PUBLIC WORKS TECHNICAL BULLETIN 200-1-69
1 FEBRUARY 2010

DEMONSTRATION OF THE ECOPOD® COMPOSTING SYSTEM AT FORT LEWIS AND FORT HOOD

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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
441 G Street, NW
Washington, DC 20314-1000

CECW-CE

Public Works Technical Bulletin
No. PWTB 200-1-69

1 February 2010

Facilities Engineering
Environmental

DEMONSTRATION OF THE ECOPOD® COMPOSTING SYSTEM AT FORT LEWIS AND FORT HOOD

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) transmits information about an innovative composting system, EcoPOD®, that was demonstrated at two U.S. Army installations. Specifically, this document includes the final report from that demonstration, which contains discussion of the operation of that system, as well as comparison with other composting systems, equipment involved, use of additives, and recommendations/conclusions regarding EcoPOD® and other composting methods. This PWTB is intended for the use of installations that are starting new composting operations, or considering changing existing operations.

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through URL:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to all U.S. Army Directorates of Public Works (DPW) and Environmental Directorate offices responsible for the planning, design, or operation of composting systems.

3. References.

a. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," Headquarters, Department of the Army, Washington, DC, 13 December 2007.

b. AR 420-1, "Army Facilities Management," Headquarters, Department of the Army, Washington, DC, 12 February 2008.

c. U.S. Army, "Army Strategy for the Environment: Sustain the Mission – Secure the Future," 01 October 2004, at: http://www.asaie.army.mil/Public/ESOH/doc/ArmyEnvStrategy.pdf

d. Executive Order (EO) 13423, "Strengthening Federal Environmental, Energy, and Transportation Management," 26 January 2007, at: http://www.ofee.gov/eo/EO_13423.pdf

4. Discussion.

a. As stated in AR 200-1, the Army is committed to environmental stewardship in all actions as an integral part of its mission and to ensure sustainability. Section III, Chapter 23 of AR 420-1 establishes policy and criteria for solid waste management at Army installations, including composting practices. It further states Army solid waste management will be in accordance with EO 13423.

b. The goals of the Army Strategy for the Environment (ASE) include improving the Army's ability to operate installations, reduce costs, and minimize impacts so the Army can do more, do it better, and enhance human health, safety, and well-being.

c. Executive Order 13423 establishes policy for Federal agencies to conduct their environmental, transportation, and energy-related activities in an environmentally, economically and fiscally sound, integrated, continuously improving, efficient, and sustainable manner. Additionally, this Executive Order sets goals requiring Federal agencies to increase diversion of solid waste as appropriate, and maintain cost-effective waste prevention and recycling programs in its facilities.

d. Military installations are generally their own municipalities and generate a great deal and variety of waste materials depending on their function. Yard trimmings and food residuals together constitute 24 percent of the U.S. municipal solid waste stream. A lot volume of waste that is send to landfills could become useful and environmentally beneficial compost instead. Composting is a means to divert large portions of the waste stream from landfills. Composting can provide materials suitable for soil conditioners, landscape mulch, backfill, resurface material for eroded areas, and landfill cover.

e. An innovative composting system, EcoPOD® technology, was demonstrated at two U.S. Army installations — Fort Hood, TX and Fort Lewis, WA. This demonstration project was conducted by MSE Technology Applications, Inc. (referred to as "MSE" throughout this PWTB) under contract to the U.S. Department of Energy's Western Environmental Technology Office. The contract was administered by the U.S. Army Engineer Research and Development Center's Construction Engineering Research Laboratory.

f. The project demonstrated the EcoPOD® technology, an innovative composting system that was thought to provide several advantages over the generally accepted means of composting materials. The EcoPOD® composting systems (supplied by Ag-Bag International, Inc., Warrenton, OR) were demonstrated at Fort Hood and Fort Lewis. The EcoPOD® system is considered an in-vessel, static, aerated-pile, composting method. The "vessel" this technology uses is a long sleeve of flexible plastic membrane that is wrapped around the composting material. Aeration is supplied through a perforated pipe centered in the pod and running the length of the pod.

g. The EcoPOD® systems were compared to other means of composting. At Fort Hood, the EcoPOD® system was compared to conventional static windrows that were exposed to the surrounding environment. At Fort Lewis, the EcoPOD® system was compared to an aerated, static pile composting method supplied by O2 Compost, the Training Program Division of Price-Moon Enterprises, Inc. (Snohomish, WA).

h. Because the States of Texas and Washington regulate composting differently, waste mixtures were developed that used feed components that would comply with those regulations. Thus the waste mixtures had to be unique to each installation. The two different mixtures allowed the study to use this inconsistency as a variable. The nutrient content of each component was evaluated prior to establishing the mixtures. Both sites had access to horse manure and substantial quantities of landscaping debris including wood chips, leaves, and branches. Treated grease trap sludge, a small amount of food waste, and urea (a nitrogen supplement) were used at Fort Hood. Petroleum-contaminated soil and biosolids were incorporated into the compost recipe at Fort Lewis. The carbon-to-nitrogen content was an important consideration in developing these recipes.

i. Mixing of the components proceeded differently at each location as the types of equipment available at each location and the recipe mix drove the recipe mixing operation. The equipment used to fill the EcoPODs® at both locations was a CT-5® hydraulic hopper and ram assembly supplied by Ag-Bag International.

j. Results of the demonstrations were mixed:

i. The compost produced by the EcoPOD® system at Fort Hood was approximately equal in quality to that produced in the static windrows.

ii. The Fort Hood EcoPOD® containing grease trap sludge reached temperatures high enough to meet regulatory standards.

iii. Neither system at Fort Lewis attained temperatures sufficient for regulatory compliance.

iv. Maintaining a good, evenly distributed, moisture content was problematic at both EcoPod® locations.

v. There were significant temperature gradients between the inner and outer material in the EcoPODs®.

k. The EcoPOD® composting system holds some promise in specific applications, particularly where: extreme weather conditions exist, waste food attracts vermin, and composting odors need to be controlled. Insulating the membrane (while not tried in this study) may mitigate some of the temperature-moisture problems. Longer-term testing with these systems would be advantageous to work out some of the operational problems experienced at Hood and Lewis and to determine the cost effectiveness of the EcoPOD® system.

l. Other conclusions and recommendations from the study include:

i. The brown waste materials used at both Fort Hood and Fort Lewis were in abundant supply, although quantities of high-nitrogen green materials were not adequate to provide that nutrient (at least at the time of year when the demonstrations took place). It is likely that composting operations will need to provide supplementary nitrogen for a substantial portion of the year.

ii. It is desirable to design composting recipes that avoid using components (waste food, biosolids, and grease trap sludge) that trigger regulatory oversight. The vast majority of compostable materials are simple vegetative waste. These materials can be converted to usable compost without the addition of the restricted materials.

iii. Facility design should take into account the types of feedstocks that will be used throughout the operation. Some feedstock recipes that are high in initial moisture content may require special features, such as leachate collection, storage, and possibly treatment.

iv. Heavy equipment is necessary for a composting operation. Both Fort Hood and Fort Lewis had large and small loaders available. For full-scale composting operations, heavy equipment dedicated to the operation would be desirable. The equipment is easily justified in a large-scale operation.

v. Based on the success at Fort Hood, it would seem that windrow-type composting processes might have intrinsic advantages due to mixing and homogenization of the pile. The feedstock/compost remains well mixed, proper moisture and aeration is easily monitored and maintained, and access to the entire windrow remains possible. Turning of the windrows using a specialized windrow turner is much more efficient than if front-loaders are used. However, the capital cost of the windrow turning machinery is a barrier to implementation.

vi. A feedstock mixer would provide a more homogeneous feedstock for all types of composting. Proportions of feedstock ingredients could be easily controlled and adjusted. Mixers specifically selected for a site could provide the capability of continuous operation when feedstock materials are available.

vii. Screening of the compost feedstocks and compost product is useful. Screening can be used to remove large wood chips and other chunks of waste that are slow to compost. The screening operation can also provide gradation or separation of compost product.

viii. A shredder would be advantageous in a large-scale compost facility. Some screening plants have shredders as an option, and this should be strongly considered if a screening plant is purchased.

m. Appendix A contains a detailed description of the innovative composting system demonstrated at Forts Hood and Lewis.

n. Appendix B to this PWTB contains a list of bibliographic references.

o. Appendix C to this PWTB contains a glossary of terms and acronyms used in this document.

p. Appendix D to this PWTB contains unit conversion factors for terms of measures used in this document.

