. vulgaris	Waksman et al. (1939b); Forsyth and Webley (1948); Erikson (1952); Gregory et al. (1963); Fergus (1964); Lacey (1973); Fermor et al. (1979)
T. sacchari	Lacey (1973); Makawi (1980)
Thermomonospora	
T. curvata	Fergus (1964); Stanek (1971)
T. viridis	Henssen (1957); Fergus (1964); Lacey (1973); Fermor et al. (1979)
Thermomonospora sp.	Hennsen (1957); Lacey (1973)

MICROBIOLOGY OF COMPOSTING

Thomas G. Tornabene
School of Applied Biology
Georgia Institute of Technology

Biochemical Aspects: Natural organic wastes, whether of agricultural, industrial or urban origin, are mixtures of proteins, lipids, carbohydrates (sugars, hemicellulose, cellulose, lignin) and minerals in a wide variety of concentrations. The composition of the wastes depends on the starting materials and their subsequent treatment. All matter will contain mixed populations of microorganisms derived from the soil, water and air. Each type of microorganism, however, has specific nutritional and environmental requirements for optimal biological activity.

Microbiology: The microbial world consists of bacteria, fungi, algae, protozoa and viruses. These microbes can be separated on the basis of nutritional requirements. Fungi, protozoa and many bacteria require organic compounds preformed by higher plants and animals. The algae and some bacteria are capable of synthesizing their own organic compounds through a photosynthetic process. Other bacteria can synthesize their organic compounds through nonphotosynthetic mechanisms by oxidizing inorganic compounds such as iron, hydrogen, nitrogen or sulfur. Of course the viruses survive by parasitizing existing cells.

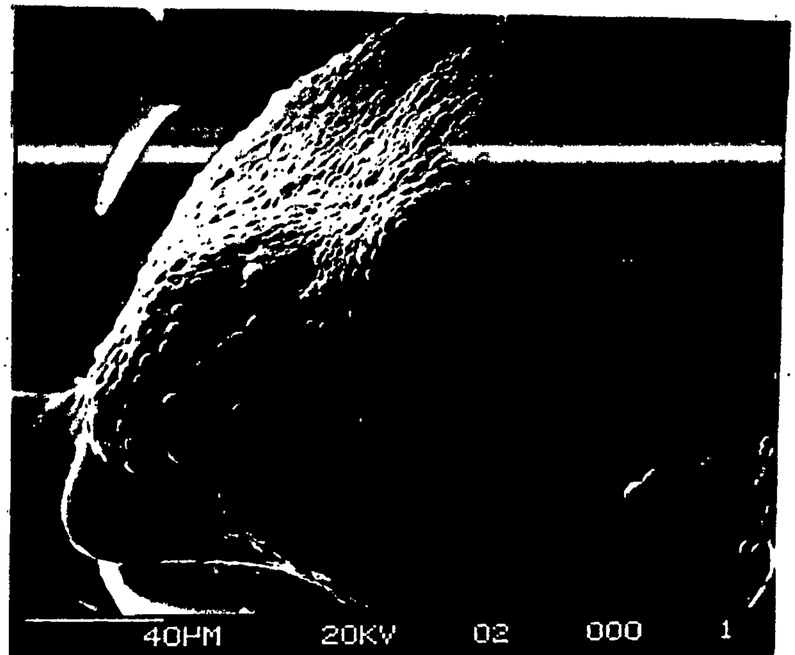
While many of the microorganisms require air to survive, there are many of them that can live, grow and multiply in either aerobic (with air) or anaerobic (without air) conditions. Others cannot tolerate even a trace of oxygen and are identified as obligate anaerobes.

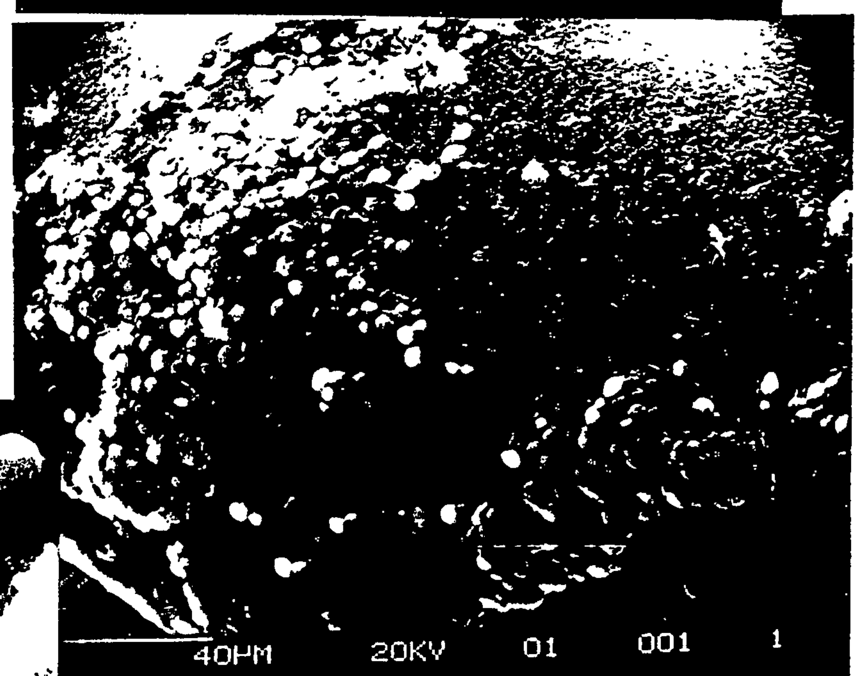
Temperature and pH are two environmental factors which control the growth of microbial populations. The optimal growth condition of many microorganisms is at temperatures between 20-37°C (68-96°F) with a pH near 7 (neutrality). There are both bacteria and fungi, however, whose optimal temperature range is 80 -100°C (175-212°F), with a pH at 7 (thermophiles), 1.0 (thermoacidophiles) or 10 (thermoalkalinophiles). There are also bacteria that live at temperatures well below 20°C (68°F).

Thus, for any given environmental and nutritional condition, selected microorganisms will be under ideal growth conditions, while others will be under physiological stress and remain in a low metabolic state until conditions are more favorable.

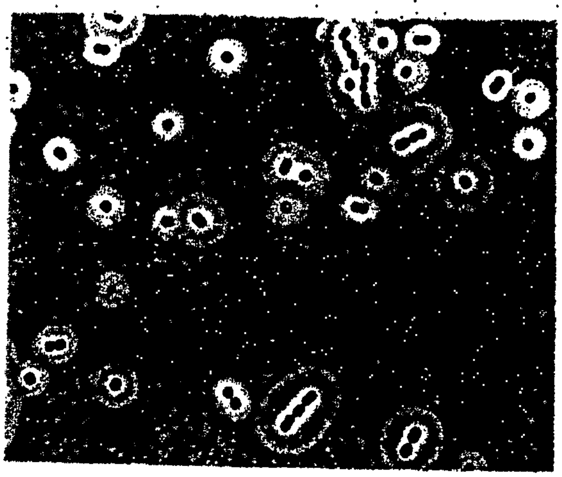
Nutritional factors: There is a natural environmental recycling system. Compounds are constantly being made, degraded and remade again. This recycling phenomenon is described as the **Carbon Cycle, Nitrogen Cycle**, or the **Sulfur Cycle**. The more complex the organic compound, the more specific the microorganism has to be to chemically change it. For example, cellulose is one

These are spherical cells that are widely found in nature. They can represent many different types of Genera such as *Streptococcus pneumonia*, *Streptococcus faecalis*, *Staphylococcus species*, *Methanococcus species*, and so forth. These pictures were taken from natural sources. The sheets of cocci (spherical cells) growing on the surface of solid particles are actually adhered to it and it is difficult to remove them. The arrangement of the cocci will vary depending on the species. It is common to find them in doublets, tetrads, long chains or grape like clusters. On occasions, cocci can form sheets with gas vacuoles clearly visible in each cell. Look closely at the lower left picture and see also very small rod shaped bacteria.

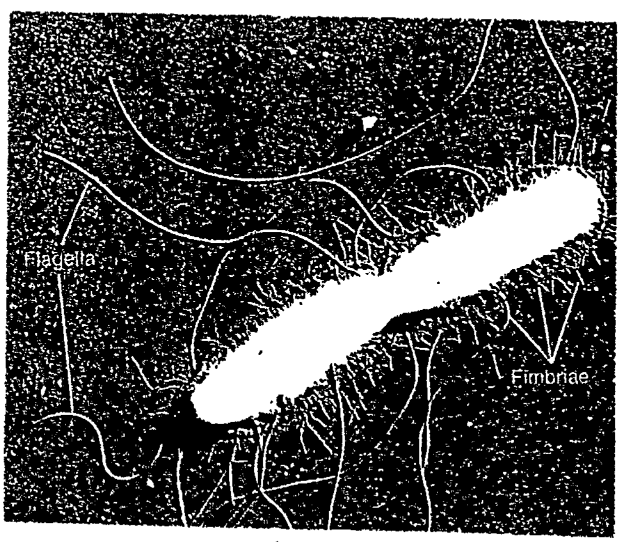


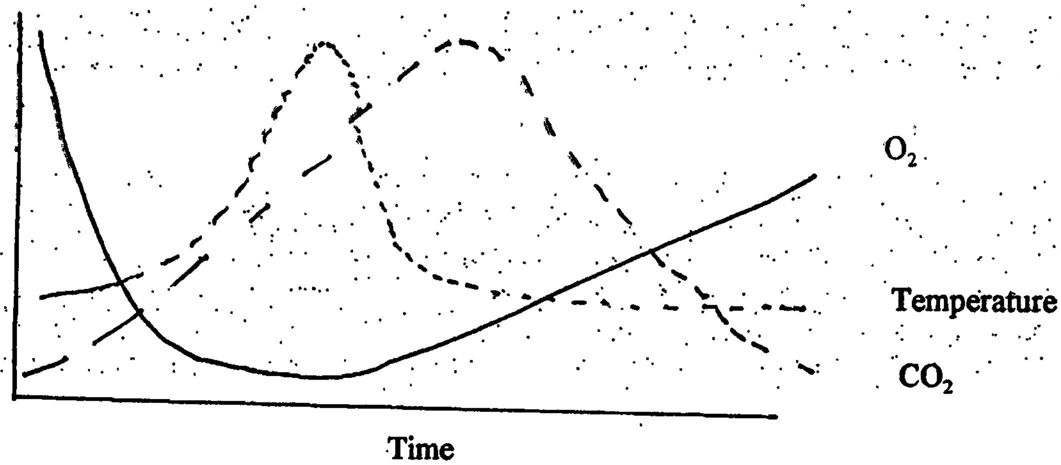


In addition there are the encapsulated bacteria which are noted for their slimy production of extracellular material. Slime molds are also prevalent in nature but generally not given an opportunity to prosper in the competitive composting process unless waste mixes with undegraded cellulose are left standing for extended time periods. In these cases, substantial amounts of slime can accumulate.



The picture shown below is a common organism (*Salmonella typhosa*), found in contaminated waters and in animal intestines, which illustrates the flagella and other protruding fibers called fimbriae that are fairly common to many bacteria.





NOTES:

Laboratory and Sampling

Field Sampling
for
Laboratory Analysis
of
Compost Materials

Sample and Analysis to Characterize:

- Feedstocks
- Process Monitoring
- Product Variability
- Product Quality

Representative Sample

- Defines a materials average characteristics typical for the entire material being sampled
- Best achieved through composite samples containing many (>15) large (>1000cm^3) sub-samples
- Replicates

Gas Phase Samples

- Important for process monitoring
- Examples: O_2, H_2S, NH_3, CO_2, DMS, MT
- Many analysis options

Test Method: Air Capacity. Field Density, Free Airspace and Water-Holding Capacity							**Units:** *See Calculations*	
Test Method Applications								
Process Management							**Product Attributes**	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Odor Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	*Safety Standards*	*Market Attributes*
03.01-C	03.01-C	03.01-C	03.01-C	03.01-C	03.01-C	03.01-C		

03.01-C FIELD DENSITY, FREE AIRSPACE AND WATER-HOLDING CAPACITY

LOOK—Interference and Limitations, and Sampling Handling issues are presented as part of the introduction to this section.

12. Apparatus for Method C

12.1 *pail*—20-L (5-gal), plastic with lip and vertical walls, fitted with hoop-type handle.

12.2 *scale*—20 kg, accurate to ±50 g.

12.3 *rule*—tape measure or ruler.

12.4 *adhesive tape*—1.3 cm (½ in.) width, brightly colored such as blue masking tape.

12.5 *marking pen*—dark colored.

12.6 *surface*—firm, flat, such as cement or pavement.

12.7 *cheese cloth*—60 x 60 cm (24 x 24 in.) square, or other equivalent material to serve as a strainer or sieve.

12.8 *strap*—90-cm (~3-ft) segment of wire, rope or cord to secure strainer or sieve over mouth of pail.

12.9 *grate*—to facilitate unobstructed drainage of pail.

12.10 *graduated cylinder*—1000-mL, plastic or glass.

13. Reagents and Materials for Method C

13.1 *water*—20 L (5 gal), tap water

14. Procedure for Method C

14.1 Collect a composite sample of compost as described in TMECC 02.01-B Selection of Sampling Locations for Windrows and Piles, or blended feedstocks as described in TMECC 02.01-D Batch Feedstock Material Sampling Strategies.

14.1.1 When performing this test on a feedstock blend, be sure to thoroughly mix the feedstocks before collecting a composite sample.

14.1.2 Determine total solids content on a parallel sample aliquot of the test material as described in TMECC 03.09 Total Solids and Moisture at 70±5°C.

NOTE 1C—It may be acceptable to dry the parallel sample aliquot at 105°C to decrease the required drying time. Absolute accuracy of total solids content is not always critical for process management.

14.2 *Preparation of Equipment:*

14.2.1 Subdivide the pail into three equal volumes. Measure from the inside bottom to the top rim of the pail; make a series of four or five marks spaced around the inside circumference of the pail with the marking pen to highlight each of two equally-spaced divisions; refer to the illustration in Fig 03.01-C.

14.2.2 Place a band of brightly colored tape over each of the two highlighted divisions on the inside circumference of the pail.

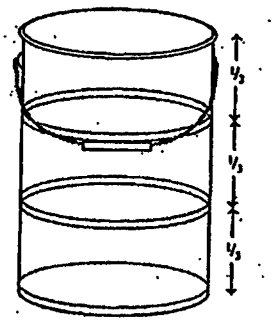


Fig 03.01-C Sample pail with three equal subdivisions.

14.2.3 Obtain the tare weight of the pail. Measure and record the dry mass of the empty pail.

14.2.4 Determine volume capacity of the pail (m^3). Fill the pail to the brim with water. Measure and record the weight of the water-filled pail. Alternatively, fill the pail using the 1000 graduated cylinder and record the volume of water used.

ASSUMPTION—1000 L of H_2O = 1000 kg of H_2O = 1.000 m^3 of H_2O; 1 Lb of H_2O = 5.94×10^{-4} yd^3 = 4.54×10^{-4} m^3

03.01 Methods Summary

16. Report

16.1 *Free Air Space*—Express free air space as a percentage, volume of free air space per unit volume of compost (%, v v, ±0.1 %).

16.2 *Bulk Density*—Express bulk density as mass per unit volume of compost on an as-received moisture basis to the nearest ±0.1 w v^{-3} (kg m^3, or Lb yd^3).

16.3 *Water-Holding Capacity*—Express water-holding capacity as a percentage of the volume (mass equivalent) of water retained per unit mass of compost (dw basis) to the nearest ±0.1 %, w w^{-1}.

16.4 *Moisture Content or Total Solids*—Report as-received moisture or total solids content as a percentage, %, w w^{-1}, wet weight basis as determined by forced-air oven-drying at 70±5°C.

17. Precision and Bias

17.1.1 *Air Capacity, Bulk Density, Water-Holding Capacity:* The precision and bias of the tests (Methods 03.01 A, B, C) have not been determined. Data are being sought for use in developing a precision and bias statements.

18. Keywords

18.1 air capacity; air space; bulk density; free airspace; porosity; pore space; water-holding capacity; field density; field porosity; field test; bucket test

5. Significance and Use

5.1 Feedstocks for compost, in-process materials and compost are present in two phases: solid and liquid.

5.1.1 Total solids, or dry matter, in composting feedstocks and compost includes combustible or biodegradable organic material, or volatile solids and inorganic material, or fixed solids making up the ash remaining when organic matter is oxidized by combustion.

5.1.2 Total solids does not include trash that is removed during feedstock recovery operations or during compost finishing. Trash includes stones, carbonate concretions, and manufactured inert materials over 4 mm, such as metal fragments, glass shards, sharps, leather, textiles, hard plastic and film plastic.

5.2 Inorganic content of compost should be measured on a dry weight basis when the product is ready for marketing. Reporting certain chemicals in biosolids compost at the time of marketing is required by EPA Chapter 40, CFR Part 503. To insure valid comparisons for chemical concentrations in two or more products, the composts being compared must be at the same level of biological stability.

6. Interference and Limitations

6.1 Compost samples are oven dried at 70±5°C for approximately 18 h to 24 h, until weight change diminishes to nil. At temperatures above 70±5°C, there is increased weight loss due to volatile loss of compounds such as CO_2 in addition to water.

6.2 Negative errors in volatile solids can be produced by loss of volatile matter during drying. Errors associated with the volatile solids determinations are increased when low concentrations of volatile solids are observed with high fixed solids. In such cases, measure for suspect volatile components by another test, for example, total organic carbon.

6.3 Composts that do not contain significant levels of semi-volatile compounds will yield identical total solids results when dried at either 70±5°C or 103°C - 105°C. The latter temperature is recommended for soils and biosolids; it significantly reduces drying time. This rapid method with higher drying temperature is not recommended for use with all composts; compost often contains significant levels of compounds that volatilize or evaporate above 75°C. Significant losses of these volatile compounds will distort reported concentrations of nutrients, metals and other parameters that are corrected to a dry weight basis.

7. Sample Handling

7.1 *Method A. Total Solids and Moisture at 70±5°C*—Perform this test on feedstocks, in-process and finished composts. The material may contain unclassified inert material.

7.1.1 Determinations are made at 70±5°C on a representative aliquot of unsieved or sieved bulk material and all sample size fractions of interest, including all sieve classes, and feedstocks.

7.1.2 This test is best performed in conjunction with sample sieving as outlined in Test Method 02.02-B.

03.09 METHODS SUMMARY

12. Report

12.1 *Total Solids*—reported as a percentage of dry solids contained in an as-received sample, ±0.1 % g g^{-1}, wet basis.

12.1.1 The ratio for total solids (oven-dried weight ÷ as-received weight) is used to correct reported values (concentration, mass, volume, etc.) to standard moisture content on an oven-dry weight basis. No correction need be made for variations in barometric pressure (altitude).

12.2 *Moisture Content*—reported as a percentage of as-received weight, ±0.1 % g g^{-1}, wet basis.

13. Precision and Bias

13.1 High relative precision can be attained by thoroughly blending and mixing the entire sample in a closed sample container prior to aliquoting the test sample. Accuracy of the test is a function of the sampling strategy employed in the field. If an adequate number of subsamples is collected and properly mixed at the time of collection, the composite sample sent to a laboratory will represent the compost in question. Refer to section 02.01 Field Sample Collection.

13.2 *Total Solids and Moisture:*

13.2.1 *Method 03.09-A Total Solids and Moisture at 70±5°C*—The precision of this test was determined by the Research Analytical Laboratory, Department of Soil, Water, and Climate; University of Minnesota for the MN-OEA CUP Project, 1993-1994. St. Paul, MN. Bias of this test has not been determined. Data are being sought for use in developing a bias statement.

13.2.1.1 Precision was determined using ten subsamples taken from a field composite sample for each of three sites for two sampling periods, (1993).

Table 03.09-A1 Total Solids, % as-received wet weight basis. Precision estimates for < 6.3 mm as-received municipal solid waste compost material, (1993).

Median	*Std Dev*	*% CV*	*Number of Samples*
58.71	1.16	2.0	10
61.29	0.65	1.1	10
70.38	0.00	0.0	10
61.19	0.43	0.7	10
66.78	0.95	1.4	10
76.07	0.25	0.3	10

Note 2A—Coefficient of Variation, %CV = Standard Deviation ÷ Mean × 100.

Table 03.09-A2 Moisture Content, % as-received wet weight basis. Precision estimates for < 6.3 mm as-received MSW compost material, (1993).

Median	*Std Dev*	*% CV*	*Number of Samples*
37.44	0.10	0.3	10
38.71	0.65	1.7	10
26.26	0.59	2.2	10
38.81	0.43	1.1	10
33.22	0.95	2.8	10
23.93	0.25	1.0	10

14. Keywords

14.1 total solids; moisture; oven-dry; oven-dried; as-received; ash; fixed solids; evaporate; volatile solids; biodegradable volatile solids may induce deviations in the desired result and sub-optimal finished compost.

3.6 *product variability, n*—heterogeneity of the chemical, biological and physical characteristics of a compost product attributable to both the composting process and the heterogeneity of input feedstocks.

3.7 *representative sample, n*—a sample that accurately reflects the average chemical, biological and physical characteristics of interest from the source of feedstock, bulk material or compost batch in question.

3.8 *sample collection frequency, n*—retrieval of representative samples at intervals that accurately represent the status within the process step of interest for the bulk of compost in question or batch of concern.

3.9 *statistical validity, n*—determinations made from a sample that accurately represent the average characteristics of the compost of interest.

4. Sampling Collection and the Composting Process

4.1 A generalized model developed to represent the aerobic composting process is presented in Fig 02.01-1 Composting Unit Operations Model.

4.1.1 Market attribute analytical values for a finished compost vary according to the type or blend of composting feedstocks and composting process. Value-added compost products are illustrated in Chapter 01.00 Fig 01.02-A2 Composting Products Model. Sampling and testing plans must be designed to suit the feedstock used in composting, the specific approach to feedstock preparation and composting process management in each composting project, and specifically for each finished product.

4.2 *Selection of Sampling Method:*

4.2.1 *Feedstock Sampling Location*—The sampling location for composting feedstock is after feedstock recovery (step 1) has been completed. Feedstock sampling is performed after routine removal of recyclable and/or problem materials. Samples should be taken before feedstock preparation (step 2), i.e., before shredding or size reduction, and before supplemental nutrients, bulking agents or water have been added. The facility operators can provide the best information for the locations to obtain feedstock samples.

NOTE 1—Once the feedstock preparation, (step 2 of the composting process model), is completed, the actual composting process begins with the material placed in piles, windrows or reaction vessels for composting.

4.2.2 *Prepared Feedstock Sampling*—Samples should be taken after feedstock preparation before composting. Facility operators can provide the best information for the locations to obtain feedstock samples.

4.2.3 *Composting and Compost Curing Process Control Sampling Locations*—The sampling location for process monitoring during composting, step 3, and compost curing, step 6, is indicated in Fig 02.01-B1 Hypothetical Sample Collection Pattern from a Compost Pile.

4.2.4 *Finished Compost Sampling Locations*—Finished compost is expected to match the needs of the customers, and may be obtained from step 3, Composting; step 5, Compost Curing; step 6, Compost Screening and Refining; and step 7, Compost Storing and Packaging as indicated in Chapter 01.00 Fig 01.02-A2 Composting Products Model. Finished compost samples are taken from the actual product that is released for distribution to an end-user.

5. Summary of Methods

5.1 *Method 02.01-A Compost Sampling Principles and Practices*—Review of sampling design schemes adapted from sampling procedure documents provided by Dr. William F. Brinton, Woods End Research Laboratory, Inc.

5.2 *Method 02.01-B Selection of Sampling Locations for Windrows and Piles*—Descriptions of sample collection as sets of compost sub-samples collected and combined to represent the average chemical, physical and biological characteristics of the compost material for a batch windrow or pile of cured or curing compost.

5.3 *Method 02.01-C Sampling Plan for Composted Material*—Review of US EPA SW-846 sampling plan guidelines and statistical procedures for estimating required minimum number of samples.

5.4 *Method 02.01-D Composting Feedstock Material Sampling Strategies*—A representative sample of feedstock is collected to identify its chemical and physical characteristics.

5.5 *Method 02.01-E Data Quality Management and Sample Chain of Custody*—Consideration for third-party sample collection and preparation. Also, an example form and description of the parameters needed for a chain of custody report.

7.2 *Method 02.01-B Compost Material Sampling Strategies*—As compost heterogeneity increases, the number of sub-samples should be increased. If insufficient numbers of samples are collected, analytical results will not represent the compost in question.

7.2.1 Moisture loss or gain during sample handling and splitting may become significant. It is therefore necessary to mix and split a sample under sheltered conditions, such as inside a building where wind, temperature and sunlight or precipitation will not distort the compost moisture.

7.3 *Method 02.01-C Sampling Plan for Composted Material*—Knowledge of or access to statistical procedures is required.

7.4 *Method 02.01-D Composting Feedstock Material Sampling Strategies*—Sample heterogeneity of feedstock may be much higher than that of the finished composted product. It is crucial that all sampling plan collection procedures are followed to maximize the reliability and accuracy of the feedstock sample analytical results.

7.4.1 Moisture loss or gain during sample handling and splitting may become significant. It is therefore necessary to mix and split a sample under sheltered conditions, such as inside a building where wind, temperature and sunlight or precipitation will not distort the feedstock moisture.

8. Sample Handling

8.1 Collect samples from areas of the compost pile that are representative of the general appearance, and avoid collecting atypically moist samples (> 60% moisture, wet basis). If balls form during the process of blending and mixing of point-samples, the compost sample is too wet. Excessively moist compost will cause unreliable physical and biological evaluation.

8.2 For most feedstock or compost samples, use containers made of stainless steel, plastic, glass or Teflon. These materials will not change compost chemical quality. Laboratories provide advice on appropriate sample containers, preservatives and shipping instructions when requested.

8.3 A representative compost sample must be collected from appropriate sampling locations and consist of no less than 15 point-samples. Sampling locations along the perimeter of the compost pile where compost point-samples will be extracted and vertical distances from the ground or composting pad surface shall be determined at random, and shall be representative of the compost on the site.

8.3.1 Determine the number and types of sampling and shipping containers to be used. The composite sample is placed in a sanitized container and thoroughly mixed. Follow proper quality assurance/quality control procedures for sample preservation, storage, transportation and transfer. Sample the cured compost and aliquot 12 L (3 gal) sub-samples from the composite sample and place in a sanitized plastic container and seal.

8.3.2 Utilize the Student's "t"-test with a confidence interval of 80% to statistically analyze the test data. Refer to TMECC 02.01-A, paragraph 9.10 *Sampling Intervals* for guidance in determining sample collection frequency.

8.4 *Test Methods versus Sampling Methods*—The laboratory test method and analytical parameter of interest dictate the method of sample collection, type of container for shipping and storage of samples and sample handling procedures required. Table 02.01-1 provides a partial list of analytical traits that are affected by sample collection and handling. In general, volatile compounds and elements, physical bulk factors and microbiological samples require special considerations when developing the sampling plan.

Table 02.01-1 Partial list of test parameters that require special sampling and handling considerations.

Test Parameter	*Principle Constraint*	*Associated Error*	*Alteration of Sampling for Corrective Action*
Total-N	Volatilization loss of NH_3 during sample handling	Underestimation of total N and volatile N	Place in container quickly with minimal stirring
Volatile fatty acids (VFA)	Volatilization loss of VFA during sample handling	Underestimation of VFA content	Place in container quickly with minimal stirring
Microbiology (pathogens)	Contamination from tools, buckets, air	Over or under estimation of pathogens	Use only clean, sterile containers and implements
Bulk Density	Excess sample moisture	Overestimation of volume/weight	Take large, oversized samples

8.4.1 In each case the determination for a trait of interest can be changed adversely by improper sample collection and handling, and consequently lead to erroneous conclusions. Analytical precision or relative variability may not be affected by inappropriate sampling, but accuracy of the expected determination may be biased and incorrect.

8.5 *Containers, Post-Sample Handling*—For each type of parameter measured after sampling specific containers and holding times should be observed prior

Table 02.01-5 *Pathogens:* Sampling containers and conditions for compost and source ingredient testing.

Test Parameter of Interest	*Container*	*Conditions*	*Maximum Holding Time Allowed in Lab*
Enteric Virus	G	-70°C	> 8 h
Enteric Virus	SP, G	4°C	8 h
Coliforms and other bacteria	SP, G	4°C	48 h
Helminth Ova	SP, G	4°C	1 month

NOTE 5—SP=Sterilized Polypropylene; G= Sterilized Glass

Table 02.01-6 *Synthetic Organic Compounds:* Sampling containers and conditions for compost and source ingredient testing.

Test Parameter of Interest	*Container*	*Conditions*	*Maximum Holding Time Allowed in Lab*
Chlorinated Herbicides, and Chlorinated Hydrocarbons, PCB	G, Teflon lined cap (2-1/2 L.A.J.)	4°C	7 d until extraction
Chlorinated Pesticides	16 oz B.R. (2-1/2 L.A.J.)	4°C	7 d until extraction
Dioxins & Furans, Nitroaromatics and Isophorone, and Polycyclic Aromatic Hydrocarbons, PAH	G, Teflon lined cap (2-1/2 L.A.J.)	4°C store in dark	7 d until extraction
Phthalate esters	G, Teflon lined cap	4°C	7 d until extraction
Purgeable aromatic hydrocarbons	G, Teflon lined septum (40-mL Glass V)	4°C	14 d prior lab testing
Semi-Volatile Organics	G, Teflon-lined Septum (2.5-L Jug)	4°C	7 d
TCLP Sample	G, Teflon-lined Septum (2.5-L Jug)	4°C	7 d until extraction
Volatile Organic Compounds (VOC)	G, Teflon lined septum (40-mL Glass V)	4°C	14 d preserved in HCl†

NOTE 6—P=Plastic; G=Glass, HDPE=High Density Polyethylene

†—Evaluation data is being sought to confirm this requirement for curing and finished composts.

of the average or median property or trait of a batch or segment of a continuous stream, rather than a specific spot trait.

9.3.2.1 *stratified sampling*—a modified composite sampling scheme is used to document gradients and define heterogeneity as a function of position within the bulk or general mass of sampled material, where the general mass is subdivided into separate zones and a series of point-samples are collected and composited within each zone. Stratified sampling should be used when heterogeneity of compost is unknown and when regulatory constraints require knowledge of the relative spatial and temporal variability. This is most often based upon the standard deviation and mean; refer to Method 02.01-B for equations applied in calculations for approximating the required number of sub-samples to accurately estimate the average value for the parameter or trait of interest.

9.3.2.2 *interval sampling*—sampling from moving conveyor belts.

9.4 *Sampling Plan*—The constraints of the material and the composting technology must be considered when an optimal sampling plan is designed. Combinations of composite and point sampling are illustrated within the four sampling schemes presented in Fig 02.01-A2. The sampling scheme selected must address limitations of the selected test parameter and should not distort the analytical result.

