Evaluation and Prioritization Of Compost Facility Runoff Management Methods

RECYCLING TECHNOLOGY ASSISTANCE PARTNERSHIP
ReTAP

AN AFFILIATE OF MANUFACTURING EXTENSION PARTNERSHIP™

ACKNOWLEDGMENTS

CWC is a nonprofit organization providing recycling market development services to both businesses and governments, including tools and technologies to help manufacturers use recycled materials. CWC is an affiliate of the national Manufacturing Extension Partnership (MEP) – a program of the US Commerce Department's National Institute of Standards and Technology. The MEP is a growing nationwide network of extension services to help smaller US manufacturers improve their performance and become more competitive. CWC also acknowledges support from the US Environmental Protection Agency and other organizations.

Evaluation and Prioritization of Compost Facility Runoff Management Methods

FINAL

Prepared for:

CWC

A division of the Pacific NorthWest Economic Region (PNWER)
2200 Alaskan Way, Suite 460
Seattle, WA 98121

January 2000

Prepared by:

E&A Environmental Consultants, Inc.
19110 Bothell Way N.E. Suite 203
Bothell, WA 98011

This recycled paper is recyclable

REPORT NO. CM-00-2

Table of Contents

Appendices: (not included in this electronic file)

List of Tables:

List of Figures:

1 Introduction

The purpose of this project is to evaluate and prioritize methods for compost facilities' management of rainfall runoff. The runoff contains contaminants that could cause problems if they migrate offsite. Therefore, compost facilities capture and treat the runoff before release or reuse. These techniques often require large amounts of space and are quite costly. This report explores and evaluates several methods to reduce, reuse, or recycle the runoff. Another water source that occurs with some composting systems – condensate – is not considered in this report.

Two existing compost sites were used to demonstrate and test these techniques. Soos Creek Organics (Kent, WA) and the Woodland Park Zoo (Seattle, WA). Soos Creek is a medium-scale yard debris composter, and the Woodland Park Zoo compost yard produces Zoo Doo from animal manure and bedding material. Both sites are on the west side of the Cascades, and therefore are inundated with rain in the fall, winter, and spring. Neither site is under cover.

The Soos Creek site was used to examine techniques to minimize the quantity of runoff generated, and therefore reduce the burden of treatment and disposal. Different feedstocks and composting techniques generate varying levels of microbial activity, and therefore use different amounts of water during the process. The more water that is used by the process, the less runoff is generated. Different compost techniques require varying amounts of impervious surface, and therefore generate vastly different quantities of runoff. The Soos Creek site was used to develop energy and runoff models, which show the quantity of runoff generated for a given storm from different compost technologies. In addition, management techniques were examined to determine how to reduce runoff from the site.

The Woodland Park Zoo compost facility is quite a bit smaller than Soos Creek, but some of the same concerns exist regarding the runoff. The Zoo produces a compost product (Zoo Doo) which has a strong market and public acceptance in Seattle. At this site, after analysis of nutrient content and testing following pathogen reduction, the project manager determined that it might be feasible to produce a compost tea (liquid plant food) from the runoff. This product (Zoo Broo) could be sold as a companion product to the Zoo Doo, and in fact might generate a substantial revenue stream. The Zoo made some product and gave it away at its quarterly compost sale. The response was quite positive, based on the surveys returned.

2 Summary

This project has revealed that there are several methods of reducing, reusing, and recycling process and non-process runoff as well as leachate from compost operations. Modification of operation technique and operating procedures can eliminate up to 90% of the runoff generated from a facility. These estimates are based on the energy and water needs of a system before and after optimizing the conditions for microbial growth. This optimization is achieved by:

- Managing composting process so that moisture and heat release occur at the same place in the pile.
- Manage the composting process such that evaporated moisture is released to the atmosphere.
- Inducing air in quantities sufficient to evenly distribute oxygen throughout the pile and remove heat (by evaporating water) when above the temperature set point.
- Reducing pad space by changing pile configuration to extended pile instead of windrows (with space between).
- Covering the compost process areas, and/or:
- Diverting rainfall pad water away from the active composting areas, thus preventing contamination.

In addition to these techniques, this report also shows that it is feasible to produce a product from the process runoff and leachate generated at a compost facility. The runoff, a disposal problem and a costly management burden, can be treated with heat in order to achieve complete pathogen destruction. The two trial tests of pasteurization generated results indicating that the pathogens can be controlled by heat generated within the pile, and by heat generated from burning propane. The results also show that re-growth does not occur within the first three weeks. The product, from the standpoint of pathogens, is safe for use by consumers.

Summary of Best Management Practice (BMP) Case Studies

The first case study considers methods of managing stormwater at the Soos Creek Organics Facility.

Most composting facilities generate runoff, and are faced with high treatment and disposal costs. Applying the principles of waste reduction, reuse and recycling to compost facility runoff management is an elegant solution to a problem currently experienced by many compost facility operators.