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Appendix A

Demonstration of the EcoPOD® Composting System at Fort Hood and Fort Lewis

Introduction

U.S. Army installations, like municipalities, generate a great deal and variety of waste materials. Army installations need to reduce the amount of solid waste being landfilled to meet their sustainability goals.

Composting is a means to divert large portions of the waste stream from landfills. Composting is the decomposing of organic waste, such as food scraps and yard trimmings, with micro-organisms (mainly bacteria and fungi) to produce compost (USEPA 1995). Many of the waste streams currently being landfilled at U.S. Army facilities are suitable for composting and include yard and landscape waste (grass, leaves, branches, etc.), food waste, fiber waste (paper, wood, cardboard), and sewage sludge (biosolids). The production of compost from these waste streams not only diverts them from limited landfill space, but also provides the facilities with a valuable product that can reduce the facility's costs for fertilizer, mulch, and other landscaping materials.

The EcoPOD® composting system was the subject of a recently completed demonstration project at Fort Hood, TX, and Fort Lewis, WA. EcoPOD® is considered an in-vessel, static, aerated-pile composting method. The technology uses plastic sleeves (EcoPODs®) as composting containers with aeration supplied by perforated pipe running the length of the pod.

The objective of the demonstration project was to compare the EcoPOD® systems to the other generally accepted means of composting. At Fort Hood, the EcoPOD® system was compared to conventional static windrows that were exposed to the surrounding environment. At Fort Lewis, the EcoPOD® system was compared to an aerated, static pile composting method supplied by O2 Composting, Inc.

Compost recipes were developed for the compost feedstock for the demonstration at each location. These recipes used components unique to each particular facility. Both sites had access to horse manure and substantial quantities of landscaping debris including wood chips, leaves, and branches. Treated grease trap sludge, a small amount of food waste, and urea were used at Fort Hood. Petroleum-contaminated soil and biosolids were incorporated into the compost recipe at Fort Lewis. The carbon-to-nitrogen content was an important consideration in developing these recipes.

Demonstration Project Goals

A primary goal of the demonstration project was to provide each site with information that would allow further development of composting facilities. At both sites, two composting technologies were demonstrated on identical feedstock mixtures in a side-by-side configuration. The composting process was monitored for each technology, and compost quality was evaluated at the end of the demonstrations. Additionally, the project at Fort Hood had an objective to provide a conceptual design for a new composting facility. An important objective of the Fort Lewis demonstrations was to evaluate the treatment of petroleum-contaminated soils (PCS) by composting (Figure A-1.)

(Photograph courtesy of Google Earth.)

Figure A-1. Fort Lewis Compost Pilot Project location.

Fort Hood Site Conditions

The primary reason for current composting at Fort Hood is to keep the large "wood items" (e.g., wood pallets and trees) out of the municipal solid waste (MSW) landfill. In the long term, Fort Hood plans to implement a composting operation that will convert numerous waste streams into a useable product that can benefit the installation.

Fort Hood currently runs an exempt compost center, which means that the compost center can accept only "brown" waste (Figure A-2). Brown waste consists of wood, yard waste, landscape trimmings, and horse manure. The Fort Hood compost center cannot accept "green" waste due to permitting restrictions. Green waste is considered to be food and food-related waste, which is collected and placed in the Fort Hood municipal landfill (except for grease trap material that is shipped off-post for solidification and land treatment). Green waste is an important component in composting mixtures because it provides important nutrients, particularly nitrogen, for the biological processes involved in composting.

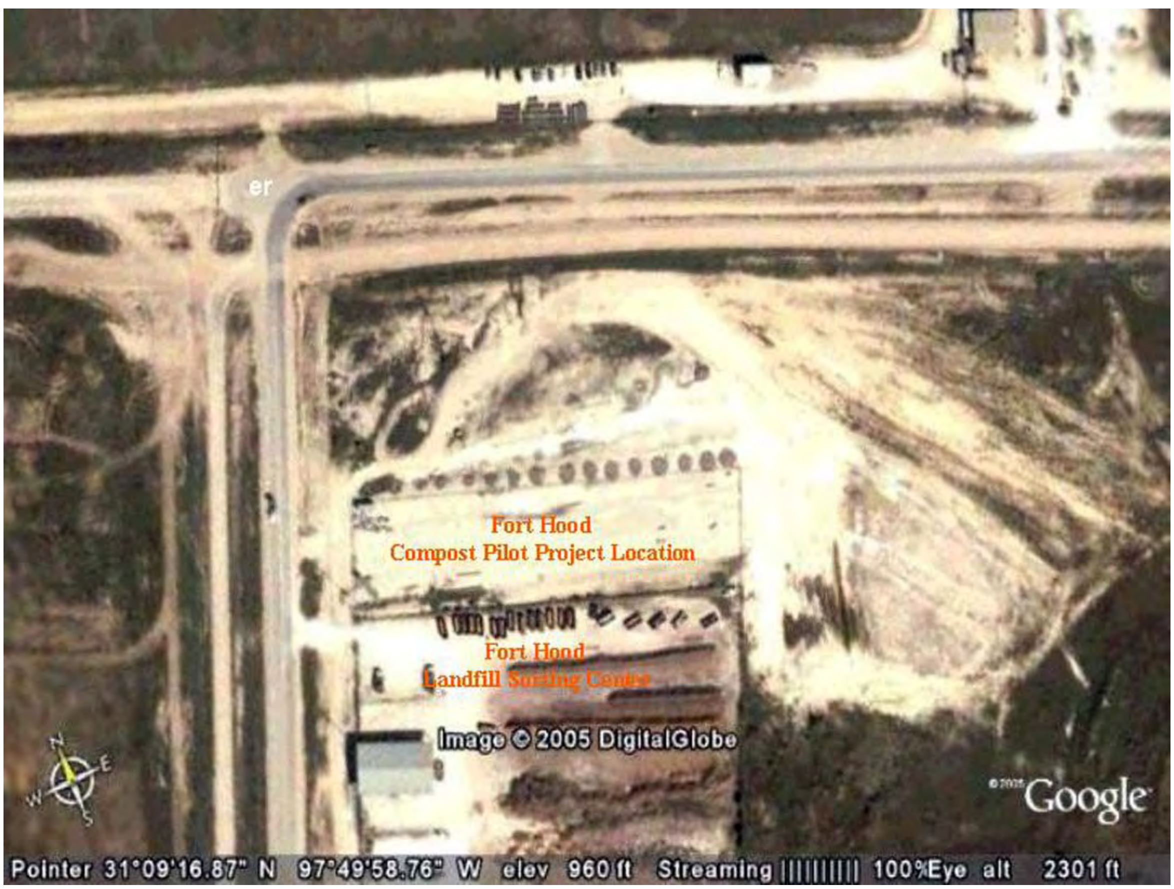


Figure A-2. Fort Hood compost pilot project location.

Fort Hood was using static, non-aerated, windrow composting prior to this demonstration project. This composting method took approximately 6 to 8 months to produce a composted material that was marginally useful as a soil amendment. Fort Hood later acquired a windrow-turning machine, which should greatly improve aeration, degradation of the waste materials, and thus improve compost quality.

It would be desirable to use green waste or other nitrogen sources to improve the quality of compost being produced at Fort Hood. One objective of the demonstration project was to research and test new composting methods that could allow Fort Hood to produce higher quality compost. The project also sought to provide Fort Hood with design parameters that would be included in future permitting actions for the compost center.

Fort Lewis Site Conditions

At the time of this demonstration project, Fort Lewis generated a variety of solid waste streams that required improved management to comply with applicable Federal, state, and county regulations and to meet the installation's sustainability goals. Waste streams at Fort Lewis were not being managed in accordance with the applicable solid waste regulations (Chapter 173-350 Washington Administrative Code), which could result in compliance violations. The installation adopted and was implementing a zero net waste sustainability goal by 2025. As a result of the zero net waste goal, past and present solid waste management practices such as landfill disposal and some nonsustainable treatment technologies were to be replaced with more sustainable options for dealing with these waste streams.

Fort Lewis closed its last active solid waste landfill cell in 2004. The closure of this cell eliminated current disposal options for PCS, petroleum-contaminated wastes, and other solid wastes. As a result of the landfill closure, Fort Lewis needs to investigate other means to manage solid waste streams that have traditionally gone to the landfill for disposal.