9.4.1 Stratified sampling (Scenario A, Fig 02.01-A2) is used to determine variability, profile gradients and spatial uniformity characteristics. In most cases, composite sampling (Scenario B, Fig 02.01-A2) is satisfactory when the amount of variability within the mass is known to be insignificant. It involves combining several representative sub-samples into one composite sample that is then thoroughly mixed, then split for shipment to the laboratory. Area or batch sampling (Scenario C, Fig 02.01-A2) and single grab- or point-sampling (Scenario D, Fig 02.01-A2) are for special cases where one sample is collected at one location. Area or batch sampling is typified by a whole mass collected as one sample unit. This method is most appropriate when moving the mass from a vessel to a curing pile. A single point-sample does not provide a representative sample for the bulk mass. Batch sampling and point sampling should be employed to characterize an obvious or potential anomaly at one specific point, time or location within a process. A good example of a single point sample to detect anomalies is shown as X in Fig. 02.01-A2 D, a location referred to as the "toe" of a static aerated pile, and one which is vulnerable to suboptimal temperatures needed to achieve pathogen reduction. For this reason, it is sometimes specifically included to verify pathogen content of compost that has finished the thermophilic phase.

9.5 *Importance of Representative Sampling*—A representative sample defines a material's average characteristic, typical for the entire material being sampled. Under virtually all composting conditions, the mass of compost material is large and heterogeneous. A representative sample of compost is not easily obtained, and sampling must be repeated over time to compensate for naturally high variations. Under proper management and as compost-curing advances, variability within a curing pile or windrow will decrease.

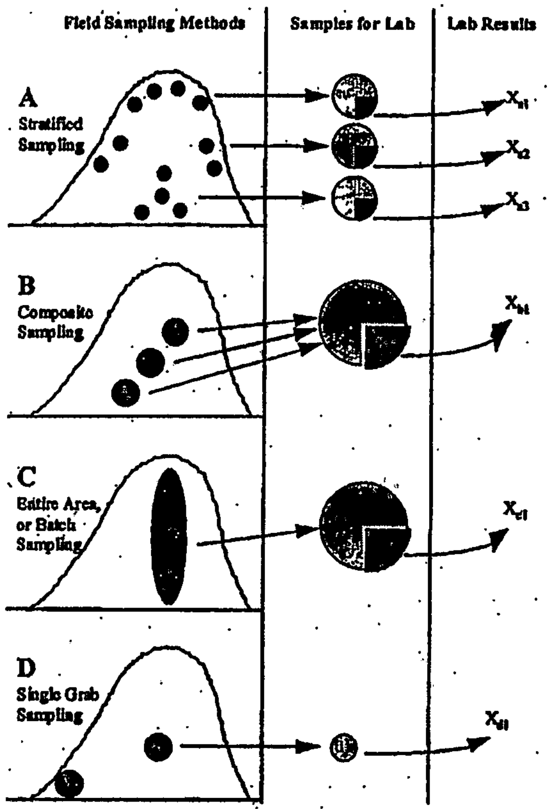


Fig 02.01-A2 The sampling schematic.

9.6 *Variables that Compromise Quality of Sampling*—Sample collection technique and variability of compost and cured compost affect the relative accuracy of sampling and the reliability of laboratory analytical determinations. Failure to adjust sampling protocols according to the nature and source of variations may invalidate test results and lead to inappropriate management or marketing decisions.

9.6.1 *Bias Introduced by the Sampler*—Inaccurate sample collection is often due to systematic or intentionally selective sampling introduced by the sampler. Significant error will result from attempts by the sample collector to counteract perceived variability. Examples include avoiding the collection of subcarefully designed to sample across any existing gradient of non-uniformity.

9.8.3 Discussion in the following section identifies technologies and primary constraints or requirements for representative sampling.

9.8.3.1 *Type A. Home Bins* come in many shapes and sizes, from fixed solid containers, loose wooden structures to rotating solid-tanks. The appropriate framework for sampling is to select the material representing the finished product. Some systems provide doors at the bottom of a bin from which samples may be easily removed; other bins require disassembling or removal from the pile and hand-mixing of the mass. Precaution must be taken to assure a homogenous mixture under any circumstance.

NOTE 7—The inclusion of home composting bins in TMECC is not a suggestion or endorsement for regulatory control, but for information and perspective only. While home composting bins are not a mainstay of commercial composting and not currently or likely to be regulated by state or local jurisdictions when the end product is used by the home generator and producer, the principles described in TMECC for assessing overall quality of compost are suitable for use on such products.

9.8.3.2 *Type B. Turned Windrows* are either batch or continuous piles. In the former common case, the entire windrow is made from similar ingredients at about the same time (e.g., within 3 d). In the latter case, materials are added lengthwise over time. In both cases, non-uniformity is observed down the length of the pile and is greatest with continuous modes of composting. Sampling of windrows requires compositing over a discrete length, either the entire pile, or a sub-section identified to have similar age or other characteristics. Windrow turning machines are useful for preparing uniform mixtures suitable for composite sampling; however, a single pass with a turning machine will not result in an evenly mixed pile, 3-4 passes commonly are required. If turning is performed frequently, the need for multiple turns prior to sampling diminishes.

9.8.3.3 *Type C. Static Piles* are recognized for their non-uniformity. These piles exhibit gradients of temperature, aeration and exposure to elements that reduce homogeneity over time. To obtain a representative sample from a static pile, extreme disruption and mixing is required. Breaking down the pile with a bucket loader and re-mixing after removal of the outer cover may be necessary. If mixing is not complete, sub-samples should be taken from each region during pile breakdown, or from the bucket as material is removed. However, if the purpose of sampling is to characterize non-uniformity, then effort must be made to get to the region of concern where a representative sample can be collected. This could be performed using a core sampler, or by breaking open the pile with heavy equipment.

9.8.3.4 *Type D. Agitated-Bed* systems generally move compost along the length of the system at a fixed rate per day. Should sampling be necessary during the process, care must be taken to understand the variability imposed by nature of daily additions to the system. In some cases, the actual technology physically restricts access for various reasons including worker safety. In such situations, samples can be collected at the discharge end where material comes off the bin. Several sub-samples should be taken each day, cooled immediately; and several days' accumulated samples (except for bacteriological and others parameters limited by a 48 h holding time) can be composited to form a bulk sample.

9.8.3.5 *Type E. Enclosed Vessel* reactors are either circular or oblong containers, bins or towers (these systems may or may not contain internal moving parts) and cannot be easily accessed for sampling. Sample collection is best performed at the vessel's discharge end. In-process sampling for quality control and process monitoring is not always practical with these systems.

9.8.3.6 *Type F. Rotating Vessels* are horizontal tanks, usually positioned on a gradient. They are used for continuous and sometimes for batch composting. Most systems do not have ports to access the material during processing, making in-process sampling impractical. As with the enclosed vessel design, sampling is usually performed at the discharge end of the vessel. Rotating vessels are often used during "Feedstock Preparation" for many technology types, and sampling is performed on the download conveyor.

9.8.3.7 *Type G. Cure Piles* are frequently very large and may contain material composited from several piles. Because of their heterogeneity and size, and the typical lack of turning and mixing, they usually display extreme gradients of moisture, maturity and bulk density. Under these circumstances, one effective way to adequately sample is to use a large tractor loader to break into the pile, moving and mixing the materials in the process. The sampling plan must incorporate a stratified sampling scheme and point sampling to distinguish gradients and map spatial non-uniformity.

9.8.3.8 *Type H. Bagged Product* results from a mixing and screening process that is assumed to produce uniform material prior to bagging. Additional mixing of the bulk mass after bagging and prior to sampling is precluded. Therefore, a statistically representative sample must consist of many sub-samples collected from different bags. Additionally, the physical constraint of extracting small sample cores from separate bags that are palletized compounds the problems of collecting proper samples.

9.8.3.9 *Type I. Source Ingredients* are notorious for non-uniformity. Large sub-samples that accurately

9.9.3 *Sampling raw source ingredients—Example 1.* Samples shall be taken from incoming material that has been shredded, tumbled or otherwise reduced in particle size. From the material exiting the shredder/mixer, one point-sample shall be obtained every 2 h, over an operational period of 6-8 h, for a total of 4 samples. Sample size should be approximately 1000 cm^3 (~ 1 qt) per sample. The four samples shall then be thoroughly mixed together (composite), and a portion of the mixture (composite sub-sample) taken for analysis. If point-sampling directly from the shredder or mixing mill is not possible, the incoming material shall be sampled no more than 24 h after passing through the shredding equipment.

9.9.4 *Example 2—Sampling compost materials.* For each sampling event, a single composite sample shall be made up of multiple sub-samples for each pile or batch, unless otherwise directed.

9.9.5 *Example 3—Sample locations.* Construct and label a diagram of sample locations for your composting system. The example provided in TMECC 02.01-B indicates a minimum of fifteen sub-samples per pile. This procedure establishes a composite or general characterization of the attributes in a compost pile.

9.9.5.1 Refer to section 02.01-B for a strategy to sample generic windrows of compost.

9.9.5.2 Samples collected during the composting process are not composited in the same manner as finished samples because point-specific problems must be identified and monitored. Factors such as anaerobic materials and volatile fatty acids (VFA) may need to be determined from point-samples extracted from multiple locations in the same pile.

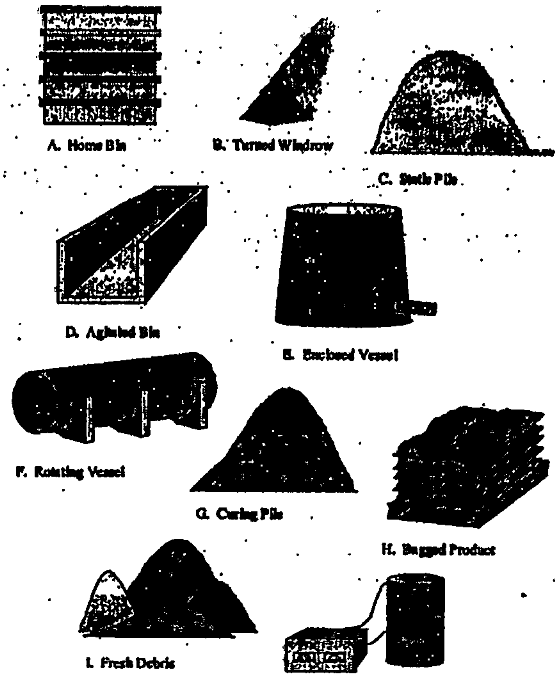


Fig 02.01-A3 Composting technologies.

9.9.6 *Example 4—Sample Variance Exercise.* The coefficient of variation (CV) expresses the relative variability for a parameter of interest across multiple samples. The CV is expressed as a percentage and calculated by dividing the sample standard deviation by the sample mean and multiplied by 100.

9.9.6.1 The ability to distinguish differences between arithmetically similar sample values decreases as the CV increases. It is difficult to draw specific conclusions about analytical results when variability is high. Under circumstances where variability is consistently high either the sampling plan must be redesigned to account for the excessively high variability, or the parameter should be discarded as a standard measure.

9.9.6.2 Consider a hypothetical case where two standard parameters are used to evaluate compost stability, C:N and VFA. Assume that the upper limit of acceptable variability for the parameters are set at 15% for C:N, and 45% for VFA. Low CV thresholds are generally assigned to system and process critical measures, and high CV thresholds are assigned to less critical standard measures.

NOTE 2A—This is a hypothetical case. It may be very difficult to establish meaningful CV limits without a large amount of data from many composts across time for a given test parameter. In addition, depending on the test, an individual test parameter may show a very large CV for repeated analysis of one sample.

Test Method: Selection of Sampling Locations for Windrows and Piles							Units: *NA*	
Test Method Applications								
Process Management							Product Attributes	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Odor Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	*Safety Standards*	*Market Attributes*
		02.01-B	02.01-B	02.01-B	02.01-B	02.01-B	02.01-B	02.01-B

02.01-B SELECTION OF SAMPLING LOCATIONS FOR WINDROWS AND PILES

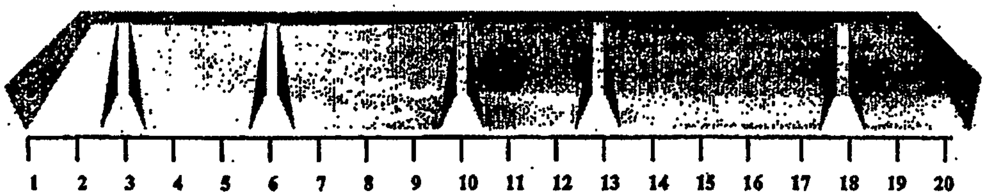


Fig 02.01-B1 Hypothetical sample collection pattern from a compost windrow.

NOTE 1B—In this example, a scale from 1-20 is superimposed on the long dimension of a compost windrow. Five distances (3, 6, 10, 13 and 18 m) are randomly selected to each side of the windrow, (e.g., numbers randomly pulled from a hat), to assign sample collection locations. Point-samples are collected from within three zones at each cutout.

NOTE 2B—The illustrated cut-outs are depicted on one side of the windrow; in a real operation, the cut-outs must be randomly assigned to each side of the windrow. Cone-shaped piles have a circular base. Measure around the base of a cone-shaped pile and randomly assign cutout positions along the pile's meridian, or circumference.

10. Apparatus for Method B

10.1 *Sampling Container*—five 16- to 20-L (4- to 5-gal), plastic (HDPP), glass.

10.1.1 *Organic Contaminant Tests*—For samples to be analyzed for the presence of organic contaminants, please refer to Table 02.01-6 Organic Contaminant Tests: Sampling containers and conditions for compost and source ingredient testing. Modify sample packaging steps presented in this section accordingly.

10.2 *Sampling Device*—silage auger, tilling spade, or other appropriate sampling device.

10.3 *Tractor Loader*—with loader, (e.g., Bobcat, etc.).

10.4 *Trowel*—high-density polypropylene (HDPP), for stirring and mixing composite sample.

10.5 *Pail*—16- to 20-L (4- to 5-gal), square pails, Use standard 5-gal plastic pails for shipping only when square pails are not available (e.g., square pails are available through Cleveland Bottle & Supply Co.; 850 East 77th Street; Cleveland, OH 44103; telephone: 216 881 3330; Fax: 216 881 7325; URL: http://www.clevelandbottle.com/squrpail.html).

11. Reagents and Materials for Method B

11.1 *Plastic Bags*—three 4-L (1 gal) durable bags with seal, (e.g., Ziploc® Freezer bags).

11.2 *Plastic Gloves.*

11.3 *Tarp*—clean plastic, canvas, or other type of mixing surface if feedstock is liquid sludge.

11.4 *Cold Packs*—chemical ice packs, or 4-L plastic bags (e.g., heavy duty Ziploc® freezer bags) filled with approximately 0.5 L of water and frozen flat. One ice pack per 4-L sample container of compost to be shipped, (e.g., three ice packs are recommended for three compost 4-L samples).

11.5 *Aluminum Foil*—lining for plastic shipping pail, and

11.6 *Packing Material*—newspaper or other appropriate bulking material to be used as packing or fill to minimize sample movement within the shipping container (square pail) during shipping.

11.7 *Adhesive Tape*—duct tape, 5-cm (2-in.) width.

12. Procedures for Method B

12.1 *Cut into Finished Compost*—Using tractor skid-loader, bobcat or shovel, or sample boring device, cut into the finished compost pile or windrow at five or more randomly selected positions. Collect samples from the full profile and breadth of the compost windrow or pile. Refer to Fig 02.01-B1.

12.2 *Collect Point-Samples*—Samples of equal volume are extracted from the compost pile at three depths or zones measured from the pile's uppermost surface. Collect no less than five point-samples from each of the three depths or zones illustrated in Fig 02.01-B2. The five point samples for each zone must be collected in a manner to accurately represent the horizontal cross-section of the windrow or pile. Use a sanitized sampling tool (a gloved hand, clean shovel or auger) when collecting samples and when transferring samples to the 5-gal sample collection pail.

Test Method: Field Sampling Plan for Composted Material							Units: *NA*	
Test Method Applications								
Process Management							Product Attributes	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Odor Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	*Safety Standards*	*Market Attributes*
02.01-C	02.01-C	02.01-C	02.01-C	02.01-C	02.01-C	02.01-C	02.01-C	02.01-C

02.01-C FIELD SAMPLING PLAN FOR COMPOSTED MATERIAL

13. US EPA SW-846 Guideline Review and Considerations

13.1 With its hazardous waste management system, the US EPA requires that certain solid wastes be analyzed for physical and chemical properties. In its hazardous waste management system, it is mostly chemical properties that are of concern, and in the case of a number of chemical components, the US EPA has promulgated levels (regulatory thresholds) that cannot be equaled or exceeded.

13.1.1 Regulations pertaining to the management of hazardous waste contain three references regarding the sampling of solid wastes for analytical purposes:

13.1.1.1 Collect representative samples of waste, so that they exhibit average properties of the bulk compost or feedstock.

13.1.1.2 Collect enough samples (but no less than four samples) over a period of time sufficient to represent the variability of the compost or feedstock.

13.2 *Sampling Plan Implementation*—The US EPA manual contains a section on implementation of the sampling plan (SW-846 Chapter Nine, part 2). Within that section there is discussion concerning the sampling program's objectives for evaluating a compost. (Refer to Fig 03.01 Sample fate).

13.2.1 The example suggests the following questions be answered:

13.2.1.1 Is the sampling being performed to comply with environmental regulation?

13.2.1.2 Samples are to be analyzed for which parameters?

13.2.1.3 Why not others?

13.2.1.4 Should samples be analyzed for fewer parameters?

13.2.1.5 What is the end-use of the generated data?

13.2.1.6 What are the required degrees of accuracy and precision?

13.2.2 These questions may or may not be as important for sampling composted solid waste.

13.3 *Sampling Plan Considerations*—The implementation section contains a category entitled Sampling Plan Considerations. The sampling plan is usually a written document that describes the objectives, and details the individual tasks and how they will be performed. The more detailed the sampling plan, the less opportunity for oversight or misunderstanding during sampling, analysis, and data management.

13.3.1 The SW-846 document suggests that a sampling plan be designed with input from the various sectors involved in the project, including the following personnel:

13.3.1.1 *regulatory sampling*—in many cases may require state permits and consultations with state officials.

13.3.1.2 *end-user*—to use the data to attain program objectives.

13.3.1.3 *field team member*—an experienced member of the field team who actually collects samples.

13.3.1.4 *analytical chemist*—to review analytical requirements for sampling, preservation, and holding times that will be included in the sampling plan.

13.3.1.5 *process engineer or equivalent*—it explain details and constraints of the production process being sampled.

13.3.1.6 *statistician*—to review the sampling approach and verify that the resulting data will be suitable for any required statistical calculations for decisions.

13.3.2 *quality assurance representative*—to review the applicability of standard operating procedures and determine the number of blanks, duplicates, spike samples, and other steps required to document the accuracy and precision of the resulting data.

13.3.3 If no one is familiar with the site to be sampled, then a pre-sampling site visit should be arranged to acquire site-specific information. Some modifications of the sampling plan may be necessary. It is necessary to have at least one experienced sampler as a member of a sampling team.

14. Statistical Validity of Sampling Plan

14.1 *Objectives*—The primary objective of a sampling plan for a compost is to collect an appropriate measured. Consequently, statistics generated by the sample (e.g. sample mean and to a lesser degree, standard deviation) are unbiased estimators of true population parameters. That is, the sample is representative of the population. A common method of selecting a random sample is to divide the population by an imaginary grid, assign a series of consecutive numbers to the units of the grid, and select the number to be sampled using a random-numbers table.

NOTE 2C—Haphazardly selected samples are not random and therefore not a suitable substitute for a randomly selected sample. That is because there is no assurance that a person performing undisciplined sampling will not consciously or subconsciously favor the selection of certain units of the population.

14.6.1 Sampling precision is achieved by collecting the appropriate number of samples that are uniformly distributed across the entire volume of compost. Precision is improved by increasing the number of samples, while maintaining a sampling pattern to guarantee a spatially uniform distribution.

14.6.2 If a batch of compost is randomly heterogeneous with regard to its chemical characteristics and if that random chemical heterogeneity remains constant from batch to batch, accuracy and appropriate precision can usually be achieved by simple or systematic random sampling. More complex stratified random sampling is appropriate if a batch of compost is known to be non-randomly heterogeneous in terms of its chemical properties and non-random chemical heterogeneity is known to exist from batch to batch. In such cases, the population is stratified to isolate the known sources of non-random chemical heterogeneity. The units in each stratum are numerically identified, and a simple random sample is taken from each stratum. This type of sampling would be advantageous only if the stratification efficiently divides the waste into strata that exhibit maximum between-strata variability and minimum within-strata variability. In composted solid waste that is frequently turned and mixed, little if any stratification is likely to occur. If little or no information is available concerning the distribution of chemical components, simple or systematic random sampling are the most appropriate sampling strategies.

14.7 *Number of Samples*—The appropriate number of samples to collect is the least number required to generate a sufficiently precise estimate of the true mean concentration of a chemical component of a compost. From the compost producer's perspective, this means that the minimum number of samples needed to demonstrate that the upper limit of the confidence interval for the true mean is less than the applicable regulatory threshold value. It is always prudent to collect a greater number of samples than indicated by preliminary estimates of the mean and variance since poor preliminary estimates of those statistics can result in an underestimate of the appropriate number of samples to collect.

14.8 *Simple Random Sampling*—For convenience, the statistical calculations for simple random sampling (wherein within-batch heterogeneity that may be encountered by a compost producer is low) are provided (adapted from SW-846 Chapter Nine, part 2, pages 13-14).

14.8.1 Obtain preliminary estimate of $\bar{x}$ for each chemical component of compost that is of concern. The above-identified statistic is calculated by Equation 14.8.1.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \textit{Equation 14.8.1}$$

where:

$\bar{x}$ = simple random sample mean,
n = total number of sample measurements,
x = variable in question (e.g., mercury),
i = individual samples ranging from 1 to n, and
$\sum_{i=1}^{n} x_i$ = sum of all x's (analytical results for individual samples), from i = 1 through i = n.

14.8.2 Obtain preliminary estimate of variance, s^2, for each chemical component of concern. The above-identified statistic is calculated by Equation 14.8.2.

$$s^2 = \frac{\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2 / n}{n-1} \qquad \textit{Equation 14.8.2}$$

where:

s^2 = variance of simple random sample,
n = total number of sample measurements,
x = variable in question (e.g., mercury), and
i = individual samples ranging from 1 to n.

14.8.3 Estimate the appropriate number of samples (n_1) to be collected from the compost through use of Equation 14.8.3 and Table 02.01-C1. Derive individual values of n_1 for each chemical component of concern (x). The appropriate number of samples to be taken from the compost is the greatest of the individual n_1 values.

$$n = \frac{t_{.20}^2 s^2}{\Delta^2} \qquad \textit{Equation 14.8.3}$$

where:

n = number of samples,
$t_{.20}^2$ = tabulated "t" value for two-tailed confidence interval and a probability of 0.20,
s^2 = sample variance, and

$$\bar{x} = \sum_{k=1}^{r} W_k \bar{x}_k \qquad \text{Equation 14.9.1}$$

where:

$\bar{x}$ = stratified random sample mean,

$\bar{x}_k$ = stratum mean, and

W_k = fraction of population represented by stratum k (number of strata *[k]* range from 1 to r).

14.9.2 Obtain preliminary estimate of s^2 for each chemical component of compost that is of concern. The identified statistic is calculated by Equation 14.9.2.

$$s^2 = \sum_{k=1}^{r} W_k s_k^2 \qquad \text{Equation 14.9.2}$$

where:

s^2 = stratified random sample variance,

s_k^2 = stratum variance, and

W_k = fraction of population represented by stratum k (number of strata *[k]* range from 1 to r).

14.9.3 Estimate the appropriate number of samples *(n_1)* to be collected from the compost through use of Equation 14.8.3 and Table 02.01-A1 Tabulated values of Student's "t" for evaluating compost. Derive individual values of n_1 for each chemical component of concern. The appropriate number of samples to be taken from the compost is the greatest of the individual n_1 values.

14.9.4 Randomly collect at least n_1 (or $n_2 - n_1$, $n_3 - n_2$, etc., as will be indicated in step 8) samples from the compost. If s_k for each stratum (see Equation 14.9.2) is believed to be an accurate estimate, optimally allocate samples among strata (i.e., locate samples among strata so that the number of samples collected from each stratum is directly proportional to the s_k for that stratum). Otherwise, proportionally allocate samples among strata according to size of the strata. Maximize the physical size (volume) of all samples that are collected from the strata.

14.9.5 Analyze the n_1 (or $n_2 - n_1$, $n_3 - n_2$, etc.) samples for each chemical component of concern. Superficially (graphically) examine each set of analytical data from each stratum for obvious departures from normality.

14.9.6 Calculate $\bar{x}$, s^2, the standard deviation *(s)*, and $s_{\bar{x}}$ for each set of analytical data by, respectively, Equations 14.9.1, 14.9.2, 14.8.4 and 14.8.5.

14.9.7 If $\bar{x}$ for a chemical component is equal to or greater than the applicable regulatory threshold (from Equation 14.8.3) and is believed to be an accurate estimator of μ (population mean), the component is considered to be present in the compost at a hazardous concentration, and the study is completed. Otherwise, continue the study. In the case of a set of analytical data that does not exhibit obvious abnormality and for which $\bar{x}$ is greater than s^2, perform the following calculations with non-transformed data. Otherwise, consider transforming the data by the square root transformation (if $\bar{x}$ is about equal to s^2) or the arcsine transformation (if $\bar{x}$ is less than s^2) and performing all subsequent calculations with transformed data.

14.9.8 Determine the confidence interval (CI) for each chemical component of concern by Equation 14.8.6. If the upper limit of the CI is less than the applicable regulatory threshold (applied in Equation 14.8.3), the chemical component is not considered to be present in the compost at a hazardous concentration, and the study is completed. Otherwise, the opposite conclusion is tentatively reached.

14.9.9 If a tentative conclusion of hazard is reached, re-estimate the total number of samples *(n_2)* to be collected from the compost by use of Equation 14.8.3. When deriving n_2, employ the newly calculated (not preliminary) values of $\bar{x}$ and s^2. If additional $n_2 - n_1$ samples of compost cannot reasonably be collected, the study is completed, and a definitive conclusion of hazard is reached. Otherwise, collect an extra $n_2 - n_1$ samples of compost.

14.9.10 Repeat the basic operations described in Steps 14.9.3 through 14.9.9 of Fig 02.01-1 Composting Unit Operations, until the compost is judged to be non-hazardous or if the opposite conclusion continues to be reached until increased sampling effort is impractical.

Test Method: Data Quality Management and Sample Chain of Custody							Units: NA	
Test Method Applications								
Process Management							Product Attributes	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Odor Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	Safety Standards	Market Attributes
02.01-E	02.01-E		02.01-E			02.01-E	02.01-E	02.01-E

02.01-E DATA QUALITY MANAGEMENT AND SAMPLE CHAIN OF CUSTODY

18. Aspects of Sampling Quality Assurance for Reported Data

18.1 Three critical steps in the sampling process precede laboratory analysis and often dictate data quality.

18.1.1 sample planning and collection;

18.1.2 sample handling and preservation; and

18.1.3 laboratory sample preparation.

18.2 Each step in the sampling process must be properly executed in a timely manner by well informed, trained individuals to ensure that the collected sample accurately represents a compost batch, windrow or pile.

18.3 *Quality Sample Management*—Regulatory and certification systems may dictate that samples are properly collected, preserved and prepared for analysis. Consider the following hypothetical example of sample management where a certified third party is introduced to manage the sampling plan.

18.3.1 The third party assumes all quality assurance and quality control responsibilities associated with:

18.3.1.1 sample planning and collection;

18.3.1.2 sample handling and preservation; and

18.3.1.3 laboratory sample preparation.

18.3.2 Responsibility for rigorous sample collection is transferred from facility management to the third party. Responsibilities associated with sample storage, preparation and laboratory analysis are also transferred from the analytical laboratory to the third party.

18.3.3 One of the principal benefits of the third party sampling system is to diminish deviations in sampling plan interpretation and implementation across separate facilities and laboratories. Third party control can decrease variability by maintaining consistent field sampling protocols across all participating facilities. Field sample collections would be implemented as described in *TMECC 02.01 Field Sampling of Compost Materials*. Consistent sample preparation protocols would also be followed for laboratory analysis as described in *TMECC 02.02 Laboratory Sample Preparation for Analysis*.

18.4 *Tracking Quality*—A sample must be properly collected and prepared for shipment, and then properly manipulated by laboratory personnel who follow specific preparation protocols designed for each analytical methodology. Previous sections emphasized the importance of properly designed and implemented sampling plans. This section introduces a protocol designed to modify data interpretation to interpret sample variability.

18.4.1 Consider the following hypothetical sampling plan that incorporates an additional step to verify accuracy of reported results using cross-validation techniques. One type of a statistically valid sample management plan requires that samples are properly collected at a very high frequency while the actual number of samples submitted for analysis remains small.

18.4.1.1 *Establish Baseline*—A significant number of samples that represent the composting process of a facility are collected over time and sent to a laboratory for analysis. Results from these samples serve to establish a baseline of information that accurately represents the compost produced by the facility and a given feedstock blend.

18.4.1.2 *Track Deviations from Baseline*—After the baseline is established, samples are collected at specified intervals, over time or per unit of compost produced (refer to *TMECC 02.01-A Equation 9.9.1 Formula to estimate sampling interval*), and held in cold storage. After a specified interval, (e.g., quarterly or monthly) a small but statically representative number of prepared samples are randomly selected from the stored samples and sent to a laboratory for analysis. Because multiple samples would be randomly selected from a larger population of samples, a more reliable statistical inference can be generated than by simply directly submitting monthly or quarterly samples for analysis.

18.4.2 Sampling programs of this nature may require that field samples, or samples prepared for laboratory analysis, are submitted to a secure or bonded cold-storage facility where frequently collected samples are inventoried and properly stored. Samples must be retained in storage for a predetermined time period to

02.01 SUMMARY

19. Report

19.1 Chain of custody forms and procedures should be used with all environmental or regulatory samples. A chain of custody form is used to track sample handling from time of collection through laboratory analysis, and data reporting. Suggested information for the chain-of-custody record includes, at a minimum: Collector's name; Signature of collector; Date and time of collection; Place and address of collection; Requested preprocessing (subsampling, compositing, sieving); Requested analyses; Sample code number for each sample (if used); Signature of the persons involved in the chain of possession. Refer to Fig 02.01-E1 Chain of Custody form for an example.

20. Keywords

20.1 accuracy; aliquot; attribute verification; bias; chain of custody; closed vessel system; composite; compost; coefficient of variation; %CV, confidence interval; feedstock; grab-sample; point-sample; point-sampling; open vessel system; precision; process monitoring; process variability; product variability; quality control; quality assurance; representative sample; sample collection frequency; sampling; sampling plan; statistical validity; stratified sampling; windrow.

Test Method: Electrical Conductivity for Compost. One Method							Units: dS m^{-1}	
Test Method Applications								
Process Management							Product Attributes	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Odor Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	*Safety Standards*	*Market Attributes*
04.10-A	04.10-A							04.10-A

04.10 ELECTRICAL CONDUCTIVITY FOR COMPOST

NOTE 1—1 Mhos = 1 Siemen's unit = 1 Ω^{-1}

1. Scope

1.1 This section covers the determination of electrical conductivity of compost.

1.1.1 *Method 04.10-A 1:5 Slurry Method, Mass Basis.*

NOTE 2—The 1:5 Slurry method is included in TMECC while the Saturated Paste Extract method (ECe) was removed with peer agreement through the TMECC peer-review process in the interest of diminishing variations in reported EC results for compost samples. The 1:5 Slurry method is more conservative, analytically sound and less prone to systematic error. It also includes sample preparation steps that account for variations in moisture content among compost samples. The 1:5 Slurry method is valid for use on compost samples that are not amended with inorganic fertilizers, (e.g., ammonium sulfate, etc.) which significantly increase measured EC values.