The following BMP methods were evaluated for Soos Creek:

- *Separation of Process Water and Storm Water on the Composting Pad* – Since winter time yard debris quantities are generally reduced significantly, the option of reducing the operating size of the pad becomes available.
- *Larger volume compost piles* – Larger composting piles will do a better job of capturing water because of increased level surface area. Larger piles will also do a better job of retaining generated heat. The expected result would be increased rainfall capture and evaporation.
- *Larger volume piles with low rate aeration* – Optimum heat utilization can be achieved by adding a minimal aeration system to the larger composting piles. The aeration will provide a continuous supply of air to capture and carry away the evaporated moisture.
- *Extended Aerated Static Pile* – This established composting process generates far more energy than needed to evaporate all rain falling on the surface. It is considered as a comparison baseline.
- *Structural Cover* – A structural method of reducing process water is to cover the composting area. This prevents the rainfall from contacting the composting material except as desired by the operator.

During this project, a spreadsheet model was developed to determine the quantity of runoff generated from different composting technologies and management practices. Application of this model to Soos Creeks situation indicates that a significant reduction in process water runoff can be accomplished by seasonally modifying the composting process. The results of the alternative comparison for that facility are provided on Table 1. All alternatives have assumed volumes of 15,000 cubic yards of material on site, and a pile depth of 12 feet.

Table 1 - Composting Process Water Management Alternatives

	Current[1]	*Pad isolation*	*Larger piles*	*Low rate air*	*EASP*[2]
Pad area (ac)	3.0	2.1	1.6	1.6	1.0
Pile runoff (%)	28	28	5	0	0
Runoff (gal)	1,650,000	780,000	315,000	255,000	145,000
% reduction		53	81	85	91
Avg. depth (ft)	5.5	5.5	7.0	7.0	10.5

[1]large static pile (no aeration)
[2]extended aerated static pile composting

The second case study involved producing a compost tea product at Seattle's Woodland Park Zoo.

The organic and nutrient content of the runoff was used to develop a valued product. Pathogens in the runoff were treated prior to reuse. This project tested two methods of pasteurization. Lab testing determined that both methods provided complete pathogen destruction.

<u>Pasteurization Method 1 – Buried Containers</u> - This method uses the residual heat of the pile to heat and pasteurize the liquid. Containers, if placed in the core of the pile, were heated to the temperature of the pile core. See the photos below.

Containers Placed in the Pile

Covering the Containers while Turning

The temperatures must exceed 55^{o} C for three consecutive days or 70^{o} C for 30 minutes.

Pasteurization Method 2 – Propane Burner - The second method of pasteurization uses a propane burner to heat a 55-gallon drum of process runoff. The process was heated to 70^{o} C (approximately 158^{o} F in approximately 100 minutes. The propane required to pasteurize 100 gallons of process runoff using this method would be approximately 1.1 gallons of propane. Therefore, fuel costs for pasteurizing 100 gallons of runoff would be approximately $1.10.

The compost tea produced in these tests was bottled and labeled as Zoo Broo. The product was distributed with a survey form at the Fecal Fest sponsored by the Zoo.

Ready for Distribution at Fecal Fest

Bottled Product

The Zoo Broo drew favorable response from the test market distribution, and nearly all participants liked the product and would be willing to pay $6 per gallon. The test batch of Zoo Broo cost approximately $1.75 per gallon to make, which indicates a good potential profit margin. This does not even take into consideration avoided cost of having to dispose of the runoff. The production of compost tea solves a problem and puts the nutrients present in the runoff to good use on plants rather than in the surface waters of the state, where they can cause substantial environmental damage.

3 Compost Facility Runoff Characteristics

The recycling concepts of reduction, reuse, and recycling have useful parallels when considering runoff management. Use of these concepts in runoff management are best understood in conjunction with the regulatory framework that differentiates between non-process stormwater runoff and composting process water based on physical contact between water and the solid waste feedstocks. Reduction would therefore involve actions that prevent rainfall from falling on compost piles or working surfaces where feedstock residuals are normally present. Providing a structural cover or reducing the size of the composting area would reduce the quantity of process water. Reuse would involve capturing process water and using it for moisture control in the composting process. Recycling could take one of three forms. First, by treating process water and discharging it to the environment, the water becomes part of the hydrologic cycle along with the other rainfall. Second, using the heat generated in the composting process, the water vapor is recycled to the atmosphere to again fall as rain. Third, process water can be treated to produce a plant growth product.

To discuss the management of water from a compost facility we need to define the runoff fractions. The quality of the water and the need for management facilities differ for each of these fractions. The runoff fractions that should be considered for a compost facility include:

1. Stormwater (non-process) runoff
2. Leachate from the composting material
3. Process stormwater runoff

<u>Stormwater (non-process) runoff</u> - Stormwater is the moisture that falls on the compost site but does not have contact with the compost. Thus, this wastewater is not contaminated with pathogens or nutrients. Examples of stormwater runoff includes water

from roofs of structures or water from paved areas, such as parking spaces, where no compost product or input materials are stored or processed.