Sewage sludge (biosolids) from the installation's wastewater treatment plant (WWTP) is currently being transported to Centralia, WA, for land application by a contracted service. The off-site management of this waste stream, as well as others, by contracted services carries the potential for liability issues associated with regulatory/permit compliance and business practices. In addition, the availability of permitted land application sites and contractors to provide this service may fluctuate or become unavailable on short notice. From a service continuity and liability reduction standpoint, Fort Lewis will have to investigate other self-management options that would eliminate the likelihood of these issues becoming a problem.

Composting Technology Description

Background

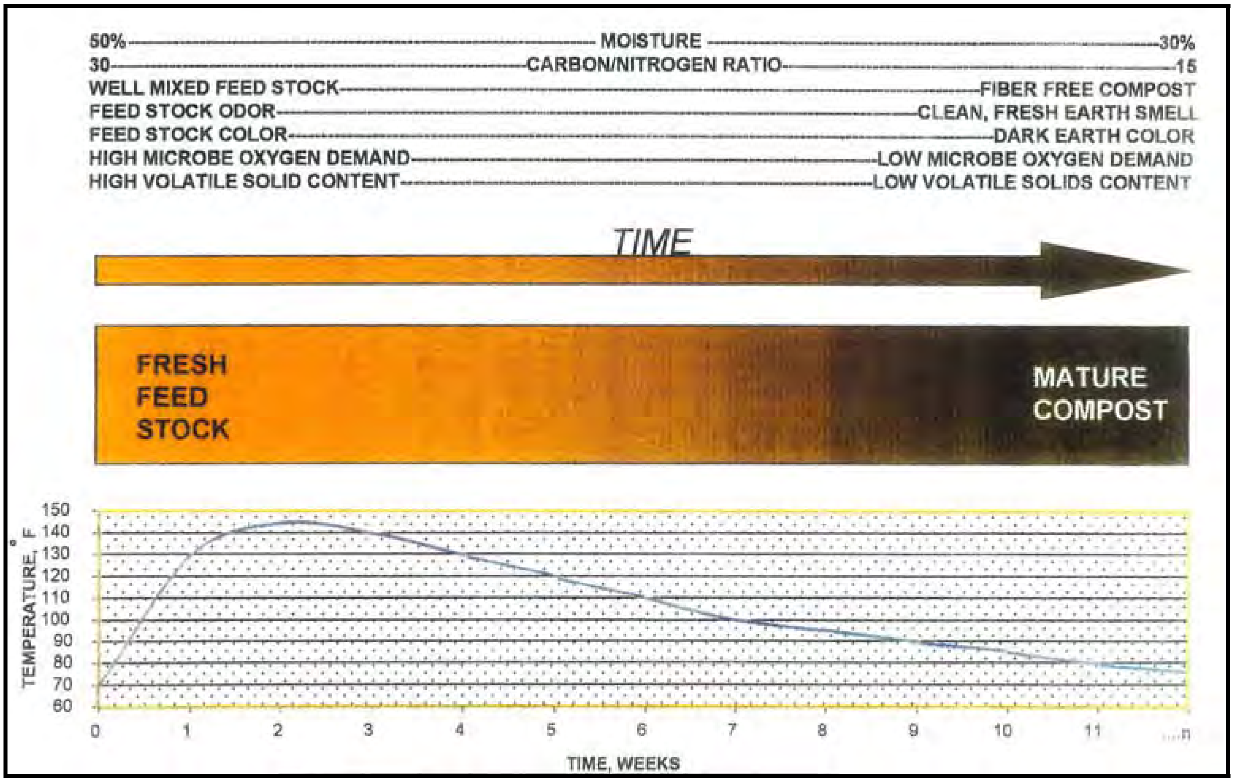
For a composting operation to be successful, certain constituents must be available. The most important constituents are nitrogen, carbon, oxygen, and moisture. These components can be supplied in a variety of materials; however, to achieve proper composting, the materials must be supplied in approximately the correct ratios.

Nitrogen for composting is normally supplied by including nitrogen-rich materials such as green grass trimmings, green leaves, waste food or food byproducts, horse manure, or biosolids. Sufficient carbon is present in wood chips, sawdust, dried leaves, and straw. Carbon and nitrogen must be supplied in the proper proportions to carry out the composting process. In general, the ratio of carbon to nitrogen in a compost feedstock must start in the range between 25:1 and 40:1.

Composting is an aerobic process where the microbes initially have a high oxygen demand, and oxygen can be supplied in a variety of ways. Historically, compost windrows and pile have been turned using heavy equipment; however, other systems are available that aerate compost without turning.

The microbes that actually perform the composting also require a significant amount of moisture. Ideally, the moisture content should start at approximately 50 percent with a decrease in moisture to approximately 30 percent at the end of the process. Monitoring and adding water for the duration of the composting process is sometimes needed to maintain moisture levels.

As the composting process takes place, the microbes generate a great deal of heat that provides pathogenic destruction as well as destroying weed seeds and fly larva. Heat generation indicates the compost process is proceeding. Temperatures during composting operations commonly rise to 150 °F. Compost piles that incorporate food wastes or biosolids must reach at least 131 °F for 3 consecutive days to comply with state and U.S. Environmental Protection Agency (USEPA) regulations. As the compost matures, microbial activity declines, temperatures begin to drop slowly, and the moisture levels drop to approximately 30 percent (Figure A-3).



Courtesy of Ag-Bag International, Inc.

Figure A-3. Compost maturity scale.

The carbon-to-nitrogen ratio falls to around 15:1 as carbon is converted to carbon dioxide (CO_2). The color of the feedstock changes to a deep dark brown or black, and the original odor of the feedstock changes to a more earthy smell.

The active composting process can take from 6 to 12 weeks. Once complete, the compost must enter into a curing phase to ensure completion of the process. During this curing process, temperatures remain slightly elevated for a period of several weeks.

The final product can then be tested for maturity. Additional checks may be required for regulatory compliance; however, once the checks are complete, the product may be released for general use.

Review of Composting Systems

Several composting systems are commercially available, and each has features that may provide advantages for a particular application. MSE reviewed literature regarding different composting methods and contacted a number of vendors. The EcoPOD®

composting system, supplied by Ag-Bag International, Inc. was selected for demonstration as part of the project. Selection was based on the features of the system and low cost of deployment. At Fort Hood the EcoPOD® system was compared to conventional windrow composting, and at Fort Lewis the system was compared to a static, aerated-pile system provided by O2 Compost and funded by Fort Lewis.

The factors driving the type of system used for composting included:

- the amount of leachate produced by any particular compost feedstock
- feedstock odors and rodent attraction
- the facility and available equipment at the composting location.

Windrow Composting System

The most common large-scale composting process is the windrow system (Figure A-4). The composting recipe is mixed, and the mixture is then placed in open-air windrows with heavy machinery. The windrows are triangular in cross-section and are commonly as much as 10-ft high, 20-ft wide, and hundreds of feet in length. The windrows are turned periodically with specialized equipment, which requires labor and associated costs, to maintain an aerobic environment and homogenize the pile.

Windrow composting is both easy to monitor and to make adjustments during the composting process. Moisture can be added by spraying water on the windrows prior to turning. However, this system can be adversely affected by climactic conditions. The most significant potential problem is excess moisture associated with heavy precipitation. This excess moisture can adversely affect the composting process and may cause runoff from the windrow.

In addition, some compost recipes will generate leachate as a byproduct of the composting process, and this leachate must be collected and disposed in a means acceptable by regulatory agencies. Lining the composting area with impermeable materials and leachate collection sumps may be required. Naturally, these concerns will add to the cost of operating a windrow composting facility.

Figure A-4. Compost windrows.

Other issues associated with windrows are a result of their open-air configuration. Compost processes can produce offensive odors that can migrate off the compost facility. Special considerations must be made if food waste is used in the composting recipe as food waste is attractive to birds, rodents, and insects.

The EcoPOD® Composting System

Ag-Bag International has developed a composting system by modifying silage production systems for livestock feed. The equipment normally used to create silage tubes for feed storage was adapted to create an in-vessel, static aerated-pile composting system. The Ag-Bag composting system uses a tubular, flexible plastic sleeve to enclose the compost materials. These compost tubes have been named EcoPODs® (Figure A-5).

