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COMPOSTING FOR ARMY INSTALLATIONS

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FACILITIES ENGINEERING
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COMPOSTING FOR ARMY INSTALLATIONS

1. Purpose. The purpose of this Public Works Technical Bulletin (PWTB) is to transmit current information on composting technology and procedures that can be implemented at Army installations.

2. Applicability. This PWTB applies to all U.S. Army facilities engineering activities.

3. References.

a. AR 420-49-02, Facilities Engineering Utility Services, 28 May 1997.

b. U.S. Environmental Protection Agency (USEPA), Composting Yard Trimmings and Municipal Solid Wastes, 530-R-94-003, May 1994.

c. On-Farm Composting Handbook, Northeast Regional Agricultural Engineering Service-Cooperative Extension, NRAES-54, June 1992.

4. Discussion.

a. AR 420-49 contains policy and criteria for the operation, maintenance, repair, and construction of facilities and systems, for efficient and economical solid (nonhazardous) waste management including source reduction, re-use, recycling, composting, collection, transport, storage, and treatment of solid waste. Chapter 3 gives general guidance on all aspects of solid waste management, including composting (in section 3-3i).

b. Organic, compostable materials comprise a large fraction of the municipal solid waste stream. Capturing these for composting will reduce the volume of waste that an installation would otherwise dispose of in a landfill. Compostable materials include yard waste, food scraps, and some paper products. The finished compost product can provide soil conditioners, landscape mulch, backfill, resurface material for eroded areas, and landfill cover.

c. Appendix A gives detailed information on composting techniques and equipment applicable to large scale operations at Army installations. Appendix B lists sources of additional information.

5. Points of Contact. HQUSACE is the proponent for this document. The POC at HQUSACE is Mr. Malcolm E. McLeod, CEMP-RI, 202-761-0206, or e-mail: malcolm.e.mcleod@usace.army.mil.

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APPENDIX A

Installation Composting Guide

1. Framework for Composting

a. Introduction.

(1) An integrated approach is vital and necessary in the planning and development of a solid waste management program. Planners in Federal, State, and local governments, and in the private sector consider a hierarchy of methods for this integrated solid waste management (ISWM) program: source reduction, recycling and composting, incineration, and landfilling. Source reduction prevents problems associated with disposal and is the most favorable waste management tool. Recycling (including composting) diverts wastes from incinerators and landfills and provides for the reuse of resources. Incinerating waste is next in the hierarchy; it reduces volume and can recover energy. Landfilling is the least preferred waste management method. (Landfills are very costly to site and maintain.) The installation ISWM program may include any combination of these methods. This guide addresses composting.

(2) Military installations could cut their reliance on dwindling landfill space by as much as 50 percent by implementing a compost program. Huge volumes of yard waste (green waste), papers, food waste, and other organics can be composted in a simple, outdoor windrow system. Diverting this large amount of municipal solid waste (MSW) from landfills could greatly aid military installations in meeting Federal/State waste reduction goals. Figure A1 shows what our solid waste is composed of, based on national averages. The potentially compostable fraction would be the yard trimmings (13.1%), food (10.4%), wood (5.2%), and 70% of paper products (27%). Of course, many paper products such as newspaper and cardboard are actively recycled. The food waste figures include uneaten food and food preparation wastes from residences, commercial establishments, institutional sources such as school cafeterias. It does not include waste from food processing industries. This is a total of 56% of the total solid waste stream. Currently, only 27% of solid waste is recycled or composted, nationwide. This does not count private citizens composting in their back yards.

(3) Most food waste is technically compostable, i.e., edible means compostable. However, some materials are difficult to handle or take longer to biodegrade such as fats, bones, and eggshells. On average, roughly 70% of food wastes would be easily compostable given that proper conditions are present.

(4) Many States have recycling goals and ban landfill disposal of materials such as yard waste and tires. Under the Federal Facilities Compliance Act, Army installations must follow State policy in these matters. Figure A-2 shows the States that

have banned yard waste from their landfills. Because yard waste can comprise nearly one half of the solid waste stream, banning the landfilling of yard waste has dramatically increased the life expectancy of some States' landfills. States also have their own recycling or waste reduction goals. Although there is no real enforcement mechanism, the military should try to meet these goals because Army installations are a large and integral part of States' economies.

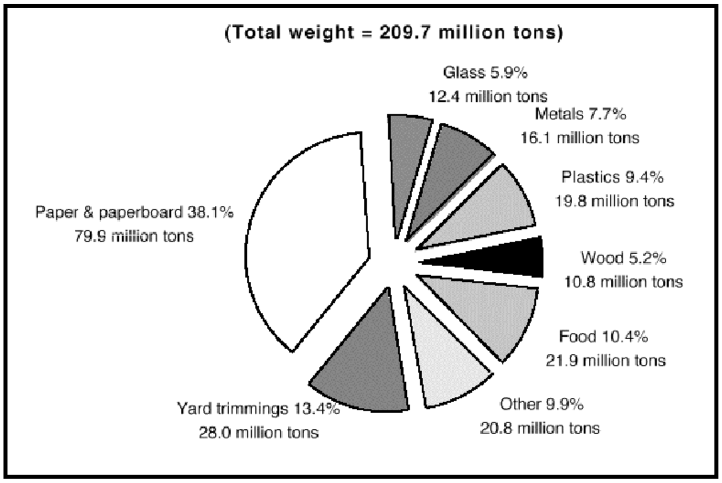

Figure A-1. Materials generated in MSW by weight. (Source: *Characterization of Municipal Solid Waste in the United States: 1997* Update; USEPA; Office of Solid Waste; Report No. EPA530-R-98-007; May, 1998.).

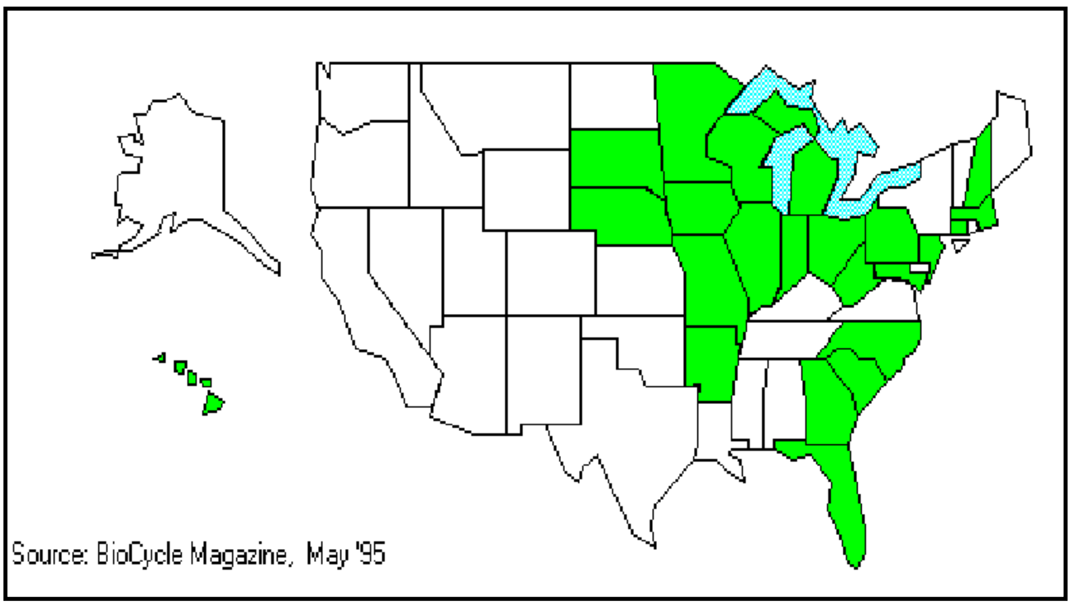

Figure A-2. States with yardwaste bans (Source: USEPA *Factbook*).