In all cases the preferred method of managing this fraction is to keep stormwater runoff physically separate from the compost operation. Procedures for managing this fraction are well established and relatively simple. The objective is to minimize the quantity of water that comes in contact with the composting operation. Stormwater is covered by a specific set of regulatory requirements.

Leachate from the composting material - Leachate is free water draining from a compost pile that has been an integral part of the compost pile matrix for a sufficient time to solubilize organic and inorganic compounds. Leachate includes rainfall that percolates through the pile. Depending on the feedstock quality, rate of decomposition and stability of the composting material, the leachate can reach high concentrations of organic compounds (BOD and COD), nutrients, and salts. If the feedstock material includes heavy metals, toxic organics, or pathogenic organisms, these materials can be present in leachate. Yard debris generally has relatively low concentrations of heavy metals and toxic organics but can have pathogenic organisms, such as salmonella, or pathogenic indicators, such as fecal coliform. Because compost materials have a large capacity to hold moisture and evaporate large quantities during the composting process, an operational objective should be to keep the quantity of leachate produced to a minimum or none at all.

Process stormwater runoff - This fraction includes any runoff from the composting site that results from precipitation that does not flow through the composting mass. This includes runoff from the pile sides and composting pad areas adjacent to the piles, including any areas where compost or input materials are stored or processed, such as tip areas or loading areas. Equipment wash down water would also be included in this category.

The character of precipitation has a direct effect on runoff quality and quantity. Runoff control at compost facilities may be significantly different in Washington's two primary climate zones. These zones are the wet temperate climate west of the Cascade mountains and the dry climate to the east that is relatively hot in summer and cold in winter. The runoff control solutions for a long wet winter will likely be different than for the snow melt and thunderstorm conditions of the east side.

There are many types of pollutants present in America's waterways and aquifers. Table 2 describes the major types of pollutants, their sources, and their effects. These constituents can be considered beneficial or pollutant, depending on where they are in the environment. Generally, organic matter and nutrients (fertilizers) are beneficial in soils but harmful in surface waters when present in high concentrations. Overloading the soils can lead to migration to surface and ground waters, which can, in turn lead to high levels of plant and algae growth. This causes premature aging or eutrophication of bodies of water.

Table 2 - Major Types of Pollutants in America's Waterways and Aquifers

Class	Examples	Major Sources	Major Effects
Nutrients	Nitrogen, Phosphorus, Potassium - all present in compost runoff - also all commercial fertilizers	Wastewater treatment plants, fertilizers, leaking septic tank systems, animal wastes, agricultural return flows	Production of excess algae. When algae die, decomposer organisms consume them. This process can use up most of the oxygen in the water, harming cold-water fish species.
Suspended Solids	Soil and silt suspended in the water	Soil erosion, flushed by wind, rain fall, and flooding	Deposits silts and sediments on lake beds and in river beds.
BOD_5	Biochemical oxygen demand - a measure of organic matter	Any organic matter such as manures, yard debris, food waste, etc.	In high concentrations, robs oxygen from the body of water, limiting the availability to aquatic life.
Sediments	Soil, sand, silt, dust, gravel	Erosion of soil by water or wind, road deicing, storm drains	Harms habitat and reproduction of fish and other aquatic life.
Pathogens	Bacteria, viruses, parasites	Agricultural return flows, cattle, horses, humans, leaking septic systems, storm drains	Makes water unsafe for human consumption.
Toxins	Hydrocarbons, heavy metals	Chemical spills, automobile products and emissions, street runoff, improper use of storm drains, leaking underground petroleum storage tanks, mining activities, improper use of pesticides	Harms wildlife, fish, and human drinking water.
Salinity	Total dissolved solids (TDS), salts.	Agricultural return flows, wastewater treatment plants, geothermal springs.	Accumulates in terminal lakes and wetlands.

A previous CWC project entitled "Evaluation of Compost Facility Runoff for Beneficial Reuse", describes data gathered to quantify the benefits and potentially undesirable characteristics of liquid runoff from four different compost facilities. The facilities included a very large yard debris and foodwaste composter, a medium sized yard debris facility, a facility affiliated with a university composting manures and brush, and a zoo manure compost facility. Runoff samples from the four facilities were taken during storm events and normal daily operations. Several parameters were examined in each of the runoff samples.

