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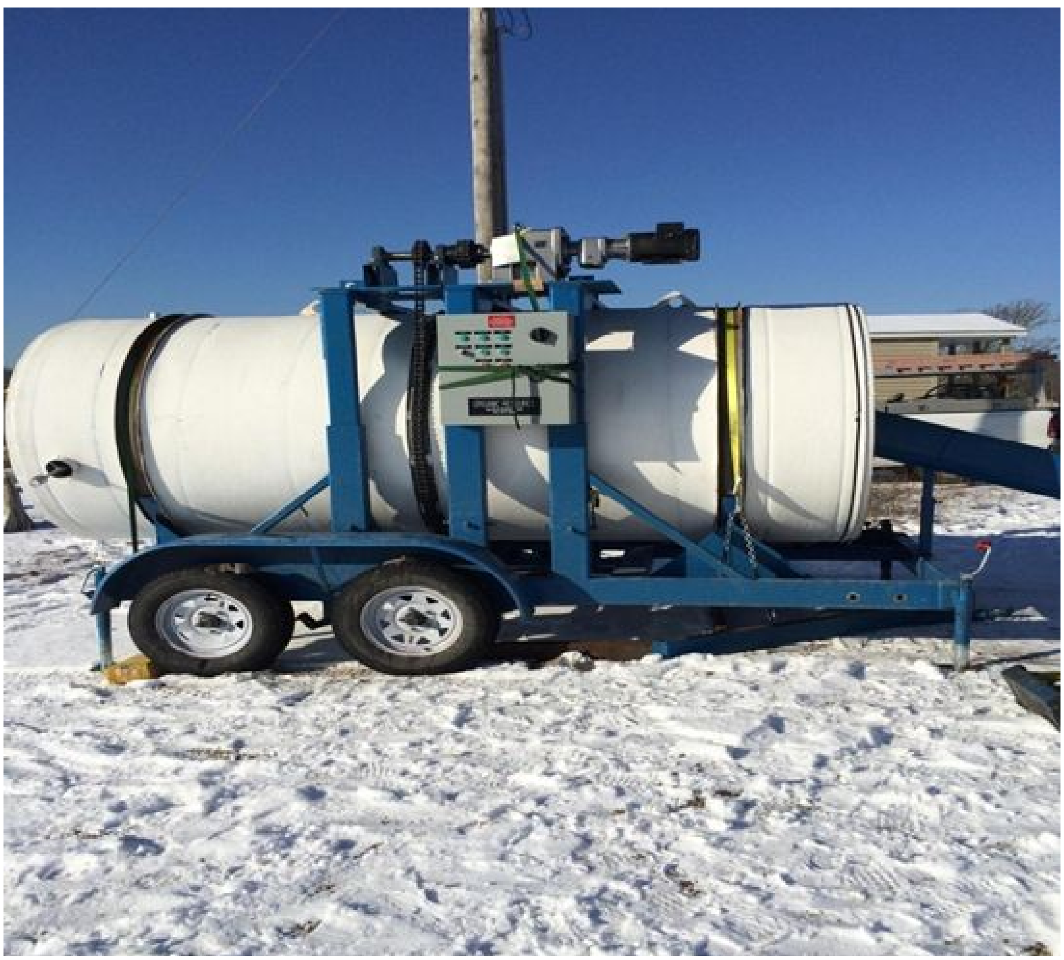
Center for the Advancement of Sustainability Innovations (CASI)

Demonstration of Combined Food and Landscape Waste Composting at Fort Leonard Wood, MO

Fort Leonard Wood Installation Strategic Sustainable Plan

Dick Gebhart, Ryan Busby, Annette Stumpf, and Susan Bevelheimer

January 2016



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Final Report

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Abstract

While nearly 90% of landscape wastes are recovered and processed into soil amendments and organic fertilizers using simple composting technologies, less than 3% of food wastes are recovered and recycled and the remainder are landfilled at considerable cost. Executive Order 13101 calls for the Department of Defense to incorporate waste prevention and recycling into their daily operations. Although most Army installations have effective landscape waste collection and recycling capabilities, they capture very little food waste for recycling. To initiate the incorporation of organic waste treatment technologies into daily activities at Army installations, this work investigated the logistical and economic feasibility of this technology and demonstrated food waste composting at Fort Leonard Wood, MO.

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Preface

This study was conducted for the Plans, Analysis, and Integration Office (PAIO) at U.S. Army Garrison Fort Leonard Wood (FLW) under Military Interdepartmental Purchase Request (MIPR) 10411458, "Investigate and Report the Logistics, Economics of Using an In-Vessel Aerobic Composting System for composting Food, landscape, and Other High Carbon Waste Materials." The technical monitor was Mark Premont, Chief of FLW Plans, Analysis, and Integration Office (PAIO).

The work was performed by the Engineering Process Branch (CF-N) of the Facilities Division (CF), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, the ERDC-CERL Principal Investigator (PI) was Dr. Dick Gebhart, CF-N. Donald Hicks was Chief, CEERD-CF-N; The Assistant Director of the Center for the Advancement of Sustainability Innovations (CASI) is Franklin H. Holcomb and Donald K. Hicks is Chief, CEERD-CF. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

LTC John T. Tucker, III was Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

1 Introduction

1.1 Background

The United States generates nearly 250 million tons of municipal solid waste annually (USEPA 2005). Of this, 34 million tons are classified as food waste and 16 million tons are classified as landscape wastes. Together, food and landscape wastes therefore represent nearly 20% of the total waste stream. Nearly 90% of landscape wastes are recovered and processed into soil amendments and organic fertilizers using simple composting technologies (Haug 1993, Renkow et al. 1994). Conversely, less than 3% of food wastes are recovered and recycled (Kim et al. 2008). The remainder, some 33 million tons, are thrown away and disposed of in landfills at considerable economic, environmental, and societal cost. Tipping fees in excess of $40.00/ton indicate that about $1.32 billion dollars are wasted on disposal alone, not to mention the value lost to individual purchasers from disposal of unconsumed food. When food waste is disposed in a landfill, it quickly decomposes and becomes a significant source of methane, a potent greenhouse gas with significantly greater potential for global warming than carbon dioxide gas (Komilis and Ham 2000, Chang and Hsu 2008). The USEPA estimates that more than 20% of all methane emissions can be attributed to landfills and decomposition of food and other organic wastes (USEPA 2010).