(5) Planning and Management

(a) This document focuses mainly on the technical aspects of composting yard wastes as well as other compostable materials. However, planners must consider several other issues.

(b) In the initial planning stages, make every effort to involve all interested parties because there are a host of regulatory, social, and economic issues that must be addressed. The siting of any type of waste management facility can spark heated citizen reactions. The situation is a bit different on a military installation, but you still want to be a good neighbor, and you certainly do not want to adversely impact soldiers in any way.

(c) The first question is, what are the goals of the composting program? Clearly define the goals and whatever pressures are pushing you to reduce waste. Then, who will own and/or operate the compost program – the Federal government or a private contractor?

(d) Then you will need to assess the solid waste stream. What fraction is compostable? Where is it generated? What type of collection system will most efficiently gather the highest portion of compostables? The type of waste will, in part, influence the choice of composting technology.

(e) If the composting facility will be Federally owned, you will have to site the facility on the installation, ideally, downwind from the cantonment area, well within installation boundaries, with clay-type soil high above the water table.

(f) Who will use the finished compost? In many cases you will have a built-in market; large troop-based installations are analogous to small cities. You must compare your potential compost generation to the demand. Also, weigh the cost of constructing and implementing composting against landfill diversion, and the value of finished compost.

(g) These types of questions must be addressed before expending funds on equipment or site design. A software tool that can be used to help estimate the cost of composting and material quantities is "Solid Waste Options," available from the listed ISD or CERL POCs for this PWTB. Appendix B lists useful references and State-by-State POCs who can answer many questions.

2. Compost Science & Techniques

a. Composting is a controlled biological decay process involving many species of microorganisms and invertebrate animals (i.e., bugs). However, humans can intervene in this natural process by manipulating the organic materials and environmental conditions to speed up the composting process. The biological and physical processes are highly interrelated.

b. Science. The main factors that influence the composting process are:

- Carbon and Nitrogen Content (C to N ratio)
- Oxygen (O2) Concentration
- Moisture Content
- Particle Size
- Temperature.

c. Carbon and Nitrogen Content

(1) Carbon (C) and nitrogen (N) are required nutrients for microorganisms to grow and multiply. Ideally, the compost operator should strive for a ratio of approximately 30 parts carbon to 1 part nitrogen (by dry weight). The correct C/N ratio (C:N) allows for rapid and efficient degradation of organic material. Typically, green, wet plant materials have a low C:N (high N), and brown, dry materials have a high C:N (high C). Table A-1 gives examples of this.

Table A-1. Examples of high N and high C materials.

Green Materials (High N)	Brown Materials (High C)
Fresh grass clippings	Dried leaves and plants
Manure	Wood chips
Garden plants	Dried crop residue
Food scraps	Hay, straw
Green leaves	Tree bark
Sewage sludge (biosolids)	Waste paper

(2) Too low a C/N ratio (low C, high N) will cause the material to degrade too rapidly, usually producing unpleasant odors, under *anaerobic* conditions. Too high a C/N ratio (high C, low N) will slow or even stop the composting process. In reality, the correct ratio can be difficult to achieve. Some trial and error may be necessary because obtaining the correct mixture is more of a learned skill than a precise science. Nonetheless, Section gives a sample calculation.

d. Aerobic Degradation

(1) Microorganisms need an adequate supply of oxygen to effectively degrade organics into carbon dioxide (CO_2), humus, and inert mineral compounds. This is called aerobic biodegradation.

(2) Without oxygen (*anaerobic* conditions) organic materials will still degrade. This is what occurs in landfills and wastewater sludge digesters. However, the products of anaerobic degradation include methane (CH_4) and noxious sulfur compounds (which yield a characteristic "rotten egg" odor). The result is a smelly mess.

(3) As the aerobic degradation proceeds, the microorganisms deplete the available oxygen inside the compost pile. Air must periodically be introduced into the pile in a variety of ways. In backyard composting, the pile is simply turned with a shovel or pitchfork. Compost is turned mechanically in large-scale composting facilities using either front-end loaders (wheel loaders) or specialized machines known as "windrow turners."

e. Moisture Content

(1) Water is another essential element for successful composting. Water dissolves the organic and inorganic nutrients in the pile making them available to soil organisms for metabolic processes. Ideally, the moisture content of the compost pile should be between 40 and 60 percent by weight. Too wet a pile will bring about anaerobic conditions, while a lack of moisture will slow or stop biodegradation.

(2) Compost facilities in regions with dry climates will have to add water periodically to maintain the correct moisture balance.

f. Particle Size

(1) The surface area of organic materials exposed to soil organisms also determines the rate of composting. The more finely ground a material, the higher the surface area per unit weight. To increase the rate of decomposition, large pieces and hard materials should be ground, shredded, chipped, or otherwise reduced in size. This is especially important for woody materials, large garden plants, and some food scraps (e.g., citrus rinds, onions, broccoli).

(2) Again, a careful balance must be struck. Small particle size does increase the decomposition rate. However, it also reduces the porosity, or air void space, of the pile. Low porosity restricts the flow of oxygen into and throughout the pile, causing oxygen depletion and anaerobic conditions.

(3) The solution to decomposition problems caused by too much "same-sized" composting materials is to ensure a combination of fine and coarse materials in the mix. A mix of leaves and grass should be augmented with a bulky material (e.g., wood chips) to increase porosity. In fact, wood chips are often referred to as a *bulking* agent, especially in large industrial composting facilities.

g. Temperature

(1) A well-operating compost systems will hold interior temperatures between 90 and 140 EF. The temperature is measured with a long stemmed thermometer (figure A-3), at a depth of at least 18 in. Temperatures above 140 E F will begin to limit microbial activity. Exceeding 160 EF can be lethal to your helpful soil organisms.

(2) Maintaining high temperatures is necessary for rapid composting, as well as to destroy weed seeds, insect larvae, and potential plant and human pathogens.

(3) All of the above physical factors are important for successful composting. However, of these, temperature is the most important for monitoring. By recording and graphing the temperature over time, the operator will have an excellent grasp of the status of the "windrow." After raw compost is first placed, the temperature will rise to a plateau of around 140 EF (depending on the external temperature). If the temperature rises above the plateau, or begins to decrease, then it is time to turn the windrow to introduce more oxygen. The act of turning will dramatically lower the interior temperature, but it will rise again to the plateau. If, after adequate time and several turnings, the temperature does not increase after a turn, this is a good indication that the windrow has finished composting.