That data indicates that the range of constituents expected for runoff from composting facilities are as shown in Table 3. Typical concentration ranges (in mg/L unless noted) for the runoff are compared to the general permit stormwater benchmark values and to the characteristics of raw sewage:

Table 3: Comparison of Yard Debris Composting Runoff with Regulation and Other Source

	Yard Debris Facilities[1]	*Stormwater Benchmark*[2]	*Raw Sewage*
Biochemical Oxygen Demand (BOD)	390-3200		100-300
Total Suspended Solids (TSS)	2000-20,000	130	100-350
Total Kjeldahl Nitrogen (TKN)	85-2,600		20-85
Ammonia	23-1,600		12-50
Potassium (K)	170-4,500		
Total Phosphorous (P)	10-170		6-20
Total Copper	0.07-0.8	0.1	
Total Lead		0.4	
Total Zinc	0.1-1.5	0.6	
Fecal Coliform (FC) MPN/100ml	110-4.9x10^6	406 (E. coli) X 10^3	>10^6

[1] Clean Washington Center Study entitled "Evaluation of Compost Facility Runoff for Beneficial Reuse"
[2] Stormwater General Permit 1200-Z (7/22/97). WA DEQ indicates possible future changes for compost facilities
[3] Only for landfills accepting biosolids and wastewater treatment facilities

It is clear that runoff from a yard debris composting facilities may require appropriate management prior to discharge. Discharge of process water without treatment would have a major negative effect on surface water quality and fisheries. There may also be some potential of public health impacts. Certainly, such a discharge would have an impact on measured levels of indicator organisms in receiving waters.

In addition, failure to capture the organic and nutrient content of the runoff is a waste of potentially valuable resources. By keeping these substances in the compost or diverting to a separate product, the value of these materials can be realized.

4 Regulations

The purpose of a process or non-process runoff or leachate treatment system is to transform the untreated water into an effluent suited for disposal or reuse, such that the wastewater can be disposed of in conformance with public health and environmental regulations.

The State of Washington Department of Ecology (DOE) has produced a compost facility resource guideline, which outlines proper practices for compost facilities in order to produce a high quality product without creating a nuisance to the surrounding area. Part of this document is devoted to a discussion of process runoff and leachate from these facilities. The draft handbook describes regulations for treating this material in order to allow discharge to the storm sewer system. The document does not address reuse, only treatment and disposal.

The DOE defines two types of water, making the distinction between leachate and stormwater runoff. Leachate, or industrial wastewater, is "water or other liquid that has been contaminated by dissolved or suspended materials due to contact with solid waste or gases therefrom" (Chapter 173-304 WAC). Leachate is also included in the definition of industrial wastewater in Chapter 173-216 WAC, the State Waste Discharge Program and in Chapter 173-240 Submission of Plans and Reports for Construction of Wastewater Facilities. Runoff from a site is defined as any water that lands on site but does not come in contact with active compost or mixing piles. Therefore, put simply, leachate touches active compost and raw materials, stormwater runoff does not. The DOE definition of leachate includes both leachate and process stormwater runoff, as described in this report, whereas the definition of stormwater (non-process) runoff, as used in this report, is identical to the DOE definition.

A compost facility in Washington State currently has the choice of three regulatory permitting alternatives to address the leachate (process runoff) generated by their facility. These three alternatives are:

- National Pollutant Discharge Elimination System (NPDES) permit
- State Waste Discharge permit

- Zero discharge (leachate and process water storage)

Table 4 - Pollutants of Concern in Leachate as Defined by DOE

Biochemical Oxygen Demand (BOD)	BOD demand is a measurement of the amount of oxygen that would be depleted from a surface water when leachate (or other oxygen demanding material) is allowed to run into it. It is a measurement of the organic content and activity in a wastewater.
Nitrogen	Nitrogen in leachate can be detrimental to surface water depending on the form it is in. Ammonia nitrogen (in high concentrations) is toxic to fish. Ammonia (in low concentrations) and nitrate provide nutrients for excessive growth of algae. In addition, the conversion of ammonium nitrogen to nitrate consumes large quantities of dissolved oxygen. Nitrate in leachate is also a potential pollutant in drinking water supplies.
Suspended Solids	Suspended solids are particles in leachate that are large enough to settle out of solutions or be filtered out. Suspended solids can lead to sediment and anaerobic conditions in receiving waters.

(DOE Compost Handbook)

The alternative that a facility will use depends upon the features incorporated into its design. For both the NPDES permit and the State Waste Discharge permits, the leachate and process runoff water must be treated before it is discharged. In addition, the surface and ground water quality standards (Chapter 173-201A WAC and Chapter 173-200 WAC, respectively) (draft DOE Compost Handbook) must be complied with. If the leachate is to be discharged to surface water, an NPDES permit is required, with treatment by All Known Available and Reasonable Methods of Treatment (AKART). The DOE makes AKART determinations on a case-by-case basis (draft DOE Compost Handbook).

If leachate or process water is to be discharged to a sewage treatment plant or to the ground water, a State Waste Discharge permit must be obtained. If the discharge is to a delegated Publicly Owned Treatment Works (POTW), a permit is required directly from the treatment facility. A delegated facility is one to which the state has delegated authority to regulate pretreatment of incoming wastewater. The DOE must be contacted for a list of these facilities. Land treatment of treated leachate or process water is an example of discharging to ground water. Soil absorption is one technique that can effectively treat waste water. Partially treated wastewater is discharged below the ground surface where it is absorbed and treated by the soil as it percolates to the groundwater. For example, in a subsurface soil absorption system, the pretreatment unit should remove nearly all settleable solids and floatable grease and scum so that a reasonably clear liquid is discharged into the soil absorption field. This discharge allows the field to operate more efficiently. Likewise, for a surface discharge system, the treatment unit should produce an effluent that will meet applicable surface discharge standards. If this option is used, an engineering report must be submitted to the DOE for review and approval.