Each U.S. Army installation is much like a small town or city and as such, is really a microcosm of a typical U.S. municipality. Landscape and food wastes produced at the installation level are likely very similar in proportion and amount when compared to USEPA statistics (2009). Executive Order (EO) 13101 calls for the Department of Defense (DoD) to incorporate waste prevention and recycling into their daily operations. Compliance with this order is evident at nearly all DoD facilities. Installations typically have cantonment areas, green spaces, and training ranges that generate landscape wastes. Most Army installations have landscape waste collection and recycling capabilities or contractual arrangements with nearby recyclers so very little landscape waste is actually landfilled or incinerated, but is instead composted to provide valuable soil amendments and fertilizers.

Like their municipal counterparts, Army installations also have food service providers (supermarkets, restaurants, schools, hospitals, and dining halls) and family housing areas where food waste is continually generated. Unlike landscape waste, however, very little food waste from these sources is captured for recycling. Instead, these wastes eventually end up in a landfill (Kim et al. 2008). There are several reasons for this disparity in the way food waste is handled when compared to landscape waste:

1. Most individuals, households, and other small-scale food waste generators are often unaware of how much food they dispose of on a daily basis that could be separated and collected for dedicated recycling.
2. Food waste separation and storage for later collection is often perceived as a relatively unsavory task due to textures, odors, and the sheer bulk of the waste material.
3. Storage and collection of food wastes is often incompatible with that of typical municipal solid waste (MSW) collection in that it requires specialized handling and transport capabilities.
4. Facilities for disposal and processing of food wastes are not common, even though they are becoming more numerous given the potential value of finished food waste compost.
5. Economies of scale that govern the processing of food waste (collection, storage, treatment, and final disposition) suggest that the process requires large quantities to be economically feasible since economic payback is directly proportional to the amount of food waste available for processing (Renkow and Rubin 1998). However, this is not entirely true; several lower cost options such as in-vessel aerobic composting technologies are available to small- to medium-sized food waste generators that can keep capital and labor costs economically manageable (Bonhotal et al. 2011).

To initiate the incorporation of organic waste treatment technologies into daily activities at Army installations, there is a need to investigate the logistical and economic feasibility of this technology and to demonstrate food waste composting in an Army installation setting. This work was undertaken to demonstrate food waste composting at Fort Leonard Wood, MO.

1.2 Objectives

The objectives of this work were to:

1. Investigate organic waste treatment technologies to identify those most appropriate to the Army installation setting

2. Select the organic waste treatment technology best suited to Fort Leonard Wood, MO
3. Demonstrate food waste composting at Fort Leonard Wood, MO and formulate "lessons learned" for application of organic waste composting at other sites.

1.3 Approach

The objectives of this work were met in the following steps:

1. Waste data specific to Fort Leonard Wood were used to provide logistical and economic data to investigate the feasibility of in-vessel aerobic composting systems to compost food, landscape, and other high carbon content waste materials at that site.
2. The parameters were devised for the actual composting demonstration in terms of waste assessment, site selection, compost system selection and operation, food and landscape waste collection, processing, and composting mixture ratios, and material/time/labor requirements associated with each parameter.
3. Results associated with a 30-day demonstration of a small in-vessel aerobic composting system for composting a mixture of food and landscape wastes produced by Fort Leonard Wood were recorded and analyzed.
4. Potential uses of the finished compost for rehabilitation, stabilization, maintenance, and improvement of training ranges and maneuver areas were identified.
5. Conclusions were drawn, and lessons learned compiled to help guide future applications of this technology at other Army installations.

1.4 Scope

Although this demonstration focused specifically on the composting of food wastes at Fort Leonard Wood, MO, the results of this work are broadly applicable to food waste composting at many DoD installations worldwide.

1.5 Mode of technology transfer

It is anticipated that the results of this demonstration will be used to initiate a permanent food composting program at Fort Leonard Wood, MO that will serve as a model for composting programs at other DoD installations.

2 Organic Waste Treatment in the U.S. Army

2.1.1 Organic waste materials description

Landscape wastes are generated from a variety of sources including mowing, tree-trimming, gardening, and other weather-driven events such as windstorms, ice storms, snowstorms, and flooding. Because most installations have protocols, facilities, equipment, and/or contractual arrangements for the efficient collection, storage, and processing of landscape wastes, the following process description will be very brief.

Processing landscape wastes usually involves some type of pre-processing such as grinding and screening to produce a substrate with good particle size distribution (Adhikari et al. 2009). Following pre-processing, these materials are usually composted using aerated windrows that facilitate decomposition through a microbial process that produces significant amounts of heat, thereby destroying pathogens and producing stabilized compost that can serve as a soil amendment or fertilizer (Epstein 1997). Windrow composting is simple and has very low capital and labor costs. Periodic watering and mechanical turning are required to optimize the decomposition process and time to completion of finished compost.

Food wastes or residuals are defined as all pre- and post-consumer foods and food by-products, as well as organic items that may accompany food, such as manufactured organics and soiled paper products (napkins, paper cups, cardboard, manufactured compostable serving ware) (U.S. Composting Council 2009). Food wastes are generated wherever people live and work and they take on many forms from pre-processed food waste (vegetable trimmings) to unsalable items (bruised fruit) to expired or spoiled items, to food scraps from a variety of venues (home, restaurant, hospital, cafeteria, school, dining hall, festivals).

Food waste diversion, collection, transport, pre-processing, and composting require significant educational awareness training and specialized equipment to minimize problems associated the diversion and collection of food residuals at their source (home, cafeteria, dining hall) (Donahue et al. 1998). Indoctrinating people regarding the concepts of food waste separation and diversion is probably the most difficult philosophical challenge in food waste recycling. From a practical standpoint, the most difficult challenge is that associated with the high moisture content and the concomitant mass and volume of the food residuals. Suitable vessels that facilitate storage and subsequent transport are absolutely essential. Transportation costs to the processing facility are usually minimal compared to landfill tipping fees, especially considering that the process achieves 100% landfill diversion of the food waste. The technical aspects of the various food waste-processing technologies are beyond the scope of this report, but management options for landscape and food waste recycling will be presented in the next sections.

2.1.2 Organic waste management options

Management options for recycling of landscape and food wastes nearly always include some type of formal collection, storage, and processing technology based on the science of composting (Haug 1993, Epstein 1998). Note that most food waste-processing technologies rely on the availability of some type of high carbon content bulking material, usually in the form of landscape or lumber processing wastes, to optimize the composting process (Campbell et al. 1997). As a result of this requirement for bulking materials, food waste processing can be complementary and synergistic to landscape waste processing, and the two can often be conducted simultaneously at the same site.