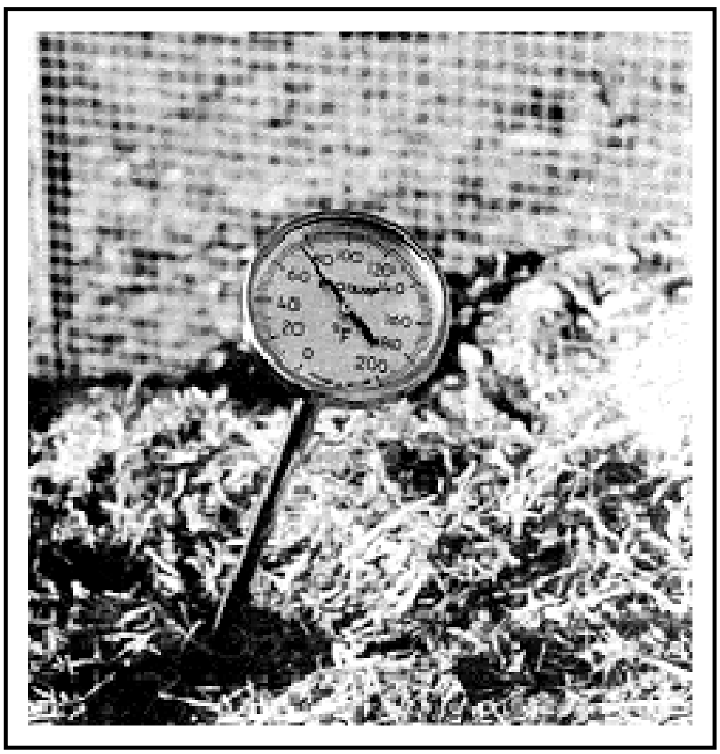

Figure A-3. Compost thermometer.

h. Summary. Table A-2 gives a summary of the optimal composting parameters discussed in this section.

Table A-2. Summary of optimal composting conditions.

Condition	Preferred Range
Carbon to Nitrogen ratio (C:N)	25:1 to 30:1
Moisture content	50 to 60%
Oxygen concentration	>5%; high as possible
Particle size	should contain a mix of sizes, from very small to 2-3 in.
pH	6.5 to 8.0 (neutral)
Temperature	130 to 140 F

(1) Mix Design

(a) Combining the above factors into a successful compost process is a learned skill. Nonetheless, a good compost mix can be planned and modeled mathematically. This can be done on paper, with a spreadsheet, or with an automated computer program. Figures A-4 and A-5 show a spreadsheet model used to calculate the correct mix between five different materials.

(b) The user may input known data about the materials into a spreadsheet. (Figure A-3 shows a good model with formulas.) In the spreadsheet shown in Figure 3, the user inputs the information in the light gray shaded cells: product name, %C, %N, %moisture, bulk density (lb/cu yd), and daily (or batch) volume (cu yd). The %C and %N are obtained through laboratory analysis or can be found in commonly available reference books. If your reference book gives %C and C:N, you can back-calculate %N, or vice versa. Percent moisture and bulk density are best determined through field measurements. Note that this spreadsheet works equally well for English or metric units. Just be consistent throughout in your choice of units for volume and weight (mass).

(c) After entering the material properties, the user simply adjusts the daily volumes by trial and error until the C:N and moisture content for the mixture fall into the acceptable range.

(d) If moisture must be added to the compost, simply add another product line to the spreadsheet for water with %C=0, %N=0, %moisture=100, and bulk density=1,685 lb/cu yd (1000 kg/m^3). Then adjust the daily volume of water until the %moisture for the mixture is about 50.

test recipe

Ingredient Data

Product	%C (dry)	%N (dry)	C:N ratio	% moisture	lb/yd^3 bulk density	daily volume
Sludge	50	5	10	80	1500	115
Yard	60	2.5	24	70	450	666
Food	30	2	15	69	400	41
Paper	40	0.25	160	19	600	446
Manure	48	1.6	30	72	1379	1.7

Carbon-Nitrogen Balance

Product	Dry weight	%C (dry)	C (weight)	%N (dry)	N (weight)
Sludge	172,500	50	86,250	5.0	8,625
Yard	299,700	60	179,820	2.5	7,493
Food	16,400	30	4,920	2.0	328
Paper	267,600	40	107,040	0.3	669
Manure	2,344	48	1,125	1.6	38
Total	758,544		379,155		17,152
TOTAL C:N=	22				

Moisture Balance

Product	% moisture	% solids	dry weight	wet weight	water weight
Sludge	80	20	172,500	862,500	690,000
Yard	70	30	299,700	999,000	699,300
Food	69	31	16,400	52,903	36,503
Paper	19	81	267,600	330,370	62,770
Manure	72	28	2,344	8,373	6,028
Total			758,544	2,253,146	1,494,602
TOTAL % moisture=		66			

SUMMARY for Mixture

C:N=	22
% moisture=	66

Fort Sill recipe

Figure A-4. Recipe spreadsheet.

(e) Figure A-5 shows the same spreadsheet as shown in figure A-4, except that the calculated values are replaced with the formulas, to allow the readers to easily reproduce this spreadsheet on their own computers.

(2) Techniques

(a) Several different techniques are used in composting. The selection of the correct method depends on the type of material to compost, the amount of land area available, and the available budget. This document focuses on windrow composting of typical yard wastes, such as grass, leaves, wood, etc. However, each technique presented in this section is described for its applicability and for the pros and cons involved in its use.

i. Home or Backyard Composting

(i) Backyard composting is the most practical and cost-effective method for managing yard wastes and some food wastes from single family housing areas. It eliminates the need for specialized collection systems (vehicles) and centralized composting facilities (permitting). This type of program is limited only by the motivation of the residents and resourcefulness of the program administrators. Additional source material can be found at URL: http://www.epa/gov/epaoswer/non-hw/compost/index.htm. Table A-3 lists materials to include in (or exclude from) backyard composting.

test recipe with formulas

	A	B	C	D	E	F	G
1	**Ingredient Data**						
2						lb/yd^3	
3	Product	%C (dry)	%N (dry)	C:N ratio	% moisture	bulk density	daily vol
4	Sludge	50	5	=B4/C4	80	1500	115
5	Yard	60	2.5	=B5/C5	70	450	666
6	Food	30	2	=B6/C6	69	400	41
7	Paper	40	0.25	=B7/C7	19	600	446
8	Manure	48	1.6	=B8/C8	72	1379	1.7
9							
10	**Carbon-Nitrogen Balance**						
11							
12	Product	Dry weight	%C (dry)	C (weight)	%N (dry)	N (weight)	
13	Sludge	=F4*G4	=B4	=B13*C13/100	5.0	=B13*E13/100	
14	Yard	=F5*G5	=B5	=B14*C14/100	2.5	=B14*E14/100	
15	Food	=F6*G6	=B6	=B15*C15/100	2.0	=B15*E15/100	
16	Paper	=F7*G7	=B7	=B16*C16/100	0.3	=B16*E16/100	
17	Manure	=F8*G8	=B8	=B17*C17/100	1.6	=B17*E17/100	
18	Total	=SUM(B13:B17)		=SUM(D13:D17)		=SUM(F13:F17)	
19	TOTAL C:N=	=D18/F18					
20							
21	**Moisture Balance**						
22							
23	Product	% moisture	% solids	dry weight	wet weight	water weight	
24	Sludge	80	20	=F4*G4	=D24/(C24/100)	=E24-D24	
25	Yard	70	30	=F5*G5	=D25/(C25/100)	=E25-D25	
26	Food	69	31	=F6*G6	=D26/(C26/100)	=E26-D26	
27	Paper	19	81	=F7*G7	=D27/(C27/100)	=E27-D27	
28	Manure	72	28	=F8*G8	=D28/(C28/100)	=E28-D28	
29	Total			0	=SUM(E24:E28)	=SUM(F24:F28)	
30	TOTAL % moisture=		=F29/E29*100				
31							
32							
33	SUMMARY for Mixture						
34							
35	C:N=	=D18/F18					
36	% moisture=	=C30					
37							
38							

Test Recipe

Figure A-5. Test recipe with formulas.