1.2 Values stated in SI units are to be regarded as the standard. Values given in parentheses are provided for information only.

2. Referenced Documents

2.1 *TMECC:*

Method 03.09 Total Solids and Moisture.

Method 04.11 Electrometric pH Determinations for Compost.

Method 05.02-E Agricultural Index (AgIndex).

2.2 *Other References:*

NCR Pub. No. 221 (Revised), Recommended chemical soil test procedures, Missouri agricultural experiment station SB 1001, January 1998.

Dahnke, W.C. and D.A. Whitney. 1988. Measurement of Soil Salinity. *In* Recommended Chemical Soil Test Procedures for the North Central Region. NCR Pub. 221 (Rev). Bul. 499, (Rev), October 1988.

US Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook No. 60. p 90. U. S. Govt. Print. Office. Washington, DC.

Rhoades, J.D. 1996. Salinity: Electrical conductivity and total dissolved solids. p. 417-435. *In* J. M. Bartels et al. (ed.) Methods of Soil Analysis: Part 3. Chemical Methods 3rd. ed. ASA and SSSA, Madison, WI. Book series no. 5.

Peters, J. R. 1963. The nature and management of saline soils. Manitoba Dept. of Agric. and Conservation. Publ. #360.

3. Terminology

3.1 *salt, n*—A chemical compound formed by replacing all or part of the hydrogen ions of an acid with metal ions or electropositive radicals.

3.2 *standard, n*—Serving as or conforming to a standard of measurement or value. Sample often referred to a standard reference sample or check of known physical, chemical or biological characteristics used to monitor analytical bias or accuracy of a physical, chemical or biological determination.

4. Summary of Test Methods

4.1 *Method 04.10-A 1:5 Slurry Method, Mass Basis*—A compost sample at as-received moisture is blended with water at a ratio of 1:5, dw/v equivalent basis. The sample is shaken for 20 min at room temperature to allow the salts to solubilize in the water. Electrical conductivity is measured in the 1:5 sample slurry. An optional extraction step is provided for situations where a conductivity measure is required for the sample extract solution.

Test Method: Electrical Conductivity for Compost. 1:5 Slurry Method, Mass Basis							Units: dS m^{-1}	
Test Method Applications								
Process Management							Product Attributes	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Oder Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	*Safety Standards*	*Market Attributes*
04.10-A	04.10-A							04.10-A

04.10-A 1:5 Slurry Method, Mass Basis

LOOK—Interference and Limitations, and Sampling Handling issues are presented as part of the introduction to this section.

8. Apparatus for Method A

8.1 *Conductivity/Resistivity Meter*—soluble salt bridge, (e.g., Industrial Instrument Inc., model RC-16B2 or equivalent).

8.2 *Stirring Rod*—approximately 15-cm length, glass.

8.3 *Conductivity Cell*—1-cm, apparatus-specific.

8.4 *Sample Flasks*—500-mL, plastic or glass Erlenmeyer flasks, with screw-cap lid or cover.

8.5 *Sample Beakers*—100-mL, plastic or glass.

8.6 *Reciprocating Shaker*—capable of shaking a sample flask at the rate of 180 reciprocations or excursions per min.

8.7 Centrifuge Extraction Apparatus (optional step)—200-mL centrifuge tubes, capable of 8000 *g*.

9. Reagents and Materials for Method A

9.1 *Water*—ammonia-free, carbonate-free, deionized, minimum resistivity of 17 MΩ·cm^{-1}.

9.2 *Calibration Standard*—Dissolve 0.7456 g KCl (previously dried at 110°C for 2 h) deionized water and dilute to 1.0 L. At 25°C±0.1°C a 0.010 *N* KCl solution will have an EC of 1.412 dS m^{-1} (mmhos cm^{-1}). For a 0.100 *N* KCl solution (7.456 g KCl diluted to 1.0 L) will have an EC of 12.900 dS m^{-1}. Standard EC calibration solutions are listed in Table 04.10-A1 and can be purchased from a scientific supply vendor.

9.3 *Filter paper (optional step)*—medium flow, Whatman No. 1 or equivalent.

10. Procedure for Method A

10.1 *Calibration Check*—Determine conductivity of calibration solutions. Refer to Table 04.10-A1.

Table 04.10-A1 Conductivity of KCl solutions at 25°C

Normal Concentration	Conductivity (dS m^{-1})
0.001	0.147
0.010	1.413
0.020	2.767
0.050	6.668
0.10	12.90
0.20	24.82
0.50	58.64

ADAPTED FROM—Rhoades, 1996

10.2 *Duplicate Samples*—Within each batch of twelve samples duplicate at least one sample to monitor precision.

10.3 *Compost Aliquot Moisture*—Determine the total solids ratio on a parallel sample aliquot.

10.3.1 Measure and record the as-received tare weight of the aliquot. Oven dry the aliquot in a microwave oven with high temperature setting for approximately 5 min, or until sample weight-change diminishes to nill. Calculate the total solids ratio by dividing the microwave oven dry weight by the as-received moist weight.

CAUTION—Metal fragments, i.e., inert contaminants in the compost aliquot, may cause the sample to ignite inside of the microwave oven.

10.3.2 If no microwave oven is available, follow the protocols to determine total solids as described in Method 03.09 Total Solids and Moisture, the procedure required for reporting sample moisture content. This choice will require that Method 04.10-A is performed after the total solids and moisture determination is completed.

10.4 *Prepare Samples:*

10.4.1 Weigh 40.0 g dry-weight equivalent of as-received moist compost (Equation 10.4.1.1) into the sample container, (e.g., 250-mL screw-cap flask).

10.4.1.1 Determine the dry-weight equivalent aliquot size.

10.4.2.1 Determine the required volume of extractant.

$$A = B - [C - 40] \quad \text{Equation 10.4.2.1}$$

where:

A = volume of extractant required, mL

B = target 1:5 slurry liquid fraction, 200 mL

C = mass of as-received compost aliquot, g, and

40 = total solids fraction of the as-received compost aliquot, g.

10.4.3 Place the 250-mL flasks with the 1:5 slurry on a shaker for 20 min at 180 reciprocations or excursions per minute.

10.4.4 Maintain slurry at ambient laboratory temperature, (e.g., 20°C to 23°C).

10.5 *Optional Extraction Step*—Extract the 1:5 solids:liquid slurry liquid fraction. Determine conductance on extact rather than on the slurry as described below. Report the inclusion of this step when reporting analytical results.

10.5.1 Transfer the slurry to a 200-mL centrifuge tube. Centrifuge at 8000 *g* for fifteen min to separate solid and liquid fractions, or

10.6 *Electrical Conductance*—Determine the electrical conductance of the 1:5 compost/water slurry with a conductivity/resistivity meter.

NOTE 1A—If the conductivity meter requires the use of a 1-cm conductivity cell, incorporate the optional extraction step (14.4) and proceed with the extract solution rather than the slurry as described below.

10.6.1 Standardize the conductivity meter using the standard KCl solution following manufacturers instructions.

10.6.2 Measure the temperature of the slurry. Set the temperature compensation dial on the conductivity meter to the temperature of the slurry.

10.6.3 Insert the conductivity electrodes into the slurry and swirl gently. Allow the instrument/sample to stabilize. Read and record the conductivity of the slurry ($dS\ m^{-1} = mMhos\ cm^{-1}$).

NOTE 2A—If the conductivity meter does not have a temperature compensator, follow the temperature correction formula provided in the appendix of this section, 04.10 Appendix. Temperature Correction.

11. Calculations and Corrections for Method A

11.1 If temperature compensation is not an option in the conductivity meter, correct the reading to 25°C as specified in 04.10 APPENDIX—Temperature Correction.

Appendix to 04.10—Temperature Correction

15. Temperature Correction for Methods 04.10-A.

15.1 *Temperature Correction Coefficient*—Measure electrical conductivity of the KCl calibration standard at laboratory temperature. Divide the 25°C standard electrical conductivity value by the measured value.

$$A = B \div C \qquad \textit{Equation 15.1}$$

where:

A = temperature correction coefficient, unitless,
B = conductivity of KCl calibration standard at 25°C, 1.41 dS m^{-1}, etc. (refer to Table 04.100-A1), and
C = electrical conductivity of KCl calibration standard at laboratory temperature, dS m^{-1}, (mMhos cm^{-1}).

15.2 Multiply the reading from each sample by the temperature correction coefficient to correctly report readings on a 25°C basis.

$$D = E \times A \qquad \textit{Equation 15.2}$$

where:

D = corrected reading for sample on a 25°C basis, dS m^{-1} (mMhos cm^{-1}),
B = reading for sample at laboratory temperature, dS m^{-1} (mMhos cm^{-1}),
A = temperature correction coefficient, unitless.

Test Method: Electrometric pH Determinations for Compost. One Method							Units: pH	
Test Method Applications								
Process Management							Product Attributes	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Odor Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	*Safety Standards*	*Market Attributes*
	04.11-A	04.11-A	04.11-A	04.11-A		04.11-A		04.11-A

04.11 ELECTROMETRIC pH DETERMINATIONS FOR COMPOST

1. Scope

1.1 This section covers the determination of pH of compost and compost feedstocks.

1.1.1 *Method 04.11-A 1:5 Slurry pH.*

1.2 Values stated in SI units are to be regarded as the standard. Values given in parentheses are provided for information only.

2. Referenced Documents

2.1 *TMECC:*

Method 04.10 Electrical Conductivity for Compost.

2.2 *Other References:*

Eckert, D.J. 1988. Recommended pH and lime requirement tests. *In* Recommended Chemical Soil Test Procedures for the North Central Region. North Dakota Agric. Exp. Stn. Bull. 499. Fargo, N.D.

NCR (North Central Regional) Method 14. 1988. pp. 34-37. *In* Recommended Test Procedure for Greenhouse Growth Media NCR Pub No. 221 (Rev), *Recommended Chemical Soil Test Procedures*, Bulletin Number 499 (Rev), October 1988.

Soils and Soil Fertility. 5th Edition. F. R. Troeh and L. M. Thompson, ed. Collage of Agriculture. Iowa State University. Oxford University Press. 1993.

US EPA Method 9045, Soil pH. *In* Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, US EPA SW-846, 3rd Edition, November 1992.

Warncke, D. 1998. Greenhouse root media. pp. 61-64. *In* Recommended chemical soil test procedures for the North Central Region. North Central Regional Research Publication No. 221 (Revised) Missouri Agricultural Experiment Station SB 1001.

Watson, M.E. and J.R. Brown. 1998. pH and lime requirement. pp. 13-16. *In* Recommended chemical soil test procedures for the North Central Region. North Central Regional Research Publication No. 221 (Revised) Missouri Agricultural Experiment Station SB 1001.

3. Terminology

3.1 *pH, n*—A measure of the acidity or alkalinity of a solution, numerically equal to 7.0 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The pH scale commonly in use ranges from 0 to 14, measures the negative log of hydrogen ion concentration (activity).

4. Summary of Test Methods

4.1 *Method 04.11-A 1:5 Slurry pH*—A slurry of compost and deionized water is blended at a ratio of 1:5, w/w or v/v basis. The sample is shaken for 20 min at room temperature to allow the salts to solubilize in the DI water. The pH is measured with an electrometric pH meter directly in the compost/water slurry or in the extracted solution. An optional extraction step is provided for situations where a pH measure is required for the sample extract solution. The measurement of pH is expressed as the negative log of the hydrogen ion activity. Activity and concentration are similar if the salt concentration is low.

5. Significance and Use

5.1 pH influences many factors in compost, including the availability of nutrients and toxic substances, and activities and nature of microbial populations. The pH affects the composting process by affecting the microbial population and by controlling availability of nutrients to microbes. The optimum pH lies between 6.0 and 7.5 for most bacteria, while the optimum pH for fungi and actinomycete activity is between 5.5 and 8.0. A pH below and higher than a specified optimum will reduce microbial activity and curtail or arrest biological processes.

5.2 In addition, pH is both an indicator of compost quality and a useful tool for determining its potential application. The pH of a compost will determine if the user needs to amend the compost to adjust the pH for a

Test Method: Electrometric pH Determinations for Compost. 1:5 Slurry pH							Units: pH	
Test Method Applications								
Process Management							Product Attributes	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Odor Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	*Safety Standards*	*Market Attributes*
	04.11-A	04.11-A	04.11-A	04.11-A		04.11-A		04.11-A

04.11-A 1:5 SLURRY pH

LOOK—Interference and Limitations, and Sampling Handling issues are presented as part of the introduction to this section.

8. Apparatus for Method A

8.1 *pH Meter*—bench top pH/ISE Meter, (e.g., Model 720A ORION No. 0720AO or equivalent).

8.2 *Glass Electrode*—hydrogen electrode.

8.3 *Reference Electrode*—silver-silver chloride or Hg calomel internal.

8.4 *Cups*—glass or plastic disposable, 37-mL (1.5 oz).

8.5 *Stirring Rod*—plastic.

8.6 *Sample Flasks*—250-mL, hard plastic or glass flasks, with screw-cap lid or cover.

8.7 *Shaker*—capable of shaking a sample flask at the rate of 180 reciprocations or excursions per min.

8.8 *Centrifuge Extraction Apparatus (optional step)*—200-mL centrifuge tubes, capable of 8000 g.

9. Reagents and Materials for Method A

9.1 *Reference Solutions*—commercial buffer, pH 7.0 and 10.0.

9.2 *Deionized Water*—minimum resistivity of 17 MΩ·cm, minimum standard.

10. Procedure for Method A

10.1 *pH Meter Calibration*—Calibrate the pH meter following manufacturer's instructions to the potential of the electrode pair with the pH 7.0 and 10.0 standard commercial buffer solutions with an accuracy of ±0.05 units.

10.1.1 Recalibrate if necessary. Rinse the electrode between readings of the buffer solutions. After rinsing, gently blot the tip of the electrode by touching once with a soft paper towel or tissue.

10.2 *Compost Aliquot Moisture*—Determine the total solids ratio on a parallel sample aliquot.

10.2.1 Measure and record the as-received tare weight of the aliquot. Oven dry the aliquot in a microwave oven with high temperature setting for approximately 5 min, or until sample weight-change diminishes to nill. Calculate the total solids ratio by dividing the microwave oven dry weight by the as-received moist weight.

CAUTION—Metal fragments, i.e., inert contaminants in the compost aliquot, may cause the sample to ignite inside of the microwave oven.

10.2.2 If no microwave oven is available, follow the protocols to determine total solids as described in Method 03.09 Total Solids and Moisture, the procedure required for reporting sample moisture content. This choice will require that Method 04.10-A is performed after the total solids and moisture determination is completed.

10.3 *Prepare Samples:*

10.3.1 Weigh 40.0 g dry-weight equivalent of as-received moist compost (Equation 10.3.1.1) into the sample container, (e.g., 250-mL screw-cap Erlenmeyer flask).

10.3.1.1 Determine the dry-weight equivalent aliquot size.

$$A = B + [C \times 0.01] \qquad \textit{Equation 10.3.1.1}$$

where:

A = mass of as-received moist compost aliquot, g
B = dry-weight equivalent of sample, 40.0 g,
C = sample total solids content, % wet weight basis, and
0.01 = factor to convert from percentage to fraction, unitless.

10.3.2 Bring the liquid fraction of the 1:5 solids:liquid slurry to an equivalent of 200 mL by adding deionized water to the as-received moist compost aliquot (refer to Equation 10.3.2.1). This step is based on the assumption that 1 mL is equivalent to 1 g of the as-received compost liquid fraction, and that 1 mL of water is equivalent to 1 g of water.

10.3.2.1 Determine the required volume of extractant.

$$A = B - [C - 40] \qquad \textit{Equation 10.3.2.1}$$

where:

A = volume of deionized water required, mL
B = target 1:5 slurry liquid fraction, 200 mL
C = mass of as-received compost aliquot, g, and
40 = total solids fraction of the as-received compost aliquot, g.

10.3.3 Place the 250-mL flasks with the 1:5 slurry on a shaker for 20 min at 180 reciprocations or excursions per minute.

04.11 METHODS SUMMARY

11. Interpretation of Results

11.1 A low pH for compost of approximately 3.0 indicates that the compost is anaerobic. At low pH, H^+ ions, sulfide, aluminum and manganese ions can reach toxic levels.

12. Report

12.1 The measurement of pH is expressed as the negative log of the hydrogen ion activity of a thin aqueous slurry of compost and deionized water. Activity and concentration are similar if the salt concentration is low.

12.2 *Minimum detectable concentration*—pH meters can be accurately calibrated to ±0.05 units. The pH should be reported to the nearest 0.1 unit.

12.3 Report the electrical conductivity method preparation used, i.e., Method 04.10-A or 04.10-B, with or without the extraction step, the as-received moisture content, compost material type (e.g., compost, feedstock, etc.), and source material (e.g., MSW, biosolids, yard waste, etc.).

12.3.1 *Optional Extraction Step*—Report use of the extraction step and all other protocol modifications that deviate from the write-up.

12.3.2 *Minimum Detectable Concentration*—±0.1 mMhos cm^{-1}.

13. Precision and Bias

13.1 An electrometric pH meter that is calibrated with standard buffer solutions should be precise to ±0.05 units. The variability within a mixed sample representing the compost in question is generally less than ±0.1 units.

13.2 *Method 04.11-A 1:5 Slurry pH*—The precision and bias of this test are not yet determined. Data are being sought for use in developing a precision and bias statement.

14. Keywords

14.1 pH; electrometric pH, 1:5 solids:liquid slurry, extract, saturation

Test Method: Biological Assays. Seedling Emergence and Relative Growth							Units: % of control	
Test Method Applications								
Process Management							Product Attributes	
Step 1: Feedstock Recovery	*Step 2:* Feedstock Preparation	*Step 3:* Composting	*Step 4:* Odor Treatment	*Step 5:* Compost Curing	*Step 6:* Compost Screening and Refining	*Step 7:* Compost Storing and Packaging	Safety Standards	Market Attributes
								05.05-A

05.05-A Seedling Emergence and Relative Growth

Look—Interference and Limitations, and Sampling Handling issues are presented as part of the introduction to this section.

Precaution—The US EPA recommends moistening vermiculite to minimize exposure to potentially asbestos-contaminated vermiculite dust. *Source:* US EPA 744-R-00-010. August 2000.

8. Apparatus for Method A

8.1 *Plastic Seedling flat*—flats with 162 cells (9 × 18 cells).

8.2 *Plant Grow Lights*—fixture fitted with grow-light bulbs connected to 24-h timer.

8.3 *Plastic Bags*—approximately 50-L, clear polyethylene, (e.g., GLAD® QUICK-TIE®, Clear Recycling Tall Kitchen Bags, 13-gal – email: glad@firstbrands.com for distributors and their locations).

9. Reagents and Materials for Method A

9.1 *Water*—distilled.

9.2 *Vermiculite*—No. 2 grade, thoroughly rinsed with DI water.

9.3 *Potting Media*—commercial, available in garden stores, (e.g., MetroMix - W.R.Grace, or equal quality).

Caution I—Do not use soil. Use a proven soilless potting mix with peat moss.

9.4 *Cucumber Seeds*—Select a commonly available, salt tolerant variety, (e.g., Marketmore 76 variety. Jordan Seeds, Inc.; 6400 Upper Afton Road; Woodbury, MN 55125).

10. Procedures for Method A

10.1 *Media Preparation and Seeding:*

10.1.1 Completely saturate a 300 cm³ aliquot of vermiculite with deionized water. Allow the vermiculite to absorb as much water as possible, allow at least four hours. Gravity-drain all excess water; properly moistened vermiculite will feel wet, but not produce free water.

10.1.2 Transfer a 300 cm³ aliquot of as-received compost into a 4-L (1-gal) mixing container, (e.g., a plastic bag).

10.1.2.1 *Squeeze Test*—A squeeze test is performed with a handful of compost. A moist sample will clump when tightly squeezed. A sample with optimal moisture will feel wet, but not produce free water. A sample that is too dry is dusty and will not clump with hard squeezing.

10.1.2.2 Moisten the compost aliquot as necessary to optimize compost moisture, i.e., to feel wet, but not produce free water.

10.1.3 Blend equal volumes of pre-moistened vermiculite and test material. Mix thoroughly by rotating and shaking the bag,

10.1.4 *Prepare the seedling flats*—Fill three adjacent 9-cell rows of the seedling flat with the blended compost-vermiculite mixture representing each sample [3 × 9 cells], Fig 05.05-A1.

Caution—The media can fall through the drainage hole that pierces the bottom of each seedling flat cell. Appropriate measures should be taken to minimize media loss through the holes.

10.1.4.1 *Positive Control*—Fill two randomly assigned 9-cell rows of the seedling flat with the pure soilless potting media [2 × 9 cells]. Each row of pure potting media is a *positive control* replicate. Do not position both replicates adjacent to the same compost sample, i.e., as neighbors of the same compost sample.

10.1.4.2 *Negative Control*—Fill one randomly assigned 9-cell rows of the seedling flat with the pure vermiculite [1× 9 cells]. Each row of pure vermiculite is a *negative control* replicate.

10.1.4.3 *Control Replicates*—Always include the positive and negative controls in each seedling flat.

10.1.5 Place two cucumber seeds in each cell, covering the seeds with approximately 1 cm of material.

10.2 *Control Growing Conditions:*

10.2.1 Place the seedling flat in a clear or translucent plastic bag.

10.2.2 Fill the bag with air and seal to prevent air loss or leakage and to conserve moisture throughout the duration of the experiment.

Table 05.05-A1. Maturity Indicator Rating.

Test Parameters	*Very Mature*	*Mature*	*Immature*
Emergence, %[1]	> 90	90 – 80	< 80
Seedling Vigor, %	> 95	85 – 95	< 85

[1] %, percentage relative to positive control (step 10.4). Never base end-use conclusions on the result of a single test.

13.2 End use instructions for a compost must be based upon application technique and the analytical results for a full suite of test parameters.

13.3 Verify bioassay outcome using additional testing. Cucumber seedlings grown in a compost with a relatively high electrical conductivity reading (e.g., > 8 dS m^{-1}) will be stunted (diminished etiolation), have a deeper green color and a thicker cotyledon cutical than the positive control seedlings. Presence of these symptoms must be verified with an electrical conductivity test using a parallel aliquot of the test sample in question.

NOTE 2A—Electrical conductivity readings are often exagerated in samples where carbonates and/or ammonium-plus ammonia-nitrogen concentrations are high.

13.4 Alternative plant species for use as bioassays are outlined in OECD Guideline for Testing of Chemicals 208 (1984). A representative plant species should be selected for use with specific compost uses, (e.g., greenhouse potting mixes, land applications, etc.).

Equipment needed for monitoring windrows

Bimetalic heavy duty compost thermometer
Reotemp Instrument Corp.
10656 Roselle St.
San Diego, CA 92121
Phone: 1-800-648-7737
Fax: 1-858-784-0721
Web site: www.reotemp.com

Will need sampling equipment including:
- Bags or sample jars
- Post hole shovel (sharp shooter)
- Small spade
- 5 gallon bucket

If mixing feedstocks you will require:
- Hanging scales

Optional Equipment

Oxygen/Temperature probe (OT-21 with 4 ft. probe)
Demista Instruments
316 E. Foster St.
Arlington Heights, IL 60005
Fax/Phone: 847-439-6857

pH and conductivity meters (Oakton waterproof pH Tetsr 2 and EC Testr High)
Item number (pH meter): 76235
Replacement electrode: 76236
Item Number (EC meter): 76441
Replacement electrode: 76432
Replacement Batteries: 76206
Will need calibration standards for both
Forestry Suppliers, Inc.
205 West Rankin
Jackson, MS 39201
Phone: 1-800-647-5368
Fax: 1-800-543-4203
Web site: www.forestry-suppliers.com

Cenco mechanical moisture balance
Item number: 12177-200
VWR Scientific
Phone: 1-800-932-5000
Web site: www.vwrsp.com

Managing the Compost Process

Managing the composting process

Jason Governo

Compost Management Concerns

- Destroy pathogens and weed seeds (Time vs. Temp)
- Manage biological activity
- Process Monitoring & Troubleshooting
- Season and Weather Management
- Odor Control (Talk about later)
- Safety and Health
- Fire Safety and Prevention
- Produce a quality, mature product (Talk about later)
- Make money

Destroy pathogens and weed seeds

- Human and animal pathogens
  - Enteric Virus (gut viruses)
  - Salmonella
  - Fecal coliform
- Weed seeds
- Pathogens and seeds are killed when maintained at a specific temp for a duration of time. CFR Part 503 is basic guideline

US EPA CFR 40 Part 503

Process to further reduce pathogens (PFRP)

Standard

	In-vessel	Windrow
Temperature	> 55°C/131°F	> 55°C/131°F
Time	3 days	15 days
Turning	-	5 times min.
Document	Yes	Yes

Manage Biological Activity

- Manage Air
- Manage Moisture
- Manage Temperature

To achieve a compost that is stable and mature

Windrow turning and mixing objectives

- Comply with US EPA 40 CFR Part 503
- Expose weed seeds, fly eggs and larvae to destructive temperatures (131°F/55°C)
- Restore and maintain pile porosity for free airspace plus water holding capacity by
  - Breaking up clumps
  - Breaking up short circuiting channels
  - Redistributing bulking materials
- Introduce oxygen into the pile and release carbon dioxide and other gases from pile (this will include water vapor and odors)
- Uniformly distribute and mix in extra water
- Rearrange and slowly homogenize feedstocks in pile

Temps, What they mean?

- Low temps signal reduced aerobic microbial activity
  - Lacking in oxygen, low moisture, or freezing conditions
  - Need aeration and/or turning
- High temps signal very high microbial activity
  - Good composting conditions, moisture, C:N, Porosity
  - > 140°F may need aeration and/or turning to cool
  - Beware of spontaneous combustion
- Temperature doesn't recover after turning
  - Process is nearing completion or low moisture
- Table C.1 on page 147 in On Farm Composting Book

Weather and Seasons

- Cold Weather
  - Increasing heat loss = slower composting process
  - Reduces microbial activity near surface
  - To help prevent, increase windrow size >3.5ft
  - Combine older piles to >5ft
- Warm Weather
  - Enhances water loss through evaporation
  - Aeration will reduce moisture
  - Water may need to be added if too dry

- Precipitation
  - Windrows absorb water from rain & snow
  - Reduce site condition quality
    - Muddy conditions and soft soil = equipment difficulties
  - Puddles and standing water
    - Can lead to anaerobic conditions at base of windrow
    - Breeding area for insects and odors
- Seasonal Changes
  - Feedstocks may only be available at certain times
  - Requires storage before processing
  - Compost only has season use – markets

Noise

Definition of noise is a sound that is <u>perceived</u> to be unpleasant or unwanted that can affect employees, customers and the neighbors

Excessive noise caused by:

- Equipment that needs maintenance
- Backup signals on loaders and trucks
- Hammermills, grinders, shredders
- Vehicles engines, dump gates, etc

Noise – How much?

- Noise, the loudness, is measured in decibels (dB)
- OSHA standards require between 85-90 dB to have hearing protection/conservation
  - Max time at 85dB is 8 hours
  - At 110dB, max time is 1min 29 sec
  - Ear plugs, ear muffs, etc
- May need to purchase decibel meter to monitor noise at property boundaries
  - City or county ordinances need to be followed

- 40 quiet office, library
- 50 large office
- 65 - 95 power lawn mower
- 80 manual machine, tools
- 85 handsaw
- 90 tractor
- 90 - 115 subway
- 95 electric drill
- 100 factory machinery
- 105 snow blower
- 110 power saw
- 110 leafblower
- 120 chain saw, hammer on nail
- 120 pneumatic drills, heavy machine
- 120 jet plane (at ramp)
- 120 ambulance siren
- 125 chain saw
- 130 jackhammer, power drill
- 130 percussion section at symphony
- 140 airplane taking off
- 150 jet engine taking off
- 150 artillery fire at 500 feet
- 180 rocket launching from pad
- 40 quiet residential area
- 70 freeway traffic
- 85 heavy traffic, noisy restaurant
- 90 truck, shouted conversation
- 95 - 110 motorcycle
- 100 snowmobile
- 100 school dance, boom box
- 110 busy video arcade
- 110 symphony concert
- 110 car horn
- 110 -120 rock concert
- 112 personal cassette player on high
- 117 football game (stadium)
- 120 band concert
- 125 auto stereo (factory installed)
- 130 stock car races
- 143 bicycle horn
- 150 firecracker
- 157 balloon pop
- 162 fireworks (at 3 feet)
- 163 rifle
- 166 handgun
- 170 shotgun

Fire Fighting

- Most fires are within the pile, hard to see but you will see smoke emitting
- Contact local authorities/fire department
- Break the piles down and spread out as thinly as possible (reason for the buffer)
- Soak with water
- Repeat process
- Compost fires take a very long time to put out
  - Loosing money by fighting it and in lost product

General Safety

- Employees should be trained on safety procedures
- Hearing protection should be worn when working in areas of 85dB or higher
- Safety glasses to protect against dust and flying objects
- Gloves when needed
- Respirator to protect against fugitive dust in relevant conditions
- When working on or around shredders, grinders, turners, hard hats ought to be worn to protect against flying projectiles

General Safety

- Conduct routine safety meetings
- Make sure all employees know the correct procedures and rules of the yard and each piece of equipment
- Make some sort of incentive for good safety
- It may seem expensive to provide and teach safe working habits, but not as much as a law suit will cost you

Product Quality, Maturity and Stability

Compost Quality

Julia Gaskin

Agricultural Pollution Prevention Program

Sponsored by the Pollution Prevention Assistance Division

Biological and Agricultural Engineering

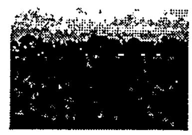
Cooperative Extension Service

University of Georgia

Compost Quality

High quality, consistent products benefits:

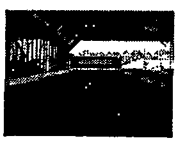
- Soil quality, disease suppression, improved yields



Low quality or inconsistent products:

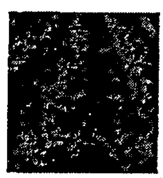
- High ammonia, fatty acids, soluble salts, odors, pathogens
- Inhibits germination, reduces growth or kills plants, ties up nitrogen

Compost Quality and Market Development Are Inextricably Linked



Compost producers say they have a good product.

Users say the product is inconsistent and often low quality.



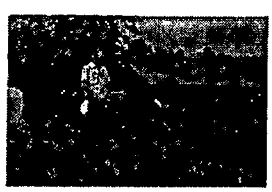
Quality Criteria - Two Big Buckets

Human health and environment - pathogens, heavy metals, toxic chemicals, and inerts (glass)

High quality product - stability, soluble salts, pH, inerts (plastic)

Quality Needed is Dependent on Use

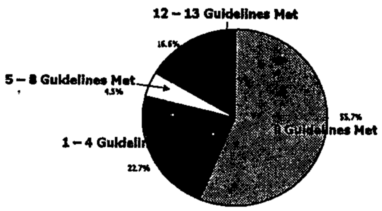
- General guidelines developed by US Composting Council
- Also standards pg 79 On-Farm Composting Handbook
- Specific applications – different requirements



US Composting Council Guidelines

Turf	Vegetable crops
Silviculture	Marginal soils
Planting beds	Nursery beds
Field nursery	Horticultural substrate
Blended topsoil	Planting backfill
Sod production	Landscape mulch
Erosion control	

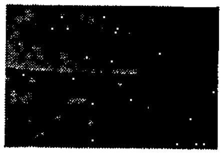
Compost Quality in Georgia



Percentage of compost produced meeting US Composting Council Guidelines for pH, soluble salts, and metals.