Processing technologies range from very simple, on-site methods with limited throughput such as vermiposting (vermi-composting), windrow composting, or in-vessel composting, to more complex and infrastructure intensive technologies involving anaerobic in-vessel composting or co-digestion with sewage sludge at under-used wastewater treatment facilities (USEPA 2006). Selection of the most appropriate technology is usually based on the amount of food and landscape waste generated and available for collection and processing that has been identified through a comprehensive landscape and food waste audit. The results of the audit will:

1. Highlight potential sources and anticipated volumes of recyclable landscape and food waste
2. Identify strengths and weaknesses in the waste diversion, separation, collection, storage, and transport chain
3. Identify opportunities for educational awareness training to facilitate efficient recycling efforts
4. Identify potential community partners to broaden scope and share costs of implementing landscape and food waste recycling programs

5. Provide guidance for selection of the waste recycling technology most appropriate for the set of circumstances identified in the waste audit.

Landscape and food waste-processing technologies range from very simple to extraordinarily complex. Despite this diversity in cost and complexity, processing technologies can be scaled to meet almost any set of waste generation and recycling scenarios. The following set of waste-processing technology descriptions are presented from simple to complex.

Simple waste processing usually implies:

1. Low capital startup and labor costs
2. Low energy, water, and transportation requirements
3. Potential ability to construct, operate, and maintain the technology on-site
4. Limited amounts and throughput of waste materials
5. A limited geographic area of interest.

Conversely, complex waste processing usually implies:

1. High capital startup and labor costs
2. High energy, water, and transportation requirements
3. Little or no potential for on-site construction and use
4. Large amounts of waste materials from many different generators
5. A large geographic area of interest.

One of the simplest of landscape and food waste-processing technologies is “windrow composting” (Haug 1993). A suitable site for composting should be level, have a concrete pad or lime stabilized surface for placing and mixing windrows, and should be of sufficient size to process the anticipated waste volume. Equipment requirements for windrow composting are minimal and should include a shredder/chipper/grinder, industrial screens, and a front-end loader. Many windrow-composting facilities deal only with landscape wastes; however, more composting facilities are beginning to accept food wastes into their composting programs because food wastes contain more moisture, have higher levels of nutrients to support microbial decomposition, require a high carbon content bulking agent (i.e., landscape or lumber processing wastes) (Liang et al. 2006) to optimize decomposition, and result in a higher quality finished compost end product.

In windrow composting, the ground and screened landscape and/or food materials are placed in long windrows about 5 to 10 ft in height, 10 to 20 ft in width, and up to 300 ft in length. Windrows are periodically turned and watered as necessary to optimize the decomposition/composting process. After about 45 to 60 days, the windrows are deconstructed and moved to a different location for additional curing and drying before resale. The entire process takes from 6 to 8 months for landscape wastes and from 4 to 6 months for a mixture of landscape and food wastes (Komilis and Ham 2004). Throughput for windrow-composting facilities varies widely and can range from 1000 to 100,000 cu yd/yr.

Under circumstances where landscape and/or food waste collection and processing is limited by defined geographic or institutional boundaries (e.g., City, County, University, Army Installation), where lack of space to accommodate windrow-composting facilities, or where local regulations prohibiting certain types of waste-processing facilities, in-vessel aerobic composting is usually the preferred technology (Kim et al. 2008). In-vessel composting technology is promoted for managing food wastes with limited space and is considered relatively complex compared to windrow composting. In-vessel systems require precise temperature, oxygen, and moisture control, high carbon content bulking agents (Liang et al. 2006), and skilled labor to operate and maintain these components. As such, capital expenses for an Army installation can be significant. However, many in-vessel system manufacturers can customize systems to optimize anticipated waste volume with capital expenditure.

Some common types of in-vessel aerobic composting systems include stationary, containerized, rotating drum and tub, and static pile. Regardless of system type, ground and screened waste and bulking materials are mixed and placed inside the vessel where moisture content, oxygen, and temperature are carefully controlled, thereby optimizing decomposition dynamics. Retention times for these systems vary from 1 to 6 weeks, depending on the complexity of the system, the type of waste feedstock, and the waste volume processed. After the initial retention time is completed, the semi-composted material is moved to an off-site area for an additional 6 to 8 weeks of curing. Throughput for in-vessel composting systems varies widely and can range from 1000 to 10,000 cu yd/yr.

Worldwide, there is a growing realization that simple, cost effective composting of landscape and food wastes can be accomplished with vermiposting, the use of select earthworm species as a means to convert organic wastes into a compost material rich in worm casts (Garg et al. 2006, Nair et al. 2006, Suthar 2008). In very specific situations, vermiposting represents a viable waste-processing technology that deserves mention. In the United States, vermiposting is done on very small scales, often in conjunction with individual homeowners or as an educational outreach activity for elementary and secondary school science classes. In other parts of the world, vermiposting is accomplished on very large scales and produces significant amounts of fertilizer that otherwise would be unavailable or far too expensive for small, family-based farms (Nair et al. 2006, National Bank for Agriculture and Rural Development 2007). The basic requirements for vermiposting are enclosure beds to house the food wastes and earthworms. The beds are maintained at 50% moisture and 80 °F and finished compost is available in 2 to 3 months. Throughput for vermiposting varies widely depending on complexity and size, and can range from as little as 1 cu yd/yr to as much as 10,000 cu yd/yr.

Availability of on-site food waste-processing technologies suitable for small- to medium- sized generators is often desirable; several manufacturers provide these technologies in the form of food waste digestors and pulpers. Fort Hood, TX, is currently testing an Organic Refuse Conversion Alternative (ORCA) food waste digestor at one of the cafeterias on the installation. Food waste digestion operates on the principal of accelerated decomposition in an environment optimized for moisture content, temperature, and aeration. Food wastes are separated and diverted to a digestor housed in or near the kitchen, dishwashing, or food preparation area. Within the digestion unit, food residuals are constantly agitated in a solution of water and enzymes until the particle size is reduced to a size that allows disposal into a sanitary sewer system. This processed water for discharge into the sanitary sewer system may also be captured and used as “greywater” or “compost tea” for landscape irrigation. However, note that this effluent has not been subjected to focused scientific research and may require additional treatment before such use is permitted. Throughput for food waste digestors varies according to manufacturer, but typically range from 0.5 to 2 cu yd/day.

Food pulpers operate somewhat similarly to food digestors, except that the water used for agitation and breakdown of food waste is recycled and the food waste particles are captured, dehydrated, compressed, and subsequently landfilled instead of being discharged into the sewer system. Food pulpers are also marketed as on-site food waste-processing units applicable for small- to medium-sized waste generators. These systems do not require the careful food waste separation and diversion steps that digestors require, and can process all food, paper, plastic, and Styrofoam wastes from a typical food service facility. The entire food waste stream is placed inside the pulper where constant agitation with water reduces particle size. The water/waste slurry is then transferred to a series of screens where the particles are captured, press dried, and bagged for landfill disposal. Food waste pulpers typically reduce waste volumes by 85 to 90% and can process anywhere from 1 to 2 cu yd/day.