Figure A-5. CT-5® composter with developing EcoPOD®.

EcoPODs® are available in 5-ft-diameter and 10-ft-diameter sizes. A specialized machine loads each EcoPOD. Both EcoPOD® sizes can be filled to lengths up to a maximum of 200 ft. The 5-ft-diameter EcoPODs® have a theoretic capacity of 145 cubic yards (cu yd) at its maximum length, and the 10-ft-diameter EcoPODs® have a theoretical capacity of 582 cu yd. Actual capacities are somewhat less because the EcoPODs® do not form true circular tubes, but are oval in cross-section when deployed. However, various components of the composting mixture have different particle size distributions, and the smaller sized material will fill up void space in the coarser material. Additionally, there is some compaction of material as the EcoPOD® is filled. These factors result in a composting mixture that is somewhat denser than the average density of the parts. It was the experience of this project that a 5-ft EcoPOD® could hold approximately 150 cu yd of feedstock when the volume of each component is measured before mixing and loading.

Stockpiled compost mixture is fed into the EcoPOD® loading machine with a standard front-end loader. The plastic sleeves are staged in an accordion-type fashion on the discharge end of the loading machine. A hydraulically powered ram presses the materials into the EcoPODs®, and the EcoPOD® plastic sleeves are gradually deployed from the end of the loading machine. As the materials are pressed into the EcoPOD®, perforated polyethylene pipe is unreeled and fed throughout the length of the plastic tube. After the EcoPOD® tube is filled with the compost mixture, the far end of the tube is sealed. The perforated pipe exits the EcoPOD® from the near end. A solid polyethylene pipe is connected to the perforated pipe, and the EcoPOD® is sealed around the solid pipe.

An electric blower unit is connected to the solid pipe to provide forced air inside the EcoPOD®; a timer controls blower operation. This blower forces air through the perforated pipe and into the compost mixture at the desired intervals. One blower unit can provide adequate airflow for several EcoPODs® at one time.

Adjustable vents are placed on the outside of the tube throughout the length of the EcoPOD® to provide an escape path for air that is forced to the inside of the EcoPOD® by the blower. The vents can be adjusted to direct the flow of air through various sections of the EcoPOD®.

The final step in the process is to adjust the timer of the blower to provide ideal airflow. The timer is usually set for a 2 to 10 minutes on and 10 to 20 minutes off. Timer settings are established based on moisture content and recipe of the compost.

Moisture lost during composting is generally controlled since the entire process is maintained within an enclosed container. If necessary, moisture can be added through the air vents; however, homogeneous distribution of this moisture is relatively difficult to achieve. Moisture could also be introduced through the blower system, but it is unknown if this technique has been tested.

Static Aerated Pile

The static aerated-pile composting system uses perforated pipe to distribute air from under an engineered pile of compost material. Air is forced though a manifold, distributed through the perforated pipe, then upward throughout the static pile. Wood chips are placed at a uniform depth both over and under the perforated pipe prior to placing compost. The wood chips aid in air distribution throughout the compost pile and thermally insulate the compost from the ground (Figure A-6). The piping associated with the forced air system is perforated polyvinyl chloride pipe. The air is forced through the piping using a timed blower system. The timing sequence is adjusted to provide several minutes of blower operation followed by 10 to 15 minutes with the blower switched off. The blower timing sequence is usually adjusted based on temperatures of the compost pile.

The static aerated compost pile is covered with a uniform layer of material to act as a biofilter, which is generally a uniform layer of wood chips. The biofilter acts as a barrier for controlling odor, retaining heat, and furthering dispersion of airflow.

Moisture losses may also occur during composting. If moisture needs to be supplied to the static aerated pile, it can be sprayed on during the composting operation. If necessary, moisture could be introduced through the blower system for the static aerated pile; however, it is unclear if this technique has been tested.

Figure A-6. Aerated static pile.

Feedstock Data

Fort Hood Feedstock Data

The first portion of the demonstration project was performed at Fort Hood. Fort Hood is home to the First Cavalry unit; consequently, the installation retains a great number of horses, both for recreational riding and as a symbolic representation of the unit's history. As a result, the installation produces a great deal of horse manure, a valuable ingredient in a compost recipe. The manure contains up to 2.3 percent nitrogen and has a carbon-to-nitrogen ratio of 25:1.

Fort Hood also normally has a great deal of green yard waste such as grass and shrub clippings. However, the demonstration project began 15 December 2004, so green materials were in short supply, and substitutions were needed to provide the nitrogen required for composting.

Urea was also added to provide an additional nitrogen source since urea has been recommended as a substitute for compost feedstocks lacking in nitrogen-rich materials. An agricultural chemical vendor was located in Florence, TX, and 1000 pounds of granulized urea was purchased and hauled to the project location at Fort Hood (Figure A-7). The urea provided approximately 56 percent nitrogen content.

Figure A-7. Granularized urea.

A total of 500 lb of urea was added to the compost feedstock for the EcoPODs®. The materials available for the composting demonstration at Fort Hood consisted of coarse wood, horse manure, some grass clippings and shrubs, food scraps, and grease trap filter cake. Two compost feedstock recipes were developed: one recipe included grease trap filter cake and one did not; otherwise, the recipes were identical. Approximately 300 cu yd of material was generated: half of the volume was generated on 18 December 2004, and the second half was generated on 20 December 2004.

Only 11 cu yd of grease trap filter cake was available. The filter cake was delivered after the first EcoPOD® was developed; therefore, the grease trap material was added only to the second half of the compost recipe.

The compost recipe was mixed using a Caterpillar 966G front-end loader. The values listed in Table A-1 correspond to the portions that were combined during the mixing operation. The compost feedstock was developed by mixing the total feedstock in six equal portions, and each portion of feedstock was added to the total feedstock pile. The total feedstock pile was mixed after each portion was added to ensure a homogeneous mixture. Table A-1also lists the breakdown of materials for each half of the compost feedstock. The recipe for each pile was approximately 150 mixed cu yd with the remaining portion of the recipe to be made up with added moisture. This recipe was applied to each EcoPOD® container. The total mix was developed in six equivalent portions.

Table A-1. Compost recipe for Fort Hood demonstration.

Material	Amount Required (cu yd)	Approximate Density (lb per cu yd)	Total Loader Buckets for Total Compost Feedstock Pile	Amount Mixed for Each of Six Equal Portions
Coarse wood	64	550	12.8	2.1 loader buckets
Grass and trimmings	14.5 (Available)	800	2.9	0.5 loader buckets
Food waste	–	–	–	Add 2 partial drums
Horse manure	98.5	650	19.7	3.3 loader buckets
Urea	–	–	–	41.65 lb per batch mixed
Grease trap filter cake	–	–	2.2	11 cu yd mixed in total
Notes: Bucket capacity of the 966G loader was 5 cu yd. Urea was added at 41.65 lb per batch of compost feedstock mixed. Water was added just before loading into the CT-5®, which minimized degradation of the urea.				

On 27 December 2004, Fort Hood and Inland Service Corporation (ISC) developed the windrow demonstration portion of the composting system. The recipe used for the Ag-Bag portion of the demonstration was also used for the windrow compost feedstock. The same proportions of ingredients were used and mixed in the same manner.

Fort Lewis Feedstock Data

The second phase of the demonstration project was held at the former landfill site at Fort Lewis. The former landfill site includes a covered facility that was previously used for recycling activities. Feedstock materials available for this phase of the project included horse manure, ground wood chips, biosolids, and leaves/yard trimmings. Table A-2 lists the ingredients of the compost recipe for the Fort Lewis portion of the demonstration project

To compensate for the lack of green materials, biosolids from the Fort Lewis WWTP were incorporated into the compost feedstock recipe (Figure A-8). Biosolids at the WWTP were in various stages of drying; therefore, moisture analyses were performed to determine the optimum moisture to coincide with the compost feedstock requirements. Once the desired material had been determined, the biosolids were hauled to the pilot project facility.

An important goal of the Fort Lewis portion of the project was to test the feasibility of treating PCS by composting. The PCS at Fort Lewis is stockpiled and passively treated at the PCS Treatment Facility, which is adjacent to the demonstration site.

Table A-2. Compost recipe for Fort Lewis demonstration.