Controlling Composting Processes

- Adequate carbon source available
  C:N ratios near 30:1
- Ways to manage moisture
- Temperature monitoring
- Adequate curing time
- Standard protocol



US Composting Council Seal of Testing Approval

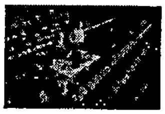
Standardizes lab testing and reporting procedures:

- pH, soluble salts, nutrient content, moisture, %OM, trace metals, pathogens, particle size, stability, and germination

Does not guarantee high quality

Does require results reported to user

CA Maturity Index



Test	Very Mature	Mature	Immature
Respiration (C/unit VS/day)	<2	2-8	>8
NH4-N:NO3-N (ppm dry weight basis)	<100	100-500	>500
Seed Germination (% of control)	>90	80-90	<80

CA EPA Integrated Waste Management Board 2002

Suggested "Do It Yourself" Minimum Testing

Moisture – feel test or moisture cans

Smell – no ammonia, good "earthy smell"

pH - strips

Inerts – sieve and weigh

Germination – tomato seeds or cress

Really Need More Testing

More information you can give user the better

Tailor quality to specific use

Pay special attention to human health bucket – metals, pathogens and dangerous inerts

Table 19. **Summary of US Composting Council (1996) compost use guidelines.**

Compost Use/ Market	Application	pH	Particle size	Soluble Salt Content	Stability
Turf	Soil Amendment	5.5-8.0	<1"	<4 dS/m	Stable
Vegetable Crop	Soil Amendment	5.0-8.0	<1"	<6 dS/m	Stable
Silviculture[2]	Soil Amendment	5.5-8.0	Must report	Must report	Moderate
Marginal Soils	Soil Amendment	5.5-8.0	Must report	Must report	Moderate
Planting Beds	Soil Amendment	5.5-8.0	<1"	<2.5 dS/m	Stable
Nursery Beds	Soil Amendment	5.5-8.0	<1"	<3 dS/m	Stable
Field Nursery	Soil Amendment	5.5-8.0	<1"	<3 dS/m	Stable
Horticultural Substrate	Soil Media Component	5.5-8.0	<1/2"	<3 dS/m	High
Blended Topsoil	Soil Media Component	5.5-8.0	Must report	<6 dS/m	Moderate
Planting Backfill	Soil Media Component	5.5-8.0	<1"	<3 dS/m	Stable
Sod Production	Soil Media	5.0-8.0	<3/8"	<3 dS/m	Stable
Landscape Mulch	Surface Application	5.5-8.0	Must report	Must report	Moderate
Erosion Control[3]	Surface Application	5.5-8.0	Must report	Must report	Must report

Note: All compost uses must report nutrient content, water holding capacity, bulk density, organic matter content, plant growth screening test, moisture contents between 35- 55%, and not exceed USEPA Part 503 Table Pollutant Concentrations[1] for heavy metals.

[1]USEPA Part 503 Table 3 Pollutant Concentration Limits (mg/kg). Arsenic - 41; Cadmium - 39, Copper - 1500, Lead - 300; Mercury - 17, Nickel - 420, Selenium - 100, Zinc - 2800.
[2]Does not have to meet USEPA Part 503 Exceptional Quality Concentration Limits for trace elements/heavy metals.
[3]Plant growth screening test not required; moisture content must be reported.

Compost Enhancement Guide

Recommendations on methods to improve the quality of your commercially-produced compost

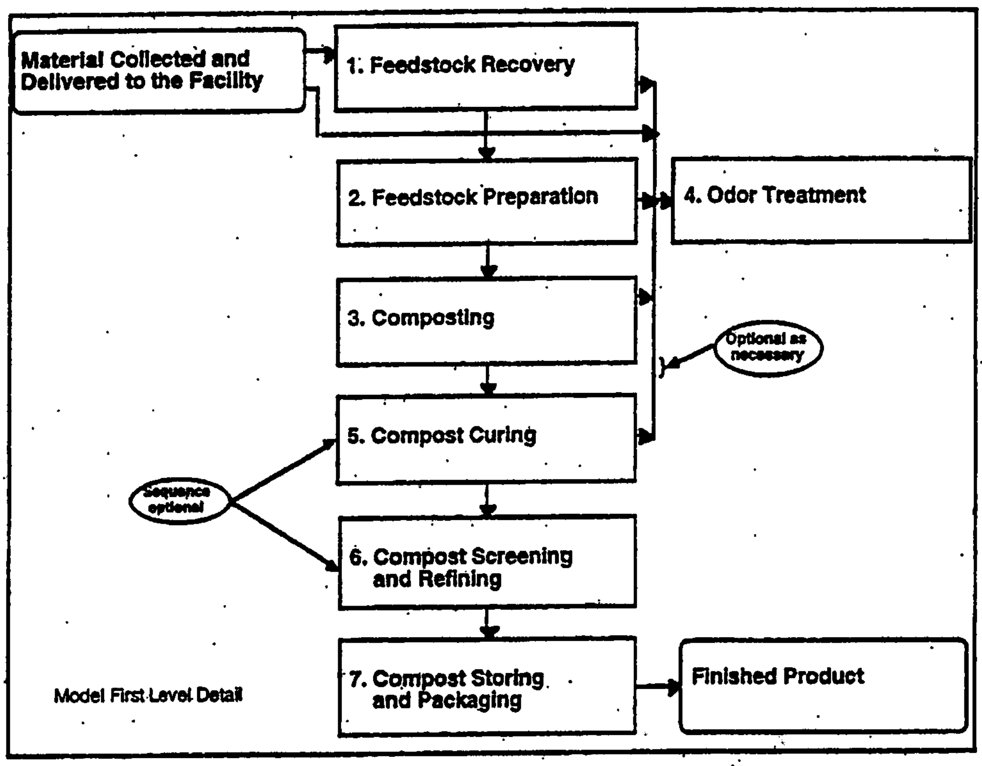
Table of Contents

pile odor generation is managed throughout the process to avoid nuisances.

4. Odor Treatment
Effective control of odor generation during each step where decomposition by bacterial activity may take place is *critical*, and treatment of odor to prevent its release from the site is often necessary for the success of the facility, so that composting operations do not become bad neighbors and political nightmares.

5. Compost Curing
Compost curing is a finishing operation and continues the decomposition process to increase product biological stability as required for some markets, continues pathogen destruction, and eliminates inhibitors of seed germination and plant growth. Pile odor generation is managed. Bulking material remaining in the compost serves to retain pile porosity to help enable aeration and advance stability status. Note: The sequence of the two finishing steps, compost curing and compost screening and refining, is sometimes reversed in order to conserve space occupied by bulking material in the curing compost, but when compost curing is completed before screening, it is generally possible to screen to a finer degree because stability is further advanced and particles are more uniformly small, which allows for removal of smaller physical contaminants.

Figure 1. Composting Process Model



6. Compost Screening and Refining
This is a compost finishing operation in which bulking material and other oversized material like stones, and man-made inerts in the compost, such as textiles, glass, metals and plastics are screened out to satisfy regulatory and market requirements. Dust generation is controlled.

7. Compost Storing and Packaging
The objective of compost storing and packaging is to maximize compost marketing opportunities while balancing year-round production with seasonal demand for the product, and in some cases to prepare compost for "high dollar" markets.

A full discussion of this and subsequent Models and Tables shown here can be found in a companion Composting Council publication titled *Compost Facility Operating Guide*, and training on the Operating Guide is provided by The Composting Council's "Best Practices Workshop on Composting".

Compost Attribute 1: pH

Specific plant species can flourish when grown within a specific pH range, and based on typical compost application rates, it is understood that the addition of compost can affect the pH of soil and growing media. Therefore, to estimate the effect, which in turn will affect soil maintenance practices or growing system management, the pH of compost must be known.

The pH of compost products typically ranges from about 5.0 to 8.5. More commonly, the pH of the finished product is in a narrower range of 6.0 to 7.5. During the composting process, biological activity will tend to neutralize the feedstock pH as the composting process progresses. In the early most active stage of the composting step, it is not uncommon for a temporary pH depression to occur. This is the result of aerobic surface degradation of large particles and anaerobic degradation below the surface, accompanied most often by a lack of adequate aeration to supply oxygen and displace carbon dioxide and other gases. This pH depression is followed by an increase, as particle size reduces and microbial populations shift from dominance by bacteria to actynomicetes and fungi, and the oxygen content within the composting mass improves. However, if prolonged anaerobic conditions persist in the composting and/or compost curing and storage steps, then organic acid build up will tend to occur, thus depressing pH.

In the feedstock preparation step pH is largely impacted by pH of the feedstock materials. For example, if materials with a source which buffers pH, such as wood ash or certain industrial residuals, are composted, pH of the resulting compost product will tend to be above neutral. Similarly, if lime or ferrous salts are used to dewater biosolids in municipal applications, pH of the resultant product will tend to be above neutral. If, on the other hand, yard trimmings that are rich in soft wood, leaves, or pine needles are the primary feedstock materials, the resultant product will tend to be more acidic. During the composting and compost curing steps, the biggest pH impact tends to be the lack of aeration and the resultant formation of organic acids. Product pH can be improved by maintaining pile porosity and free airspace during composting and compost curing, by use of a suitable bulking material and by frequent turning to break up clumps and air channels as an aid to aeration whether by forced aeration or convective aeration. Another common problem occurs during the compost curing step when the lack of aeration and large storage piles tend to increase production of acids, thereby depressing product pH. Retaining bulking material in the pile until just prior to distribution will help provide the needed porosity. Positive aeration can be provided during compost curing and storage using small blowers providing air to a diffuser system beneath the piles. Turning compost curing piles for aeration can improve pile oxygen percent. Decreasing pile heights to six feet or less to avoid slump and compaction is a method that can be used to improve the oxygen content of the material, thereby decreasing acid production. The final product can be adjusted by the addition of amendments, such as liming agents to increase pH or sulfur products to lower pH if desired for specific applications.

Compost and Storage Manipulations to Modify Compost Product Quality

Attribute: pH Normal Range: 5.0-8.5 Preferred Range: 6.0-7.5		
Process Step	Adjustments - If High	Adjustments - If Low
Feedstock Preparation	• For biosolids/sludges dewatered with lime and ferric, change to dewatering with polymers. • Add low pH bulking agent. • Avoid reusing finished compost as bulking agent.	• Add high pH bulking agent (wood ash, cement kiln dust, etc.) in small amounts (< 15% by weight) to increase pH and buffering capacity. • Maintain pile porosity through use of appropriate bulking agents.
Composting and Compost Curing	• Increase compost curing retention time prior to product distribution	• Adjust type and or size of initial bulking material to preserve its impact on pile porosity. • Retain bulking material in piles until distribution. • Add aeration in compost curing to prevent buildup of acids. • Decrease non-aerated composting. • Decrease compost curing storage pile height to six feet or less. • Turn composting windrows more frequently for porosity maintenance.

Compost Attribute 4: Water Holding Capacity

Water holding capacity is the ratio of water filled pore volume relative to the total volume of compost or soil. In this case it is the ability of compost or soil, on a dry weight basis, to hold water. Water holding capacity measures the potential benefit of reducing the required frequency of irrigation applied to an amended soil, as well as gross water requirements for a crop.

The water holding capacity of compost or soil is generally related to the organic matter content, particle size and texture. The primary means of improving the water holding capacity of a composted product are to adjust the feedstock mix ratio to provide a greater portion of organic matter in the feedstock, and to increase compost stability to reduce particle size and insure a uniform texture.

Certain composts tend to have more water holding capacity than others which is sometimes related to feedstock type. Feedstock materials that are rich in cellulose and lignin content, such as paper, heavy paper leaf bags and grocery bags, cardboard, plant stems, bagasse, birch and pine, produce composts that have a higher water holding capacity when stable than do others, all else being equal. Reducing the addition of "fixed solid", mineral additives such as lime or ash increases the relative proportion of "volatile solids", i.e., organic matter.

All composts that are stable tend to improve water holding capacity of soils because compost particles are small and the texture is uniform, and because small pore spaces are typically uniformly distributed throughout the compost. Water is held in the pore spaces and on the particles. Good process control through proper pile porosity, proper feedstock carbon to nitrogen ratio, proper pile oxygen percent, proper composting temperatures, and adequate processing time are necessary in order to achieve stable compost. Finer composts that are very stable with uniformly small particles and small pore spaces typically hold more moisture than do composts containing significant quantities of coarser particles having large pore spaces that typically accompany bulking agents such as wood chips.

Compost and Storage Manipulations to Modify Compost Product Quality

Attribute:	Water Holding Capacity	
Normal Range:	75-200%	
Preferred Range:	100% or greater	
Process Step	**Adjustments - If High**	**Adjustments - If Low**
Feedstock Preparation		• Reduce or eliminate the addition of composting additives such as lime or ash to increase the proportion of organic matter content in the compost. • Adjust feedstock mix ratio to provide greater organic matter content. • Set the key process variables at or near the ideal, including initial pile porosity at 45-60%, carbon to nitrogen ratio at 25-40:1, carbon to phosphorus ratio at 100-140:1 and moisture at 55-60%.
Composting and Compost Curing		• Maintain good process control by maintaining pile porosity above 35%, pile oxygen above 16%, pile moisture above 45%, and adjusting pile aeration rates to maintain pile temperature in the mesophilic range (25-45°C/77-113°F) after thermophilic temperatures required for pathogen and weed seed kill (55°C/131°F) are satisfied.
Finished Product		• Screen to remove coarse particles.

Compost Attribute 7: Organic Matter Content

Organic materials have carbon atoms (C) as their main building blocks. Compost is a significant source of organic matter when used as a soil amendment. Organic matter is an important reservoir of carbon and a dynamic component of soil and the carbon cycle. It improves soil and plant efficiency by improving soil physical properties including, drainage, aeration and other structural characteristics. The soil nutrient status is enhanced by organic matter as a nutrient reservoir and a source of energy for beneficial microbes. Soil organic matter content can be increased through repeated applications of compost.

The amount of organic matter present in compost is dependent upon the feedstock material characteristics as well as the extent of compost processing. In order to increase the organic matter content in a compost product, either the feedstock material should be adjusted by increasing the proportion of its volatile solids and reducing its fixed solids (mineral) content and/or the composting or compost curing retention time should be reduced so that the organic matter does not continue to degrade. The only constraint on retention time for compost is that it will have undergone the "Process to Further Reduce Pathogens", a time/temperature/turning requirement.

Reduced length of composting, however, will result in the production of compost that is less stable. Alternatively, increasing the composting processing time will decrease the organic matter content as the available organic matter is biologically degraded. Unfortunately, organic matter content decreases with increasing stability, but to conserve organic matter producers should work with customers and users to accept compost with the lowest level of stability they can use. Producers may find that compost that has the highest organic matter content also has the highest relative commercial value involving the least investment to produce, in those cases where a stable or very stable product is not important. Extreme care is urged in developing markets that understand the advantages and disadvantages in using compost with high organic matter content but low biological stability, accompanied with perhaps large and inconsistent particle size and poor texture, low initial water holding capacity, low bulk density, and risks being phytotoxic if used without a period of being spread and lying fallow in the field and being decomposed by entirely natural means at the whims of the weather. Note: These are similar precautions to the use of uncomposted material, with the exception that uncomposted material also risks the presence of pathogenic material.

Screening or air classification or mechanical separation of inorganic contaminants can be employed to increase the proportional organic matter content of the compost but only to a small degree. For example, glass and stone separators have been used to mechanically separate out these contaminants from a compost product, thereby enhancing its organic matter content. Obviously, this process will only increase the organic matter content in proportion to its content of man-made inerts.

Compost and Storage Manipulations to Modify Compost Product Quality

Attribute:	Organic Matter Content	
Normal Range:	30-70%	
Preferred Range:	50-60%	
Process Step	Adjustments - If High	Adjustments - If Low
Feedstock Preparation		• Add organic matter rich bulking agent.
Composting and Compost Curing	• If high organic matter content is indicative of poor stability, increase the composting and compost curing retention time.	• Decrease the composting and compost curing retention time.
Compost Screening and Refining		• Screen out large woody material and contaminants such as plastics, rocks, etc. • Destoners can be used to separate glass and stones from compost. • Air classifiers can be used to separate film plastic from the product.
Finished Product	• Blend with sand, soil, or other inert material.	

Composting and Compost Curing	• Agitate pile to maintain porosity by breaking up clumps and air channels. • Do not screen bulking material from compost until preparing it for sale, in order to maintain pile porosity as long as possible. • Check pile oxygen percent often. Maintain oxygen levels above 16% throughout the compost pile. • Maintain pile moisture during composting between 45-60%, ideally 55%, and during compost curing between 45-50%. • Provide positive aeration during compost curing. • During PFRP do not let pile temperature climb above 60°C/140°F because this immobilizes or kills microorganisms needed for decomposition. Reduce pile temperature after PFRP to a maximum of 50°C/122°F if possible to improve the environment for diverse microbial activity.	• Decrease retention time in composting or compost curing.
Finished Product	• Blend with soil or stable organic material. • Allow additional curing during compost storage. • Provide positive aeration during compost storage.	

* See Appendix A for additional information on stability.

† The *Compost Facility Operating Guide* provides C:N ratios of many common feedstock materials, and provides the methodology and formulas to determine proportions of materials to start at the ideal C:N ratio. Several other references exist which provide general data on the C:N ratios of compost feedstocks and bulking agents. Two of these publications include the *On-Farm Composting Handbook*, NRAES 54, 152 Riley-Robb Hall, Cooperative Extension, Ithaca, NY 14853-5701 and *The Rodale Book of Composting*, The Rodale Press, Book Reader Service, 33 East Minor Street, Emmaus, PA 18098.

Compost Attribute 12: Man-Made Inerts

Man-made inerts consist of materials which are synthesized or made by humans in origin and may be a part of the waste stream. These include the following materials: textiles, glass, plastic, and metal objects. When put into the composting process, these materials are not decomposed but may be degraded to some extent in physical characteristics, primarily through size reduction. These materials can decrease the value of the finished compost product because they offer no benefit to the compost and, in many cases, are aesthetically offensive.

A common means of controlling man-made inerts is to minimize their entry into the waste stream being composted through separation at the source or during feedstock recovery at the composting facility. Source-separation of materials being composted can reduce the introduction of glass, metal materials, high density plastic and film plastic. Plastic bags are often used to contain various components to be composted and can result in physical contamination of finished compost. Collection in containers other than plastic bags will reduce the introduction of some film plastic into the compost.

Studies show that urban yard debris contains 10% or more of items that can physically contaminate compost, and that source-separated household debris contains 3-9% of similar items that can physically contaminate compost. If this contamination in the finished product is objectionable, all but a tiny fraction can be removed by the combined efforts of the feedstock recovery step, the feedstock preparation step and the compost screening and refining step. Carefully removing materials such as glass shards, metal fragments, and others that are sharp including sewing needles, straight pins and hypodermic needles is particularly important for human health and safety reasons.

In the final compost screening and refining step after compost curing is complete, man-made inerts can be removed through the use of screens to remove plastics, glass, and metals, the use of ferrous magnets to remove metals, the use of air knife technologies, sometimes called fluidized bed separation, to remove film plastics, and the use of destoners, also called fluidized bed separators, for the separation of heavy inert materials such as glass, metals, and hard plastics. Natural inerts, such as rocks and stones, can also be removed using these same techniques.

Compost and Storage Manipulations to Modify Compost Product Quality

Attribute:	Man-Made Inert Content	
Normal Range:	Up to 4 or 5% by dry weight basis greater than 4 mm particle size	
Preferred Range:	Up to 3/4 to 1 1/2% by dry weight basis greater than 4 mm particle size	
Process Step	Adjustments - If High	Adjustments - If Low
Feedstock Collected and Delivered to the Facility	• Source separation of feedstocks to prevent addition of plastics, glass, and metals. • Collect feedstocks in bulk or reusable containers, or biodegradable Kraft or degradable polymer bags rather than non-degradable plastic bags.	
Feedstock Recovery at the Facility	• Remove ferrous contaminants with magnetic systems.	
Feedstock Preparation	• Pre-screen materials to remove film plastic and large contaminants.	
Compost Screening and Refining	• Remove glass, metals, and heavy plastics through screening or the use of destoners. • Remove ferrous metals through the use of magnetic systems. • Remove film plastics through use of a smaller screen size and/or the use of air knife or air flotation systems after compost curing.	

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Interim Guidelines For Compost Quality

Publication #94-38
Solid Waste Services Program
April 1994

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APPENDIX IV: STABILITY

There are several methods for evaluating compost stability. However, experts agree that there is no single best method. A few methods are listed below.

Reheating Test

A highly stabilized compost generally will not reheat to 20 degrees C above ambient temperatures. To determine if the material will reheat to 20 degrees C above the ambient temperature, use the following procedure:

> Repile compost into a pile at least six feet in diameter and four feet high. Provide aeration to this pile or mix the pile thoroughly by turning several times prior to building. Moisture content of the material in this pile must be between 45-60 percent in order for this test to be valid. Three days after the pile has been formed, the temperature of the compost should be measured at a point about two feet into the pile. This temperature should be compared to the ambient temperature.

Reduction of Organic Matter

The percent reduction of organic matter is a measure of the loss of decomposable material in comparison to the amount present prior to composting. For most composts a reduction in organic matter of greater than 50-55 percent represents a stable product.

To make this comparison, the use of EPA method 160.4 and the following procedure is recommended:

> Test the material for the percent organic matter on a dry weight basis prior to composting and then again after composting is complete. Use these two test results to calculate the percent reduction in organic matter using the following formula where % A is the percentage organic matter after composting and % B is the percentage organic matter before composting:

$$\text{percent reduction} = \left[1 - \frac{\%A\,(100 - \%B)}{\%B\,(100 - \%A)} \right] \times 100$$

Cress Seed Germination and Root Elongation Bioassay

Overview

This test procedure entails the following steps:

- Production of compost water extract
- Germination of water cress seeds in the extract and a distilled water control.

11. Place ten water cress seeds into each petri dish. The water cress seeds should be stored in a refrigerated airtight container. The seed supplier is:

Liberty Seed Company
P.O. Box 806
New Philadelphia, Ohio 44663
330 ~~(216)~~ 364-1611
Ask for seed lot 4935. Orders can be made over the phone.

12. Secure the petri dish lids with a strip of parafilm. This step is necessary to prevent the water extract from evaporating.

13. Incubate the petri plates for 40 hours at 30°C.

14. After the incubation period step root growth by adding 1 ml of 50 percent methanol to each petri dish. Count the number of seeds germinated in each dish and measure the root length of each germinated seed. Record the data onto a cress seed germination lab worksheet (shown on the following page).

15. Calculate the percent germination by dividing the mean percent germination of each treatment by the mean of the control. Calculate the percent root length by dividing the mean root length in cm (ungerminated = 0 cm) of each treatment by the mean root length of the control. The Germination index is calculated for each treatment by multiplying the percent germination by the percent root length and then dividing the product by 100.

This method has been adapted from "A Protocol for Assessing Compost Stability in the Field: Development, Evaluation and Feasibility of Implementation" for The Clean Washington Center by E&A Environmental Consultants, Inc., June 30, 1993; and Grebus, M. 1992 M.S. Thesis, Ohio State University. The Clean Washington Center study describes other methods which may be valuable in evaluating compost maturity.

This method is still under development and has not yet been standardized nor results calibrated extensively. A higher Germination Index value indicates a compost extract quality closer to the control; seeds germinated in deionized water. Some preliminary findings suggest that there may be mild phytotoxicity associated with Germination Index values of between 30 to 60 when the final volume of compost exceeds 30 percent of the final growth medium. The robustness and validity of this method should be verified or discounted as more test data is created and analysis performed in the next few years.

The Dewar Flask test was first developed in Germany as a simple, reliable means to determine relative compost maturity. It has been extensively researched there and in the U.S. It is used in the following manner:

1. Collect a representative sample of compost from material to be tested.
2. Mix material and sub-sample 1 gallon (4 liters) volume.
3. Determine if moisture content is ideal:
   - if material releases water upon squeezing tightly, it is too wet
   - if material is dry and crumbly it is too dry
   - material which sticks together and wets your hand with squeezing but which does not release free water is ideal.
4. Add or remove moisture if material is too dry or wet
   - Add water with a watering can slowly until compost is sticky without any free water (see above test)– allow to equilibrate for 1 hour before test
   - If compost is too wet, add straw, hay or leaves from the same pile and/or allow to dry overnight by spreading on a flat, clean surface. The dry straw or leaves can be blended by rubbing the entire mass through a coarse screen (like 3/8" hardware cloth or commercial compost sieve).
5. Fill flask loosely with room temperature compost which has been recently sampled. Gently shake to simulate natural settling. *Maintain vessel at 18-22°C (65 – 70°F) for the duration of the test.*
6. Insert high-point reading thermocouple probe into flask to a point about 2" from bottom of flask. *Do not push against the bottom of flask.*
7. The electronic thermometer records the max & min compost and ambient temperatures. Use the memory function of the thermometer to get the maximum compost and maximum ambient temperatures, and take the difference between the two.
8. For daily readings, use the below format to record self-heating test results:

Sample Id	*Date entered:*	*Time Start*	*Person*	
______	______	______	______	
TERM:	Date/Time:	FLASK °C/F	AMBIENT °C/F	NET RISE° (Flask – Amb)
Day 0	______	______	______	______
Day 1	______	______	______	______
Day 2	______	______	______	______
Day 4..... etc.	______	______	______	______
			Maximum:	______
			Stability Rating:	______

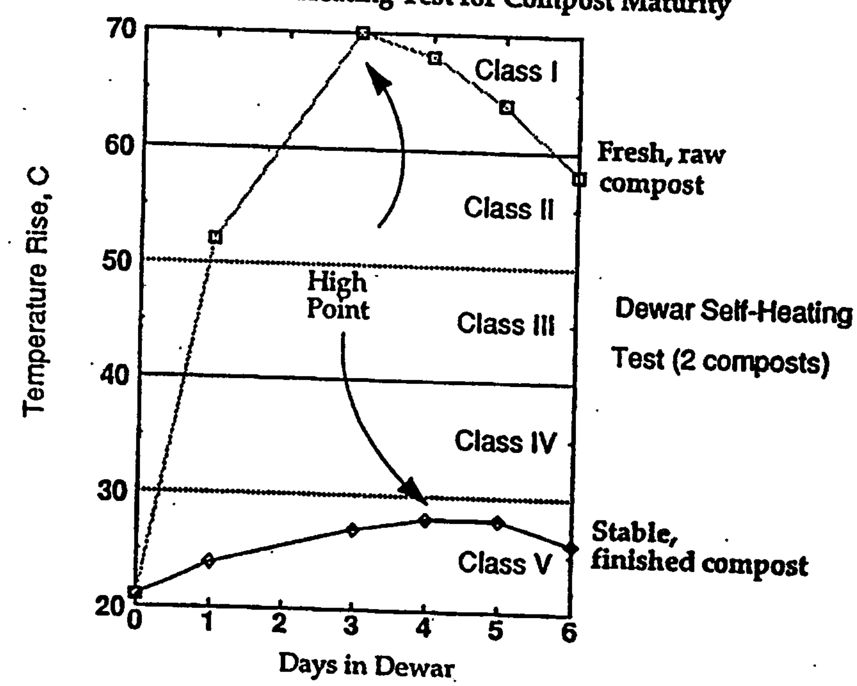
a. The compost will normally achieve its highest temperature within the first several days. Sometimes, if the sample has been very cold or needed to be re-moistened, it may require 5-10 days to heat. Continue reading temperature until it declines for at least two days after the maximum is reached.

b. The stability index is computed as the *difference* between the *highest* temperature minus the *ambient*. The thermometer provided with the kit holds the high point. Subtract the ambient temperature after recording. It is optional to plot the temperature rise to maximum and subsequent fall (*see Figure 1*).

TABLE 1. Compost Stability Index Determined from Dewar Self Heating Test

Temperature Rise Above Ambient		Class of Stability	Description of Maturity / Stability
Celsius:	Fahrenheit:		
0 – 10° C	0 – 18 °F	V	Very Mature Compost
10 – 20°	18 – 36 °	IV	Maturing, curing compost
20 – 30°	36 – 54 °	III	Material still decomposing
30 – 40°	54 – 72 °	II	Immature, active compost
40 – 50° (or more)	72 – 90 °	I	Fresh, raw compost

Figure 1. Dewar Self-Heating Test for Compost Maturity



Odor issues in Composting

K.C. Das

Univ. of Georgia

What is an odor ?

- Chemical compounds
- Inhaled and sensed by the olfactory system in the human nose

Quantification and Description of odors

- Intensity
- Concentration
- Odor character
- Hedonic tone
- Analytical methods

Handout test results

Odor intensity

- Strength of the odor – ASTM E544 Butanol intensity
- Each sample is compared w/ intensity of known concentration of n-butanol
- Intensity is related to odor concentration

Not all odors are created equal

- Hedonic tone...
- Intensity [Strength] of odors
- Pervasive vs. Non-pervasive [Hydrogen sulfide vs. Ammonia]

Steven's Law

Non-pervasive

Pervasive

Type of odors depend on feedstock

Source	Odorous products
Carbohydrates [C]	**Alcohols** **Volatile organic acids Aldehydes** **Ketones**
Proteins [C N S]	**Ammonia → Amines** **Sulfide** **Mercaptans** **Volatile organic acids**
Lipids [C N S P]	**Alcohols** **Sulfide and Mercaptans** **Volatile organic acids**

Odorous organics in biosolids composting

Compound	Mean Conc., ppmv	Odor Conc., D/T
NH_3	171	30
H_2S	0.7	61
DMS	0.5	493
DMDS	0.3	208

Van Durme et al (1990)

Odor types in food waste composting

Smet et al., 1999

MSW Composting odors

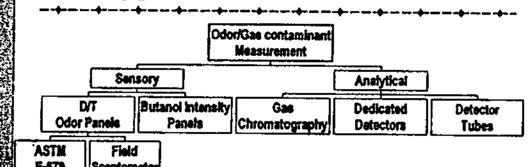
Source locations	D/T
Ambient air	
Tipping floors	50-500
Pre-treatment areas	50-500
Composting areas	600 – 1,000
Ducted air	
Invessel drum exhaust	20,000 – 80,000
Aerated windrow exhaust	5,000 – 25,000

Homans and Fischer, 1992

When are odors released

- Most of the odor release occurs in the first 14 days
- Immediately after turning concentrations are 10-25 times higher
- Concentrations return to baseline after 4 hours.