Zero discharge requires the containment of all leachate and process runoff water generated at a facility or the prevention of production of leachate and process water. This can be accomplished by composting under a roof or in an enclosed building, or by storing leachate and process water in a tank or lagoon. Storage lagoons must be lined with impervious material.

Stormwater (runoff) discharge to surface water or to the municipal storm sewer must be covered under the Baseline General Stormwater Permit. This permit covers stormwater only, not industrial wastewater (leachate and process water). The purpose of the permit is to incorporate Stormwater Pollution Prevention Plans into the design of facilities, to prevent overflow events and contamination of the surrounding waters. The DOE Stormwater Unit will assist facility managers in deciding what stormwater permits are appropriate for their facilities (draft DOE Compost Handbook). Steps required to get DOE and Health Department approval for land application as a nutrient reuse technique would include approval of pre-treatment techniques, nutrient loading expectations, water balance for the site, and assurance that the pollutants would not reach surface or ground water. This type of a reuse will be evaluated on a case-by-case basis.

5 Process Water Management Capacity Characteristics of Composting Methods

5.1 Factors that Influence the Water Management Capacities of Composting Processes

The capacity of a composting facility to manage rainfall on site depends on the rainfall intensity, feedstock processed, and composting methods.

5.1.1 Rainfall Intensity

Climatic conditions at the composting site together with regulatory requirements for use of a design statistical rainfall intensity and duration probability determine the quantity of rain per unit area that must be managed over a given time period. For purposes of runoff management, rainfall during the wet season must be considered in order to provide on-site control. To date, the Washington Department of Ecology has used the 10 year statistical wet year as the basis for compost facility runoff management. Based on historical correlations of monthly rainfall distribution, the 10 year return interval peak three month period would have an estimated rainfall total of 27.9 inches. In other words, looking forward to a wet season the probability is 9 of 10 that less than 27.9 inches will fall during the peak three month period. If the compost facility's runoff management system is designed to handle 27.9 inches of rain, then excess, unmanaged rainfall will probably occur one year out of ten.

5.1.2 Feedstocks

Feedstocks display varying degradation energy levels. Energy is also released at varying rates. For example, grass is composed of primarily high level of energy constituents with a high fraction that is quickly degradable while tree trimmings are also high energy but have a small fraction that is degradable and a very slow degradation rate. Generally, the quantities and energy levels of yard debris vary seasonally. Typically, as winter quantities are reduced, the available degradation energy is also reduced. The reduced quantities allow reduction in the composting area from which rainfall becomes process water. The reduced degradation energy results in a lower potential for water evaporation.

5.1.3 Evaporation Capacity

Seasonal variations in energy available for evaporation of water are a known constraint. In the Pacific Northwest, the peak winter rains occur when yard debris consists of the lowest energy materials. The low energy level has increased the challenge for composters to maintain desirable composting conditions in the piles while controlling the impact of runoff.

5.1.4 Water Holding Capacity

Composting materials have the ability to absorb and hold quantities of water greater than present upon delivery to a composting facility. This capacity could be used to incorporate rainfall moisture in the final product rather than allowing it to contribute to the site runoff. However, moisture content is a critical parameter for a number of factors, including screening. Overly moist compost sticks to the larger particles during screening and provides a poor product yield. Also, the addition of process or leachate moisture to compost product can result in contamination with undesirable bacterial indicator organisms. For these reasons, the moisture holding capacity of the material cannot always be fully utilized for runoff reduction.

Moisture content of final compost is an important factor for a number of marketing reasons as well. Additional moisture increases the weight of the compost, which increases transportation costs. Wet compost is also more difficult to apply, which reduces its value to the end user.

5.1.5 Volumetric Water Management Capacity

A calculation of energy available in yard debris using the following assumptions indicates that a cubic foot of winter yard debris has sufficient energy to evaporate 36 pounds of water:

- 90% Volatile Solids (VS)
- 45% degradable fraction
- 600 lb./cubic yard density

- 50% initial moisture content
- Sufficient detention time to release degradable energy
- 6,500 BTU of energy released / lb of degraded organics
- 1,010 BTU required to evaporate 1 lb of water
- Insignificant energy used to heat solids mass

As will be discussed in the following assessment, by stacking the piles deeper, the rainfall falling on the pile is decreased while the energy available to evaporate the rainfall is increased. However, this capability is not useful unless the water falling on the surface of the pile can be evaporated by the released energy. Some composting processes do not effectively accomplish the needed distribution of water through the pile. These factors are all important from an operational perspective since they impact the amount of leachate and/or process runoff produced, which needs to be treated. They are also important from a compost product perspective, as a very wet composting mass will not stabilize as quickly and will produce a lower quality compost in the same time period.