Material	Approximate Density (pound per cu yd)	Buckets Per Batch Mixed
Coarse Wood	700	6
Leaves/Yard Trimmings	700	2
Biosolids	1600	2
Horse Manure	650	1
Soil (for second portion of both compost systems)	3000	1

Figure A-8. Biosolids material for compost feedstock.

Soil from this stockpile was mixed into the compost recipe to evaluate the potential to treat PCS with composting. The project team decided that half of the developed compost would contain PCS and that smaller, permeable containers with diesel fuel-spiked mixtures would be inserted into the two compost systems.

The PCS used in the second portion of the compost recipe had previously been passively treated and contained only minor residual amounts of petroleum contamination. The soil was processed thorough a screening plant to remove the coarse (+3/8-in.) gravel and cobbles. It was determined by Fort Lewis that the level of petroleum contamination in the coarse fraction was below the hazardous level of 2000 parts per million (ppm) established by regulatory agencies.

In addition to the soil added to the second portion of the compost recipe, spiked samples of PCS were added to the two compost systems. The spiked samples were generated at levels of 2,000 ppm, 10,000 ppm, 25,000 ppm, and 50,000 ppm. Mixing the petroleum and soil in a portable cement mixer generated each sample. The highly contaminated soils were then loaded in 1-cu ft samples into porous containers and strategically placed throughout the compost systems.

Demonstration Descriptions

Fort Hood Demonstration

The composting demonstration at Fort Hood began in mid-December 2004 and was staged at the site of the Fort Hood landfill (an outdoor facility). The demonstration site measures 500 ft by 140 ft and is enclosed with a chain link fence (north of the landfill sorting center). Electrical power was available on the site through a control trailer. The demonstration area was graded and sloped to the east and north, and very little vegetation was present on the site.

Weather at the site during compost preparation was relatively cool with temperatures reaching only into the high 60s. The mornings were generally overcast; however, the skies cleared by late morning. Very little precipitation fell during the compost preparation period. Varying winds were present almost every afternoon, and the humidity was relatively low.

The current contractors associated with the Fort Hood landfill (ISC) provided equipment and labor to perform mixing and monitoring of the compost. Materials for the compost were available on site, having been hauled to the location before project kickoff.

The west gate in the fence provided the best access to the site. As a result, materials were brought into the demonstration area through the west gate and staged on the west side.

The first 150 cu yd of compost material were mixed 2 days before placement into the Ag-Bag EcoPODs®. Approximately 250 lb of urea were added in equal portions at the time of compost feedstock mixing (Figure A-9). Water was applied to the feedstock to increase moisture content before loading the material into the CT-5®, and an Ag-Bag inoculate was added as the feedstock was loaded into the CT-5®.

Figure A-9. Compost feedstock with urea.

On 20 December 2004, the material was pressed into the EcoPOD®, and tube development began toward the east. Approximately 150 cu yd of material was loaded into the first EcoPOD®, the plastic tube was sealed, and the blower connections to the supply pipe were made. The tube vents were then added and adjusted to provide airflow from the EcoPOD®. This EcoPOD® was designated 1-S.

Mixing of the second batch of compost feedstock was performed on 21 December 2004. The constituents were the same as the material contained in the first EcoPOD® with the exception that 11 cu yd of grease trap filter cake were added to this feedstock.

The compost feedstock for the second EcoPOD® was mixed and immediately loaded into the CT-5® for placement inside the EcoPOD®. Again, water and inoculate were added as the material was loaded into the plastic tube. This EcoPOD® was designated 1-N. Daily monitoring of both EcoPODs® began once the second tube was filled.

Temperatures were measured at the center of each EcoPOD® with a 3-ft-long thermometer. Temperatures were recorded each day on normal business days. The ambient air temperature was also measured and recorded at the same time. Small grab samples of the compost mixture were removed weekly through every other vent hole. The moisture content of the mixture was calculated by weighing the samples, drying the samples in an oven, and then comparing the dry weights to the wet weights. Also, the blower timer settings were recorded when the on and off times were originally set and when the settings were changed. One week after the development of the EcoPOD® composting system, Fort Hood used the same recipe (with the exception of grease trap filter cake) to develop windrows for a comparison. The materials were brought to the project site and mixed in the proper proportions. The windrows were then placed to the east of the EcoPODs®.

Monitoring of the windrow systems began as soon as they were complete. The windrows were turned several times a week. They were initially turned using a front-end loader; however, Fort Hood procured a Scarab windrow turner that could turn the windrows in a very short time (Figure A-10). The Scarab windrow turner was used for the remaining portion of the project.

Fort Lewis Demonstration

The second segment of the demonstration project at Fort Lewis began in late March 2005. This segment of the project saw the generation of a compost feedstock recipe that was lean in nitrogen-rich green material, but heavy on wood chips. Dry leaves, horse manure, and biosolids were available for the compost recipe; no food waste or grease trap materials were mixed in.

The project was staged at the site of the Fort Lewis landfill to the west of the scale house. The proposed location was under an unsided metal cover structure. Several drains were available for leachate collection, and electrical power, water, and lights were available (Figures A-11 and A-12). Both the Ag-Bag EcoPOD® system and the static-pile system remained under the covered facility. Some soil and biosolid materials required relocation prior to project kickoff. The feedstock materials were available on location with the exception of the biosolids from the WWTP, which were trucked into the project facility as the compost feedstock mixing operation was being set up.

Figure A-10. Scarab windrow turning machine.

Figure A-11. Fort Lewis covered compost demonstration facility (front view).

Figure A-12. Fort Lewis covered compost demonstration facility (side view).

The weather conditions at the site were not monitored since the project was compiled under the metal roof structure. The cool, humid environment of the area was reflected in the higher than normal level of moisture in most of the compost ingredients.

The mixing operation for the Fort Lewis compost feedstock used a Farm Shop EzMix Model 380 Special agricultural mixer (Figure A-13) to mix all the feedstock ingredients. The ingredients were added to the mixer in proportions established for the compost recipe. Mixed material was discharged out the side of the mixer and placed directly into the CT-5® for pressing into the EcoPOD® plastic tube. No water or inoculate were added to the feedstock prior to placement in the EcoPOD®.

The compost feedstock mixing was performed in two phases. Approximately 150 cu yd of compost feedstock material was generated for the first phase, and the first phase of the feedstock did not contain any soil as part of the compost recipe. Half of the first phase of mixed compost feedstock was placed in the EcoPOD® while the second half was placed in the aerated static pile. Spiked PCS samples in permeable containers were placed in both the aerated static pile as well as the EcoPODs®.

Figure A-13. Fort Lewis compost feedstock mixer.

The second portion of compost feedstock was generated with the addition of loose PCS at 10 percent by volume. Again, the feedstock was split, with half being placed into a second EcoPOD® and the remaining portion placed in the static aerated pile.

The aerated pile was split by plywood that provided a divider between the compost feedstock containing soil and the feedstock without soil. Spiked soil samples were placed in the second section of the aerated pile. Following placement of all the feedstock, the biofilter was placed. For this demonstration, the biofilter was a 1-ft-thick covering of coarse wood chips.

Once both systems were fully established, blower operation times were set, and operation of both systems was established. However, monitoring of the two systems by Fort Lewis did not begin until 18 April 2005, approximately 2 weeks after the systems were completed. Temperatures were measured with a long-stem thermometer once each business day at 1-ft and 3-ft deep through the vents in the EcoPODs®. The same thermometer was also used to measure temperatures in the static aerated pile. Temperatures were measured at 1-, 2-, and 3-ft depths at the top, middle, and bottom of the pile. Blower settings were noted when initially set and when changed. Neither system required any significant maintenance.

Demonstration Project Results

Fort Hood Results

Monitoring of the windrow compost and the EcoPOD® compost operations took place from mid-December 2004 to mid-May 2005. Based on the temperature data taken, it appeared that EcoPOD® 1-N was successful in reaching the criteria of 131 °F to further reduce pathogens by averaging over 132 °F during the first 14 days of monitoring (22 December 2004 through 4 January 2005). EcoPOD® 1-S did not reach temperatures as high as did 1-N, averaging approximately 115 °F over the same time period (Figure A-14).

These results indicate that the addition of grease trap filter cake to the 1-N bag was an important factor, and the data also indicate that the compost mixture in EcoPOD® 1-S was too low in nitrogen for successful composting. Temperatures dropped off substantially from the high temperatures achieved during the early phase of composting; however, the temperatures began to stabilize close to ambient temperatures after 1 February 2005.