Types of measurement



Composite Concentration D/T [ou]

Individual Compounds ppmv

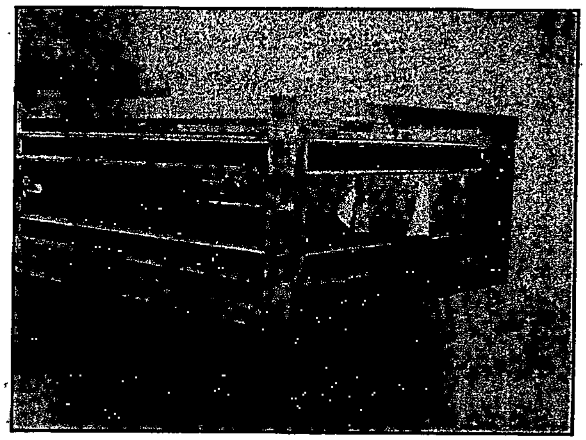
Dynamic Olfactomety
Key Features

- 3-samples [1 true + 2 blanks] presented at each step
- Ascending concentration
- Trained panel of 8+ persons

Testing procedure

Panel	Judgments of panelists							
	Dilution factors of presentation (low to high conc.)							
	3645	1215	405	135	45	15	D/T	Log (D/T)
1	0	+	+	0	+	+	78	1.89
2	+	0	+	+	+	+	701	2.85
3	0	+	0	0	+	+	78	1.89
4	0	0	0	0	+	0	9	0.94
5	+	0	0	+	+	+	234	2.37
6	+	+	+	+	+	+	6313	3.80
7	0	+	+	0	+	+	78	1.89
8	+	0	0	+	+	+	234	2.37
								Σ= 18.00
						D/T = 177.8	←	Avg. =2.25

pp. 22 in Composting Odor Workshop



Odor Control through Process Management

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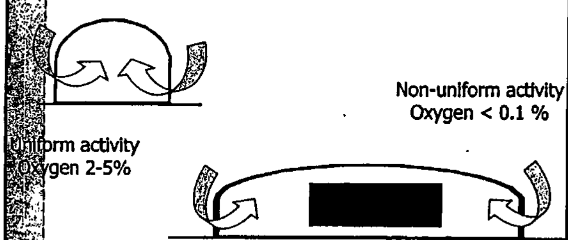
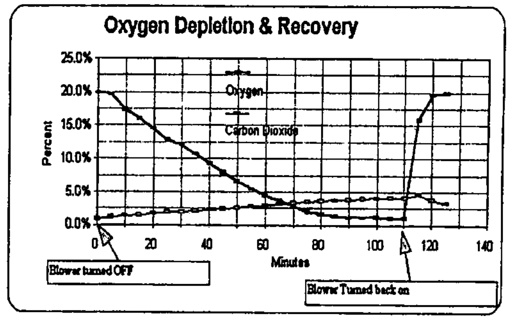
Pile configuration



Michel, 1996, 1999



Influence of turning rate

- Goal of Turning is to homogenize
- Identical windrows:
  Turned 1 per month
  Turned 7 per month
  NO DIFFERENCE in product
  [Michel, 1996]

Odor release after turning

- After turning Odor Conc. is 12-25 times higher than baseline [Iacoboni, et al. 1984]
- Most odors are present in 1-14 days [Bidlingmaier, 1992]
- Delay turning piles till 15th day or Time the turning for max dispersion

Prevent fugitive odors

- Enclosed areas under Negative pressure
- Remove standing water/leachate immediately
- Avoid stockpiling unstable compost

Prevent fugitive odors

- Wet feedstocks – Leachate accumulates at the base of the windrow
- Prevent this by having a bed of wood chips [or draining material]

Siting related approach

Typical siting method

- Convenient access to site
- Location relative to feedstocks
- Already owned property
- Ease of permitting ....

Recommended siting approach

- Have 2-3 options for sites
- Preliminary design to approx emission rate
- Evaluate odor-control approaches
- Evaluate impact using dispersion models
- Fine tune to achieve 5 D/T @ receptor

Buffers

- Buffer requirement depends on:
  - Type of feedstocks
  - Type of neighbors
  - Amount of discharge
  - Prevalent weather patterns
  - Type of containment available
  - Type of odor treatment

Recommended buffer distances

- Generally 2000 ft to closest neighbor [good to have 3500 or more]
- Case examples ....

Lewiston Auburn, Maine

- 7 dry tons/day – Biosolids; 75,000 CFM
- Large buffer available
  Permit target @ Biofilter exit 1000D/T
- 12 neighbors in 3000 ft radius [mostly farms]
- Successful operation

Odor Management

The Practical Handbook *of* COMPOST ENGINEERING

1993

Roger T. Haug

LEWIS PUBLISHERS
Boca Raton Ann Arbor London Tokyo

THEOREM 5 — WHAT SMELLS OK TO YOU IS PROBABLY AN ODOR TO SOMEONE ELSE

None of what has been said so far depends on the type of composting system. The only caveat is that anaerobic systems are not included. While there may be some differences between aerobic systems, their odor characteristics are all governed by the same laws of nature. Therefore...

THEOREM 6 — MOTHER NATURE DOESN'T MUCH CARE WHAT COMPOST SYSTEM YOU HAVE

and

THEOREM 7 — ITS NOT NICE TO FOOL MOTHER NATURE WITH A BAD DESIGN OR BAD OPERATION

Some odors will be produced even with good design and proper operation. However, a bad design or bad operation guarantees higher emission rates. One must also understand the energy balance and make sure that there is sufficient energy supply to meet the energy demands. If not, odors will usually increase because the process will be stressed and failure may be near. Therefore...

THEOREM 8 — YOU REALLY SHOULD KNOW SOMETHING ABOUT YOUR SUBSTRATES

The range of total solids, volatile solids, degradability, and rate constants should be known for each substrate entering the process.

Despite the best efforts of design engineers and the claims of equipment vendors you should always remember the following:

THEOREM 9 — ODOR TREATMENT IS NEVER 100%

The only possible exception to Theorem 9 is thermal oxidation which is capable of near complete odor destruction. Multistage wet scrubbing is generally capable of achieving outlet ED_{50}s in the range of 50 to 100. Lower levels are very difficult to achieve. For one thing, the contribution of the scrubbing chemicals to the outlet odor becomes significant at low outlet levels. The same is true of biofilters. Exhaust ED_{50}s in the range of 20 to 150 seem to be typical. Lower levels are not readily achievable because the biofilter matrix begins contributing to the outlet odor. There has been a subtle but persistent tendency for the design community to ignore Theorem 9. This leads to the following:

THEOREM 10 — MANY PAST DESIGNS DIDN'T RECOGNIZE THEOREM 9

Scrubbers and biofilters are often designed with no attention to dispersion of the treated gases. It is common to see scrubbers with short stub stacks, low outlet velocities, scrubbers located near large buildings with their plumes caught in the building downwash, rain caps on top of discharge stacks, and other examples of poor dispersion design. It's as though the designer assumed 100% deodorization. This should never be assumed.

The subject of atmospheric dispersion is complex and was discussed at some length in Chapter 17. There is one important theorem derived from my experiences with the atmosphere:

Things to avoid with a point source discharge include (1) locating the plume within the zone of building or stack downwash, (2) low velocity discharges from the sides or roofs of buildings, such as ridge ventilators, (3) using rain caps on roof ventilators or the scrubber discharge stack, (4) low stack velocity, and (5) bad topography such as valleys. Avoiding bad topography is like avoiding the common cold, easy to say but hard to do. The topography is always "greener" in the next political jurisdiction.

For groundlevel sources, such as open windrows, static piles, or biofilters, dispersion can be enhanced by (1) providing adequate buffer, (2) using wind machines to maintain minimum air flow over the area source, and (3) using barrier walls to induce turbulence. I realize that providing buffer really isn't an example of enhanced dispersion. It's more like giving nature enough room to solve the problem herself.

If the above measures are not adequate, the groundlevel source can be enclosed and converted to an elevated source. By comparison with elevated sources, groundlevel sources are subject to the worst met conditions and lowest dispersion rates. Also, the nearest downwind receptor will be the most effected. Therefore, ground-level sources, and their surrounding topography, must be carefully considered in any odor management plan.

THEOREM 16 — YOU CAN STOP ALL OF THE ODOR SOME OF THE TIME, BUT YOU CAN'T STOP ALL OF THE ODOR ALL OF THE TIME

Theorem 16 is a recognition that, after all the planning and design studies, after all attempts to reduce emission rates, after all the collection, treatment, and dispersion, nature will periodically impose such severe met conditions that odors may occur. If the risk of odor cannot be reduced to zero, then we must establish an "acceptable odor risk". Engineers may want to hide Theorem 16 from their politicians. Odor objectives vary from study to study. The point is not that they vary, but that they were established in the first place and provided a guide for evaluating alternative designs and solutions. Remember, every facility needs a target odor objective. Be the first on your block to have one.

Finally, my last theorem...

THEOREM 17 — DON'T DESPAIR, ODORS CAN BE MANAGED

Despite odor problems at some facilities, the future for composting is optimistic. The industry generally recognizes that odor compounds are likely to be released, a milestone of major significance. Recognition of the problem is the first step toward its solution. The science of odor treatment, particularly with wet scrubbers, biofilters, and activated sludge is advancing rapidly. More engineers and operators now speak about met conditions and dispersion as if they were amateur meteorologists. Finally, regulators and industry groups have moved with unusual leadership to help the industry by encouraging the spread of these new ideas to the composting community. Watching the industry mature as it gears up to solve current problems, it's hard not to be optimistic.

One concern is the apparent difficulty in transferring lessons learned by the sludge composters to other members of the composting community. For example, some recent refuse composting facilities in the U.S. have been implemented with essentially no provisions for odor control. These facilities are destined to repeat past mistakes already learned with sludge. Consultants and firms active in the sludge industry in the U.S. are generally not the same as those active with other substrates such as refuse. The flow of information from one group to another is not automatic. We all need to work on this.

Facility Siting and Design

Compost Facility Siting and Design

Using the Compost Wizard©

Jason Governo
Engineering Outreach Service

Issues for new composting facilities

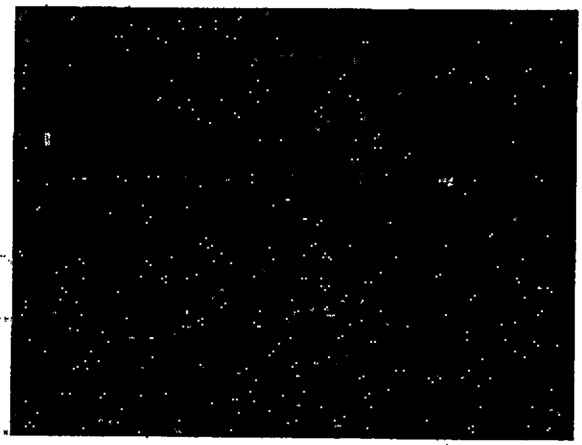
- Determination of feasibility
- Logistics of wastes and markets
- Permitting process
- Financing
- Management practices
- Land availability
- Throughput capacity
- Public perception

Design Feasibility Questions

1. How much land is required for the entire operation?
2. How much capital will it take to start?
3. What size equipment will it require?
4. How many employees will it require?
5. What will be the operating costs per year?
6. How much money will it make?
7. What will it cost per ton to compost ($/ton)?
8. Should I even do it?????

Four steps of design process

1) Compost area sizing
2) Runoff collection pond sizing
3) Land treatment system design for captured runoff
4) Economic evaluation



Windrow turning equipment

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

3. Determine composting windrow dimensions and volume: Formula Bar

Enter compost windrow length:	[redacted]	feet
Enter compost windrow height:		feet
Enter compost windrow base:		feet
Space between windrows:		feet

4. Composting and feedstock processing area:

Composting windrow volume=	444	cu yds
Volume of compost in composting area=	6,621	cu yds
Number of composting windrows=	15.0	windrow(s)
Windrow area square footage=	240,480	sq feet
Composting and feedstock processing area=	5.5	acre(s)

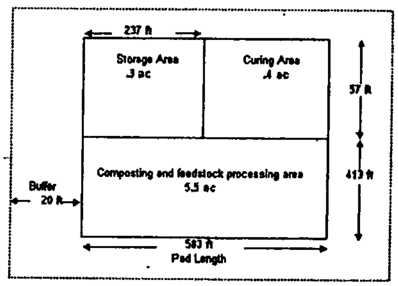
5. Determine compost curing area:

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

7. Total area required for composting pad:

Enter buffer around compost site: [redacted] feet

Total area required for compost pad= 7.3 acre(s)



Proceed to Retention Pond Page

Runoff collection pond sizing

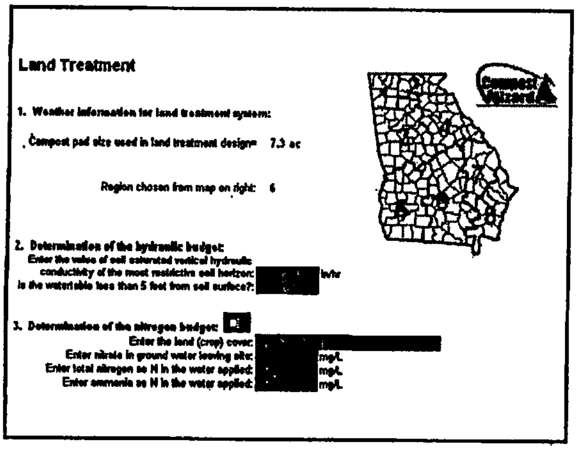
- Based on highest monthly expected runoff from a 30-year historical weather data
  - Provides a slightly more conservative design when compared against standard 24 hour 25-year rainfall events
- Uses location specific weather data
  - State is divided into eight regions
- Variables
  - Mmp = Maximum monthly precipitation
  - Tca = Total composting area + buffer area
  - ET = Evapotranspiration rate
  - RF = Reduction factor (0.3 Nov-Mar, 0.5 April-Oct)

Land treatment design cont.

User Inputs	Wizard Outputs
- Soil hydraulic conductivity	- Acres required
- Water table depth	- Design loading rate (in/wk)
- Land cover (crop)	- Total N leaving site (mg/L)
- Groundwater nitrate limit	- Net plant uptake (lb/acre/yr)
- Total N in applied water	- Avg. daily flow (mgd)
- Total ammonia as N in applied water	- Whether to base land application on water budget or the nitrogen balance

Nitrogen balance table

1. Average daily flow (mgd) (Based on max runoff)	0.06
2. Average design wastewater loading (in/week)	2.00
3. Acres Required	13.6
4. Nitrogen input to site from applied wastewater (lbs/acre/yr)	290
5. Nitrogen input to site from rainfall (lbs/acre/yr)	5
6. Total nitrogen input to site (lbs/acre/yr)	295
7. Ammonia volatization at 5% ammonia applied (lbs/acre/yr)	1.4
8. Denitrification at 10% of total nitrogen applied (lb/acre/yr)	29
9. Net plant uptake and storage (lbs/acre/yr)	125
10. Nitrogen in water applied to site (lbs/acre/yr)	139
11. Precipitation (in/yr)	57
12. Wastewater applied to land site (in/yr)	104
13. Potential evapotranspiration from land site (in/year)	39
14. Percolate (Water sprayed on land site (in/yr))	123
15. Estimated total nitrogen leaving the site (mg/L)	5.0



Economic evaluation cont.

<u>Operational Costs</u> – Reoccurring expenses
- Insurance – Employee, equipment, site
- Utilities – fuel cost, electricity
- Supplies – office supplies, analytics, advertising
- Maintenance – replacement costs
- Salaries – employees, contract work

<u>Cash Flow</u>
- Feedstock costs
- Tipping fees
- Sales
- Interest rate, loan life
- Cost avoidance

Economics

1. Equipment and labor cost estimates:
   Enter the number of turns per windrow per cycle: [redacted]

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

Equipment	Name	Cost/unit	Hp	yds/hr	# of Units	Hours	Total Cost
Turners	[redacted]	$ 25,000	90	950	[redacted]	577	$ 25,000
Loader	[redacted]	$ 83,000	110	70	[redacted]	964	$ 83,000
Screener	[redacted]	$ 40,000		20	[redacted]	712	$ 40,000
Trucks	[redacted]	$ 20,000	200	10	[redacted]	1,424	$ 20,000
						3,577	$ 168,000

Capital cost summary table:

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

How well does it work?

- Program compared against 9 existing operations
- Specific operator inputs about their sites were used in the program such as:
  - Tonnage of feedstocks
  - Windrow dimensions
  - Equipment type
  - Length of time for each process
- Validation of model unit processes:
  - Not all facilities utilize each unit operation
  - Limited available economic data due to propriety concerns

Biosolids

•Municipal operated

•Located in S.E. Georgia

•Composted 35 tons/day yardwaste and 10 tons/day biosolids

•Total processing time was 45 days

	Case Study	Compost Wizard	% Error
Total land required (ac)	4.2	4.3	+2.3
Capital costs ($)	232,887	225,500	-3.3
Operating cost ($/yr)			
Maintenance	14,927	22,550	+33.8
Total O&M	118,527	145,427	+18.5
Processing cost ($/ton)	11.70	17.04	+31.3

Agricultural Waste

•Privately operated

•Located in S.W. Georgia

•Composted 134 tons/day of vegetable culls, yard trimmings

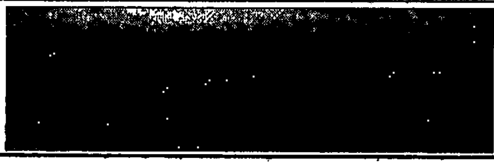
•Total processing time was 90 days

	Case Study	Compost Wizard	% Error
Total land required (ac)	35.0	32.7	-7.0

Foodwaste Two

- Institutional - Prison operated
- Located in S. Georgia
- Composted 16 tons/day of foodwaste and yard trimmings
- Total processing time was 135 days

	Case Study	Compost Wizard	% Error
Total land required (ac)	6.2	6.6	+6.1



Foodwaste Three

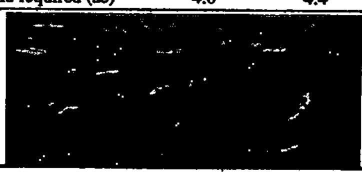
- Institutional - Prison operated
- Located in S. Georgia
- Composted 5 tons/day of foodwaste and yard trimmings
- Total processing time was 180 days

	Case Study	Compost Wizard	% Error
Total land required (ac)	3.3	3.8	+13.2

Animal Manure One

- Private operated
- Located in N.E. Georgia
- Batch processed – 2,380 tons/yr, hen manure and woodchips
- Total processing time was 180 days

	Case Study	Compost Wizard	% Error
Total land required (ac)	4.0	4.4	+9.1



- They will be able to do all of their own site work and grading since they have the equipment and know how in the landfill personnel
- They have minimum equipment for this project since all that they currently have is used for operating the landfill.
- They will need to get an amendment to their Solid Waste Handling Permit to allow for the operation at the landfill.
- They have pretty good backing from the community.....
- Marketing of the finished product is a concern for them, both from a quality and price angle. They feel that they can do a good job selling if they had someone to focus on marketing.
- They currently pay $20/ton for disposal of the biosolids (includes hauling)
- They currently pay a contract grinder $60,000/yr to grind the yard trimmings.

As the Consultant

- Your job is to do a preliminary feasibility design for the proposed operation.
- Each group may ask only 3 questions
- Make the design conservative and realistic using the information you have learned and the design manual in the notebook.
- Good luck

Compost Wizard Design Manual

Tables

Figures

Compost Wizard© Design Manual

Introduction

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

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

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

Special Requirements

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

How to Install Solver Add-In

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

General Instructions

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

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

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

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

Table 1. Color representation

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

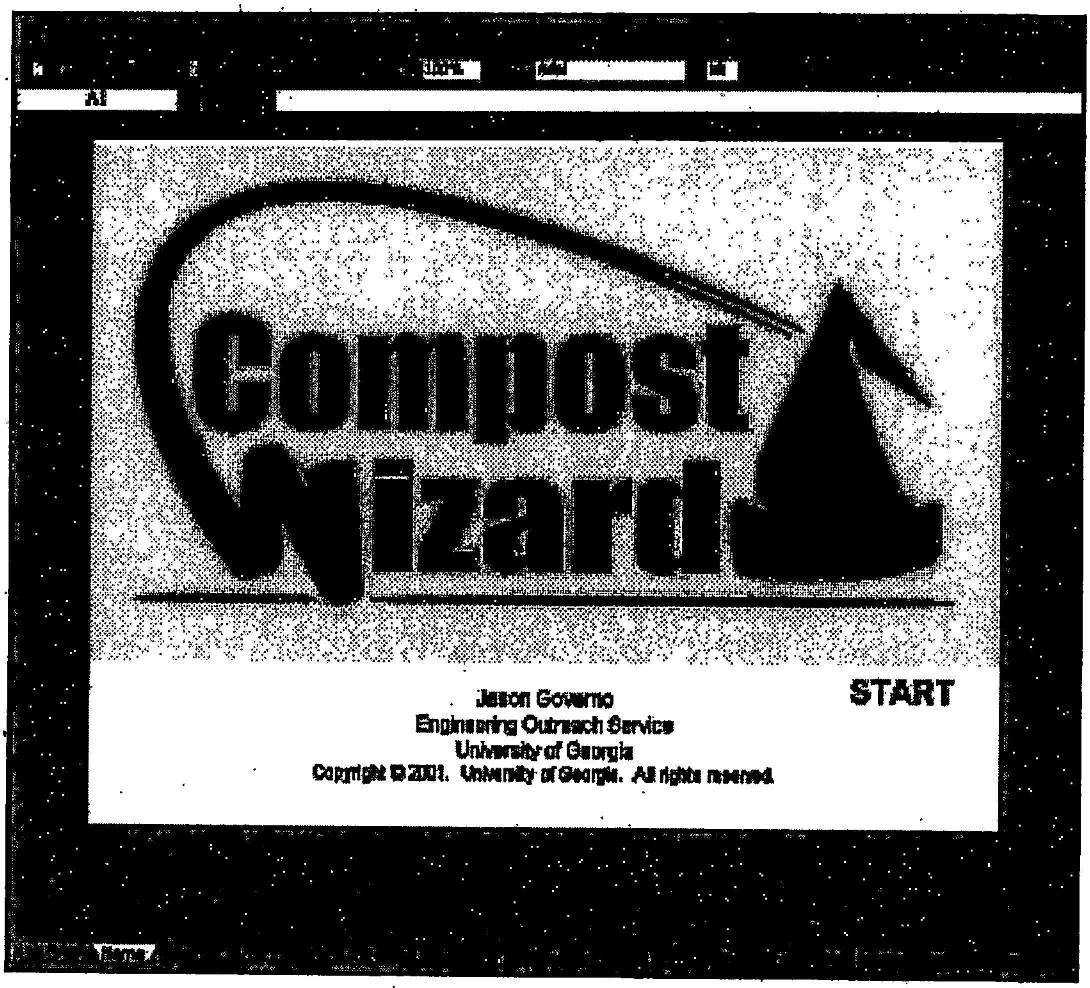


Figure 3. Home page

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

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

changed significantly, the default value in the maximum number of batches will also change.

Carbon and Nitrogen Sources

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

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

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

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

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

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

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

estimated composting periods for common feedstocks obtained from the literature. If unsure of the composting periods for your particular feedstock, use a composting period of 90 days. This takes into account the time period required to achieve stable compost for most feedstocks. It is better to use a more conservative estimate (longer period).

Table 3. Duration of composting and curing for different feedstocks

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

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

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

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

Section 3. Determine composting windrow dimensions and volume

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

Another thing to keep in mind is that just because a vendor says that a turner can handle a 6' x 12' windrow, it may not be wise to "max out" the capacity of the turner. The larger the windrow, the harder the turner has to work which correlates into higher operating costs through increased wear and tear on the equipment. For example, if the maximum capacity of a turner is 6' x 9' windrow, you may want to run a design using a 5' x 8' windrow and see the difference it makes. This small size reduction may actually increase production by increasing the speed at which the turner can work while reducing the maintenance costs associated with running your equipment at full capacity.

Section 4. Composting and feedstock processing area

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

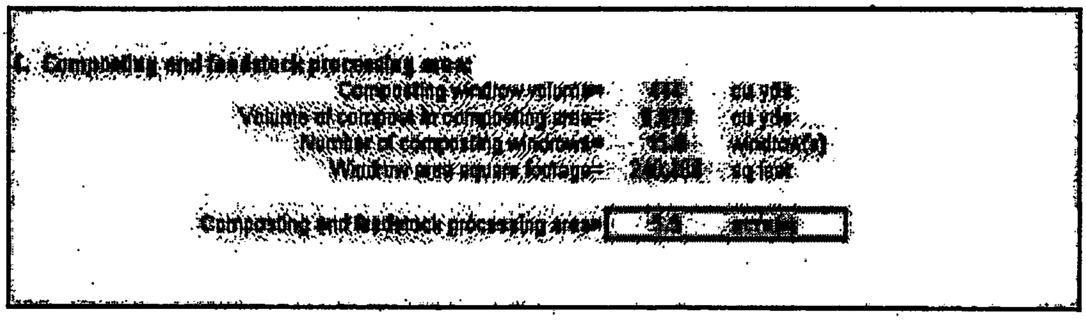


Figure 7. Composting and feedstock processing area

Section 5. Determine compost curing area

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

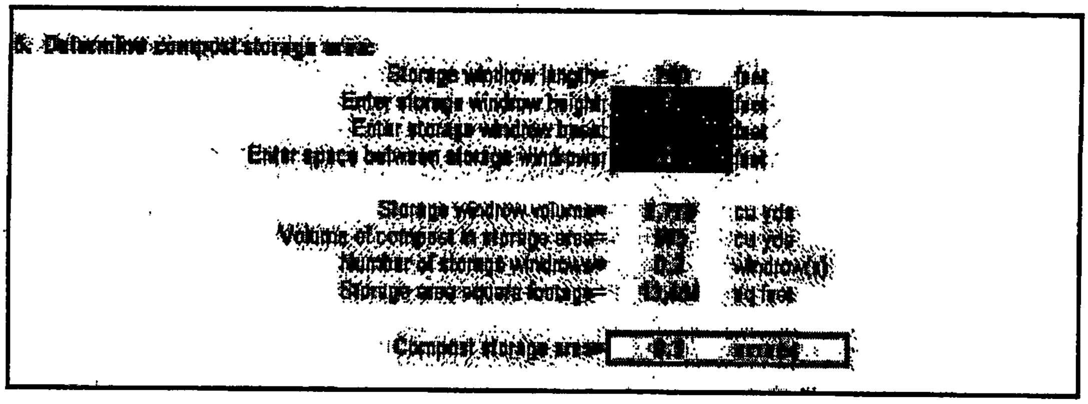


Figure 9. Determine compost storage area

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

Section 7. Total area required for composting pad

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

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

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

Module 2. Retention Pond

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

Section 1. Weather information for retention pond

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

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

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

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

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

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

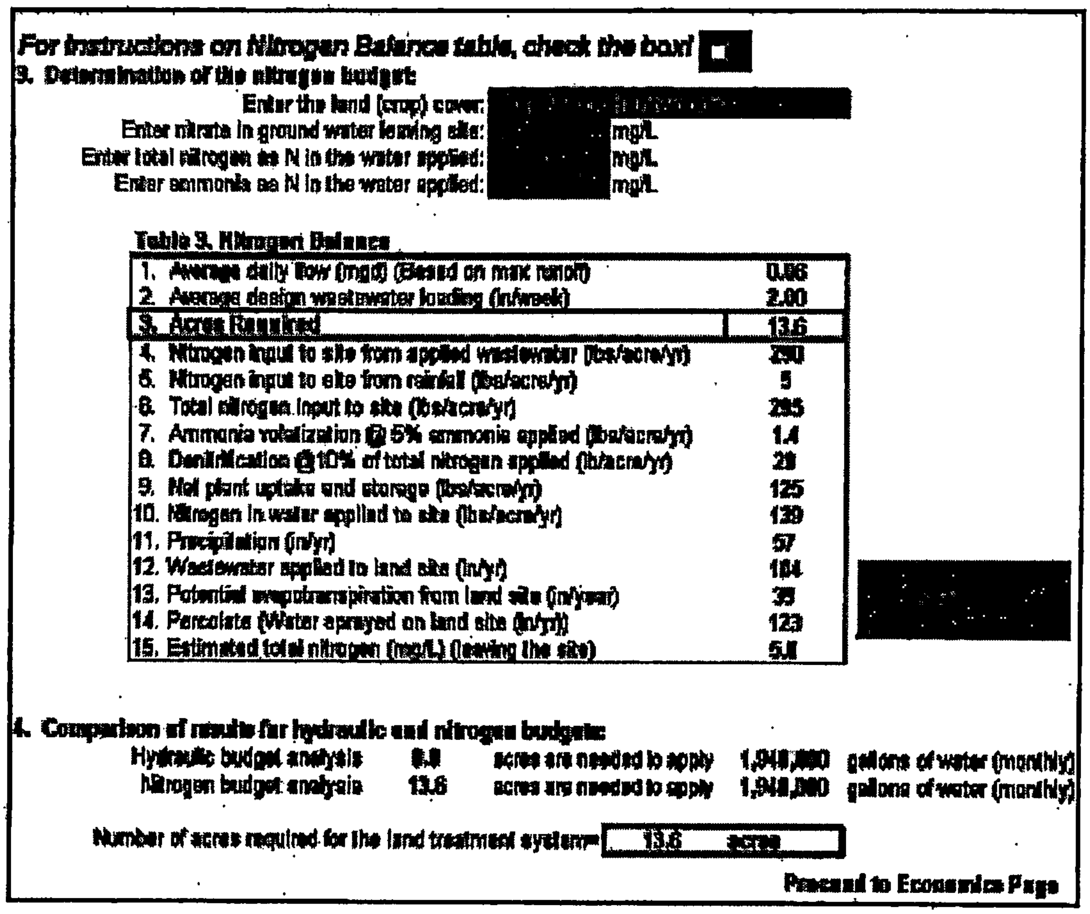
be suitable for land application without some sort of drainage improvement. A message stating this fact will appear.

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

Section 3. Determination of the nitrogen budget

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

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



For instructions on Nitrogen Balance table, check the box!

3. Determination of the nitrogen budget:

Enter the land (crop) cover: [redacted]
Enter nitrate in ground water leaving site: [redacted] mg/L
Enter total nitrogen as N in the water applied: [redacted] mg/L
Enter ammonia as N in the water applied: [redacted] mg/L

Table 3. Nitrogen Balance

1. Average daily flow (mgd) (Based on max runoff)	0.06
2. Average design wastewater loading (in/week)	2.00
3. Acres Required	13.6
4. Nitrogen input to site from applied wastewater (lbs/acre/yr)	290
5. Nitrogen input to site from rainfall (lbs/acre/yr)	5
6. Total nitrogen input to site (lbs/acre/yr)	295
7. Ammonia volatilization @ 5% ammonia applied (lbs/acre/yr)	1.4
8. Denitrification @10% of total nitrogen applied (lb/acre/yr)	29
9. Net plant uptake and storage (lbs/acre/yr)	125
10. Nitrogen in water applied to site (lbs/acre/yr)	139
11. Precipitation (in/yr)	57
12. Wastewater applied to land site (in/yr)	104
13. Potential evapotranspiration from land site (in/year)	39
14. Percolate (Water sprayed on land site (in/yr))	123
15. Estimated total nitrogen (mg/L) (leaving the site)	5.8

[redacted]

4. Comparison of results for hydraulic and nitrogen budgets:

Hydraulic budget analysis	[illegible]	acres are needed to apply	1,948,000	gallons of water (monthly)
Nitrogen budget analysis	13.6	acres are needed to apply	1,948,000	gallons of water (monthly)

Number of acres required for the land treatment system= 13.6 acres

Proceed to Economics Page

Figure 13. Determining the nitrogen budget

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

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

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

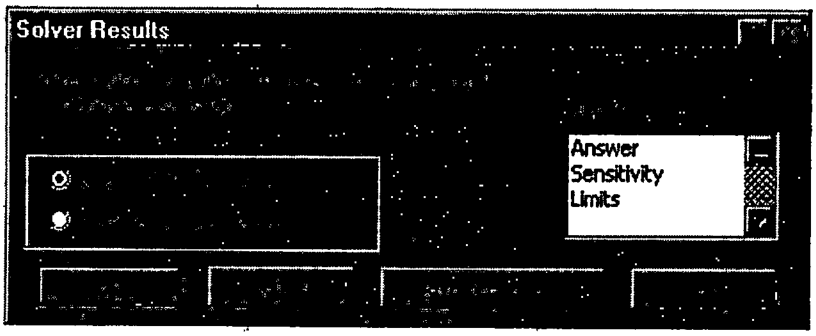


Figure 14. Solver results

Section 4. Comparison of results for hydraulic and nitrogen budgets

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

approximately 12 hours per day, 5 days a week. Realistically, this is not possible. One should increase the number of turners by using the drop down list for turners under the # of units column. This reduces the working hours required for each machine, however it may require an additional employee to operate the second piece of equipment. If you do not wish to add more employees, the design may require a turner that has a larger throughput capacity.