(ii) Factors against backyard composting include: lack of command support, lack of space in yards, resistance from residents, and the low percentage of residents in single family housing.

(iii) The most common method for backyard composting is to place an appropriate mixture of materials into a bin or a series of bins. These bins should be at least 1 cubic yard in size to properly maintain heat.

(iv) Composting bins can be purchased or constructed from inexpensive materials. A simple wooden compost bin could easily be made with discarded wood scraps (like those taken from old pallets). A more sophisticated three-section wooden bin (figure A-6) could be used in turning the compost and/or to allow the composting of different materials at different stages. If you are constructing bins of wood, *do not* use pressure-treated lumber unless you are certain that the resulting compost will not be used in growing food.

Table A-3. Materials to include in and exclude from backyard composting.

Materials Suitable for Backyard Composting	Materials Not Suitable for Backyard Composting
Plants, weeds, grass	Bones
Bread, coffee grounds and filters, egg shells	Pet manures (e.g., dog or cat)
Farm animal manures	Dairy products
Garden trimmings	Diseased plants
Leaves	Meat scraps
Straw	Mayonnaise, salad dressing, cooking oils, lard
Soiled or nonrecyclable paper (shredded)	Noxious weeds like poison ivy or nightshade
Wood chips, twigs, shredded branches, and sawdust	Weeds that have gone to seed
Fruit and vegetable scraps	

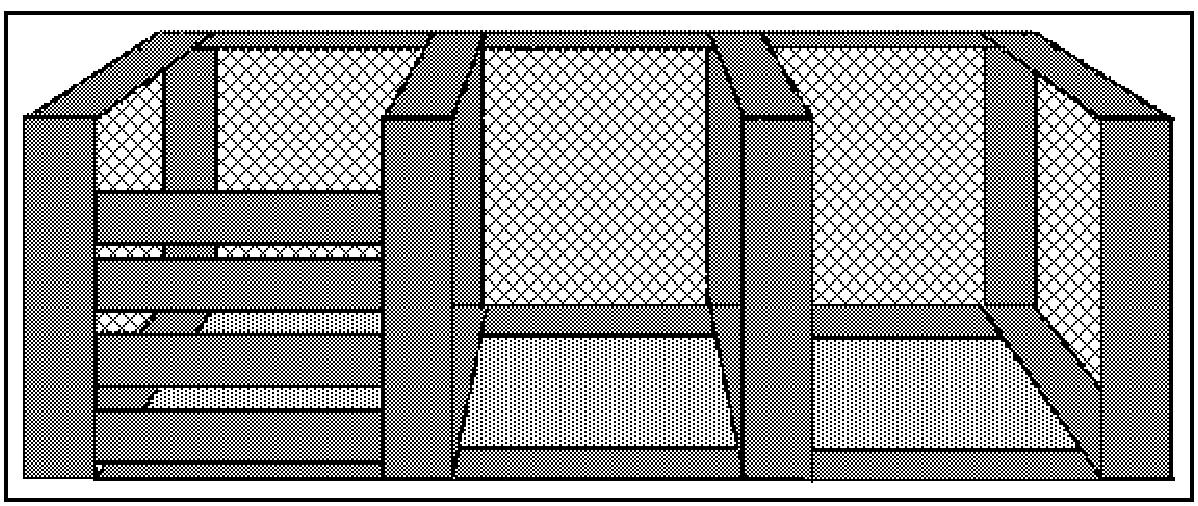

Figure A-6. Three section wood bin.

(v) Bins are also available commercially at garden centers. Most of these are made from plastic to prevent rotting. The least expensive bins could be made of a simple plastic cylinder, which might be used as an enclosed backyard bin. The enclosed models might be more appropriate when there is little backyard space, or when composting a high percentage of food scraps. Some of the enclosed models are insulated to allow backyard composting throughout the winter months in cold climates.

(vi) One of the most dramatic impacts that a resident can make is to simply leave grass clippings on the lawn. There is no reason to bag grass clippings, especially with the current availability of mulching mowers. The clippings will decompose naturally and return some nutrients back to the soil.

ii. Static Pile

(i) A comprehensive composting program will require a central facility to handle compostable materials from residential areas, grounds maintenance, and possibly food wastes and nonrecyclable paper. Four different types of centralized composting facilities are applicable to Army installations: static pile, turned windrows, aerated windrows, and in-vessel.

(ii) Static piles are the simplest and least expensive method of large scale composting. In fact, the word “composting” may not really apply. The idea is to simply make a large pile of homogeneous materials that you wish to decompose over time. The best example is a leaf pile.

(iii) A static pile should only be used for materials with high carbon content (very high C:N). The goal is to have the pile degrade very slowly to eliminate the need for any human intervention. Too much N will cause rapid decomposition and require that the pile be turned to avoid anaerobic conditions.

(iv) Static piles should be kept in windrow formation for convenience and safety reasons. In the unlikely event that the pile should begin to smolder, it would be much easier to reach and extinguish the material in a windrow rather than a pile that is high, wide, and deep.

(v) Static windrows are also used for curing and storing finished compost.

iii. Turned Windrows

(i) Turned windrows are the most common type of central composting facility. They are most often used for yard wastes, leaves, wood chips, and manure. They can also be used for food wastes, sewage sludge, and nonrecyclable paper under carefully controlled conditions.

(ii) Windrows do require a large land area for implementation, not only for the rows themselves, but to allow enough space for mixing, stockpiling, and maneuvering the large machinery involved in moving and turning material (see Section 3, p A-14). Figure A-7 shows compost windrows at Fort Riley.

Figure A-7. Windrows at Fort Riley.

(iii) Because windrows are exposed to the elements, aeration, moisture, and temperature must be monitored and maintained. Composting time is quite variable with this system. The time depends largely on frequency of windrow turning.

(iv) Turned windrows require environmental permits from State regulators.

iv. Aerated Windrow

(i) An aerated windrow is not turned mechanically to increase oxygen. Rather, the compostables are piled over a series of perforated pipes to which a blower is attached (Figure A-8). This process is most applicable for co-composting sewage sludge, municipal solid waste (MSW), and yard wastes.

(ii) These systems can incorporate electronic controls that adjust the blower based on the internal temperature of the pile. The blower can either pull or push air through the pile. Pushing air through the pile guards against clogging the pipe. Pulling the air through allows you to trap any odors in a biofilter – a container of activated carbon, finished compost, or similar organic material.