5.2 Comparison of Composting Methods

Site layout determines the relative areas of composting material and working surface on which rain will fall. This is important because the composting material has the capability of absorbing rainfall whereas the impervious working surface converts almost all rainfall into runoff. Since the working surface near composting activity normally has organic debris that is pulverized by operations traffic, this runoff carries a load of soluble and suspended organic matter (i.e., process runoff).

The type of composting process used and the resulting pile configuration is the primary factor determining the capability to control site runoff. Appendix A contains a spreadsheet model analysis of a range of composting processes used in the Pacific Northwest. Since rainfall is an areal phenomenon, the runoff management parameters of interest are also areal. For example, deeper piles reduce the amount of rainfall on the active composting area. Deeper piles normally also reduce the associated impervious surface in aisles and for peripheral pile access. Therefore, the pile depth (mass per area) is a critical factor. Equally important is the evaporative energy contained in the feedstock. A deeper pile has more energy per unit area and therefore more evaporative capacity per inch of rainfall.

Table 5 provides a summary of the analysis results for typical conditions and for a range of processing technologies. The technologies considered include:

- *Big pile* - Large consolidated static piles with minimal turning and long duration as practiced by GroCo Inc., Kent, WA and Pacific Topsoils, Inc., Bothell, WA. Built with stacking conveyors and track dozers.
- *Machine turned windrow (MTW)* - Traditional windrow composting turned frequently with a straddle type machine with rotating drum mounted flails.
- *Loader turned windrow (LTW)* - Windrows formed and turned infrequently with front end loaders.
- *Extended aerated static pile (EASP)* - Aerated static piles with insulated exterior surface. Typically formed and broken down with loaders. Temperature controlled by forced aeration. This variation uses the mass bed configuration.
- *Scat turned aerated mass bed (STAMB)* - Mass bed piles turned with a lifting face/side cast turning device as practiced by Land Recovery, Inc., Puyallup, WA. Temperature is controlled by forced aeration. Moisture control is provided during turning.
- *Excavator turned aerated mass bed (ETAMB)* - Same as previous except that piles are deeper and turned with excavators. This method (although unaerated) is used by facilities in Vancouver, B.C. and Portland, Oregon.

Table 5 - Potential Water Removal Comparison of Compost Technologies

	Big Pile	*MTW*	*LTW*	*EASP*	*STAMB*	*ETAMB*
Pile Depth (feet)	20	6	10	8	8	15
Potential water evaporation (lb/sf)	550	135	250	280	280	470
Excess energy (10^6 BTU)	4.2	(1.1)	2.1	2.6	2.6	3.8
Energy and Moisture coincident	Poor	Good	Limited	Limited	Excellent	Very Good
Removal of evaporated water	Poor	Moderate	Limited	Excellent	Excellent	Excellent

The energy of degradation can only be utilized for evaporation of rainfall if:

1. Sufficient moisture is present to allow the microbes to degrade the available organics.
2. The rainwater can be placed in proximity to the energy release.
3. The evaporated moisture is removed from the pile without condensing.

These factors are highly influenced by the composting process used. While the big pile approach has a large amount of energy available, the rainfall is not distributed through the pile. The moisture is therefore available neither for maintaining a moist environment nor for cooling the pile. The machine turned windrow pile is so spread out that the rainfall exceeds the capacity of the material for evaporation. Turning allows only two minutes of air release (volume approximately equal to pile volume) every three to five days. The result is over saturation and cooling of the piles such that the energy is not released efficiently. Loader turned windrows are an improvement in terms of potential energy and distribution of the water throughout the pile. The aerated static pile process is excellent at controlling and utilizing moisture that falls on the piles but is seldom available for handling runoff from impervious surfaces due to the static nature of the system. Aeration is a very effective method of removing moisture from the composting piles. Piles are aerated three to five minutes every 15 minutes, and therefore much higher volumes of hot steamy air is released. The turned and aerated mass bed systems provide the optimum combination of aeration to carry off the evaporated moisture and turning which provides the opportunity to uniformly add water.

Care must be taken in the use of runoff for pile moisture control to prevent contamination of material that has satisfied pathogen treatment standards. Addition of process runoff-derived moisture or leachate prior to time and temperature controls is the recommended operating strategy. Also, use of biofiltration for odor control results in a significant portion of the evaporated moisture being captured as condensate. Condensate can be a management issue as significant as process runoff.

6 Best Management Practices

Most composting facilities could effectively use a combination of methods for managing process and non-process rainfall runoff. Applying the principles of waste reduction, reuse and recycling to compost facility runoff management is an elegant solution to a problem currently experienced by many compost facility operators. Although a variety of potential solutions have been proposed, none are capable of fully addressing the technical constraints associated with stormwater runoff. A blend of strategies as described below can be adapted to the specific needs of each facility.