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

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

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

Table 6. Windrow turning equipment[1], size, cost and corresponding windrow dimensions (Rynk, 1992)*

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

*Approximate values

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

Table 9. Truck specifications

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

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

Section 2. Capital cost summary table

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

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

operating cost table summarizes and allows you to determine many of the operating costs for the facility (Figure 17). The table is broken down into three main headings: Equipment, Employee, and Miscellaneous.

3. Operating cost summary table: [illegible]

	%/yr	$/unit	Total Cost ($/yr)
Equipment			
Fuel Cost ($/gallon)		[illegible]	$ 32,182
Maintenance & Repair	[illegible]		$ 19,680
Facility Insurance	[illegible]		$ 3,339
Equipment Replacement	[illegible]		$ 19,680
		Total Equipment	$ 74,731
Employees	# employees		
Skilled Labor	[illegible]	[illegible]	$ 48,000
Unskilled Labor	[illegible]	[illegible]	$ 12,000
	%/wages		
Employee Benefits	[illegible]		$ 15,240
		Total Employee	$ 71,240
Miscellaneous	hrs/yr		
Contract Work	[illegible]	[illegible]	$ 18,750
Other costs	[illegible]	[illegible]	$ -
Feedstock Costs	tons/yr	$/ton	
[illegible]	[illegible]	[illegible]	$ -
[illegible]	[illegible]	[illegible]	$ -
[illegible]	[illegible]	[illegible]	$ -
Landfill Costs	[illegible]	[illegible]	$ -
		Total Miscellaneous	$ 18,750
		TOTAL OPERATING COSTS ($/YR) --	$ 164,721

Figure 17. Operating cost summary table

Equipment

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

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

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

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

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

Section 4. Revenue generation summary table

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

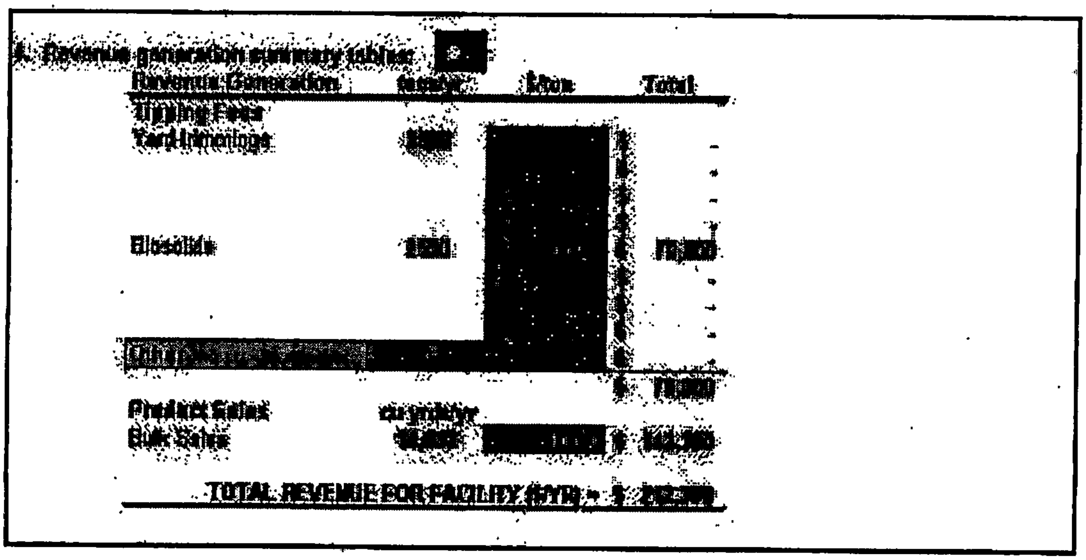


Figure 18. Revenue generation summary table

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

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

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

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

Total Monthly Revenue is the total revenue for a facility found in Section 4 divided by twelve months a year. This value should exceed the total monthly expenses in order for an operation to be sustainable. Although revenue is presented on a monthly basis, compost sales are usually seasonal and as such, actual accounting techniques used should account for this to ensure adequate cash flow.

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

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

Module 5. Summary Page

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

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

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

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

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

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

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

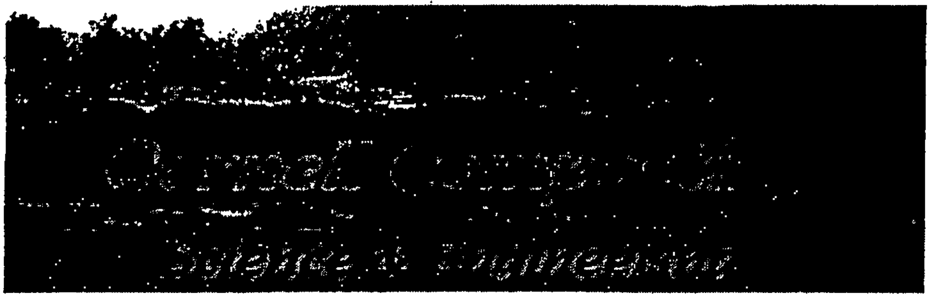
Soil Hydraulic Conductivity is the speed that water can flow through soil.

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

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

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

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

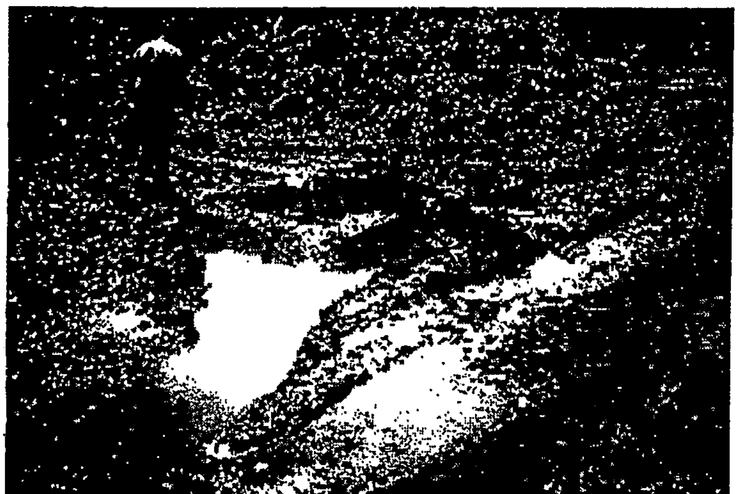


Water Quality Protection

Tom Richard

Composting has long been viewed as an environmentally beneficial activity. To maintain that positive reputation it is essential that compost facilities consider and mitigate any adverse environmental impacts. Water quality protection can be accomplished at most composting facilities by proper attention to siting, ingredient mixtures, and compost pile management.

The results of water quality monitoring studies at Cornell and elsewhere indicate that outdoor windrow composting can be practiced in an environmentally sound manner (Richard and Chadsey, 1994; Rymshaw et al., 1992; Cole, 1994). However, there are a few aspects of this process that can potentially create problems. For leaf composting, the primary concerns are BOD and phenol concentrations found in water runoff and percolation. Biochemical Oxygen Demand and phenols are both natural products of decomposition, but the concentrated levels generated by large-scale composting should not be discharged into surface water supplies. Additional potential concerns when composting nutrient rich materials such as grass, manure, or sewage sludge include nitrogen compounds such as nitrate and ammonia, and in some cases phosphorus as well. With manure or sewage sludge there may also be pathogen concerns. These concerns, while important, are readily managed, and can be mitigated through careful facility design and operation.



A water quality threat?

Facility Design

Selecting the right site is critical to many aspects of a composting operation, from materials transport and road access to neighborhood relations. From an environmental management perspective, the critical issues are soil type, slope, and the nature of the buffer between the site and surface or groundwater resources. Soils can impact site design in a variety of ways. If the soils are impermeable, groundwater is protected from nitrate pollution, but runoff is maximized which increases the BOD, phosphorus, and pathogen threat to surface water. On the other hand, highly permeable soils reduce the runoff potential but may allow excessive nitrate infiltration to groundwater. Intermediate soil types may be best for sites which are operated on the decomposition. Carbon availability is particularly variable, depending on the surface area or particles and the extent of lignification of the material. Composting occurs in aqueous films on the surfaces of particles, so greater surface area increases the availability of carbon compounds. Lignin, because of its complex structure and variety of chemical bonds, is resistant to decay. For both of these reasons the carbon in large wood chips is less available than that in straw or paper, so greater quantities of wood chips would be required to balance a high nitrogen source like manure.

The data from experimental studies indicates low C:N ratio mixtures can generate nitrate levels above the groundwater standard (Rymshaw et al.; 1992, Cole, 1994) Much of this nitrate in runoff and leachate will infiltrate into the ground. While microbial assimilation and denitrification may somewhat reduce these levels as water passes through the soil, these processes will have a limited effect and are difficult to control. Proper management of the C:N ratio is perhaps the only practical way to limit nitrate contamination site short of installing an impermeable pad and water treatment system.

The other important factor to consider when creating a composting mixture is water content. From a microbial standpoint, optimal water content should be in the 40 to 60% range. This moisture content is a balance between water and air filled pore space, allowing adequate moisture for decomposition as well as airflow for oxygen supply. The ideal water content will vary somewhat with particle size and density, and fine, dense organic substrates should be drier if adequate aeration is to be assured. Excess water, in addition to increasing the odor potential via anaerobic decomposition, will increase the runoff and leachate potential of a composting pile during rainfall events.

With both C:N ratios and moisture content, the optimum water and nitrogen levels for rapid composting may create a greater than necessary water pollution threat. Increasing the C:N ratio from 30:1 to 40:1 and decreasing the water content from 60 % to 50% may slow down decomposition somewhat, but can provide an extra margin of safety in protecting water quality.

Once the materials are mixed and formed into a compost pile windrow management becomes an important factor. Windrows should be oriented parallel to the slope, so that precipitation landing between the windrows can move freely off the composting area. Pile shape can have a considerable influence on the amount of precipitation retained in a pile, with a flat or concave top retaining water and a convex or peaked shape shedding water, particularly in periods of heavy rain. These effects are most pronounced when the composting process is just starting or after a period of dry weather. In the early phases of composting a peaked windrow shape can act like a thatched roof or haystack, effectively shedding water. Part of this effect is due to the large initial particle size, and part is due to waxes and oils on the surfaces of particles. Both of these initial effects will diminish over time as the material decomposes. During dry weather the outer surface of even stabilized organic material can become somewhat hydrophobic, limiting absorption and encouraging runoff.

If a pile does get too moist, the only practical way to dry it is to increase the turning frequency. The clouds of moisture evident during turning release significant amounts of water, and the increased porosity which results from turning will increase diffusion and convective losses of moisture between turnings. This approach can be helpful during mild or warm weather, but caution must be exercised in winter when excessive turning can cool the pile.

Runoff management

Implementation of the preventative measures described above can considerably reduce the water pollution threat. However, some facilities may require additional management of runoff from the site. As indicated above, the runoff pollutants of primary concern are BOD and phosphorus, largely associated with suspended solids particles. Pathogenic cysts may either be absorbed on particles or be free in solution, and again the relative significance is not adequately researched. Four readily available strategies exist to help control these pollutants: vegetative filter strips, sediment traps or basins, treatment ponds, and recirculation systems.

This simplest runoff management strategy is the installation of a vegetative filter strip. Vegetative filter strips trap particles in dense surface vegetation. Grasses are commonly used, and must be planted in a carefully graded surface over which runoff can be directed in a thin even layer. Suspended particles flowing slowly

Summary

Water quality protection at a composting site can be accomplished through proper site design, operations, and runoff management. Composting facilities vary widely in size, materials processed, and site characteristics, and all these factors will effect the design of appropriate preventative measures. Although the available evidence is limited, current indications are that runoff from composting windrows has BOD and nutrient levels comparable to low strength municipal wastewaters. Land treatment systems which have proven effective for these alternative wastewaters we can expect to be effective for windrow composting facilities as well.

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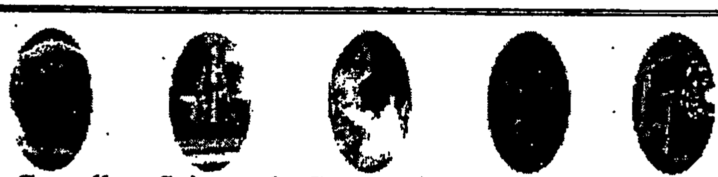

For general questions about composting, please browse this and other composting websites, or make use of the compost listserves.

For specific comments related to this page, please contact: Sue Fredenburg (format and style), or Tom Richard (technical content).

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The URL of this page is http://www.cfe.cornell.edu/compost/waterqual.html

BUILDING A PAD FROM LIME STABILIZED SOIL

Innovative approach is used to produce a compost pad impervious to water and suitable as an all weather surface for vehicular traffic.

Lawrence J. Sikora and Harry Francis

COMPOSTING facility siting and design are important in the successful production of quality compost. Throughout the year, facilities receive and process hundreds to thousands of cubic yards of organic by-products. These materials contain water soluble nutrients that, if not managed properly, will leach into and affect ground and surface waters.

Composting sites should be located on relatively impervious surfaces, and runoff directed to buffer areas or treatment ponds. Clay soils satisfy the requirement of an impervious soil, but when wet, they become very slippery and are not conducive to vehicle traffic. Portland cement concrete or asphalt are effective, but can be costly for some operations. This article describes a lime stabilized soil process that generally is considerably less expensive than either concrete or asphalt. Lime soil stabilization produces an impervious layer so water does not penetrate, as well as an all-weather surface that allows vehicular traffic under all conditions. Although most soils can be lime stabilized, some soils are more easily stabilized than others.

STABILIZATION OF CLAY, SANDY-SILTY SOILS

Soils with clay content above ten percent become a gel when the pH is raised above 11.5, due to the addition of lime products. This 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. (A pozzolon in soil is the clay-like material that contains the aluminate and silicates. When soils do not have sufficient pozzolons, amendments of fly ash or cement are needed to produce the cement glue for the pad.) The pH decreases over several days as the mixture adsorbs atmospheric carbon dioxide and particles bind together into crystals forming a natural cement.

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 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 level is sufficiently high and availability, transportation and manipulation costs are economical. Even when these materials are free, their transportation costs and additional soil manipulation required to achieve stabilization often make them uneconomical.

Lime stabilized soils may achieve a hydraulic conductivity similar to clays, i.e. 10^{-7} cm/second, preventing leaching of soluble nutrients from composting mixtures through the soil profile. The cured soils do not swell or shrink with water availability and create a strong load bearing capacity material.

Sandy or silty soils containing less than ten percent clay will need a source of silicates and aluminates to build the "bridges" between soil particles for the natural cement to form. One source 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. Enough fly ash is needed to bring the pozzolon (clay) content above ten percent.

CURING 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. The stabilization and strength gain continues slowly with time. 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°F (2°C) to assure the natural cementing chemical reactions proceed. The site can be reworked within a few days or weeks using the same techniques if unforseen probbearing capacity — unconfined compressive strength — of the final mixture. This test, which requires specific engineering equipment and can be performed by geotechnical consulting companies, determines the maximum weight of equipment that the site will bear. 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. It assures that cementing products are formed.

ECONOMICS, SAFETY

Soil stabilization is generally more economical than the cost of concrete built to bear the same weight. The equipment needed to stabilize soils for a compost pad is a front-end loader to apply the lime amendments, a rototiller to mix the ingredients, water to begin the reaction, and a roller to pack the surface. A comparison of costs is provided in the accompanying sidebar.

Caution must be exercised when working with quicklime (CaO) because very high temperatures are generated 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). The reaction is generally complete within about 30 minutes.

Alternatively, calcium hydroxide can be purchased to mix with the soil, but it is less reactive than quicklime, requiring about 25 percent more material. While it is safer to handle from the heat generating aspect, it is a dry powder and dusty, requiring masks during the application. The dry powder hydrated lime can be made into a slurry using water prior to application. A 30 percent solids slurry is made by mixing one ton of hydrated lime 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.

The following publications are helpful in designing a lime stabilized soil composting pad: 1) National Lime Association Publication #326 — Lime Stabilization Construction Manual; 2) National Lime Association Pamphlet A-2, "Lime Dries up Mud;" 3) Fly Ash Facts for Highway Engineers — FHWA-SA-94-081, 1985; 4) *Soil Stabilization in Pavement Structures; A User Manual*. Vol. 2. Mixture Design Considerations. FHWA-IP-80-2., 1979; 5) American Society of Testing Materials: C-997. Appendix X1. ■

Larry Sikora is with the USDA-Agricultural Research Service, Beltsville, Maryland and Harry Francis is a consultant in Elliston, Virginia. Mr Francis served as technical manager for the National Lime Association from 1989 to 1997.

THE BELTSVILLE PAD EXPERIENCE

THE U.S. Department of Agriculture's Beltsville Research Compost Facility uses a lime stabilized compost pad. The soil was stabilized with quicklime, fly ash and cement kiln dust. In the design, the intention was to use recycled materials like the fly ash and cement kiln dust. In retrospect, these recycled materials were not necessary because the clay content of the soil was considerably more than the ten percent minimum. Only quicklime was necessary.

The pad has performed very well. Vehicles are able enter the site under all weather conditions. In late 1998, the pad was expanded using the same techniques and commercial contractor. When a section of the pad subsided in 1999, repair was performed using clay and quicklime and following the recipe recommended from the Eades-Grim pH test. Aside from not being able to use that section of the pad for a few weeks while it cured, the repair was easily and successfully accomplished.

The cost of the pad was about $4/square yard, eight inches deep. The site was graded by USDA prior to lime stabilization. We considered poured, reinforced concrete, which we estimated to be about $22/square yard. Since the pad was built, we learned that a cement soil stabilization procedure exists where cement is used instead of lime when clay or "pozzolonic" material in soil is below about ten percent. Cement stabilization costs about 25 percent more than lime stabilization.

For cement or lime stabilization, the majority of cost is manipulation of soil mixtures. At Beltsville, the cost of soil manipulation was about 62 percent of the total cost of lime stabilization. The contractor used large road building equipment and lime stabilized the pad in two days. Use of smaller farm-size equipment would take longer, but because curing takes a minimum of a week, quickly finishing the pad is not a requirement and therefore smaller rototillers and rollers can be used.

Since we built the lime stabilized pad, the University of Maryland Dairy Research facility in Clarksville constructed its second compost pad of lime stabilized soil. The first pad was a concrete floor from a demolished barn.

(From left to right) Site prior to construction of compost pad; Lime is added after soil is ripped; Adding water and rotary tilling, cause release of steam; Site after lime stabilization; Compost windrows are prepared.

RULES OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
CHAPTER 391-3-4 SOLID WASTE MANAGEMENT

TABLE OF CONTENTS

Effective Date: August 20, 1997

(a) Yard trimmings composting operations are excluded from regulation as solid wastes handling facilities. To be considered exempt from regulation, yard trimmings must be kept separate from solid waste and must be converted to a useable compost or mulch product.

(b) Any person involved in the composting of solid waste or special solid waste, other than yard trimmings as provided in paragraph (a) above or covered by a permit-by-Rule, shall comply with the following permit requirements:

1. Design Standards: a design and operation plan prepared by a professional engineer registered to practice in Georgia and proposed as a part of the permit application must include, but is not limited to, the following standards:

a. Capacity. The facility shall be adequate in size and capacity to manage the projected incoming solid waste and residue volumes.

b. Equipment. The equipment must be capable of producing a compost or mulch that is nonpathogenic, free of offensive odors, biologically and chemically stable, and free of injurious components or particles.

c. Storage Time. The facility shall provide for a minimum storage capacity of at least three (3) times the daily capacity of the composting equipment. No incoming material shall be stored in excess of the permitted capacity.

d. Types of Waste. The application must include the sources, types, and weight or volumes of solid waste to be processed, including data on the moisture content of the waste, and information concerning special environmental pollution or handling problems that may be created by the solid waste.

e. Air Quality. The facility shall be designed in such a manner as to meet any air quality standards of the Division.

f. Wastewater. Any wastewater generated by the facility shall be discharged to a wastewater treatment system and, before final release, shall be treated in a manner approved by the Division.

g. Fire Protection. Facility design shall provide for fire control equipment placed near the storage and charging area and elsewhere as needed, and additional fire fighting equipment shall be made available for emergencies.

h. Disposal of Surplus Compost. Any composted material not sold or otherwise beneficially reused must be disposed in a manner approved by the Division.

2. Performance Standards: all persons owning and/or operating composting facilities shall comply with the following requirements:

Compost as Erosion Control

Using Compost to Control Runoff, Erosion, and Nutrient Losses

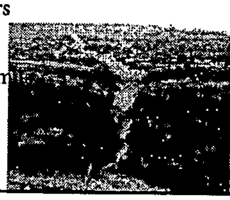
Dr. Mark Risse, Britt Faucette, Dr. Mark Nearing, Julia Gaskin, and Dr. Larry West

The University of Georgia, Biological and Agricultural Engineering and Crop and Soil Science Departments

The USDA-ARS National Soil Erosion Research Lab, West Lafayette, Indiana

Sediment from Soil Erosion

- Important Water Quality Issue
  - carries other pollutants
  - turbidity and aquatic health
  - sedimentation in reservoirs
- Sources include:
  - construction, NPDES perm
  - roads
  - agriculture



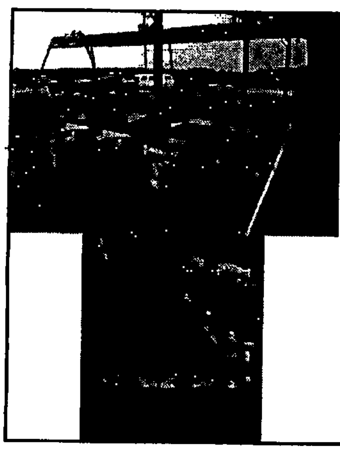
Phase 1:Treatments

Name	Description/Primary Feedstocks	Reps
PLC1	Poultry Gold Compost/PL	2
PLC2	Sargents Nutrients/PL	2
PLC3	Greener Organics/PL, Vegetable culls, yard waste	1
PL	Aged Poultry Litter/ Layer manure	2
MSC	Cobb Co. Compost/ MSW Compost, biosolids	2
BSC	Erthfood compost/Biosolids, peanuts hulls	3
FWC	Creative Earth/Food residuals, wood waste	2
YWC	FGACompost/Yard & wood waste, some manure	3
WMf	Woodtech Superfine Mulch/Fine wood mulch	2
WMm	Woodtech Medium hardwood mulch	3
WM2	Rockdale Co Mulch/Course ground waste wood	2
Soil	Bare Soil Control/ screened	3

Treatment selection based on availability in Georgia.

Experimental Setup

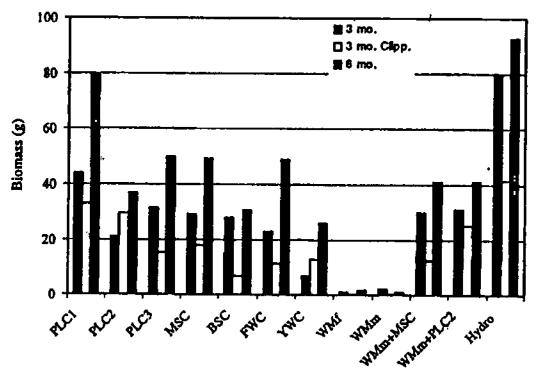
- Approx. 1m² pan
- 6 in deep, 2 in soil, 2 in of treatment
- plywood w/ holes, cheesecloth, soil, treatment
- Surface smoothed and leveled
- soil pre-wet before run



Methods

- Norton Rainfall Simulator
- Approx. 16 cm/hr (Over 6 in/hr)
- Measure RO, SL, nutrients
- Sampling strategy

Figure 3. Dry biomass after three and six months.

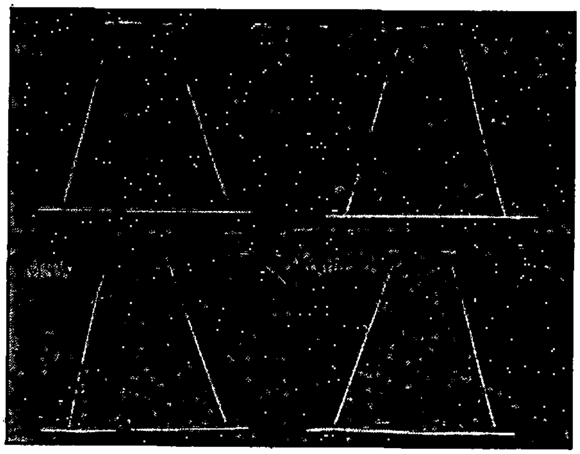


Phase 3: Field Study

- Conducted on 3'X 15' plots
- 10% slope
- Treatments applied followed by 1 hour of 4" rain
- Follow-up sampling at 3 months and 1 year.

Treatments in field study

- BS: Bare soil
- HS: Hydroseed w/ silt fence
- HM: Hydroseed w/ mulch berm
- BC: Biosolids w/ biosolids berm
- MS: MSW compost & mulch w/ berm
- PL: Poultry litter compost & mulch w/ berm
- YW: UGA yard waste compost w/ berm

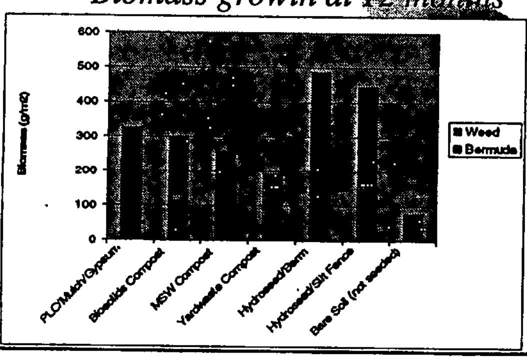


Vegetation, % Cover

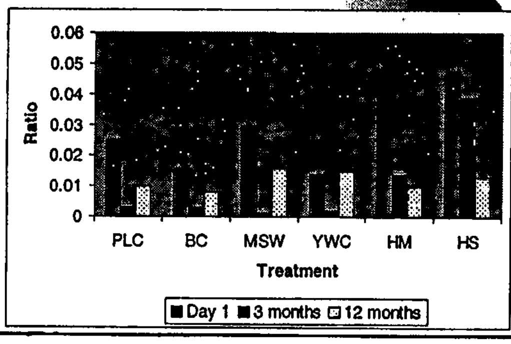
Treatment	3 months	12 months
PLC/Mulch/Gypsum	63.82a	72.93a
Biosolids Compost	56.81a	85.83a
MSW Compost/Mulch	58.54a	71.9a
Yardwaste Compost	62.16a	68.03a
Hydroseed/Mulch Berm	21.95b	86.23a
Hydroseed/Silt Fence	21.67b	80.53a
Bare Soil (not seeded)	17.15b	24.17b

12 month cover was correlated to N additions in treatment

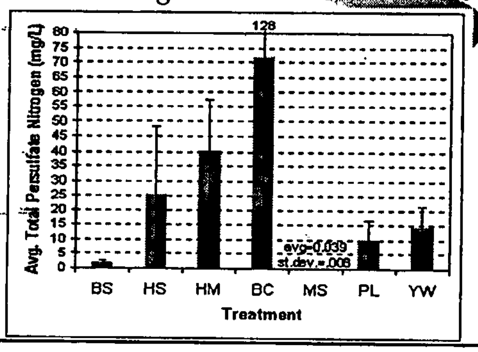
Biomass growth at 12 months



Erosion Data

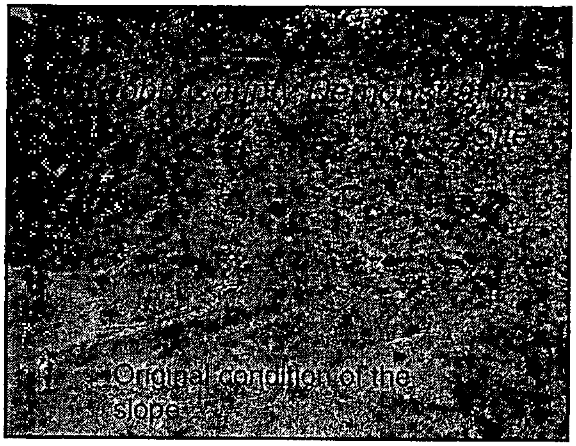


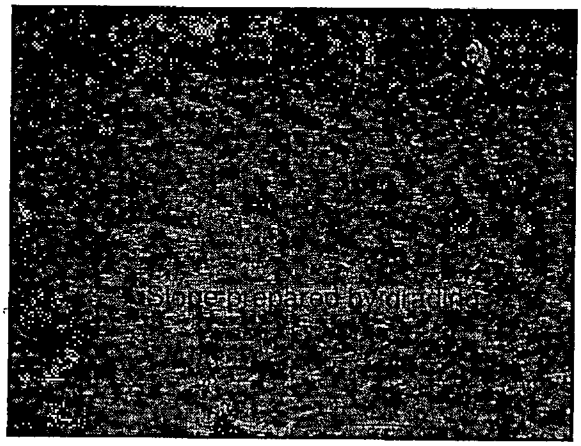
Nitrogen: Initial Simulation

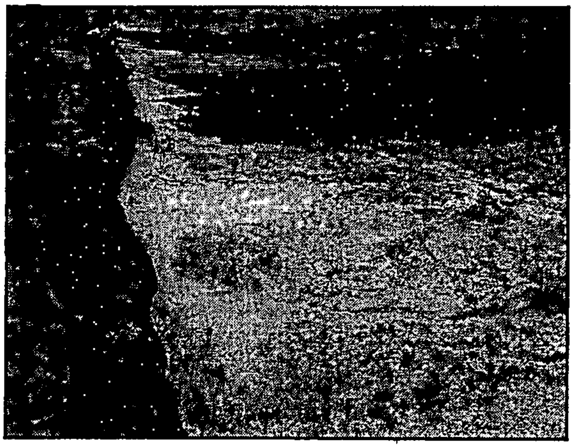


Total N Load (mg/m²)

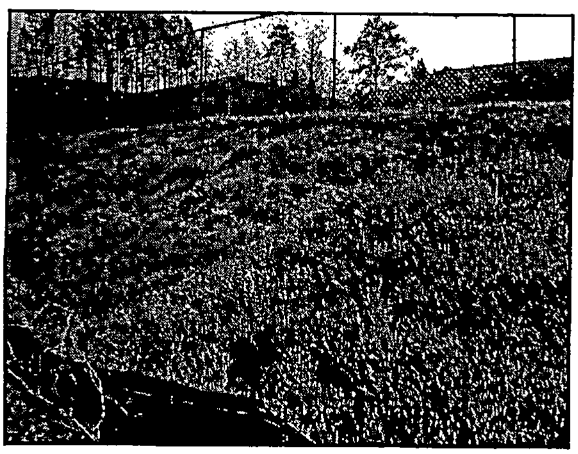
Treatment	DAY ONE	THREE MONTHS	TWELVE MONTHS
PLC/Mulch/Gypsum	842 bcd	25 b	40 b
Biosolids Compost	4061 a	254 a	42 b
MSW Compost	8 e	23 b	47 b
Yardwaste Compost	450 cde	39 ab	34 b
Hydroseed/Berm	1391 b	90 ab	43 b
Hydroseed/SiltFence	1008 bc	188 ab	40 b
Bare Soil	76.7de	92 ab	103 a

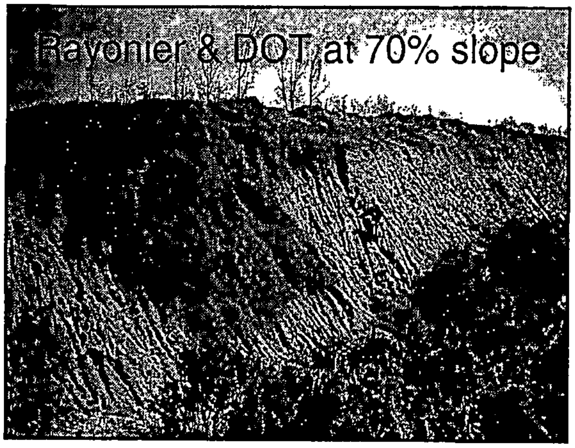

Original condition of the slope



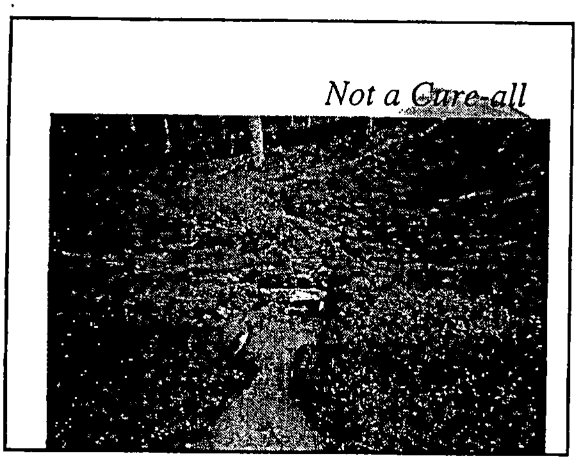


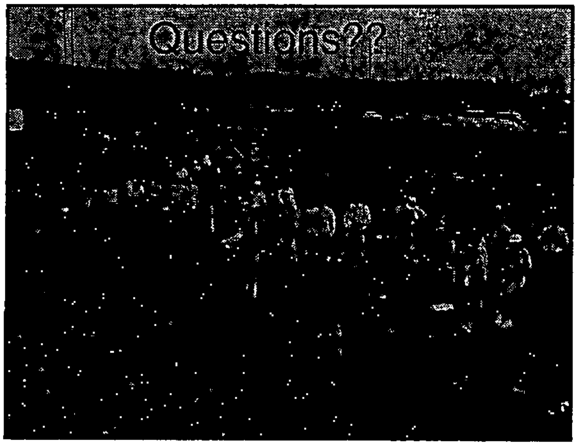

6 months




Rayonier & DOT at 70% slope


Rayonier
Paper
Products
GA DOT


Not a Cure-all


Questions??