2.1.3 Future opportunities and challenges for the Army

There are several obvious shortcomings and future needs when exploring landscape and food waste management in the context of a U.S. Army installation. First, there is a general lack of qualitative and quantitative data pertaining to landscape and food waste management at Army installations. It does not appear that a comprehensive food audit has ever been conducted, and as such, recommendations concerning options for complementary landscape and food waste recycling would be nearly impossible to make. Even if food waste management recommendations could be suggested, the need for educational awareness, the lack of familiarity with the food waste recycling process, and the lack of Army experience with recycling technologies or ability to use existing infrastructure and workforce in managing food waste-processing technologies would be problematic in the short term. These typical issues that any user of a novel or new technology would experience are not insurmountable given the proper exposure, education, and context. In the longer term, the Army has the infrastructure, the workforce, and “can-do” attitude to become a leader in the management, recycling, and beneficial reuse of food and landscape wastes.

3 Proposed Organic Waste Treatment for Fort Leonard Wood, MO

3.1 Food and landscape waste assessment

Based on data from Mr. William Moffitt, Installation Food Program Manager, Fort Leonard Wood serves about 9 to 12 million meals per year in its dining facilities (DFAC or DFACs). Other sources and locations of food wastes identified as potentially collectable include the hospital, commissary, and food courts. Based on an analysis of the volumes, potential for cross-contamination, and ease of collection, it was agreed that the primary food waste source for this demonstration effort should be DFACs, which generate 1 to 2 tons/day that could be easily collected. Local landfill tipping fees for the disposal of this food waste average about $200/ton, indicating that disposal of this material costs between $75,000 and $150,000 annually. Closer examination of the data with Mr. Moffitt revealed that the food waste stream exhibits little variability and is consistent from day to day in terms of volume, an important consideration when selecting an appropriately sized composting technology capable of processing this waste stream on a sustained and predictable basis. Further, this waste source is relatively free of non-compostable, inorganic materials. With minor adjustments in the way pre- and post-consumer food waste is collected, sorted, and processed, contamination can be significantly minimized.

Because landscape wastes are an integral part of food composting and must be available in the volume ratio of 2 to 3 parts landscape waste to 1 part food waste, the generation, collection, types, availability, and seasonal variability of landscape wastes needed for food composting was investigated through discussions and site visits coordinated with Mr. Craig French, Solid Waste and Recycling Program Manager. Since the majority of the food waste from Fort Leonard Wood DFACs is pulped, dewatered, and bagged, the volume ratio of landscape to food waste for composting purposes was assumed to be closer to equal parts of food and landscape waste. Fort Leonard Wood generates about 250 to 300 tons of leaves, grass clippings, and other landscape wastes annually. There is some seasonal variability in this waste stream as one might expect for a temperate climate. For the purposes of this demonstration, this landscape waste volume was considered sufficient for mixing and composting with food waste. However, one of the limiting factors for long term use may be the availability of wood chips, which are a necessary component of food waste composting as they give the decomposition process much needed bulk for proper aeration. Mr. French advised that Fort Leonard Wood does not have a chipper/tub grinder (at a cost of $600K for a model adequate to the task) and that they rely on a contractor to conduct chipping for them. This is not done on a regular basis, but there may be other options including chipped pallets from local sources provided they do not have nails or other metals in them as this is a compliance issue.

3.2 Composting site selection

Because all landscape wastes at Fort Leonard Wood are currently stored at the "stump dump" site, this location was selected as the demonstration site since transportation of landscape wastes, the most significant component of a food waste composting operation, would be minimized. Additionally, the current "stump dump" site has access to electricity and also has some site improvements that make it amenable to movement of equipment and personnel associated with a composting facility and associated activities. Siting and placement issues for the compost system were investigated and several permits and other documentation were required. (However, these were minimized since the total site is less than 2 acres in size.) Permits and other documentation required to gain regulatory and compliance approval for using the "stump dump" site included:

1. An Environmental Checklist for National Environmental Policy Act (NEPA) determination to verify no adverse impacts to solid waste, clean water, and clean air provisions
2. A Composting Exemption from the Missouri Department of Natural Resources, Solid Waste Program, allowing a 30-day exemption to cover the period of demonstration
3. A completed and approved Record of Environmental Consideration (REC) in support of the food waste composting demonstration.

3.3 Composting system selection and acquisition

Several composting systems were evaluated for their capability to process food waste generated from the DFACs at Fort Leonard Wood. Note that, without regard for system type/technology, some equipment and labor requirements are common to each. Among these are requirements for pre-processing/composting equipment that can shred/grind, mix, and convey food and landscape wastes, as well as space requirements for post-composting curing piles that are necessary to allow the compost to "finish" before being used. Depending on types of landscape wastes used, the shredding/grinding equipment may be minimal, requiring only a small commercial grade shredder/chipper costing between $5,000 and $10,000. There are a number of ways to process and mix landscape and food waste before composting, including the use of tub mixers or small tractors with front-end loading capabilities. For composting operations processing between 4 and 6 cu yd of food/landscape waste per day, a general rule of thumb suggests a labor commitment of 4 to 6 work-hours per week to accommodate shredding/grinding, mixing, loading, unloading, and creating/mixing curing piles for the semi-finished compost.

3.3.1 Aerated pile systems

This type of composting system consists of several bins constructed from treated wood or concrete. Each bin is an independent composting system that is filled to capacity with processed food/landscape wastes and allowed to naturally decompose with periodic turning and mixing in place. After the first bin is filled and composting is initiated, processed food/landscape wastes are then added to the second bin until it is filled to capacity, at which point the process is repeated for bin number three and so on and so forth. With periodic turning and mixing, each bin will produce finished compost in 40 to 60 days. Given the food and landscape waste volumes from Fort Leonard Wood, it is estimated that four bins (15x8x6 ft) would be sufficient. Advantages of these types of systems include their lower startup costs and ease of operation; shortcomings included their longer retention times, incomplete odor control, sensitivity to environmental conditions (cold and wet), and potential to attract vermin. Prices for these types of systems can vary significantly due to material and construction costs, but typically range from $20,000 to $50,000.