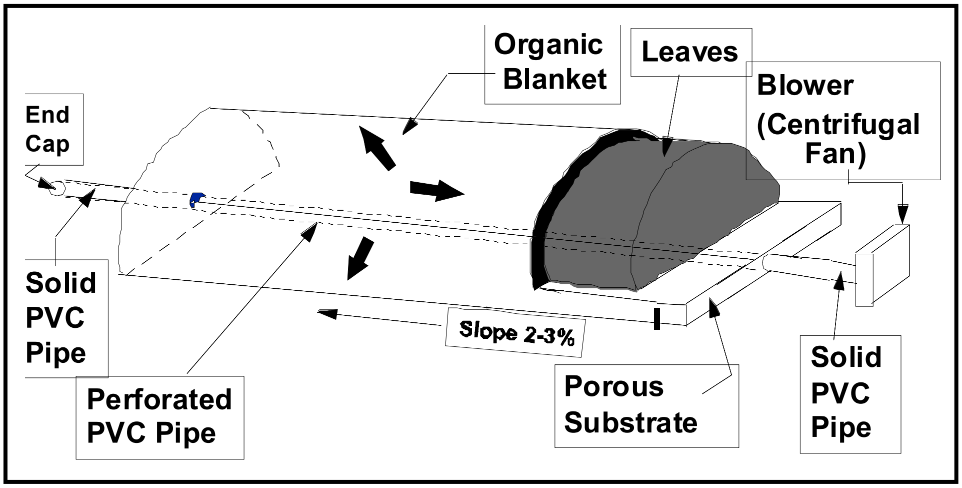

Figure A-8. Aerated static pile.

(iii) Properly controlled, the piles are not turned until the end of the process. Aerated windrows would also require environmental permits.

v. In-Vessel Systems

(i) In an in-vessel composting system, materials are first batch mixed* in a special mixing device to achieve the correct C:N and moisture content, then placed into an enclosed chamber or vessel. These containers can take many forms, but a common format uses modified roll-off boxes (figure A-9). These proprietary systems can be quite sophisticated and are designed to minimize composting time. Air is blown into the box to provide aeration.

(ii) Because these systems are closed, all the requisite environmental conditions (i.e., aeration, temperature, moisture) are kept at optimal levels throughout the composting process, which can take as little as 1 week.

(iii) In-vessel composting is ideally suited for handling materials, such as food waste or sewage sludge, that might cause odor or pest problems if left exposed. This system does not take up much space since all material is containerized.

(iv) The cost of equipment necessary for an in-vessel system is on the order of tens to one hundred thousand dollars. However, these systems are modular in nature and can be easily expanded as material volumes increase.

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*Batch mixing” refers to placing certain proportions of materials together in a container for mixing. After mixing, the container is emptied, and the process is repeated. This term is used to distinguish from a continuous mixing process.

Figure A-9. In-vessel containers.

(v) The big advantages to in-vessel systems is that there is no runoff to control, and they can be used without complex site preparation. These avoided costs may outweigh the expense of the specialized equipment. Because there is no significant earthwork or infrastructure required, these systems can be set up at several, or varying locations across the installation. They can be moved relatively easily, whereas you cannot move a tradition outdoor windrow site.

i. Summary. Table A-4 summarizes the pros and cons of the composting methods discussed above.

3. Heavy Machinery for Composting. Currently, relatively few installations use composting as part of their integrated solid waste management strategy. One barrier to implementing a compost program is unfamiliarity with and expense of the specialized equipment typically used in large-scale compost operations. This guide gives some basic information on size reduction equipment, windrow turners, and screens available, and lists the pros and cons of these equipment types. Appendix B lists manufacturers.

a. Size Reduction Equipment

(1) The particle size of organic materials slated for composting must be small enough to promote rapid decomposition. For a given amount of material, smaller particle size means

greater surface area exposed to soil organisms that perform the desired biodegradation. However, some fraction of larger pieces should remain to increase porosity and allow for natural aeration through convection. Unless the incoming material consists only of small items (e.g., leaves and grass), some sort of mechanical reduction will likely be necessary. Two broad categories of size reduction equipment are high speed grinders and low speed shredders. "High" and "low" speed refer to the rotational speed of the hammers or cutters, and not necessarily machine throughput.

Table A-4. Summary of compost methods.

Method	Land area required	Pros	Cons
Static pile	Controlled only by amount of material	Low maintenance, may not require permit	Limited types of material, slow degradation
Turned windrow	Large, for materials and equipment	Simple and effective for wide range of materials; large or small scale	Requires State permit, heavy machinery, monitoring
Aerated windrow	Moderate area, less intensive material handling	Direct odor control, parameters electronically monitored and controlled	Expense, complexity of control equipment; not for very large scale
In-vessel	Small area; concrete pad required	Odors and vectors controlled; may not require State permit; fast compost times; no runoff; no earthwork for site preparation	Complex, specialized equipment required; potential high capital cost

(2) Tub Grinders

(a) Tub grinders are the most common type of high speed grinder. The entire unit is roughly the size of a semi-trailer (figure A-10). It consists of a large "tub" that rotates over a high speed, horizontal hammer mill. The output particle size is controlled by a perforated grate under the hammers. Tub grinders process organic wastes, especially woody materials, very quickly and produce a uniform, chipped product. They do not tolerate contamination with metals, as a large metal object in the chamber could do significant damage in a short time. Drawbacks to using tub grinders include noise and flying debris. Because the hammer chamber is open, the high speed hammers can eject material a significant distance from the machine unless the operator keeps the tub full.

Figure A-10. Tub grinder.

(b) This equipment allows the tub to tilt up (Figure A-11) to allow access to the hammers, to ease maintenance, and to remove any debris that becomes stuck. The hammers themselves each weigh 5 pounds and the wear surfaces can be coated with a sacrificial weld material to extend their useful life. The hammers swing freely on their axis as the entire drum turns at high rotational speed (Figure A-12).

(c) The size of the output from the tub grinder is governed by the size of the holes in the grate under the hammers. Usually the perforations range in size from about ½ to 3 in.

Figure A-11. Tilted tub grinder.

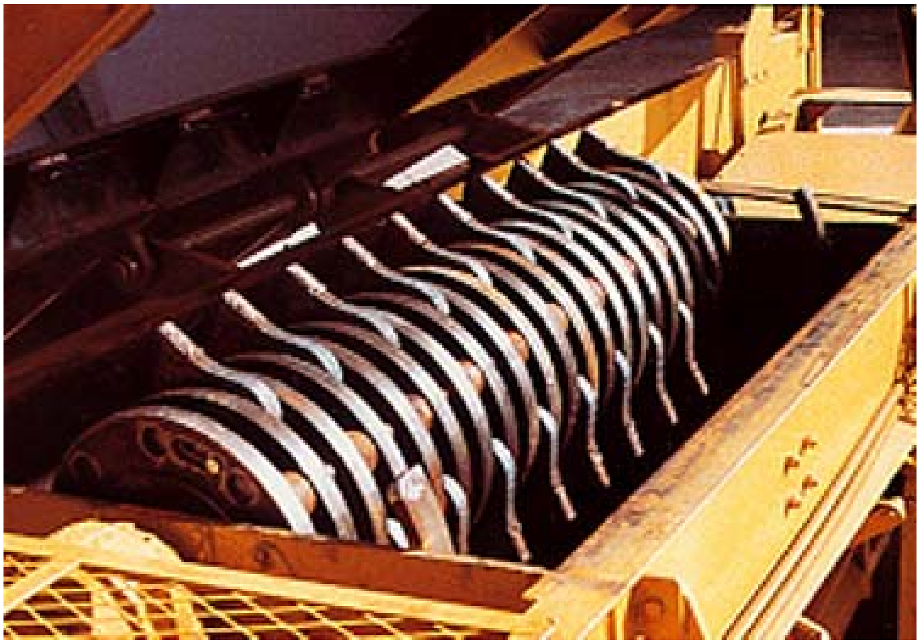

Figure A-12. Tub hammers close up.