6.1 Source Reduction of Process Stormwater Runoff

The most positive method of control is to prevent rainfall from coming in contact with feedstock or composting materials. This can be accomplished by constructing a cover and diverting the runoff to a stormwater management system or by reducing the operating area upon which contact can occur.

Structural cover is completely effective but expensive. Temporary covers have also been used but can create problems by restricting air flow. Temporary covers are only effective if the water diverted from the pile does not come in contact with material on the operating surfaces.

During winter the quantity of materials processed normally declines. The volume reduction can allow processing on a smaller portion of the operating surface. By providing a curb or some other physical separation of the pad, it is possible to divert runoff from the separated area to the stormwater management system, thereby reducing the volume of process water produced. The winter operating area could be reduced even more by using a space conserving composting process during the winter.

6.2 Process Water Recycle

Once rainfall has contacted feedstock material it can be recycled for other uses or reused in the composting process. Recycle options include producing a marketable product or returning the water to the hydrologic cycle.

6.2.1 Compost Tea Product

The organic and nutrient content of the process water runoff or leachate can be used to develop a product. An in depth discussion of this option is outlined in Section 7.

6.2.2 Evaporation

Evaporation returns the moisture to the atmosphere where it will eventually be converted to some form of precipitation. As shown earlier, the material has excess energy for evaporation provided that it is properly processed to take advantage of the available energy.

6.2.3 Treatment and Discharge

Treatment and discharge to surface or groundwater is another recycling options. Treatment at the site or at a wastewater treatment facility are available but potentially costly options. Treatment requirements may vary depending on the receiving water body but are in general very stringent. As new information is developed, regulatory constraints also change; thus, the treatment process must be very flexible or easily modified to meet new requirements.

6.3 Reuse of Process Water

Process water, as well as collected stormwater runoff, can be used in the early phases of composting as a source of moisture for the composting process. If stormwater runoff is collected, it can also be used later in the composting process without degrading compost quality. Storage of water can be expensive due to the high seasonal volume of rain in parts of Washington.

7 Management Practice Case Study: Compost Tea (Zoo Broo) Production at Woodland Park Zoo

7.1 Potential Fertilizer Value of Process Runoff

The process runoff from compost facilities were analyzed as part of a previous study ("Evaluation of Compost Facility Runoff for Beneficial Reuse") and was found to have many of the qualities of conventional fertilizers, as well as commercially available organic fertilizers. However, in order to make a product suitable for sale, the runoff must not have pathogen contamination. Pathogens can be reduced or eliminated through pasteurization. Pasteurization, as defined by the EPA for wastewater treatment, is a process by which the liquid is heated to at least 70^{o} C for a minimum of 30 minutes. When these conditions are met, the liquid is considered pasteurized and ready for public use. This case study evaluated pasteurization procedures for runoff generated at the Woodland Park Zoo in Seattle, using two methods of elevating temperatures:

1. Container in the active composting pile.
2. Heating with a propane burner.

There are many types of pollutants generated at composting facilties. These constituents can be considered beneficial or pollutant, depending on where they are in the environment. Pathogens (bacteria, viruses, parasites, etc.) present in agricultural return flows, whether from cattle, horses, humans, leaking septic systems, and storm drains make water into which these materials are introduced unsafe for consumption or recreation.

The process runoff and leachate from the Woodland Park Zoo contains extremely high levels of fecal coliform bacteria, which precludes its reuse as a fertilizer product. Fecal coliform is an indicator organism for all pathogenic organisms. High concentrations of pathogens could cause illness if ingested accidentally (from materials on hands, or through children eating soil, etc.). Pathogens can be destroyed through heat processes such as composting or pasteurization, as directed by the EPA.

In a previous CWC funded project ("Evaluation of Compost Facility Runoff for Beneficial Reuse"), the runoff liquid was used in growth trials in comparison to MiracleGro. Table 6 shows a summary of data from these growth trials. The nutrient content of runoff from the four composting facilities varies, but compares favorably to the nutrient content of MiracleGro fertilizer. Potassium levels in the runoff are 5.5 and 2.7 times higher than that of the fertilizer solution Marigolds and radishes were grown to compare bud generation and root growth. Root growth differences were significantly better for the runoff applications. Potassium encourages root growth and increases plant resistance to disease. It produces larger, more uniformly distributed xylem vessels throughout the root system. Xylem vessels are a complete tissue in the vascular system of higher plants, and function chiefly in support and storage. The xylem typically constitute the woody element of the plant. Potassium increases size and quality of fruit and vegetables and increases winter hardiness (Western Fertilizer Handbook, Horticulture Edition, 1985).