3.3.2 Aerated static piles or containerized batch systems

This type of composting system is very similar to the aerated pile, except that mixed food/landscape wastes are placed in covered piles or containerized bins into which air is circulated through a piping system designed to provide aeration without physically having to turn the pile with a tractor or mixer. As with aerated piles, several static or containerized piles/bins are required to accommodate large volumes of waste as each individual pile/bin requires 20 to 30 day composting retention times, followed by storage in curing piles before final use. Advantages of these types of systems are their lower labor requirements, better odor control, shorter retention times, and lesser sensitivity to environmental conditions; their principal disadvantage is their substantially higher startup cost. Prices for these types of systems vary depending on design (enclosed containers versus ag-bag technology) and capacity, but typically range from $30,000 to $75,000 for units capable of processing the volume of food waste produced by DFACs at Fort Leonard Wood.

3.3.3 Continuous containerized (in-vessel) systems

As their name implies, continuous containerized (in-vessel) systems operate continuously and would require little retention time or multiple units to accommodate the volume of food waste produced at Fort Leonard Wood. Processed and mixed food/landscape waste is loaded into one end of an elongated, insulated metal vessel, which is periodically rotated by means of an electric motor and gearbox. Over the 5- to 7-day residence time inside the vessel, the food/landscape mixture, which reaches temperatures over 130 °F, undergoes accelerated decomposition before being expelled at the opposite end of the vessel where it is collected and placed into curing piles for about 60 to 90 days before being used. During the curing period, the piles are turned/mixed every 7 to 10 days to promote good quality compost. Advantages of these types of systems include their low labor requirements, small footprint (smaller than any other system), superior odor control, the short retention times (shorter than any other system), and virtual absence of sensitivity to environmental conditions (due to the use of an insulated vessel); their principal disadvantage is that they have the highest startup costs of the various composting systems. Prices for in-vessel systems capable of processing 4 to 6 cu yd of mixed food/landscape waste per day range from $40,000 to $90,000.

3.3.4 Final system selection

The conditions at Fort Leonard Wood that limited the utility of the pile and containerized batch systems, and that favored the acquisition and demonstration of a containerized in-vessel system over the other types of systems/technologies, were:

- space limitations (<2 acres available for the site)
- pre- and post-demonstration labor and equipment requirements
- relatively extensive permitting requirements
- necessity for site improvements such as concrete pads and roofing to minimize rainfall capture, retention, and run-off.

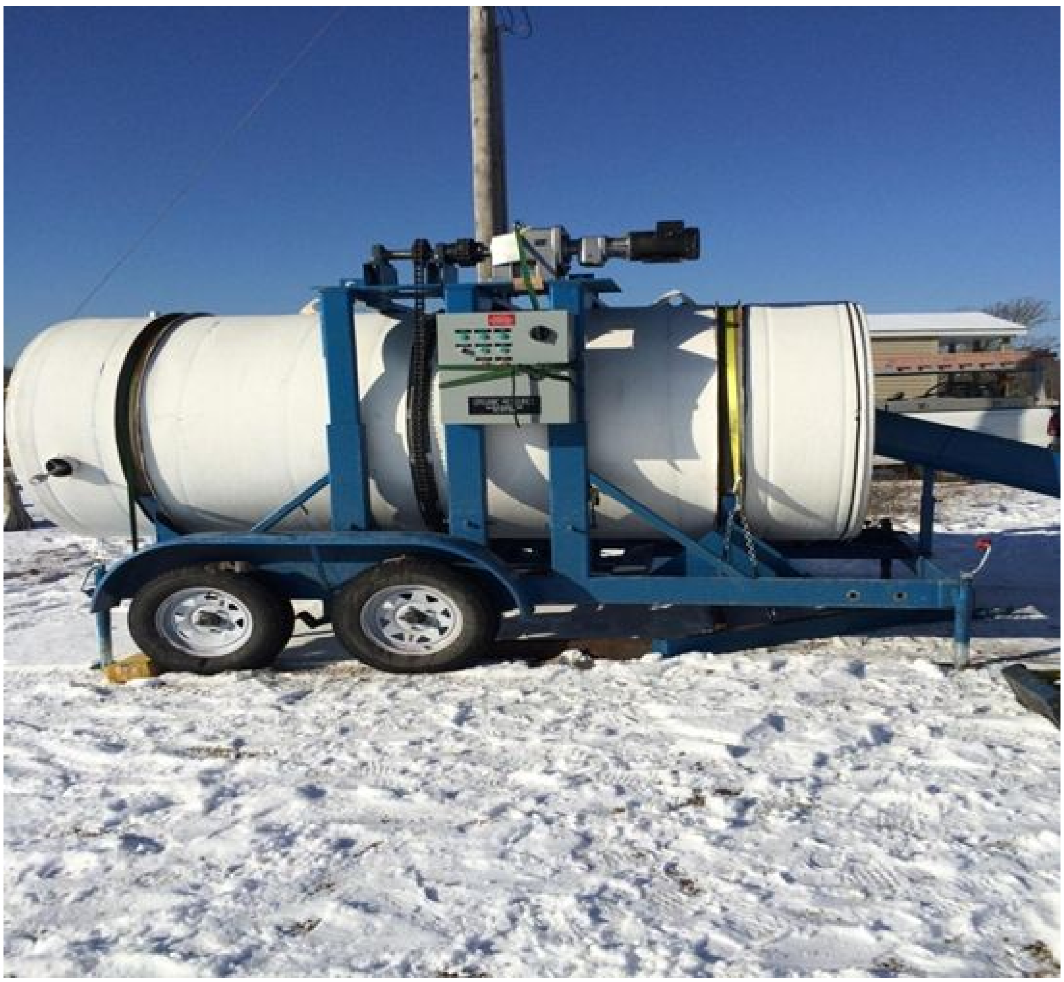
3.3.5 System specifications and acquisition

Based on USEPA tables relating weight to volume for food and landscape wastes (USEPA 2006), Fort Leonard Wood DFACs generate about 2 cu yd of food waste each day, which is about 60 to 75% water. The addition of equal amounts of landscape waste absorbs excess water and reduces the total volume by nearly 50% over the course of 24 to 36 hours (U.S. Composting Council 2009) as decomposition and evaporation proceed. Given these relationships, a request for proposals was developed using the following technical specifications:

- Acquire a tandem axle trailer-mounted aerobic, in-vessel, rotary drum system for composting food and landscape wastes at the current compost/stump dump site at Fort Leonard Wood, MO.
- The system shall be classified as a closed system and shall not provide access for entry of naturally occurring precipitation such as rain or snowfall.
- Technical specifications for this system were:
  - Trailer-mounted with tandem wheels and hitch for vehicle towing.
  - Capacity of 6-cu yd with dimensions of approximately 5 ft in width by 12 ft in length.
  - Input/output capacity of 2 cu yd per day.
  - The vessel shall be able to maintain an internal temperature of at least 131 °F for a period of 72 hours when operating under ideal moisture conditions and waste material carbon to nitrogen ratios.
  - The rotating drum motor shall be electrically powered with a minimum of 0.33 hp and appropriate gearing mechanisms capable of turning the drum a minimum of four revolutions per hour.
  - Specifications for the shredding/mixing and conveyance systems were:
    - Volume matched with rotary drum composting system to accommodate input/output capacity of 2 cu yd per day.
    - Electric powered shredder/mixer with a minimum of 4.0 hp motor.
    - Hopper capacity shall be between 0.5 and 2.0 cu yd.
    - Electric powered, auger conveyor system with a minimum of 0.25 hp for conveyance of mixed waste materials into the rotary drum unit.