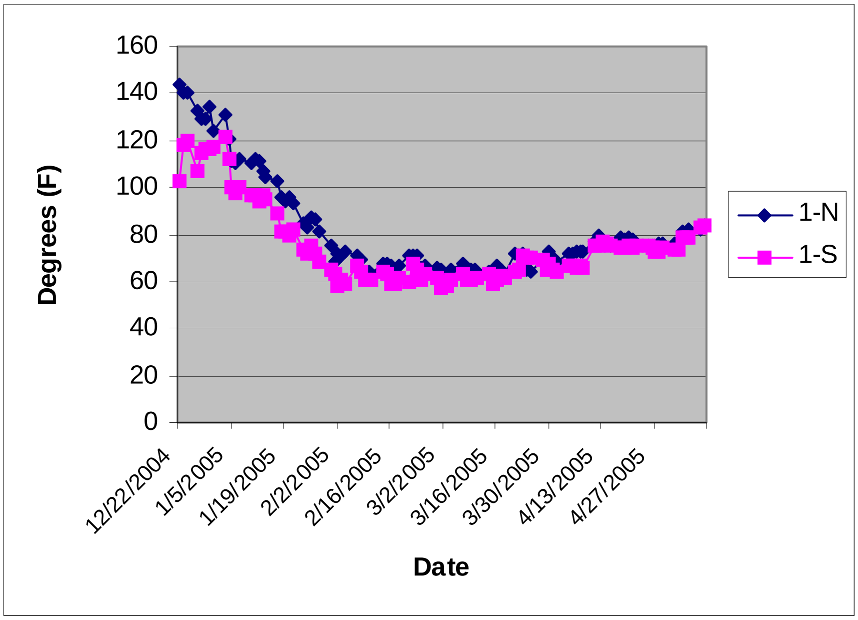


Figure A-14. Fort Hood EcoPOD® temperatures.

Following 22 weeks of composting, the Fort Hood EcoPODs® were opened, and the compost was removed from the plastic tube and analyzed. The material was dry from the center of the compost to approximately 6 in. from the outside. The outside 6 in. of material was extremely wet. Some leachate was present in the bottom of the plastic tubes, and this was collected and added back to the compost.

Visually the compost feedstock looked significantly developed. The outside layer looked relatively unprocessed, very close to raw compost feedstock. The dry inner center of the compost appeared to be dark and mostly decomposed, approaching the ideal curing phase of composting.

Solvita® "Compost Maturity" tests were performed on the compost that was being processed in both the EcoPODs®. Table A-3 lists the results of those tests.

Table A-3. Results of Fort Hood Solvita® compost maturity tests.

Sample	CO_2	NH_3
East side of south pile (no grease trap material)	4	4
West side of south pile (no grease trap material)	5	5
East side of north pile (grease trap material added)	3	5
West side of north pile (grease trap material added)	4	4

The CO_2 analysis was based on a range of 1 to 8 with 1 representing raw compost and 8 indicating very mature compost. The results for the CO_2 analysis reveal that the compost was immature, that cellulose had not been highly degraded, and that the compost could continue to mature if sufficient nitrogen was available.

The ammonia (NH_3) analysis is based on a range from 1 to 5 with 1 representing a very high level of NH_3 and 5 representing a low level of NH_3. The results of the NH_3 test show that the compost was producing very little NH_3 and was moderately mature. The NH_3 results also support the idea that the compost mixtures did not have sufficient nitrogen content initially to achieve full composting activity.

The combination of NH_3 and CO_2 analyses shows the stage of maturity of the compost. The results of the samples drawn from Fort Hood reveal compost that is in the ideal active range to the ideal curing range. Additional curing was required prior to distribution.

The Scarab windrow turner was used to turn the compost that had been removed from the EcoPODs®, and curing of the two compost piles from the EcoPOD® process began immediately. Temperatures rose steadily for 2 to 3 weeks, then stabilized in the 115 to 120 °F range, indicating active compost curing (Figure A-15).

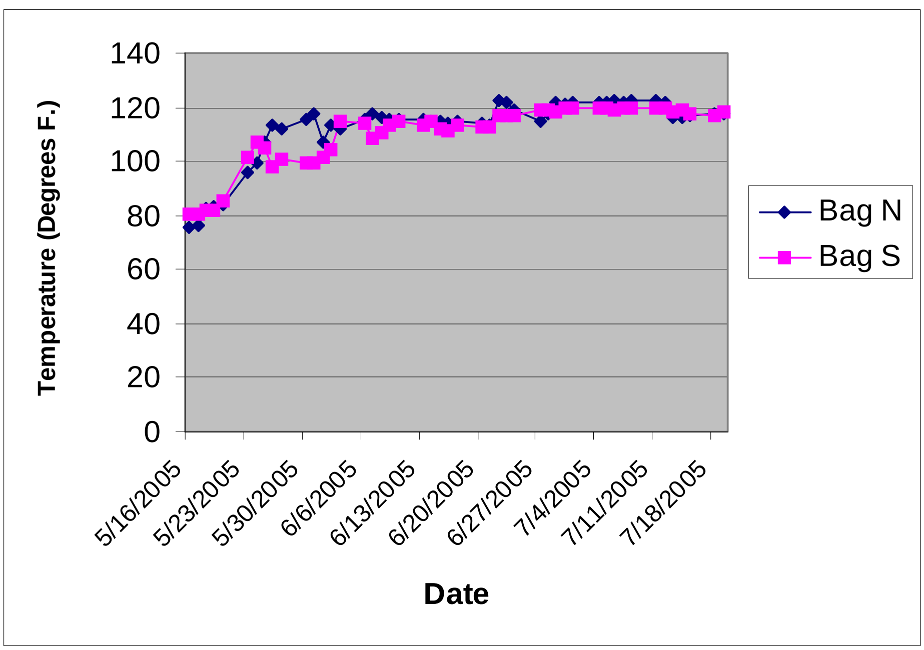


Figure A-15. Fort Hood compost temperatures after bag removal.

A visual inspection of the windrow composting system revealed that the compost process system was very near complete (Figure A-16). The compost was a deep dark color with an earthy smell. The material was well decomposed, and the particle size was small. A Solvita® compost maturity test did not appear necessary and was not performed on the windrow compost system.

Composting appeared to degrade the wood significantly; however, the compost from the windrow composting system required screening to remove the large pieces of wood. If screening of the compost was performed, it appeared that the screened wood could be used again to provide compost feedstock porosity.

Fort Lewis Results

The portion of the demonstration project held at Fort Lewis was monitored for approximately 4 weeks after 18 April 2005. The temperatures of the EcoPODs® were highest at the start of the temperature monitoring period and declined thereafter. Temperatures of the static aerated pile rose substantially after the monitoring began and then declined significantly in the 4th week of monitoring. It is important to note that the delay in starting temperature monitoring may have resulted in missing pile temperatures that were higher than those measured after April 18 (Figure A-17).

Figure A-16. Fort Hood windrow system compost.

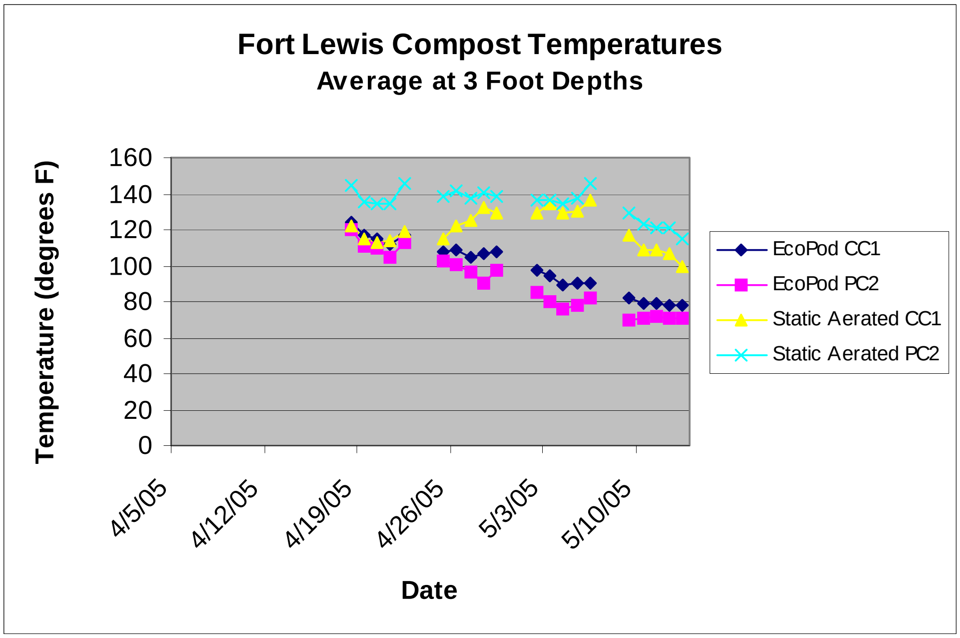


Figure A-17. Fort Lewis compost temperatures.