(3) Horizontal In-Feed Grinders

(a) The other common type of high speed grinder consists of an enclosed horizontal shaft hammer mill with an in-feed conveyor or platform. A front-end loader places material to be reduced in the central section of the machine. The material is then moved with a belt or hydraulic ram into the hammer mill chamber.

(b) These machines can handle a wider range of materials than tub grinders, depending on power and configuration. Machines of this type (figure A-13) can grind many different types of debris, short of metals or rock. It uses small, hardened teeth on a the high speed rotating drum. Particle sized is determined by a perforated grate like a tub grinder. Processing material through a grate results in uniform-sized output, which is good for producing wood chips, but (because the grate is solid and has no “give”) it is more prone to clogging.

(c) A lighter duty grinder is best suited for preparing mixed yard waste for composting, but not for producing uniformly sized wood chips (figure A-14). Such a grinder uses a set of small, free-swinging hammers that rotate on a drum through a set of parallel bars, like a comb (figure A-15). (Photos courtesy of Fecon, Inc. Composting Equipment. (photo courtesy of Fecon, Inc. Composting Equipment) This arrangement results in less clogging and an end product that looks more shredded than chipped. Because the processed material is not uniformly sized, it yields a good mix of high surface area and porosity, important elements for ventilation, as discussed in Section 2 (p 8).

Figure A-13. Heavy duty grinder.

Figure A-14. Grinder with in-feed conveyer.

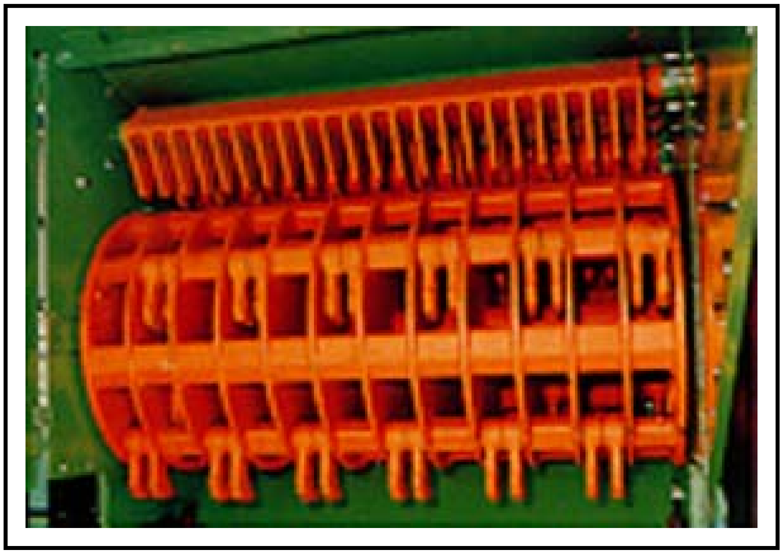

Figure A-15. Flails and sizing "combs."

(d) In general, both these machines are easier to load than a tub grinder, using a standard wheeled front-end loader (as shown in Figure A-14).

(4) Chipper-Shredders. A chipper-shredder is a small, portable grinder, used exclusively for tree limbs and branches. Chipper-shredders are typically used by electrical utilities and tree services in their tree trimming operations. They are easily towed behind a truck as it moves to many locations in a day. The chipped wood is ejected at high speed through the chute at the top, into the back of an enclosed truck (figure A-16). A chipper shredder could be used as part of an installation compost program if the only material needing size reduction is a relatively low volume of tree limbs and brush. This might not be adequate for a large troop installation.

Figure A-16. Chipper-shredder.

(5) Low Speed Shredders

(a) The second main category of size reduction equipment are low speed, high torque, shearing shredders (figure A-17). These machines consist of two (or three) shafts with meshed cutting disks. Different widths are used depending on the toughness of the material to shred, and the size of the end product desired. The hydraulically powered shafts turn at a very slow speed (a few rpm), but with very high torque, which allows the machine to shred all types of materials: yard wastes to plastics to light steel.

Figure A-17. Shearing shredder.

(b) Shredders would not be the first choice for reducing solely yard wastes. Because they employ no particle size control, the output tends to be in longer strips rather than in chips. However, it could be used as a primary processor for a modest secondary grinder or perhaps a chipper-shredder. This would be an ideal arrangement if the installation needs to shred many different materials in addition to yard wastes (e.g., at the DRMO): scrap metals and surplus, construction and demolition debris (C/D), or normal municipal solid wastes. These machines have shown at least a four-to-one volume reduction in shredding C/D.

(6) Summary. Table A-5 summarizes the throughput and purchase cost of the equipment described above. Periodic grinding/shredding tasks can often be done through contractors, thereby eliminating the need to purchase equipment. Vendors are typically not interested in renting out equipment. They make their money from sales. The logistics involved in continually transporting and maintaining these devices makes rentals impractical. However, contractors would be willing to operate a machine at an installation on a periodic basis, because the

contractor's fee would include maintenance, transportation, and the contractor's time for operating the machine.

Table A-5. Summary of size reduction machinery.

Type	Average Throughput (ton/hour)	Cost Range	Notes
Tub grinder	10-25	$160-200k	Good for uniformly chipping woody materials
Horizontal grinder	15-30	$150-190k	Grinds variety of materials; many configurations avail.
Shear shredder	25-45	$300-400k	Shreds anything; not best for yard waste only

b. Windrow Turners

(1) As microbes work to degrade organic material in a compost windrow, they use up available oxygen inside the windrow. Also, air spaces in the windrow compress due to gravitational settling. Without adequate oxygen, the windrow can begin anaerobic decomposition, which results in malodorous byproducts. To ensure adequate oxygen, the windrow must be turned. There are many different types of machines available to do this.

(a) Wheel Loader

i. The simplest windrow turning device is the front-end loader or wheel loader (figure A-18). The windrow is just scooped up and dropped a little at a time, down its length. Composting can also be done in a series of side-by-side concrete bunkers, similar in concept to a backyard bin with three sections. A wheel loader would be the only choice in that situation.

ii. The obvious advantage of using a wheel loader to turn compost is that they are relatively common. Even a modest sized compost operation will need one for placing and loading raw and finished product. On the downside, a wheel loader is slower than a specialized windrow turner and may not mix as well.

(b) Towed Rotor. A small, specialized windrow turner is the towed rotor type (figure A-19). This unit is towed with a tractor or tracked vehicle and powered by its own engine or via a power take-off linkage (PTO). A horizontal drum with flails or knives rotates at high speed and rides close to the ground to engage the windrow and shoot it to the rear or to the side. It does a good job of mixing and aerating smaller windrows. This type of machine is ideal for smaller or startup operations that do not want to make a large capital equipment investment. They are relatively inexpensive and use existing equipment for towing.