Several vendors responded to the request for proposals and the purchase order was eventually awarded to Texas Microbial Applications* based on its competitive price, ability to deliver according to technical specifications, reference list, operator training program, and length of warranty. Acquisition cost including overhead was approximately $80,000. Figure 3-1 shows the rotary drum system supplied by Texas Microbial Applications.

Figure 3-1. Photograph of rotary from in-vessel composting system provided by competitive bid from Texas Microbial Applications.



* Texas Microbial Applications, Inc. 17774 Preston Road, Dallas, Texas 75252.

4 Composting System Demonstration

Conducting the formal demonstration required that many variables of the composting process be carefully controlled and documented. These included variables such as food waste weight, volume, and moisture content; landscape volume; in-vessel temperature and moisture content profiles; and compost curing pile volumes and temperatures. This careful control over the process, in addition to intensive labor and manpower requirements necessary to physically collect, inspect, weigh, transport, and load/unload food and landscape wastes limited the demonstration to using the food waste from only one DFAC. The 787th Battalion was selected as the test DFAC based on several criteria including proximity to the "stump dump" site, tenure and ability of kitchen staff to adapt to a new process, and an active and motivated environmental officer, Lt. Jessica Moot, who went far beyond expectations by providing soldier briefings and preparing professional signage for placement near the DFAC tray return area explaining the specifics of the demonstration and asking for assistance in making it a resounding success.

4.1 Food waste specifics

Food waste was collected from the 787th Battalion DFAC at Fort Leonard Wood from 13 April 2015 until 1 May 2015. All food waste from the 787th Battalion DFACs was processed using a pulping system whereby the waste was ground, dewatered, and collected in bags for transport to the demonstration site. Since the DFAC processes both pre- and post-consumer food waste, there was the potential for it to contain small amounts of materials such as plastic or paper food packaging, eating utensils, and condiment containers. To eliminate this contamination, a five-stage protocol was implemented:

1. Soldier briefings were conducted and signage was placed near the tray return areas explaining which materials were considered food waste contaminants that were to be segregated and thrown into trash containers before returning the food trays to the kitchen.
2. The protocol consisted of kitchen and ERDC staff standing near the tray return area and providing guidance to soldiers regarding what contaminant items still remained in their food waste.
3. Food wastes were physically inspected as they were discharged from the pulping system and all observable contaminants were removed.
4. Contaminants from the food waste were eliminated at the demonstration site before landscape wastes were loaded and mixed. As the food wastes

were transferred from bags into 5-gal containers for volume determination, they were again physically inspected for visible contaminants before being loaded into the batch mixer with landscape wastes.

5. The food-landscape compost was again inspected as it was expelled from the in-vessel rotary drum after processing. Less than 1 gram of inorganic contaminants per cubic yard of compost (approximately 1500 lb) was collected at this final stage, indicating that the protocol was very effective.

Food waste discharged from the pulping system was collected in plastic bags and weighed before transport to the demonstration site. Subsamples of food waste were randomly collected from breakfast, lunch, and dinner services to determine moisture content. Table 4-1 summarizes these moisture contents by date and meal service. The moisture content averaged 85% across dates and meal service and exhibited little variability.

Because of time and manpower constraints, it was nearly impossible to collect food waste from every meal service during the 30-day demonstration. To ensure that time and temperature requirements for food waste composting were met (i.e., 131 °F for 72 hours), food waste was only collected through 1 May 2015 to allow for sufficient residence time inside the composting vessel before the end of the formal 30-day demonstration period.

Table 4-1. Moisture content (%) of food waste across dates and meal services.

Date	Meal Service	Moisture content (%)
14 April 2015	Breakfast	84.6
	Lunch	87.5
15 April 2015	Lunch	83.8
	Dinner	87.3
16 April 2015	Lunch	78.1
	Dinner	84.6
21 April 2015	Breakfast	89.4
	Lunch	89.1
22 April 2015	Lunch	85.3
	Dinner	78.8
28 April 2015	Breakfast	85.9
	Dinner	82.8
30 April 2015	Breakfast	86.4
	Dinner	86.0
Average		85.0

Once collected from the DFAC, weighed, and transported to the demonstration site, the food waste was carefully transferred to 5-gal buckets and re-weighed to determine weight-to-volume relationships that would be used to estimate landscape to food waste volume ratios in the final composting recipe. Table 4-2 lists the weight and volume of food waste collected across dates and meal services from 14 April 2015 through 1 May 2015. As would be expected, there is variability between days and meal services due to fluctuations in menu entrees and numbers of soldiers served. During this time period, a total of 5123 lb of food waste was collected with a volume of 722 gal, or about 3.6 cu yd. The volume measurement is important as this allows the landscape to food waste compost mixture ratios to be determined based on volume rather than weight since landscape waste varies significantly with type (leaves, grass, wood chips) and age (fresh versus aged). The next section discusses these landscape waste specifics in greater detail.

4.2 Landscape waste specifics and mixture with food wastes for composting

The vast majority of the landscape waste used in this demonstration consisted of oak leaves and partially decomposed grass clippings, which had moisture contents between 5 and 13%. At the beginning of the demonstration, landscape waste was mixed with food waste in a batch mixer at a volume ratio of two parts landscape waste to one part food waste. This was done following each meal service collected (Table 4-2) so that food waste was never stored on site, but was always transferred immediately to the in-vessel composting system as per Missouri Department of Natural Resources compost exemption requirements. After about 14 days, the mixture in the vessel had a moisture content exceeding 65%, so the ratio of landscape waste to food waste was increased to five parts landscape waste to one part food waste by volume.