After temperatures declined significantly, the temperature data were sent to the State of Washington for regulatory review. The state rejected all the compost for unrestricted release, citing that the temperatures had not achieved the minimum temperature for the required timeframe throughout the EcoPODs® and static aerated pile.

Operation of both composting systems was discontinued, and both systems were disassembled. As the aerated static-pile system was disassembled, steam was released from deep within the compost. The compost appeared to still be active; however, additional composting to reach temperatures above 131 °F would be required for unconditional release of this compost (Figure A-18).

The EcoPODs® were cut and the plastic was pulled back. Very little composting appeared to have taken place at the center of the EcoPOD®, which was dry while the outside 6 in. were very wet. It is theorized that this variation in moisture content is caused by water being evaporated from the warmer center of each EcoPOD® and then transported by airflow toward the vents and condensing in the cooler outer areas. This hypothesis is supported by temperature data that showed substantially cooler temperatures toward the outside of each EcoPOD®. Additional composting and/or modifications to the composting procedure would be required for this compost to be qualified for unconditional release.

Figure A-18. Opened aerated static pile at Fort Lewis.

Both composting systems contained soil and spiked samples of PCS. Neither composting system obtained the temperatures required for regulatory compliance. Both systems had to be disassembled. Thus, it was difficult to determine if composting is an acceptable alternative for PCS remediation. All the spiked PCS samples were removed from the composting systems, and samples of the spiked PCS and background samples were taken for laboratory analysis. The analysis of these samples was ambiguous, and there apparently is substantial difficulty in the laboratory procedures for measuring petroleum hydrocarbons within an organic-rich matrix such as compost. Although substantial quantities of petroleum were removed during the composting process, it is impossible to determine whether the removal mechanism was volatilization or biodegradation.

A Solvita® compost maturity test was performed on the EcoPOD® compost at Fort Lewis (Figure A-19). The results of the Solvita® test indicate that the compost was immature.

Conclusions and Recommendations

Fort Hood — Conclusions

The Fort Hood composting recipes worked adequately in both the windrow and Ag-Bag composting systems. Although additional water was added during preparation, the composting mixtures were slightly low on moisture, and this may have slowed the composting process. Mixing of the feedstocks was performed in the same manner for both systems; therefore, no conclusions can be drawn based on differences in the compost feedstock-mixing portion of the process.

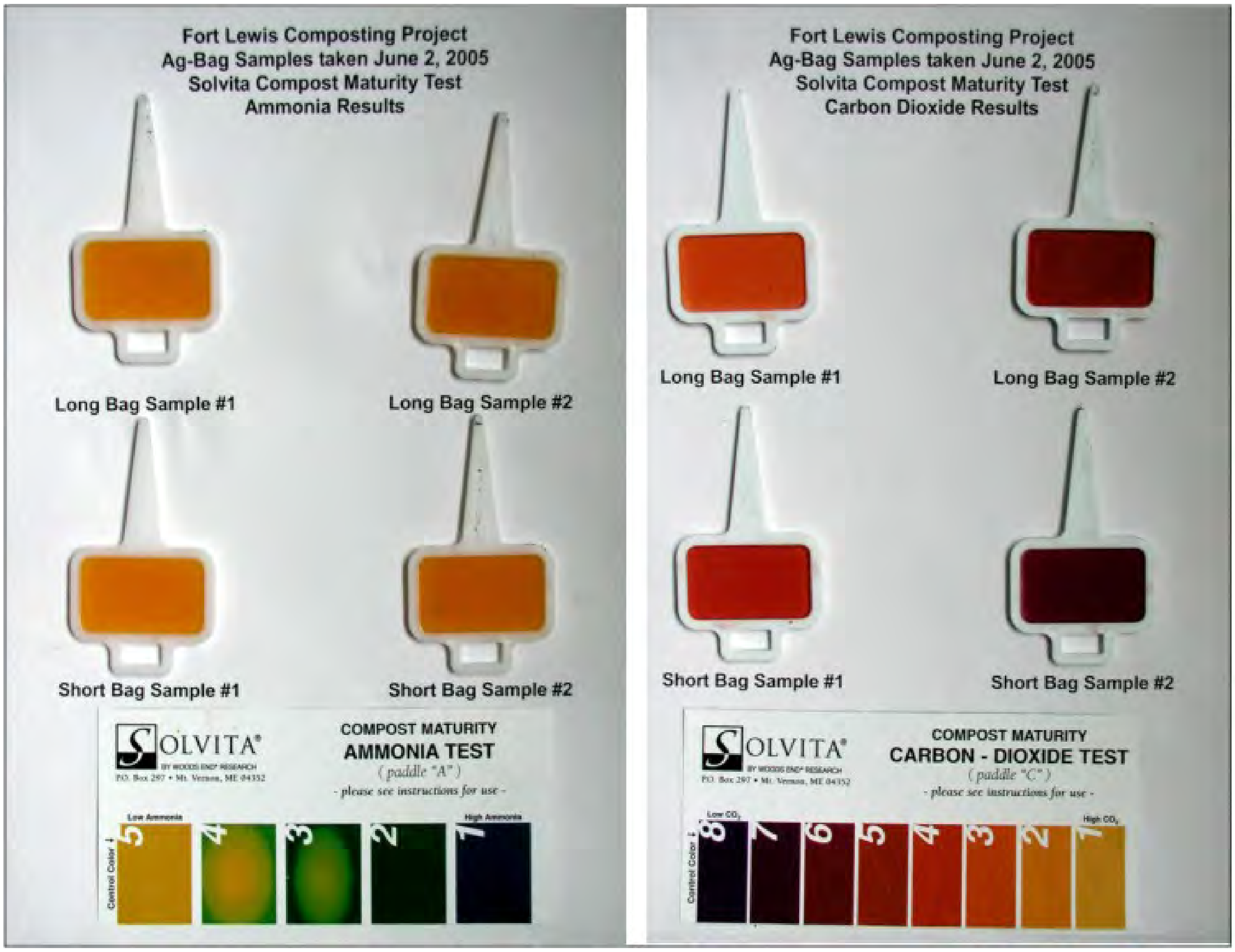


Figure A-19. Fort Lewis Solvita® NH_3 and CO_2 compost results.

The addition of urea or some other concentrated source of nitrogen appears to be advantageous for compost feedstocks low in fixed nitrogen; this situation is prevalent during winter composting operations. The addition of grease trap sludge also appears to be beneficial. It is also likely that food waste and biosolids would be beneficial compost components; however, the regulatory issues surrounding the use of these materials would make their continuing use problematic.

The inner portion of the EcoPODs® near the aeration pipe became dry during composting, and outer portions of the EcoPODs® contained substantially more moisture. It is possible that the blower times were too long, causing excessive drying and heat loss. Condensation at the outer margins of the EcoPODs® probably caused the excess moisture noted there. It is also possible that the excess moisture in the outer margins caused airflow channeling, further reducing the uniformity of compost aeration.

The windrow compost process progressed very well and achieved temperatures significantly higher than the EcoPODs®. A Scarab windrow turner was used to turn the compost windrows at Fort Hood. The windrow turner is capable of turning a windrow in a short time, creating a homogenous mixture, and it is possible that the homogenizing effect of turning is an important factor in achieving higher temperatures. It is also possible that the higher insulating properties of the larger piles are a determining factor in composting temperatures.

Fort Hood – Recommendations

The Ag-Bag composting system at Fort Hood initially worked well, and temperatures rose to adequate levels. The decrease in moisture over the demonstration led to a slowing in the composting process. Additional analysis would provide information that could determine when moisture could be required within the EcoPOD® units. Providing moisture through the EcoPOD® air vents or through the air blower system should be investigated. In any event, it appears that moisture management is critical to the success of this system.