Figure A-18. CAT wheel loader.

Figure A-19. Towed windrow turner.

(c) Elevating Face. Another major type of windrow turner is the elevating face (figure A-20). This self-propelled or towed machine uses a wide, inclined conveyor to lift the windrow and drop it off the back. Wide windrows can be turned with two passes. This machine does well at aerating and “fluffing” the pile and does not produce high speed projectiles. It is ideally suited for materials that are relatively homogeneous or materials you wish to avoid scattering (e.g., food wastes). Towed units are moderately priced, but would not do as well in mixing or size reduction as the drum rotor models.

(d) Windrow Straddle. Windrow straddle type turners are the largest, most effective, and the most expensive machines available (figure A-21). This self-propelled machine rides over the entire windrow and turns it via a horizontal, high speed, rotating drum with flails. It thoroughly mixes, aerates, and ejects the composting material out the back, reforming the windrow. The high cost (over $200k) is the only drawback to this type of machine. Any long term, high volume compost program should seriously consider the investment.

Figure A-20. Elevating face windrow turner.

Figure A-21. Straddle type windrow turner.

(e) Trommel Screens

i. The consistency (particle size distribution) of the finished compost will vary based on the original materials. Some end uses for compost will dictate what it must look like. For example, if the finished compost will be spread on damaged training lands to encourage revegetation, it would not matter if the compost contained larger wood chips or chunks of tough plant stems. However, if the compost will be used in gardens and flower beds, then it is more important that the compost have a uniform, fine texture. The best way to accomplish this is to screen the end product before distribution.

ii. There are different types of industrial size screening machines available for different types of bulk materials. The most suitable for compost operations is the trommel screen. A trommel screen is basically a large, rotating, cylindrical sieve (figure A-22). A wheel loader dumps compost on the in-feed conveyor, then the compost goes through the center of the trommel. Fine material passes through the mesh, and the oversize is carried all the way through, and falls out the far end. The trommel screen can use two different sized meshes to separate the compost into three different size classifications. For example, the first screen would be ½ in. and the second, 1 in. The result would be three separate piles: smaller than ½-in.,½- to 1-in., and larger than 1-in. Conveyors can be used to put the sorted materials into distinct piles.

Figure A-22. Trommel screen.

iii. Large brushes at the top of the trommel rotate with the trommel to prevent the screen from clogging.

4. Army Case Studies. Although composting has not yet become widespread in the Army, some installations have developed successful composting programs. Their successes and “challenges” will pave the way for the rest of the Army. This section profiles composting programs at Fort Riley, KS and Fort Sill, OK.

a. Fort Riley

(1) The composting program at Fort Riley is managed by the Directorate of Environment and Safety (DES). It is part of a complex called the Environmental Waste Management Center (EWMC). In addition to composting activities, the Center collects and processes antifreeze, fuels, and household hazardous wastes. They also have an enclosed area where, in cooperation with State regulators, they are trying different bioremediation strategies on soil contaminated by leaking underground storage tanks. DES has several employees stationed at the EWMC, but their duties are quite varied. The composting program alone requires the equivalent of 1.5 full-time employees.

(2) The actual composting takes place on a concrete pad (roughly 100x300 feet in area) surrounded by an earthen berm. Because this was one of the first large scale composting operations in the State of Kansas, State environmental regulators were somewhat stringent in their site requirements, preferring to err on the side of safety.

(3) Grass, leaves, and wood chips comprise the majority of materials composted. Fort Riley also composts manure and bedding from horse stables and a bison herd. Contractors pick up yard wastes from the residential areas and deliver them to the compost site. Residents may set out either paper or plastic bags, but paper is preferred, because DES employees often have to de-bag the yard waste in plastic bags by hand. Paper bags are allowed to compost with the yard waste. In the future, DES staff may perform the residential collection themselves since, that way, they could better ensure that contamination would be eliminated from the yard waste. Soldier and contractor grounds crews bring grass clippings and other debris from around buildings in the cantonment area. All of the raw material delivered to the compost site is placed directly on the concrete pad in windrow formation (figure A-23). Most of this material requires no grinding as it is mostly grass and leaves.

(4) Windrows are turned about once per week using a Sittler towed rotor type windrow turner (figure A-8). Staff track the temperature and moisture content of the windrows. They have a sprinkler system available in case the piles dry out due to lack of rain and high winds. Their typical mixture of leaves and grass takes an average of 4.5 months to fully compost. After the

degradation process is complete, the material is run through a trommel screen with 0.5 and 0.75-in. openings. This results in a fine, uniform, rich compost (figure A-24) that is used for landscaping on post, and by the Natural Resource and Land Management offices. In fact, the finished compost is of such high quality, the Directorate of Public Works is considering bagging it for distribution to the housing areas.

Figure A-23. Fresh compost at Fort Riley.

Figure A-24. Finished compost at Fort Riley.

(5) The compost program at Fort Riley processed about 1,200 cu yd of material in fiscal year 1996. The POC for the Fort Riley compost program is:

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b. Fort Sill

(1) The Fort Sill compost program is an ambitious, large-scale, long-term project. Planning began in 1992 in the Directorate of Environmental Quality (DEQ). They prepared a Compost Facility Business Plan that went into much detail on regulatory requirements, solid waste assessment, composting operations, cooperation with their host community, and, especially, an economic analysis of the program. The original plans called for the eventual composting of many different types of materials: land clearing debris, leaves, food wastes, sewage sludge, and nonrecyclable paper. Construction was scheduled to begin shortly thereafter; several years were allowed for the construction and permitting process.

(2) One of the most important considerations is how to market, or otherwise use the finished compost. Fort Sill is the Army’s field artillery school, and has a high volume of military vehicle traffic as part of training exercises. This type of activity invariably rips up vegetation and causes erosion problems. This is an especially serious problem because the native soil and vegetation is rather poor. Therefore, a rich source of organic material is just what they need. Directorate of Natural Resources (DNR) staff estimated that they could use more compost on the training lands than the composting site could ever produce. This built-in market eliminates the concern for finding public or commercial markets outside the base.

(3) The site selected for the compost operation was an empty field adjacent to the landfill (figure A-25). This site is a few miles northeast of the main cantonment area, thereby eliminating the possibility of odor complaints. Also, trucks delivering compostable materials could use the scales already at the landfill. Site design was performed in-house. Special care was taken with the grading and earthwork to ensure correct slopes that drain to a runoff collection pond (figure A-26). The natural soil in southwest Oklahoma is a thick, red clay. Almost all of the 33 permitted acres passed the State-required permeability test on the first try. The areas that did not pass

were simply recompacted. Also constructed at the site was a cinder block building to be used as a testing laboratory, with benches, a restroom, and a double bay garage. The total startup cost, including site preparation, building, and equipment purchase was under $300k.

Figure A-25. Compost site prior to construction.

Figure A-26. Earthwork and grading.

(4) Three full time employees are required to keep the site operational. Their duties include: sampling and testing, material handling, equipment maintenance, and recordkeeping. Employees from both the DEQ and DNR have participated as this program has progressed. Total annual cost for operating the compost facility at capacity is estimated to be about $650k. This includes, equipment, labor, and operations and maintenance (O&M).