For example, the 14 April 2015 breakfast service food waste volume was 20 gal, so 40 gal of landscape waste were used in the compost mixture, whereas the 28 April 2015 breakfast service food waste volume was 23 gal, so 115 gal of landscape waste were used in the compost mixture. When the landscape waste to food waste volume ratios were increased on 28 April 2015, straw and wood chips became the primary landscape waste type added to the mixture. This served to decrease the bulk density of the compost mixture by reducing the moisture content and improving aeration by acting as a mixture bulking agent.

Table 4-2. Weight and volume of food waste collected from 787th Battalion DFAC from 14 April 2015 through 1 May 2015.

Date	Meal Service	Food Weight (lb)	Food Volume (gal)
14 April 2015	Breakfast	151.2	20
	Lunch	140.2	19
15 April 2015	Lunch	106.6	14
	Dinner	204.9	27
16 April 2015	Lunch	272.2	38
	Dinner	150.6	20
17 April 2015	Breakfast	93.8	14
	Lunch	124.6	18
20 April 2015	Lunch	165.2	23
	Dinner	199.4	28
21 April 2015	Breakfast	121.3	17
	Lunch	169.0	24
22 April 2015	Breakfast	109.3	15
	Lunch	152.6	22
	Dinner	178.6	26
23 April 2015	Breakfast	126.3	18
	Lunch	185.0	27
	Dinner	171.1	25
24 April 2015	Breakfast	133.4	19
	Lunch	173.2	25
27 April 2015	Lunch	143.2	20
	Dinner	207.3	29
28 April 2015	Breakfast	160.1	23
	Dinner	203.2	29
29 April 2015	Lunch	182.4	26
	Dinner	190.1	27
30 April 2015	Breakfast	133.3	19
	Dinner	206.3	30
1 May 2015	Breakfast	163.4	23
	Lunch	167.7	23
	Dinner	237.4	34
Total		5122.9	722

During the course of the demonstration, approximately 10 cu yd of landscape waste had been diverted to the composting process. When the food waste additions were stopped on 2 May 2015, the compost mixture moisture contents had declined in the range of 40 to 50%, which is considered ideal for decomposition in these types of in-vessel systems (Kim et al. 2008).

In-vessel temperatures were monitored during the demonstration to ensure that the magnitude and duration of the compost temperatures met or exceeded the USEPA standard of 131 °F for a period of 72 hours necessary to kill any potential pathogens. A temperature probe was inserted into the center of the vessel compost mixture and allowed to equilibrate for 15 minutes before readings were measured. Table 4-3 lists temperature data for selected dates from 16 April 2015 through 8 May 2015.

4.3 Compost system unloading and curing pile construction

On 12 May 2015, the compost that had been accumulating in the rotary drum system was expelled and placed into curing piles to allow for continued decomposition and return of piles to ambient temperatures, indicating that the compost is stabilized. As per the compost exemption provided by the Missouri Department of Natural Resources, the curing piles were placed on an impermeable tarp and completely covered to prevent precipitation from entering the pile and leachate from percolating into the soil. The volume of the finished compost was approximately 3 cu yd, indicating an 80% reduction in the original volume of food and landscape waste used over the course of the demonstration. Figure 4-1 shows the overall appearance of the finished compost before the curing pile was constructed.

Table 4-3. Summary of in-vessel temperatures for food/landscape compost mixture across several dates.

Date	Time	Temperature (°F)
16 April 2015	p.m.	128.2
17 April 2015	p.m.	130.3
20 April 2015	p.m.	134.4
22 April 2015	a.m.	132.7
23 April 2015	p.m.	133.4
24 April 2015	a.m.	131.6
28 April 2015	p.m.	132.3
30 April 2015	a.m.	131.2
4 May 2015	p.m.	131.8
5 May 2015	p.m.	133.7
6 May 2015	p.m.	131.4
7 May 2015	p.m.	126.4
8 May 2015	p.m.	122.2

4.4 Potential use for finished compost

The benefits of applying compost to soils that are very sandy, lack organic matter, have poor water holding capacity, and/or are highly eroded or compacted are well known. Application rates as low as 10 to 15 tons per acre (about 0.25 in. thick) have been shown to significantly increase organic matter content in sandy soils (Torbert et al. 2007, Zhang et al. 1997). The benefits after one initial application often carry over into subsequent years (Mamo et al. 1998, Watts et al. 2012a, Watts et al. 2012b). Any increase in organic matter content improves water holding capacity and the moisture-release dynamics of soils (Turner et al. 1994, Giusquiani et al. 1995), thereby supporting more desirable plant communities (Watts et al. 2012a).

Military maneuver training frequently results in heavily compacted soils and compost applications nearly always decrease bulk density (Turner et al. 1994, Giusquiani et al. 1995, Pagliai and Vittori-Antisari 1993), thereby minimizing erosion risk and improving water infiltration, porosity, and storage for plant use as the growing season progresses (Zhang et al. 1997). In collaboration with Directorate of Public Works (DPW) Environmental and Range Control, several Land Rehabilitation and Maintenance (LRAM) sites will be identified for potential compost application.

Figure 4-1. Photograph of the food/landscape waste compost immediately after being expelled from the rotary drum composting system

5 Conclusions, Recommendations, and Lessons Learned

5.1 Conclusions

It is concluded from the results of this demonstration that food waste composting is a viable alternative to collection and landfilling at considerable cost. The current 6-cu yd rotary drum system would be capable of processing the food waste produced by Fort Leonard Wood DFACs.

Although this demonstration was conducted under carefully controlled conditions requiring significant time and labor commitments to capture quality data and meet regulatory exemptions, it is also concluded that, with some automation (front-end loader or similar) and waste hauler contract modification to provide suitable food waste collection containers and delivery to the compost site, a full scale food waste composting program is achievable. For composting operations processing between 4 and 6 cu yd of food/landscape waste per day, much like Fort Leonard Wood, a general rule of thumb suggests that the process would require a labor commitment of 4 to 6 work-hours per week to accommodate shredding/grinding, mixing, loading, unloading, and creating/mixing curing piles for the semi-finished compost (Donahue et al. 1998).

5.2 Recommendations

To fully implement a food waste composting program at Fort Leonard Wood, it is recommended that several specific required items be pursued:

- Among the most challenging would be obtaining the necessary regulatory permits to operate a food waste composting facility at this site. Suitable infrastructure pertinent to composting operations such as concrete pads and roofing systems to control both natural precipitation and leachates from curing piles can often be a prerequisite to securing the necessary regulatory permits.
- Acquisition of some type of front-end loader would be absolutely essential for moving and loading landscape waste into the batch mixer and unloading and moving finished compost into curing piles.
- Modification of existing waste hauling and management contracts would be required to effectively collect and transport food waste for composting. Specialized collection containers allowing ease of transport, volume determination, and subsequent deposit of food waste

directly into the batch mixer would provide the level of automation necessary to effectively deal with the 2000 to 4000 lb of food waste produced daily. Given that landfill tipping fees for the disposal of this waste range from $75,000 to $150,000 annually, the savings resulting from diversion of the food waste would pay for the specialized collection containers and the labor required to operate the process at the composting site.