Standard Specifications for

Compost for Erosion/Sediment Control

Completed by:

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*** These specifications contain all of the technical text found in the 'Official' American Association of State Highway & Transportation Officials (AASHTO) versions found in their 2003 AASHTO Provisional Standards manual. The Compost for Erosion / Sediment Control 'Filter Berms' is designated as specification MP 9 - 03, and the 'Compost Blankets' as specification MP 10 - 03. For copy of the official AASHTO specifications, contact AASHTO's Publications and Communications Technical Assistant at 202-624-5800**

Standard Specification for
Compost for Erosion/Sediment Control (Filter Berms)

SCOPE

This specification covers compost produced from various organic by-products for use as a filter berm media for erosion/sediment control. The technique described in this specification is primarily used for temporary erosion/sediment control applications, where perimeter controls are required or necessary.

This technique is appropriate for slopes up to a 2:1 grade (horizontal distance : vertical distance) and on level surfaces and should only be used in areas that have sheetflow drainage patterns (not areas that receive concentrated flows).

GENERAL DESCRIPTION

Compost is the product resulting from the controlled biological decomposition of organic material, occurring under aerobic conditions, that has been sanitized through the generation of heat and stabilized to the point that it is appropriate for its particular application. Active composting is typically characterized by a high-temperature phase that sanitizes the product and allows a high rate of decomposition, followed by a lower-temperature phase that allows the product to stabilize while still decomposing at a slower rate. Compost should possess no objectionable odors or substances toxic to plants, and shall not resemble the raw material from which it was derived. Compost contains plant nutrients but is typically not characterized as a fertilizer.

Compost may be derived from a variety of feedstocks, including agricultural, forestry, food, or industrial residuals; biosolids (treated sewage sludge); leaf and yard trimmings; manure; tree wood; or source-separated or mixed solid waste.

Proper thermophilic composting, meeting the US Environmental Protection Agency's definition for a 'process to further reduce pathogens' (PFRP), will effectively reduce populations of human and plant pathogens, as well as destroy noxious weed seeds and propagules.

Compost is typically characterized as a finely screened and stabilized product that is used as a soil amendment. However, most composts also contain a wood based fraction (e.g., bark, ground brush and tree wood, wood chips, etc.) which is typically removed before use as a soil amendment. This coarser, woody fraction of compost plays an important role when compost is used in erosion and sediment control. It is even possible to add fresh, ground bark or composted, properly sized wood based materials to a compost product, as necessary, to improve its efficacy in this application.

Compost products acceptable for this application must meet the chemical, physical and biological properties outlined in the section below.

PRODUCT PARAMETERS

Compost products specified for use in this application must meet the criteria specified in Table 1. The products' parameters will vary based on whether vegetation will be established on the filter berm.

Only compost products that meet all applicable state and federal regulations pertaining to its production and distribution may be used in this application. Approved compost products must meet related state and federal chemical contaminant (e.g., heavy metals, pesticides, etc.) and pathogen limits pertaining to the feedstocks (source materials) in which it is derived.

FIELD APPLICATION

The following steps shall be taken for the proper installation of compost as a filter berm for erosion/sediment control on both level and sloped areas.

Parallel to the base of the slope, or around the perimeter of affected areas, construct a trapezoidal berm at the dimensions specified in Table 2. In general, when compost filter berms are used to control erosion/sediment near, or on a slope, the base of the berm should be twice the height of the berm.

Compost shall be applied to the dimensions specified in Table 2.

Table 2 – Compost Filter Berm Dimensions

Annual Rainfall/Flow Rate	Total Precipitation & Rainfall Erosivity Index	Dimensions for the Compost Filter Berm (height x width)
Low	1-25", 20-90	1'x 2' – 1.5' x 3' (30 cm x 60 cm – 45 cm x 90 cm)
Average	26-50", 91-200	1'x 2' - 1.5' x 3' (30 cm x 60 cm – 45 cm x 90 cm)
High	51" and above, 201 and above	1.5'x 3' – 2' x 4' (45 cm x 90 cm – 60cm x 120 cm)

Compost filter berm dimensions should be modified based on specific site (e.g., soil characteristics, existing vegetation) and climatic conditions, as well as particular project related requirements. The severity of slope grade, as well as slope length will also influence the size of the berm.

In regions subjected to higher rates of precipitation and/or rainfall intensity, as well as spring snow melt, larger berms should be used. In these regions, and on sites possessing severe grades or long slope lengths, berms possessing a larger dimension may be used. Berms may be placed at the top and the base of the slope, a series of berms may be constructed down the profile of the slope (15-25' apart), or berms may be used in conjunction with a compost blanket (surface applied compost). In these particular regions, as well as regions subject to wind erosion, coarser compost products are also preferred for use in filter berm construction.

In regions subject to lower rates of precipitation and/or rainfall intensity, smaller berms may be used. However, the minimum filter berm dimensions shall be 1' high (30 cm) by 2' wide (60 cm). Also, specific regions may receive higher rainfall rates, but this rainfall is received through low intensity rainfall events (e.g., the Northwestern U.S.). These regions may use smaller berms.

Larger berms should also be used where required to be in place and functioning for more than one year.

Compost shall be uniformly applied using an approved spreader unit; including pneumatic blowers, specialized berm machines, etc. When applied, the compost should be directed at the soil surface, compacting (settling) and shaping the berm to some degree. The filter berm may also be applied by hand when approved by the Project Engineer or Landscape Architect/Designer.

On highly unstable soils, use compost filter berms in conjunction with appropriate structural measures. If used in conjunction with a silt fence, the silt fence fabric shall be laid on the soil surface with the lip facing the slope. The compost filter berm shall be constructed at the base of the silt fence (downhill side) and over the entire fence fabric lip.

Seeding the berm may be done, if desired, in conjunction with pneumatic blowing, or following berm construction with a hydraulic seeding unit, or by hand.

Table 1 – Compost Blanket Parameters

Parameters[1,4]	Reported as (units of measure)	Surface Mulch to be Vegetated	Surface Mulch to be left Un-vegetated
pH[2]	pH units	5.0 - 8.5	N/A
Soluble Salt Concentration[2] (electrical conductivity)	dS/m (mmhos/cm)	Maximum 5	Maximum 5
Moisture Content	%, wet weight basis	30 – 60	30 – 60
Organic Matter Content	%, dry weight basis	25 – 65	25-100
Particle Size	% passing a selected mesh size, dry weight basis	• 3" (75 mm), 100% passing • 1" (25mm), 90% to 100% passing • 3/4" (19mm), 65% to 100%passing • 1/4" (6.4 mm), 0% to 75% passing • Maximum particle length of 6" (152mm)	• 3" (75 mm), 100% passing • 1" (25mm), 90% to 100% passing • 3/4" (19mm), 65% to 100%passing • 1/4" (6.4 mm), 0% to 75% passing • Maximum particle length of 6" (152mm)
Stability[3] Carbon Dioxide Evolution Rate	mg CO_2-C per g OM per day	< 8	N/A
Physical Contaminants (man-made inerts)	%, dry weight basis	< 1	< 1

[1] Recommended test methodologies are provided in Test Methods for the Examination of Composting and Compost (TMECC, The US Composting Council)
[2] Each specific plant species requires a specific pH range. Each plant also has a salinity tolerance rating, and maximum tolerable quantities are known. When specifying the establishment of any plant or turf species, it is important to understand their pH and soluble salt requirements, and how they relate to the compost in use.
[3] Stability/Maturity rating is an area of compost science that is still evolving, and as such, other various test methods could be considered. Also, never base compost quality conclusions on the result of a single stability/maturity test.
[4] Landscape architects and project (field) engineers may modify the allowable compost specification ranges based on specific field conditions and plant requirements.

Very coarse compost should be avoided if the slope is to be landscaped or seeded as it will make planting and crop establishment more difficult.

In regions subject to higher rates of precipitation and/or rainfall intensity, higher compost application rates should be used. In these particular regions, as well as regions subject to wind erosion, coarser compost products are preferred.

Notes: Specifying the use of compost products that are certified by the US Composting Council's Seal of Testing Assurance (STA) Program (www.compostingcouncil.org) will allow for the acquisition of products that are analyzed on a routine basis, using the specified test methods. STA participants are also required to provide a standard product label to all customers, allowing easy comparison to other products.

Where water quality is an issue, or in areas in proximity to sensitive water bodies, the appropriate compost product should be used, and vegetating the compost blanket should be considered.

APPENDIX FOR SPECIFICATIONS

COMPOST SAMPLING AND CHARACTERIZATION OF COMPOST

Sampling procedures to be used for purposes of this specification (and the Seal of Testing Assurance program) are as provided in 02.01 Field Sampling of Compost Materials, 02.01-B Selection of Sampling Locations for Windrows and Piles of the Test Methods for the Examination of Compost and Composting (TMECC), Chapter 2, Section One, Sample Collection and Laboratory Preparation, jointly published by the USDA and USCC (2002 publishing as a part of the USDA National Resource Conservation Technical Bulletin Series). The sample collection section is available online at http://tmecc.org/tmecc/.

Test Methods to be used for purposes of this specification are as provided in The Test Methods for the Examination of Compost and Composting (TMECC), Jointly published by the USDA and USCC (2002 publishing as a part of the USDA National Resource Conservation Technical Bulletin Series). A list of such methods is provided in the table below and online at http://tmecc.org/tmecc/.

Test Methods for Compost Characterization

Compost Parameters	Reported as	Test Method	Test Method Name
pH		TMECC 04.11-A	Electrometric pH Determinations for Compost. 1:5 Slurry Method
Soluble salts	dS/m (mmhos/cm)	TMECC 04.10-A	Electrical Conductivity for Compost. 1:5 Slurry Method (Mass Basis)
Primary plant nutrients:	%, as-is (wet) & dry weight basis		
Nitrogen	Total N	TMECC 04.02-D	Nitrogen. Total Nitrogen by Combustion
Phosphorus	P_2O_5	TMECC 04.03-A	Phosphorus. Total Phosphorus
Potassium	K_2O	TMECC 04.04-A	Potassium. Total Potassium
Calcium	Ca	TMECC 04.04-Ca	Secondary and Micro-Nutrient Content. Calcium
Magnesium	Mg	TMECC 04.04-Mg	Secondary and Micro-Nutrient Content. Magnesium
Moisture content	%, wet weight basis	TMECC 03.09-A	Total Solids and Moisture at 70±5°C
Organic matter content	%, dry weight basis	TMECC 05.07-A	Matter Method. Loss On Ignition Organic Matter Method
Particle size	Screen size passing through	TMECC 02.12-B	Laboratory Sample Preparation. Sample Sieving for Aggregate Size Classification.
Stability (respirometry)	mg CO_2-C per g TS per day mg CO_2-C per g OM per day	TMECC 05.08-B	Respirometry. Carbon Dioxide Evolution Rate
Maturity (Bioassay) Percent Emergence Relative Seedling Vigor	 % (average) % (average)	TMECC 05.05-A	Biological Assays. Seedling Emergence and Relative Growth

Compost Sales and Marketing

Compost Sales/Marketing Workshop

October 14, 2004
Athens, Georgia

Sponsored by:

Presented by:
Ron Alexander
Principle, R. Alexander Associates, Inc.
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COURSE NOTES

1. The Economics of Compost Marketing

Economic Comparisons

Market Damage (own facility, others)

2. Compost – a *'different animal'*

What it is… What it's not

Comparing Compost to Other Products

General Comparison of Compost to Other Horticultural/ Agricultural Products[1]

	Compost	Canadian peat	Native peat	Mineral topsoil	Fresh manure	Ground pine bark
Macronutrients	medium - high	very low	very low	low	high	low
Micronutrients	medium - high	very low	very low	low - medium	medium - high	low
Soluble salts	low - medium	very low	very low	low	high - very high	low
pH	medium	low - very low	low - very low	medium	medium	low
Bulk density	medium	Low	low	high	high	low
Moisture holding capacity	medium	very high	high	low	low - medium	low
Organic matter content	medium - high	very high	high	low	medium - high	medium - high
Stability in soil	good - excellent	Excellent	excellent	n/a	low - medium	good - excellent
Microbial population	good - excellent	Poor	poor	poor - good	good	good - excellent

Note: These are general guidelines. Individual products may vary. N/A = Not applicable

[1]The Field Guide to Compost Use, US Composting Council, 1996

Benefits of Compost Use[3]

- Improves the soil structure, porosity, and bulk density – creating a better plant root environment
- Increases moisture infiltration and permeability of heavy soils – improving drainage and reducing erosion and runoff
- Improves moisture holding capacity of light soils – reducing water loss and nutrient leaching
- Improves and stabilizes soil pH
- Improves cation exchange capacity (CEC) of soils – improving their ability to hold nutrients for plant use
- Supplies a variety of macro and micro nutrients
- Supplies significant quantities of organic matter
- Supplies beneficial micro-organisms to the soil – improving nutrient uptake and suppressing certain soil-borne diseases
- Can bind and degrade specific pollutants

[3]The Field Guide to Compost Use, US Composting Council, 1996

Compost Applications[4]

- Soil Incorporant
  - Turf Establishment
  - Garden Bed Preparation
  - Reclamation / Remediation
  - Nursery Production
  - Roadside Vegetation
  - Agricultural Production
- Growing Media Component
  - Container/Potting
  - Landscape (e.g., rooftop, raised planters)
  - Backfill Mixes (tree and shrub planting)
  - Golf Course (e.g., tee, green, divot mixes)
  - Manufactured Topsoil
- Surface Applied
  - Garden Bed Mulch
  - Erosion Control Media
  - Turf Topdressing

[4]The Practical Guide to Compost Marketing and Sales, R.Alexander Associates, Inc., 2003

Volume vs. Value Markets[5]

Value Markets	Volume Markets
Landscapers	Agriculture (conventional)
Sports Turf	Reclamation
General Turf	Roadside Projects*
Wholesale Nurseries	Sod Farms
Resellers	
Topsoil Manufacturing*	
Agriculture* (organic)	
Erosion Control*	

*could be categorized in either market depending upon the specific customer and application

[5]The Practical Guide to Compost Marketing and Sales, R.Alexander Associates, Inc., 2003

Bulk vs. Bagged

Distribution Options

Derivative Products/Blending[6]

Screening	Blending
Turf Topdressing	Manufactured Topsoil
Landscape Mulch	Growing Media/Substrate
Erosion Control Substrate	Sports Turf
	(sand based mixes, topdressings, tee/green media, etc.)
	Landscape Planter Mixes
	Environmental Mixes
	(landfill closure, biofilters, erosion control, etc.)

[6]The Practical Guide to Compost Marketing and Sales, R.Alexander Associates, Inc., 2003

Compost Feedstock and its Acceptance within Select Compost Markets[8]

	Land-scapers	General Turf	Sports Turf	Topsoil Manufacturing	Agriculture	Erosion & Sediment Control	Reclamation	Resellers	Wholesale Nurseries
Yard Trimming	√√√	√√√	√√	√√√	√√	√√√	√√√	√√√	√√√
Biosolids	√√√	√√√	√√√	√√√	√√√	√√	√√√	√√	√√√
Manure	√√√	√√√	√√√	√√√	√√√	√√	√√√	√√	√√√
MSW	√√	√√	√	√√	√√	√	√√√	√	√√
Food Waste	√√√	√√	N/a	√√√	√√√	N/a	√√√	N/a	N/a

N/a – little current experience with this type of compost in this particular application

[8]The Practical Guide to Compost Marketing and Sales, R.Alexander Associates, Inc., 2003

Realistic Ranges (Typical Characteristics)

Modifying Characteristics

Common Mistakes

Monitoring Product Quality

Certification Programs

6. General Sales Principles and Requirements

The Compost Supplier

Important Attributes of a Compost Supplier[9]

- Produce compost possessing attributes/characteristics that meet end user or application requirements
- Supplies/Produces a consistent product
- Has implemented an on-going quality assurance or testing program
- Can supply current compost characterization data (quantifying and qualifying their product's attributes)
- Provides good overall customer service, employs a "service minded" staff
- Can assure prompt and reliable delivery (size of truck and mode of unloading are also important)
- Possesses adequate storage to ensure availability
- Can provide technical assistance regarding end use

[9] The Field Guide to Compost Use, US Composting Council, 1996.

The Compost Salesperson

Problem Solver

Skills/Knowledge Base

The *Green Industry*

The Benefits of Compost Use

The Composting Process

Relevant Regulation

Services

Product Delivery

Application Equipment

Technical Assistance from Staff and Specialized Consultants

Training Presentations

Informational Library

Prospecting

Identify and Rate Potential Customers

Databases – Prospect List

Refine Prospect List – Rating Prospects

Lead Generation

Referrals

Promotional/Educational Activities

Agriculture

Compost Uses:

1) Soil incorporant for field crops, vegetables and fruit crop fields
2) Plasticulture/raised planting bed component
3) Hothouse crop media component
4) Organic and/or certified organic fertilizer

Benefits of Compost Use (sales points):

1) Source of stabilized organic matter – doesn't degrade readily when added to soil, doesn't cause proliferation of disease organisms
2) Provides more organic matter than cover crops
3) Allows for faster plant growth and extensive rooting (improves soil structure and supplies mycorrhizae)
4) Rich in plant nutrients (micro and macro) – will allow for a reduction in fertilization
5) Cation exchange capacity of compost helps soil retain nutrients
6) Disease suppression of various soil borne diseases
7) Can increase crop yield
8) Can increase fruit size (yield of larger fruit)

Erosion and Sediment Control

Compost Uses:

1) Soil blanket (for slopes)
2) Filter berms
3) Media for vegetation

Benefits of Compost Use (sales points):

1) Reduces erosion and sediment movement – more effective than current
2) Economically competitive with current erosion/sediment control techniques and products
3) Binds and degrades a variety of chemical contaminants

6) Promotes deep rooting/better establishment – plants can better cope with environmental and cultural stresses
7) Superior short and long-term results (helps long-term sustainability of landscape)
8) Reduce chemical fertilizer and pesticide dependency

Reclamation

Compost Uses:

1) Manufactured topsoil component
2) Soil incorporant (upgrading marginal soils)
3) Bioremediate contaminated soils (e.g., heavy metals, petroleum based contaminants)
4) Remediate organically 'dead' soil
5) Flower bed establishment
6) Tree/shrub backfill mix component
7) Turf establishment/renovation

Benefits of Compost Use (sales points):

1) Replaces more expensive contaminated soil treatment methods, or soil removal and disposal
2) Can re-establish organic matter, carbon and nitrogen cycles in the soil
3) Microbial activity can degrade various petroleum based contaminants
4) Cation exchange capacity of compost helps soils retain nutrients and bind heavy metals
5) Specific elements in compost help to reduce bioavailability of certain heavy metals
6) Allows for faster plant establishment and growth, and extensive rooting (improves soil structure and supplies mycorrhizae)

Benefits to Selling Compost and Manufactured Topsoils:

1) Excellent profit margin
2) Will only distribute through a limited number of locations (only a small percentage of resellers can handle bulk products)
3) Can manufacture own unique products, brand name them
4) Can increase the value and utility of substandard soils
5) Can provide topsoil dealers the ability to diversify their product line

Turf - General

Compost Uses:

1) Soil incorporant for turf establishment
2) Soil incorporant for turf renovation
3) Turf topdressing (or topdressing component)
4) Turf divot media (or divot component)
5) Seed germination media
6) Organic fertilizer (Nitrogen, Iron)

Benefits of Compost Use (sales points):

1) Lack of good topsoil available
2) Few inexpensive turf topdressings are available
3) Rich in plant nutrients (micro and macro) – will allow for a reduction in fertilization, can act as fall fertilization on turf, often rich in nitrogen and iron (long-term 'greening' effect)
4) Supplies nitrogen over a three (3) year period
5) Allows for faster turf growth and extensive rooting (improves soil structure and supplies mycorrhizae)
6) Disease suppression of various turf diseases

Wholesale Nurseries

Compost Uses:

1) Component to greenhouse and container mixes
2) Soil incorporant for field nurseries
3) Soil incorporant for nursery beds
4) Nursery bed and/or field nursery mulch
5) Organic fertilizer

Benefits of Compost Use (sales points): *Greenhouse/Containers*

1) Weed-free
2) Less expensive than peat moss and many bark products (organic fraction of media)
3) Allows for faster plant growth and extensive rooting (improves media structure and supplies mycorrhizae)
4) May improve the quantity of plant inflorescence (flower buds)
5) Rich in plant nutrients (micro and macro) – will allow for a reduction in fertilization, can replace nitrogen needs for potted/containerized plants for several weeks, can reduce or replace micro nutrient additions to potted/containerized plant media
6) Suppression of various fungal diseases – in many cases have eliminated fungicidal drenches and fumigation)

Texas Municipal Compost Marketing Manual

A Publication of the Texas Natural Resource Conservation Commission
Office of Pollution Prevention and Recycling

tion regarding specifications and prices of currently used materials. Ideally, specifications can be established to give preference to in-house compost for all municipal work.

For many small and medium size facilities, in-house use can absorb a large proportion of their product. Even large metropolitan programs may find this market strategy to be significant. A market study conducted for New York City found that in-house use was a major potential market. In-house use can be decreased as other marketing efforts grow, or it may be maintained to fill in during periods when commercial or residential usage is low. Some municipal departments may not have stringent standards for compost quality because of the nature of their work; compost which does not meet horticultural standards may be usable for landfill cover or in roadside turf establishment or erosion control.

Since there are many possible municipal uses for compost, there is little risk involved in this marketing strategy. Cooperation between municipal departments should facilitate compost distribution as well as the establishment of educational forums. Although a large municipality may require more coordination, overall this strategy requires a low allocation of marketing resources.

Distribution to Citizens

A distribution program in which local residents can pick up compost for free, a nominal charge, or in exchange for compostable materials is a good strategy for publicizing the compost program and educating the public about beneficial reuse. This type of distribution and use builds support for the composting program and can increase participation.

It is important to avoid the perception that compost is a valueless product. Some programs have found that pricing compost at a nominal fee boosts interest in the product, simply because it classifies compost as a commodity rather than as a waste material. Another option is to let citizens take one or two bags free but charge for bulk quantities.

Promoting compost use among local residents is a good basis for other marketing strategies. A community that is familiar with and supportive of compost use can influence landscapers and nurseries in the area. A good educational program, including information on quality control and appropriate usage, must accompany compost distribution in the form of leaflets, technical data sheets, signage at the site, and a recognizable program logo. Visible demonstration plots and endorsement from the Cooperative Extension Service or a local landscaper can help initiate a program. Information on the environmental benefits of composting can be distributed in schools or community publications.

However, when a municipal facility distributes large amounts to residents for free, garden centers and retail nurseries may be less willing to sell the product. In fact, some may even actively discourage customers from using your product.

As a first step in compost marketing, distribution to residents can also be used as an opportunity to learn more about end user's concerns. A survey conducted at the compost pick-up site can compile data about the status and cost of competing products and customer satisfaction or complaints about this product. As the marketing program is developed, information from past users can be used for direct advertising and promotional efforts.

Distributing compost at low or no cost has very low risk for a small facility. Once a reputation for a quality product is established, word of mouth among local residents will provide the most effective advertising. There are many small composting facilities that cannot produce enough material to supply residents, small commercial users, and in-house use. Larger facilities will require more active marketing, but overall the net cost for this type of program should not be large because revenues generated will offset many costs.

Wholesale Marketing to Commercial Users

Potential users in the commercial sector are already very familiar with soil characteristics and the benefits of adding organic materials. Marketing should, therefore, focus on the specific qualities of your product and the potential user's specific applications. Since these sectors use large quantities of compost, they are likely to be concerned with storage and handling issues. Marketing will include coordination for product availability and delivery. Agriculture and landscaping are also very seasonal in nature; the marketing program must therefore have contingency markets and storage capacity which will utilize compost throughout the year.

Retail Marketing

Unlike bulk marketing to commercial users, retail marketing to the home and garden sector requires development of a product identity. In-house use and distribution to residents can develop a market for the compost; promotional materials must transfer the message, along with a highly recognizable name and logo, to the retail market.

This market sector has the highest unit price potential; however, it also requires the most investment into packaging and relies solely on bagged products because it is more time consuming to develop these markets. It is more expensive and the logistics of distribution are more complex. Bulk sales generally account for the majority of material distributed.

Examples

Selecting the right distribution and marketing strategy depends in part on the level of responsibility, commitment of staff, and presence in the consumer market that a community is willing to assume. Many other factors will influence the decision including the size and structure of the regional markets. The following examples briefly describe the strategies that two fictitious cites have selected.

Large Metropolitan Facility:

A large city in west Texas (population 150,000) plans to produce up to 30,000 cubic yards per year of compost and mulch. Due to the large volume and limited staff, the facility must develop large bulk markets. The facility manager chooses to contract with a single broker to handle all distribution and marketing to blenders and other brokers because in-house use and other local markets may not be sufficient and the City does not want to commit additional resources or to compete with the private sector.

The broker establishes certain minimum quality and quantity standards and guarantees a certain level of income for a specific marketing fee for a specific period of time. In return the broker guarantees to take all product produced to spec up to 50,000 cubic yards per year and pay $2 per cubic yard. At this price, the City requires that the broker is responsible for all market development. It does not provide any product support other than periodic testing.

The contract requires that all product be removed from the facility by the broker. Given the effort required to secure markets, the broker requires a guaranteed marketing contract for five years. The facility reserves a certain amount of material from the brokering agreement for in-house use and a give away program. In-house use concentrates on municipal plantings, landscaping, parks maintenance, and athletic field restoration.

Small to Medium Size Facility:

A small county on the Gulf Coast plans to develop an organics recycling facility that will produce an estimated 5,000 cubic yards annually of compost and 2,000 cubic yards annually of wood mulch. The facility design includes a small portable trommel screen that will be shared with a neighboring county. Based on a market survey, public agency and bulk material suppliers will generate sufficient demand. Based on this information, an in-house market program is planned. Distribution to local residents is identified as an important component of building wide public awareness and acceptance.

The facility produces enough compost for use in-house, sale to residents at a nominal cost, and distribution to local landscapers. The give away program is set up to allow local residents to take small quantities free of charge once a year. Larger quantities are sold to residents for a nominal fee. Professional private sector users are charged $20 per cubic yard for loads of 10 cubic yards or less and $15 per cubic yard for larger loads.

Figure 4-1 Sample Compost Technical Data Sheet

ABC Compost Co.

Main Street, Anytown, Texas 00000

999-888-9999

Compost Quality Information:

ABC Compost is a soil amendment that provides many benefits to soils and plants. ABC Compost is rated Class A per TNRCC regulations. This product is approved for unrestricted distribution and can be utilized to improve soils, landscapes, home gardens, lawns, and in potting soils.

As a soil amendment ABC Compost has the following properties:

Quantified Parameters	Typical ABC Range	ABC 1994 Average
pH	6.8 - 7.3	7.1
Nitrogen	1.0 - 1.3%	1.1
Phosphorus	0.6 - 0.9%	0.8
Potassium	0.2 - 0.5%	0.3
Organic Matter Content	35 - 45%	38
Moisture Content	45 - 50%	47
Water Holding Capacity	100 - 120%	105
Bulk Density	900 - 1000 lbs/cu. yd.	945
Soluble Salts	2.0 - 3.0 mmhos/cm.	2.1
Particle Size	> 90% passes 3/8 in. sieve	98%

Usage Instructions:

ABC Compost has detailed instructions available for a variety of uses. For more information on ABC Compost quality and use instructions, call our customer service department at 999-888-9999.

Additional parameter information that may be necessary for specific uses:

Ash Content (e.g. golf courses)
Boron (e.g. greenhouse/nursery)
Manganese (e.g. greenhouse)
Calcium Carbonate Equivalence (e.g. landscape, turf, agriculture)
Particle Size Ditribution (e.g. nursery, golf course)
Stability/Maturity (e.g. field crops, nursery)

Adapted from: William Greggs, The Proctor & Gamble Company sion-makers and public officials that the revenue may offset the cost of the market program but will not cover the cost of operating the organic recycling facility. Any net revenue should be considered as "gravy."