The 5-ft-diameter EcoPOD® has a much higher surface-to-volume ratio than a larger 10-ft-diameter unit, which indicates a larger heat loss per unit volume of compost. The larger EcoPOD® should be able to retain more heat and provide a better composting environment. It might also be possible to insulate the EcoPOD® system in order to better retain heat.

The EcoPOD® system minimizes labor associated with compost aeration. The system also provides containment for odors, blowing materials, leachate, and vermin infestation. However, it is not recommended that Fort Hood include food waste, biosolids, or grease trap sludge in its composting recipe. Without these components to contend with, the advantages of the EcoPOD® system are minor.

The windrow system appeared to produce more mature compost in a shorter time. This system requires additional labor and maintenance in the turning operation; however, the equipment at Fort Hood is very efficient in performing the turning. Given the fact that Fort Hood has acquired the windrow turning machine, it is recommended that any full-scale composting be conducted in open-air windrows.

Fort Lewis – Conclusions

The feedstock used in both the EcoPOD® and the static aerated-pile composting systems could not be processed fully into usable compost as the temperatures achieved were not those necessary for unlimited release of the product. The temperatures of both composting systems also began an early decline and stabilized at a much lower value than expected.

The feedstock generated at Fort Lewis was probably low in nitrogen because relatively few green materials were available and biosolids were substituted in place of the green materials. The nitrogen content of the biosolids was estimated based on previous analysis and appeared to be less than that required for the composting process.

The static aerated-pile compost system appeared to provide a marginally better composting environment than the EcoPOD® composting system. However, additional labor is associated with the static aerated pile over the EcoPOD® system. Disassembly of the static aerated pile may require screening for removal of the biofilter, and some of the aeration piping may become damaged during pile removal. Temperatures in some areas inside the static aerated pile may be difficult to monitor, and this may be an issue with regulatory agency approval prior to distribution of the compost.

Again, it is likely that the insulating properties of the small EcoPODs® are not sufficient to maintain high temperatures in the pile.

The use of composting as a means of degrading PCS could not be reliably determined. It appears that a significant quantity of petroleum is either degraded or vaporized during composting; however, no accurate quantitative determination of these effects was achieved.

Fort Lewis – Recommendations

Each of the systems used at Fort Lewis had advantages and disadvantages. Both systems demonstrated at Fort Lewis were set up and operated under a covered facility; however, a large-scale composting facility might not be able to be completely covered. Further opportunities for composting processes in an open environment should be investigated.

More accurate methods for determining petroleum content are required before the facility could proceed with composting treatment of PCS.

Fort Lewis is situated in a humid, moist environment, and this may be an advantage with a forced air composting system, as the moisture may minimize drying of the feedstock due to aeration.

Given the fact that neither process was able to meet regulatory standards, it is impossible to make a recommendation of either system. However, it is likely that any composting system used should employ larger piles than those of the 5-ft-diameter EcoPODs®.

Overall Conclusions and Recommendations

The brown waste materials used at both Fort Hood and Fort Lewis were in abundant supply, although quantities of high-nitrogen green materials were not adequate to provide that nutrient (at least at the time of year when the demonstrations took place). It is likely that composting operations will need to provide supplementary nitrogen for a substantial portion of the year.

It is desirable to design composting recipes that avoid using components (waste food, biosolids, and grease trap sludge) that trigger regulatory oversight. The vast majority of compostable materials are simple vegetative waste. These materials can be converted to usable compost without the addition of the restricted materials.

Facility design should take into account the types of feedstocks that will be used throughout the operation. Some feedstock recipes that are high in initial moisture content may require special features, such as leachate collection, storage, and possibly treatment.

Heavy equipment is necessary for a composting operation. Both Fort Hood and Fort Lewis had large and small loaders available. For full-scale composting operations, heavy equipment dedicated to the operation would be desirable. The equipment is easily justified in a large-scale operation.

Based on the success at Fort Hood, it would seem that windrow-type composting processes might have intrinsic advantages due to mixing and homogenization of the pile. The feedstock/compost remains well mixed, proper moisture and aeration is easily monitored and maintained, and access to the entire windrow remains possible. Turning of the windrows using a specialized windrow turner is much more efficient than by using front-loaders. However, the capital cost of the windrow turning machinery is a barrier to implementation.

A feedstock mixer would provide a more homogeneous feedstock for all types of composting. Proportions of feedstock ingredients could be easily controlled and adjusted. Mixers specifically selected for a site could provide the capability of continuous operation when feedstock materials are available.

Screening of the compost feedstocks and compost product is useful. Screening can be used to remove large wood chips and other chunks of waste that are slow to compost. The screening operation can also provide gradation or separation of compost product.

A shredder would be advantageous in a large-scale compost facility. Some screening plants have shredders as an option, and this should be strongly considered if a screening plant is purchased.

Appendix B

References

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Solvita®, http://www.solvita.co.uk/.

U.S. Environmental Protection Agency, "Decision Makers' Guide to Solid Waste Management." EPA530-R-95-023, August 1995, http://www.epa.gov/epaoswer/non-hw/muncpl/dmg2.htm.

General guidance on composting is provided on USEPA web site, http://www.epa.gov/epawaste/conserve/rrr/composting/index.htm

Appendix C

Glossary and Acronyms

Term	Definition/Spellout
AR	Army Regulation
ASE	Army Strategy for the Environment
Biosolids	Sludge, or "biosolids," are the byproduct of the treatment of domestic and commercial wastewater or sewage in a wastewater treatment plant. Biosolids refers to treated and tested sewage sludge that can be beneficially used as soil amendment and fertilizer.
CERL	Construction Engineering Research Laboratory
CO2	Carbon Dioxide
Composting	Decomposing organic waste, such as food scraps and yard trimmings, with micro-organisms (mainly bacteria and fungi) to produce compost. Compost is organic material that can be used as a soil amendment or as a medium to grow plants (USEPA 1995).
DA	Department of the Army
DPW	Directorate of Public Works
EO	Executive Order
ERDC	Engineer Research and Development Center
HQUSACE	Headquarters, U.S. Army Corps of Engineers
ISC	Inland Service Company
Leachate	Liquid that has percolated through solid waste or another medium and has extracted, dissolved, or suspended materials from it. Because leachate may include potentially harmful materials, leachate collection and treatment are crucial at municipal waste landfills (USEPA 1995).
MSE	MSE Technology Applications, Inc.
NH3	Ammonia
PCS	Petroleum-contaminated soil
PDF	Portable Document Format
PPM	Parts per million
POC	point of contact
PWTB	Public Works Technical Bulletin
Solvita® "Compost Maturity" Test	The Solvita® test measures the biological activity of naturally occurring micro-organisms in soil or compost by checking the amount of carbon dioxide being given off. This "respiration" provides important information about the health and quality of the soil or compost being tested (http://www.solvita.co.uk/).
Sustainable	To create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations of Americans (EO 13423).
USACE	U.S. Army Corps of Engineers

Term	Definition/Spellout
USEPA	U.S. Environmental Protection Agency
URL	Universal Resource Locator
WM&PP	Waste Minimization and Pollution Prevention
WWTP	Wastewater Treatment Plant
WWW	World Wide Web

Appendix D

Acknowledgments

The work was performed for the U.S. Army Engineer Research and Development Center Construction Engineering Research Laboratory (ERDC-CERL) by the Facility Modernization and Sustainability Program at MSE Technology Applications, Inc. and the U.S. Department of Energy Environmental Management Consolidated Business Center. MSE was the primary contractor for the Waste Minimization and Pollution Prevention (WM&PP) Program managed by ERDC-CERL, through which this study was funded.

The major contributors to this project include:

- Gary Gerdes, ERDC-CERL, WM&PP Project Manager
- Jeff Salmon, Fort Hood Army Project Manager
- Ron Norton, Fort Lewis Solid Waste and Recycling Program Manager
- Rich Gillespie, Fort Lewis Landfill and Recycling Operations Supervisor
- Ben McConkey, Fort Lewis Sewage Treatment Plant Manager
- Dave Perry and Oliver Smith, Inland Service Corporation
- Steve Antonioli, MSE Program Manager.

Appendix E

Unit Conversion Factors

Multiply	By	To Obtain
cubic yard	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
inches	0.0254	meters
feet	0.3048	meters
pounds	0.45359237	kilograms