- Modification of an existing batch mixer to accommodate front-end loading of food and landscape wastes would also be required to automate the loading and mixing process as much as possible.
- Development of an education program for soldiers using DFACs to minimize or preferably eliminate inorganic contaminants in the food waste that might otherwise pass into the pulpers for processing. Observations from a few random DFACs indicate that there are significant amounts of inorganic trash/contaminants in food waste coming from the pulping systems. The staff, soldiers, and Environmental Officer for the 787^{th} Battalion proved beyond a doubt that, with a little effort and education, the contaminants can be significantly minimized.

Since the rotary drum system is already in place and fully operational at Fort Leonard Wood, it is recommended that several items be pursued to maximize the benefits of the system:

- Continue to operate the system using only landscape wastes to produce high quality compost. While this feedstock takes much longer to decompose, the end result is still a very high quality compost that would be valuable to the local gardening community, or perhaps the Veteran Farmer program among others.
- The "care and feeding" of the rotary drum system could be accomplished through the use of volunteers or by compost site users. For example, encourage those users with bagged leaves, stable wastes, and grass clippings to deposit these materials into the batch mixer instead of just dumping them at the perimeter of the "stump dump" site. The soldiers observed at the compost site expressed their enthusiastic willingness to dump the bags of leaves and landscape wastes in any appropriate location. Since they are required to open the bags and shake out the contents, they could just as easily shake the contents into the mixer for feeding into the rotary drum. This way the system continues to get used while an interim decision regarding a full scale food waste composting facility is considered.

- The daytime caretakers of the "stump dump" site have expressed an interest in the rotary drum system and have acknowledged that they have spare time that could be used for feeding and care of the system. It may be possible to effect a contract modification to require some caretaker involvement to allow for continued system use.
- It may be possible to pursue the engagement of contingency base personnel in this effort as well. These systems have some applicability in contingency operations and this aspect may deserve further consideration and exploration.

5.3 Lessons learned

Each composting system/technology has a unique set of requirements that must be met for the system to operate effectively and efficiently. For the rotary drum system, the greatest challenge was in ensuring that adequate electrical power was available to operate the batch mixer, auger, and rotary drum motor. Motors can be specified to operate with 110 or 220 volt service and since many of the rotary drum systems are custom built, it is imperative to know what type of electrical service is available so that the acquisition contract language can reflect the power requirements. In this demonstration, for example, the Texas Microbial Applications rotary drum system motors, which were originally supplied with 220 volt service, had to be stepped down to accommodate 110 volt service, which resulted in a delay in delivery date.

When reviewing bid proposals for composting system acquisition, pay very close attention to any express or implied warranties the manufacturer provides for the system. These can become very important. For example, the rotary drum system supplied by Texas Microbial Applications was operated by a control panel that failed during initial set-up and operation. The express warranty covered the replacement of this control panel by a qualified technician within 2 days. Additionally, the rotary drum motor was also inappropriately matched to the system and had to be replaced during the initial set-up and operation. Again, the express warranty covered the replacement of this expensive component within a short period of time.

One of the downsides of DFAC pulping systems is that, while they efficiently process food waste and reduce volume, they also encourage the introduction of inorganic waste (Styrofoam, cellophane, food wrappers, and condiment packaging) into the food waste stream. This contamination is not acceptable. According to the compost exemption from the Missouri

Department of Natural Resources, food waste compost with significant amounts of trash cannot be land applied. It was noted during early visits to several DFACs that significant amounts of inorganic materials were present in the pulped food waste, limiting its desirability as a feedstock for a composting program. Therefore, it is important to have a well planned educational program in place to instruct DFAC users and personnel about the specifics of food waste composting to include what kinds of materials (Styrofoam, cellophane, food wrappers, and condiment packaging) absolutely cannot be tolerated in this waste stream.

As discussed previously, and to the credit of the 787^{th} Battalion, the educational program (soldier briefings, signage, and tray return line observation and individual instruction) was very effective at minimizing the amounts of inorganic waste materials present in the pulped food waste. The Battalion Environmental Officers should be engaged early in this educational process and well before any food waste collection is planned to ensure a contaminant free pulped material for composting.

End users of the compost, such as DPW and Range Control/Integrated Training Area Management (ITAM), should be engaged early in the process to ensure that the benefits of compost application to their respective landscaping and training range rehabilitation efforts are well understood and can be incorporated into current business practices. For example, instead of the current view of compost as something that someone other than themselves should be responsible for, the loading, delivery, and use of the compost should be viewed as a free and beneficial resource that is part of their respective work plans and activities. Again, a well planned educational program and programmatic directives aimed at taking leadership and responsibility for this valuable resource would help change this perspective.

Acronyms and Abbreviations

Term	**Definition**
ANSI	American National Standards Institute
CASI	Center for the Advancement of Sustainability Innovations
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
DFAC	Dining facility
DoD	U.S. Department of Defense
DPW	Directorate of Public Works
EO	Executive Order
ERDC	U.S. Army Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
FLW	Fort Leonard Wood
hp	horsepower
ITAM	Integrated Training Area Management
LRAM	Land Rehabilitation and Maintenance
MIPR	Military Interdepartmental Purchase Request
MSW	Municipal Solid Waste
NEPA	National Environmental Policy Act
NSN	National Supply Number
OMB	Office of Management and Budget
ORCA	Organic Refuse Conversion Alternative
PAIO	Plans, Analysis, and Integration Office
PI	Principal Investigator
REC	Record of Environmental Consideration
SAR	Same As Report
SF	Standard Form
TR	Technical Report
USEPA	U.S. Environmental Protection Agency

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While nearly 90% of landscape wastes are recovered and processed into soil amendments and organic fertilizers using simple composting technologies, less than 3% of food wastes are recovered and recycled and the remainder are landfilled at considerable cost. Executive Order 13101 calls for the Department of Defense to incorporate waste prevention and recycling into their daily operations. Although most Army installations have effective landscape waste collection and recycling capabilities, they capture very little food waste for recycling. To initiate the incorporation of organic waste treatment technologies into daily activities at Army installations, this work investigated the logistical and economic feasibility of this technology and demonstrated food waste composting at Fort Leonard Wood, MO.

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