Develop Product Utilization Guidelines

The marketing plan must identify the guidelines that will be provided to potential users and how those guidelines will be developed. As with product specifications, it is important to provide users with guidance on how to use your compost and mulch products. Good guidelines will encourage proper use which, in turn, translates into satisfied users. Over 60 percent of biosolids composting facilities surveyed in 1994 published literature regarding use of their products. Table 4-2 provides general usage guidelines.

Several different guidelines will be required for separate end users and market segments. For example, landscape contractors and residents will need information on mixing ratios to amend soils in your region, application rates for topdressing lawns, planting mix ratios, etc. Nurseries may need to have information on proper mix ratios for potting media for specific crops.

The plan also needs to describe how the guidelines will be developed. Depending on the size of the marketing program and the targeted markets, it may be necessary to develop product-specific and region-specific utilization guidelines. In this case, the market plan will need to identify the steps to be taken. This may include growth trials and plot studies in coordination with an agricultural college or the TAEX to determine proper utilization or compiling existing research data.

Develop a Product Identity

The marketing plan needs to establish whether and how a specific name, logo, and identity will be developed for your products. This can be especially important for medium to large size facilities. An easily recognized product identity augments the marketing program. It is helpful to use a professional firm for developing and rendering a logo. Some brand names that are currently used for municipally produced compost and mulch include Dillo Dirt, TriGro, NutriGreen, EarthLife, AllGro, NutraMulch, ComPro, and Garden Care. A brand name can also be developed using a community campaign to generate a large pool of possible names. This approach helps to build involvement, support, and awareness of your plans to market your products.

Determine a Pricing Structure

Based on survey information, the market plan must establish standard unit price(s) for the products and determine whether separate prices are appropriate for different users or quantities purchased. A number of programs set a lower unit price for larger, bulk purchases. This helps to sell more product. The pricing structure can favor bulk purchases of a certain minimum size which corresponds with sizes typically purchased by the targeted users. Most well-run marketing programs charge $7 and higher.

Plan Research and Demonstration Activities

Research and demonstration activities are an integral part of a marketing program. The information generated from research into product utilization is employed in development of utilization guidelines and product specifications. Demonstration activities help to promote your products use and value to targeted users. They also build general awareness of the product's availability and benefits.

Research activities include: 1) gathering and review of existing data on product utilization, and 2) field research to verify product benefits and develop utilization guidelines. Based on review of this information, it is possible to determine what research needs to be conducted on your products. Actual design of the research study should be done in close coordination with trade associations for the potential users (e.g., Texas Association of Nurserymen), Texas A&M, or end users in your market region.

Research needs to focus on crops and end uses which have the potential to utilize large volumes of product. Given the fact that growth trials can be expensive and time consuming, this research should be limited to that which is essential to developing information for targeted markets. In some cases, research has already been conducted for the particular market or application you have targeted. In these cases, it may only be necessary to show that your product has the same or similar characteristics as the product used in the research.

Plan Public Relation and Education Activities

Public relations and education activities are closely linked with research and demonstration activities. The marketing plan needs to define the time schedule and scope for research and demonstration activities and how they will be publicized.

has addressed this latter problem by producing a free media packet. The packet includes promotional material, ad slicks, and scripts for radio commercials.

Displays

Displays can features live demonstrations in the form of potted plants, grass growth comparisons, and product samples. Product literature and prominent displays of a product logo help to build name recognition and generate new inquiries and new customers. This can be done at professional green industry trade association meetings, home shows, flower shows, or at retail locations.

Facility Tours

Tours of the organics recycling facility should be made available to both the public and specific potential users. Potential users should be encouraged to tour the facility so that they can get hands-on experience with the production process and quality control.

Hotline for Questions and Comments

Providing and widely advertising a phone number provides an increased level of convenience to potential customer who wish to inquire about your products.

Ensure Permits and Regulatory Compliance

The marketing plan needs to address compliance with regulations. The plan should clearly state that biosolid compost products will meet existing Federal Part 503 and Texas Chapter 312 regulations and all products will comply with forthcoming Texas compost regulations. The plan should detail all applicable rules and required permits. It should describe who will be responsible for compliance testing schedules, permit renewal requirements, and administrative structures needed to ensure compliance.

Current Texas fertilizer regulations pose a minor barrier to marketing compost. The regulations define any product which claims to enhance plant growth and/or guarantee N-P-K content to be a commercial fertilizer. All commercial fertilizers are subject to an inspection fee of 32 cents per ton distributed in the state. Given the prices charged for compost, this fee represent more of an administrative concern than an economic one for most facilities. For example, a large compost facility producing 60,000 cubic yards per year of compost (average density 1,000 lbs/cy) would pay $9,600 yearly while total product revenue would be $480,000 if prices average $8 per cubic yard. In this case the fee equals 2 percent of total revenue.

Common Aspects of Successful Programs

Based on review of dozens of marketing programs throughout the country, several common aspects are found in successful programs. When designing your marketing program these common aspects can serve as a check list to help ensure a marketing plan that will lead to success.

Your product should be perceived as valuable by you and the public

Product marketing implies value and income. Selling your products should be the goal of your distribution and marketing program. If compost and mulch products are given away, they may be perceived as valueless. In this case, the program is really only a distribution program. For medium to large scale facilities a give away program can be ineffective; sufficient demand is rarely created. Staff members producing the product must understand the product's value and user needs, as this is necessary to assure consistency.

Understand the composting process

Anyone responsible for marketing compost and mulch needs to be familiar with how the products are made. A firm understanding of the biological process and the transformation that occurs during composting will help you market and sell compost. Similarly, it is important to know how the facility is designed and operated to control product quality, eliminate contaminants, and ensure product consistency for both compost and mulch products. This knowledge will help to address users concerns about the products.

Produce a consistent, high quality product

Your compost and mulch products need to be of the highest quality obtainable given available staff, equipment, and financial resources. Not all facilities can produce "greenhouse-grade" compost or decorative mulches. However, the marketing plan needs to identify the markets that will utilize a product of the quality you produce. It is essential that product quality is consistent. If your products do not perform consistently for end users, it will be very difficult to secure long-term, stable markets.

Examples

Every distribution and marketing program will have its own unique marketing plan. It must clearly lay out program objectives and strategies for attaining them. More than a document on the shelf, the plan is really a living document and an ongoing planning process that changes as the program develops. The following examples provide a brief description of two fictitious community plans:

Large Metropolitan Facility:

A city in Central Texas (population 100,000) is developing a yard trimmings compost program. It is projected that 20,000 cubic yards per year of compost and wood mulch will be produced. Based on the results of a market survey and feasibility study completed by an independent consultant, the city has decided to operate its own distribution and marketing program. Due to the size of the planned facility, a marketing plan is completed before the facility construction begins. The plan concentrates on the initial program start-up.

A pilot scale facility is planned to produce some material before full-scale operations begin. The plan calls for hiring a full-time marketing program coordinator with specific knowledge of the green industry. The coordinator will then manage the development of a public promotion and education program, a demonstration site, field trials with potential users, public campaign to name the product, product testing, and a quality control program. Future year activities are planned to be less intensive with the main focus on expanding markets and maintaining good customer service.

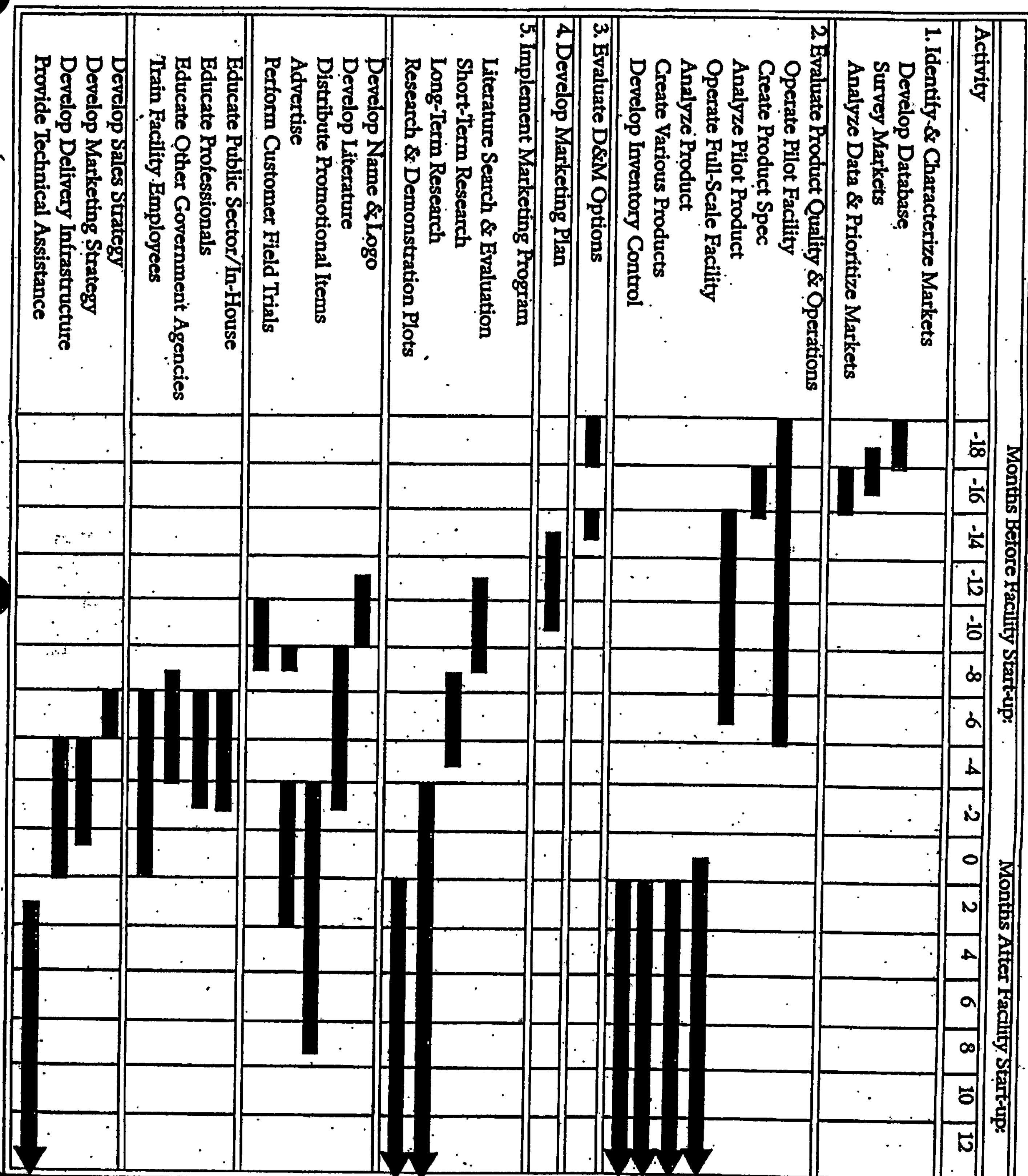
Small- to Medium-Size facility:

A small city in the Texas Panhandle (population 10,000) has started a yard trimmings compost program. The marketing program was not considered until after the facility began operations. It produces approximately 3,000 cubic yards per year of compost and wood mulch combined. A survey has found that much of the material could be used by public agencies. Distribution to residents is also planned. The marketing plan is a five page document that lays out the objectives, target markets, and logistics for distribution. It calls for the facility foreman to spend 25 percent time for at least a year coordinating with parks and public works departments to set up trials and provide information on proper utilization. A demonstration site is called for in cooperation with the parks department. Public outreach efforts will include a utility bill insert announcing the availability of products, public presentations, and facility tours. The plan establishes a policy of charging $8 per cubic yard but allows residents to take two bags per year for free. The market plan also calls for a quality control program at the facility to address problems of inconsistent product and to improve product stability by optimizing the composting process.

Table 4.4 Benefits of Using Compost

1. Improves the soil structure, porosity, and density, thus creating a better plant root environment.
2. Increases infiltration and permeability of heavy soils, thus reducing erosion and run-off.
3. Reduces water loss and leaching in sandy soils.
4. Supplies significant quantites of macro and micro nutrients.
5. Controls or suppresses certain soil-borne plant pathogens.
6. Supplies significant quantities of organic matter.
7. Improves cation exchange capacity (CEC) of soil and growing mixes, thus improving its ability to hold nutrients for plant use.
8. Improves soil and growing mixes microbiologically, by improving its microorganism population.
9. Stabilizes soil pH.

Table 5-1 Sample Time Line for Large Scale Composting Facility – Market Development



to create a reference library and information clearinghouse for both in-house education and support of the public education and promotion program. Next, it involves deciding whether in-house staff or an outside company will be responsible for marketing your products and bringing the right people on board to do the work. The marketing staff (whether in-house or not) must have a good understanding of the products and user needs. Typically a technical background in horticulture, agriculture, and soil science is crucial. A background in marketing or sales is an advantage and a background in marketing organic materials is ideal. Staff need to be trained and oriented to the specifics of your program: facility operations, local markets and market conditions, product characteristics, and product information and research data.

Technical assistance and information needs to be distributed to potential users. Efforts can draw from many resources: the reference library, marketing staff, researchers, TAEX agents, local innovators, and other experts who may be brought on to augment the development of markets.

Staffing

Large organic recycling facilities may require one or more full-time staff to manage the marketing program. Smaller facilities may only need to dedicate part of an existing staff person's time to marketing. The work load is determined by making a complete list of activities and projecting the time requirements. The list should include developing product identity, meeting with users, setting up demonstrations, coordinating research trials, publishing findings, and working with other agencies and the public to promote the value of the products. The staff may also coordinate a quality control program, oversee testing, handle logistics of delivery and transportation, manage recordkeeping, and meet regulatory requirements. Some large facilities may wish to hire an outside consultant to run the program under contract.

Broker Managed Marketing Program

If a broker is used to handle distribution and marketing you will need to perform the following for each potential product:

- Determine the level of broker/city responsibility desired.
- Develop request for qualifications.
- Shortlist potential brokers.
- Develop request for proposals.
- Choose preferred broker.
- Negotiate broker contract.

Broker/City Responsibilities

There are any number of ways in which the community and the broker can share the risks and responsibilities of a market program. Table 5-1 lists issues which should be addressed. Many of these issues will be negotiable throughout the procurement process, but since some can affect final facility design and some may not be negotiable, it is often better to at least discuss your preferences so that any solicitations will reflect these preferences while not necessarily precluding other alternatives.

You should reserve a certain amount of product for in-house use and keep this material outside of the contract. Alternatively, you may require the broker to handle all of the product produced between a guaranteed minimum amount and a ceiling amount with a provision that the community can purchase a certain amount yearly at a favorable price. A final alterative is that you may guarantee all product to the broker and purchase any you need on the open market. A larger quantity of material for sale will be viewed more favorably by a broker as it will be easier to amortize costs.

It also is necessary to determine the maximum length of a contract and what options should be included. It only makes sense that if a vendor knows that they will be in business marketing a product for a number of years that they would make more of an effort to promote the product than if they

Table 5-1 Options for City/Broker Contract Negotiations

- Amount of material to be marketed
- Length of contract
- Sole source contract
- Pick-up schedule
- Analytical responsibilities
- Record keeping responsibilities
- Revenue sharing
- Reimbursable costs
- Storage costs
- Storage locations
- Loading/access requirements
- Bonding/guarantee requirements
- Educational/promotional responsibilities

On-going Testing Requirements

Answering the following questions will help maintain a testing program appropriate for your facility and your markets. Testing requirements will include both the type of test and the testing frequency. The testing program needs to balance user and regulatory requirements against the costs associated with sampling and testing.

Are you required to comply with any State or Federal standards for compost?

Currently, only biosolids composts must comply with the standards established by the Federal Part 503 and Texas Chapter 312 regulations for heavy metals and pathogens. Composting regulations will be expanded on the state level to require the same level of testing for all composts. Forthcoming state composting regulations will specify required testing parameters, testing frequency, and sampling and testing protocols for all composting operations.

What are the primary concerns for your market?

A market survey can help you to understand the concerns of a specific market or market sector in your geographic area. Experience with compost marketing nationwide indicates that each sector has different requirements for compost. The testing program needs to address these user specific concern, in addition to any test required for regulatory purposes.

Do you use your testing program as a marketing tool?

Establishment of a testing program shows that your facility is committed to producing a quality product. Quality control program information should be advertised on bags or in pamphlets distributed with compost.

Quality Control

On-going quality control is essential. It requires close coordination between marketing efforts and facility operations. It needs to concentrate on two aspects: how can quality be controlled and how can product consistency be guaranteed.

Some parameters are a function of feedstock characteristics. In this case, mitigation through feedstock collection processes will affect compost quality. For example, leaves collected through a street sweeping program may have a higher concentration of heavy metals or contaminants than a bagged collection program; plastic bags can cause more inert contamination than paper bags; and biosolids quality can be improved through pretreatment programs. Some feedstock characteristics can be altered during the compost process with amendments (nutrients, lime) or by changing the process (screening, grinding). Other parameters such as stability and pathogen reduction are functions of how a compost facility is operated.

Regulations covering biosolids composting determine testing frequency based on facility size. For other parameters, frequency should be based on the overall consistency of your product. If the feedstock to the facility fluctuates seasonally, the testing schedule should reflect this. Certain large volume users may request or require a certain testing frequency in order to ensure product consistency and to provide information necessary to tailor their operations to variations in product characteristics.

Refining and Expanding the Marketing Program

Stay in touch with your markets on a regular basis. Meet with them to discuss how the compost or mulch products are performing and how well they are meeting the users needs. It is important to have marketing staff (in-house or contracted) who are familiar with how the users operate. For example, it is necessary to have a good understanding of what is important to landscapers and how they use the products in order to fully understand the product quality and customer service required to maintain a loyal customer base. A knowledgeable sales staff can provide good technical assistance to users - answering questions, discussing special uses, etc.

Suggestions for Success

Marketing compost and mulch is not an exact science. Each facility needs to assess its own unique situation and devise a marketing program tailored to its area markets, resources, and limitations. Some specific suggestions can be made to help improve the marketability of your product and improve the success of your program.

Produce more than one product

If your facility has the equipment and you have the resources available, it is good to produce more than one product. This allows you to meet a broader range of user demands. The most common practice is to screen finished product into specific size categories for different uses. Compost screened to 1/4 inch minus can be ideal for topdressing, seeding and sodding, and certain container mixes. A medium texture compost can in the nursery and landscape contractor associations and the farming community and concentrate your efforts on gaining their support so that they may become official or unofficial spokespeople.

Develop a program with diverse types of end users

Over reliance on one market sector can create difficulties if regulations and/or market/economic conditions change in the future.

Develop a demonstration site

An area should be set aside for demonstrating the uses and benefits of your product. The site may be located at the facility or it may even be located at a more visible location, such as city hall. The site should be a microcosm of various potential uses and should include signs that explain the uses and benefits of your products. The site may also serve as a test site for experimenting with different application rates, mixing ratios, growth trials, etc. The site serves as a great education and sales tool. Ultimately an educated customer is a compost user.

Develop a good sales staff

The sales staff must be trained and knowledgeable in the product's uses and benefits. They must believe in the product and its value. Finally, a good sales staff is hard working and dedicated to moving the product to the markets.

Keep up to date on new research

Efforts are continuing to expand our knowledge of how compost and mulch can be used. Research will also continue to address issues of health and safety in use of these products. For example, recent projects have researched and demonstrated the beneficial use of compost for athletic field maintenance, wetlands reconstruction, and roadside management. These represent new potential markets that may be worth developing in your program. By staying in touch with the research community, state composting staff, and industry trade journals in both waste management and the green industry, you can stay abreast of developments in the field.

Examples

Implementing a distribution and marketing program can involve many parallel activities or it may involve managing a contract with a single broker/blender who is responsible for the program. The following examples briefly describe how two fictitious facilities might complete this task:

Large Metropolitan Facility:

A facility in an East Texas city (population 70,000) producing 15,000 cubic yards of mulch and 25,000 cubic yards of compost plans to manage the marketing program itself. The market plan outlines two distinct phases. Phase I concentrates on marketing to landscapers, distribution to citizens, and in-house use by government agencies. Phase II targets development of specialty markets in the greenhouse and nursery sectors.

The facility was constructed before a marketing plan was developed and the facility has accumulated a backlog of 10,000 cubic yards of products. Due to this situation, a number of activities are undertaken simultaneously. Product testing establishes a guaranteed product quality. A technical data sheet and specific utilization guidelines are printed. A full-time staff person is dedicated in the initial year to developing markets, building consumer awareness, and providing technical assistance. Field trials are set up with a prominent landscaper and with city agencies. Citizens are actively encouraged to come get a free two-bushel sample. As a special promotion, 3,000 potted geraniums planted in a mixture containing the compost are sold at cost at a spring flower show. A comprehensive promotion program includes printed literature, regular contact with users, displays at civic events, and demonstration sites at city hall and the central park.

Based on a survey of private sector users, the facility determines that a delivery service can significantly increase demand. A local hauler is contracted to provide the service.

While efforts to build near-term markets are in high gear, the facility is setting up growth trials in coordination with the local agricultural college. Research objectives include comparison of watering and fertilization requirements against a standard potting media. Existing research on suppression of soil-borne diseases and plant growth is compiled. Regular product testing and a quality control program assure Phase II markets of a high quality and consistent product.

Small- to Medium-Size Facility:

A facility in West Texas (population 10,000) producing 4,000 cubic yards of compost and mulch per year has identified local agriculture, citizens, and other public agencies as its markets. The facility composts biosolids and yard trimmings. Efforts to increase citizen and in-house demand concentrate on setting up demonstration sites at the composting site and at city hall. Flyers describing the many benefits of compost and mulch and how to use them are mailed to all citizens along with a utility bill in the spring and fall.

Miscellaneous

COMPOSTING INDUSTRY INFORMATION

"Composting News" published 12 times a year
Published by McEntee Media Corporation
13727 Holland Road
Cleveland, OH 44141
Telephone: 216-362-7979
Fax: 216-362-6553
e-mail: mcenteemedia@compuserve.com
Internet: www.recycle.cc

Waste Age" published monthly
Published by PRIMEDIA, Inc.
Suite 300, 4301 Connecticut Avenue, NW
Washington, DC 20008
Telephone: 202-244-4700
e-mail: wasteage@envasns.org
Web site: www.wasteage.com

WEB SITES AND CONTACTS

The United States Composting Council, Post Office Box 407, Amherst, Ohio 44001-0407, USA
http://www.compostingcouncil.org/Index.html

The Composting Council of Canada, 16 Northumberland Street, Toronto, Ontario M6H 1P7, Canada
Phone: 416-535-6710, Fax: 416-536-9892

The United States Environmental Protection Agency, Washington, D.C.
http://www.epa.gov/osw

Cornell University, Department of Agriculture & Biological Engineering, Riley Robb Hall, Cornell University, Ithaca, NY 14853-5701, USA
http://www.cals.cornell.edu/dept/compost/
http://www.cfe.cornell.edu/compost/calc/cn_ratio.html

Master Composters
http://www.mastercomposter.com/
http://www.mastercomposter.com/calcc_n.html
http://www.mastercomposter.com/glossar1.html

COMPOSTING INDUSTRY INFORMATION

SAMPLING AND MEASUREMENT TOOLS

Instruments to measure pile key process variables-

Hand held instrumentation, instant readout only, for pile temperature and pile oxygen percent:

Demista Instruments
316 E. Foster St.
Arlington Heights, IL 60005
Telephone: 847-439-6857

Oxygen-Temperature Monitor Model No. OT-21

Hand held instrumentation, instant readout only, for pile temperature:

Reotemp Instrument Corporation
11568 Sorrento Valley Road # 10
San Diego, CA 92121
Telephone: 619-481-7737
1-800-648-7737
Fax: 619-481-7150

Temperature Probes

Hand held instrumentation, instant readout and data logging, other:

Marcom Industries, Inc.
948 Highland Ave.
Greensburg, PA 15601-4300 USA
Telephone: 724-832-0140
1-800-338-1572
Fax: 724-832-8185
Email: webmaster@marcom-ind.com
Internet: http://www.marcom-ind.com/
Internet: http://www.marcom-ind.com/compostccmain.htm#basic
Internet: http://www.marcom-ind.com/compost/ccprice.htm

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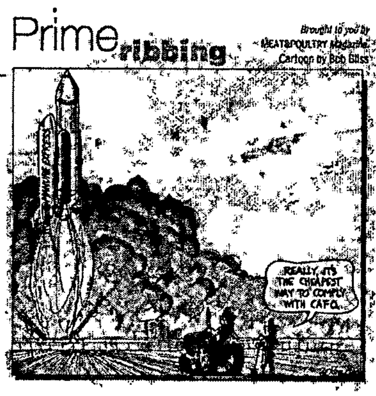
Federal ID No. 23-2073156

Composting Poultry Litter

Dr. Casey W. Ritz
Department of Poultry Science
The University of Georgia



Value of Layer Manure

40 lbs Nitrogen / ton	@ 35 cents / lb =	14.00
160 lbs Phosphorus / ton	@ 25 cents / lb =	40.00
80 lbs Potassium / ton	@ 12 cents / lb =	5.00
800 lbs Lime / ton	@ 2 cents / lb =	16.00
	Total	$75.00 / ton

$75 / ton x 600 tons = $45,000 or 45 cents per bird

Compost Nutrients

- A pound of nitrogen in the organically bound form has a significantly slower mineralization rate than does a pound of soluble nitrogen (Beegle, 1990; Simpson, 1991).
- Application of composted litter in which most of the nitrogen and phosphorus is organically bound is similar to split applications of commercial fertilizer (Bugbee and Frink, 1989).
- Good compost applied at the correct rate will generally out-perform a similar level of nutrients supplied by synthetic fertilizer (Holden, 1990).

- Compost can be applied at rates up to 50 tons per acre without environmental problems (Gouin, 1989). It is not clear if this rate is yearly; however, it is significantly higher than for raw litter.
- The high rate of application potential of compost attests to the stability and the safety of the material.
- Compost does not generate the odor and fly problems typically associated with raw litter (Murphy, 1991).

- Biocidal temperatures are achieved quickly when composting is done properly.

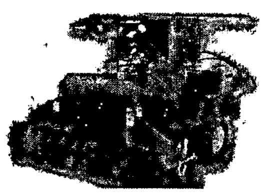
Composting Methods

Static pile – material is stacked and natural processes produces compost over a long time.

Aerated static pile – air is injected into pile with air ducts.

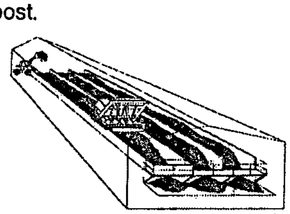
Composting Methods (contd.)

Windrow – Long piles turned with powdered turner that goes down lines.



Composting Methods (contd.)

In-vessel channel – Material is placed into long piles and roto-tiller machine travels on rails and turns the compost.



- How much dry matter with this C content would be needed? This is calculated as follows: Used litter: 80 tons of dry matter
- C-content: 39% N-content: 3.6%
- 80 tons x .036 = 2.88 tons or 5,760 lb of N
  80 tons x .39 = 31.2 tons or 62,400 lb of C
- At least 15 times the N-content is needed, therefore:
- 15 x 5,760 lb = 86,400 lb of C necessary
- Since 62,400 lb of C are already available in the house,
- 86,400 lb of C needed- 62,400 lb of C available
  24,000 lb of C must be added
- The C source is 53.6% C. Therefore,
- 24,000 lb of C needed ÷ 0.536 = 44,776 lb
  or 22.4 tons of litter must be added (dry matter basis).

How is water addition calculated?

- First, calculate the amount of dry matter in the house.
- Total litter weight: 114 tons Moisture: 30% or 34 tons Dry matter: 70% or 80 tons
- Total topdress weight: 48 tons Moisture: 50% or 24 tons Dry matter: 50% or 24 tons
- Combined totals in house after topdressing
- Dry matter: 104 tons Moisture: 58 tons Total: 162 tons
- To achieve the desired 45% moisture content, the following calculations will be necessary. Total dry weight of litter at 45% moisture or 55% dry matter:
- 104 tons D.M. + 0.55 = 189 tons
- Total necessary water addition:
- 189 tons - 162 tons = 27 tons of water
- How many gallons are needed?
- 27 tons x 2,000 lb/ton = 54,000 lb of water
  54,000 lb + 8.333 lb/gal = 6,480 gallons of water needed

Too little water:

- The heat required for proper composting (140-150°F) will not be attained in the first stage.
- The second stage composting temperatures will be very disappointing.
- Length of temperature rise and maintenance will be shortened.

Composting Points

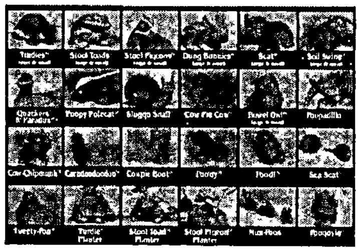
- A compost mass is self insulating.
- Composting materials produce ammonia, carbon dioxide, carbon monoxide, and methane. Therefore, compost in a ventilated facility or in the open.
- First stage compost should be turned when the center of the pile drops below 135°F. This should require 7 to 10 days.
- Mixing and reincorporation into Stage II compost is necessary for more thorough heating, uniformity, pathogen control.
- Stage II should heat very quickly and attain a center temperature of approximately 150°F within 24-48 hours.

Salt

- Soluble salts such as sodium or chloride can be a problem with some plants
- Potassium salts predominant in animal manures
- Some growers use salt to treat poultry house floors

Alternative Uses of Poultry Litter Products

Niche market merchandizing



Developing Markets for Compost

Making product is relatively easy, marketing product can be hard.

- Product must be uniform.
- Must be in quantities needed by buyer.
  - Wal-Mart will not want only 100 tons
- Screened compost can be bagged and sold at higher market value than unscreened compost that is sold in bulk.
- Pelleting makes a more desirable product.

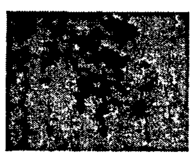
Rationale

Composting of contaminated litter and carcasses destroys pathogens in poultry houses, thus reducing the potential for disease spread.

Previous research suggests that Avian Influenza virus can be inactivated at 140°F (60°C) in 10 minutes or 133°F (56°C) in 15 to 20 minutes (Senne et al. 1994).

Points of Clarification for Existing Regulations

- Mortality compost may be land applied on property other than that of the poultry production operation as long as it is well composted.
- Typically, this means a minimum of two heating cycles are needed before the material is appropriate for land application.

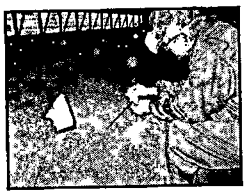


Composting Methods

- Layering
- Mixing

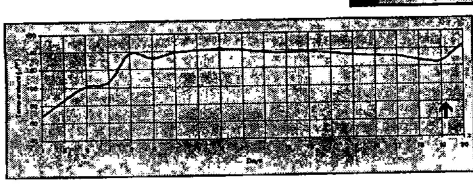
All Methods Require Temperature Monitoring

Use a long-stem composting thermometer to check daily temperatures. The temperature should reach a minimum of 135°F (57°C) within 5 days after compost formation.



All Methods Require Turning

After 10 to 14 days, the compost temperature will decline. As it drops below ~130°F, turn the windrows.



For All Methods Cap The Turned Windrow

Cap the new windrow with a minimum of 6 inches of litter or sawdust to cover any exposed carcasses.