(5) Through the summer of 1995, landscaping and Natural Resources crews had delivered compostables on an irregular basis. This allowed the staff to become familiar with the equipment and monitoring procedures. In the summer and fall of 1995, the command decided it was time to begin composting as much as possible to make use of their large investment in the compost site. The various compostable materials were collected in three ways, in addition to the landscaping material:

(a) From the office and break room areas using special containers lined with biodegradable plastic bags.

(b) From the housing areas using the biodegradable plastic bags for inside the house (food wastes), and wheel plastic carts (yard waste) to take to the alley or curb. Figure A-27 shows back alley containers, for compostables and trash.

Figure A-27. Compostable sand recyclables collection from housing.

(c) From troop units, shop activities, etc., using dumpsters placed around the post. Figure A-28 shows two dumpsters near the recycling center—one for compostables, and the other for trash. Figure A-29 shows the sticker placed on compostable bins at each residence and dumpster.

(6) Materials arriving on the site are dumped in a concrete bunker (figure A-30). There they are mixed with a wheel loader, then transferred to a Rotor Grind, horizontal shaft hammer mill for grinding (figure A-31). Fort Sill purchased this grinder because if its high power and ability to grind a wide variety of materials. For the most part, the grinder worked very well, but it would sometimes get plugged up with some of the softer or wetter material. Windrows are turned with a Scarab straddle turner, which worked very well, although the turner would occasionally get stuck in the mud.

(7) In case of drought (a common Oklahoma occurrence), the windrows are kept moist with a pump set up to draw water from the run off retention pond connected to a sprinkler system (figure A-32). The installation has recently begun to use a water truck similar to those used in street cleaning.

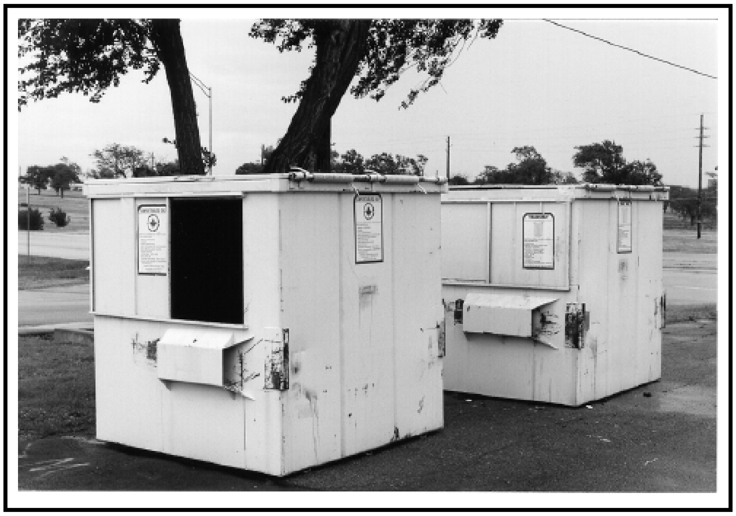

Figure A-28. Compostables and recyclables collection via dumpster.

Figure A-29. Sticker on compostable receptacles.

Figure 30. Mixing bunker.

Figure 31. Grinder.

Figure 32. Water pump.

(8) The described system of collecting all compostables from all sectors did net large quantities of materials—an average of 500 tons per month. However, the volume and mix of materials also caused some problems with unacceptable levels of contamination. Staff estimated that only 2 percent of the office compostables were sorted correctly. The contractor collecting from households was not discriminating enough. Staff received many calls from households trying to decipher just what was and was not compostable. The collection via dumpsters was a completely hit-or-miss situation. It appeared that most people did not notice or may have simply disregarded the instructions on the sticker (figure A-29).

(9) Eventually, the windrows contained too much contamination (especially plastics) to be useful. In the summer of 1996, the decision was made to suspend the program, pending a re-evaluation of the collection procedure and a cleanup of the composting site. Fort Sill restarted the program in the fall of 1996 using a “phased approach,” that is -- running at full capacity on "simple" homogeneous materials (like grass and leaves) first, and then start adding other materials one at a time.

(10) In simple terms, the lesson that Fort Sill’s experience shows is to “learn to walk before you run.” Begin composting with simple materials until you get the bugs worked out of your systems. Start with a mix that has a slightly higher C:N

concentration (for example, 30:35). This will slow the degradation and minimize the chance of anaerobic odors while getting a program started. Public education also plays a big role in eliminating contamination and will take time. Remember that people did not start recycling overnight.

(11) Fort Sill has an excellent compost site, and some of the best equipment available. The program has grown into a successful venture that now composts a high volume of organics. Their current mix includes 50% tree trimmings, 30% pallets and ammo boxes, 15% sewage sludge, and 5% grass and leaves. Their material sources include land clearing for new construction, DPW grounds crews, and various supply locations (recycling collection sites). Fifteen percent of finished compost is used by DPW grounds crews for landscaping and the rest is used for land conservation in training areas.

(12) The POC for the Fort Sill compost program is:

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APPENDIX B

References

1. This appendix lists many different resources the reader can turn to for additional information.

a. Recommended Documents

(1) Composting Yard Trimmings and Municipal Solid Waste. USEPA-Office of Solid Waste and Emergency Response. EPA530-R-94-003. May 1994.

(2) On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service - Cooperative Extension. NRAES-54. June 1992.

Address:

Northeast Agricultural Engineering Service
152 Riley-Robb Hall
Cooperative Extension Service
Ithaca, NY 14853-5701
(607) 255-7654

(3) Solid Waste Options. Software Planning Tool. Used to estimate costs and material quantities. Distributed as Installation Support Division Public Works Technical Bulletin 420-49-07, 19 November 1996. Contact ISD at (703) 428-6085.

b. Periodicals

JG Press (publishers of BioCycle and Compost Science and Utilization)
419 State Avenue
Emmaus, PA 18049
phone: 610-967-4135
http://grn.com/grn/news/home/biocycle/index.html
e-mail: BioCycle@aol.com

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d. Websites. A few web sites on composting with compost information and links to other related sites:

US Army, Office of the Director, Environmental Programs—ACSIM

http://www.hqda.army.mil/webs/acsimweb/env/env1.htm

Cornell University Compost Site

Much technical information and further resources.

http://www.cals.cornell.edu/dept/compost/

Rot Web

Provides information on a variety of issues related to home composting. Includes a list of home composting publications and links to other sites.

http://net.indra.com/~topsoil/Compost_Menu.html

The Composting Resource Page

Provides access to information on composting from backyard to large scale systems. Includes an interactive bulletin board for questions and answers, and a list of vendors.

http://www.oldgrowth.org/compost

Compost Correspondence Course

This course is sponsored by the University of Wisconsin-Madison.

gopher://epd_hp9k.engr.wisc.edu:70/11/iscourses/composting

USEPA Non-Hazardous Solid Waste

http://www.epa.gov/epaoswer/non-hw/index.htm

e. Organizations

The Composting Council (a trade and professional organization)

114 South Pitt Street

Alexandria, Virginia 22314

703-739-2401

703-739-2407 (fax)

e-mail: ComCouncil@aol.com