Table 6 - Growth and Potassium Treatment Differences

Plant Group	Root Growth		Flowers and Buds		Potassium Applied	
	Weight (g) Average	% difference from fertilizer	# average	% difference from fertilizer	mg/plant average	% diff. fertilizer
Fertilizer Group	2.80	0%	11.0	0%	14.5	0%
Application 1	5.24	87%	13.2	20%	79.8	450%
Application 2	8.64	208%	12.4	13%	39.9	175%
Application 3	3.36	20%	11.2	2%	16.0	10%
Control Group	2.50	-11%	9.6	-13%	0.0	-100%

Micronutrients (calcium, magnesium, zinc, etc.) also play a role in the production of flowers in ornamentals and in the development of root systems. Strong production of flowers is recognized as a sign of a balanced nutrient (macro and micro) loading. Growth studies that use compost as a medium have shown strong flower production when compared to other potting mixes, and this has been determined to be affected by the micronutrients present in the compost (Gouin). Because the runoff is from a compost facility, it is likely that there are balanced micronutrients present. Because of budget constraints, the lab analyses performed for this project did not include full micronutrient analysis. Historical data from the large yard debris composting facility gathered before the start of this project indicate the presence of many micronutrients in the process stormwater runoff.

Also, it has been shown that an unbalanced nutrient loading will push top (green) growth in root based crops (Gouin). The data from the growth study shows that in all of the radish groups on which nutrients were applied, the average root growth and the average green weights were higher than those for the control. Furthermore, the plant groups treated with runoff showed increased root growth over the fertilized group. This increase indicates that the nutrient balance was more appropriate for root growth in the process runoff groups than for the fertilized group. The better balance is most likely because of the presence of the micronutrients in the process runoff.

In addition to higher levels of potassium and the potential presence of micronutrients, the runoff might have elevated levels of humic acids. Humic acids are present in compost and are known to stimulate shoot and root growth. They consist of organic materials that are difficult to breakdown. Humic acids would likely be present in any runoff that comes in contact with the composting process or the finished product. Some of the main effects attributed to humic substances on plant growth are an enhanced germination rate, stimulation of root initiation, accelerated water uptake, enhanced cell elongation, and mobilization of microelements (Inbar, Chen, & Hoitink).

The runoff contains nutrients as well. Limited tests done to-date indicate that the N:P:K ratio of the runoff from Woodland Park is approximately 5:1:10 on a dry weight basis. More testing will be required to determine runoff variability. There are many commercially available organic fertilizer products. The concentrations of nutrients in Woodland Park compost runoff compare favorably to these products. For example, Alaska Fish Emulsion and MiracleGro crystals are sold in a concentrated form with instructions for dilution in order to properly apply nutrients

The directions on the MiracleGro box indicate that one tablespoon should be mixed with one gallon of water. Alaska Fish Emulsion is mixed at a rate of three tablespoons per gallon of water. After mixing, the liquids have the N:P:K ratios (on a wet weight basis) as shown below in Table 7. The Woodland Park Zoo runoff, for comparison, is also shown. As can be seen, the runoff, if cleaned of its pathogen contamination, could be used straight out of the tank on yard plants, gardens, flowers, etc. If it is diluted by water at three parts water, one part runoff, it can be used on most houseplants. This is based on the most recent nutrient analysis.

Table 7 – N:P:K of Commercial Fertilizer Products and Woodland Runoff as Packaged and as Mixed

Product	Description	State of product	N:P:K as packaged	N:P:K as mixed
Woodland Park runoff	Zoo manure compost runoff	Liquid	0.03 : 0.01 : 0.1 (bottled off pad)	0.03 : 0.01 : 0.1
Alaska Fish	Fish emulsion, 4% chlorine	Emulsion	5 : 1 : 1	0.06 : 0.12 : 0.12
MiracleGro	Crystal fertilizer	Powder	15:30:15	0.06 : 0.12 : 0.06

As can be seen above, the process runoff from the Woodland Park compost facility has many of the qualities of conventional fertilizers, as well as other commercially available organic fertilizers. This is likely true for numerous other compost facilities that compost high nitrogen products, such as animal manures or biosolids, as well. The pollutant of concern is pathogen contamination. In order to make a product suitable for sale, the runoff must be rid of pathogen contamination. Pathogens can be reduced or eliminated through pasteurization. Pasteurization, as defined by the EPA for wastewater treatment, is a process by which the liquid is heated to at least 70^{o} C for a minimum of 30 minutes. When these conditions are met, the liquid is considered pasteurized and ready for public use. This section describes the results of a bench scale thermodynamic pathogenic reduction test for the runoff generated at the Woodland Park Zoo.

There are many commercially available organic fertilizer products. The retail value of commercially available products are shown below. As can be seen, the values are quite high, and the concentrations of nutrients in process runoff compare favorably. The values of the five products are shown in the Table 8. For example, Alaska Fish Emulsion is sold in a concentrated form with instructions for dilution in order to properly apply nutrients. Side panel information informs the consumer that the product contains an N:P:K ratio of 5:l:l, which is diluted for application. The solids content is approximately 18%, and is sold in half-gallon sizes. The half-gallon plastic jugs sell at the retail level for $7.99.

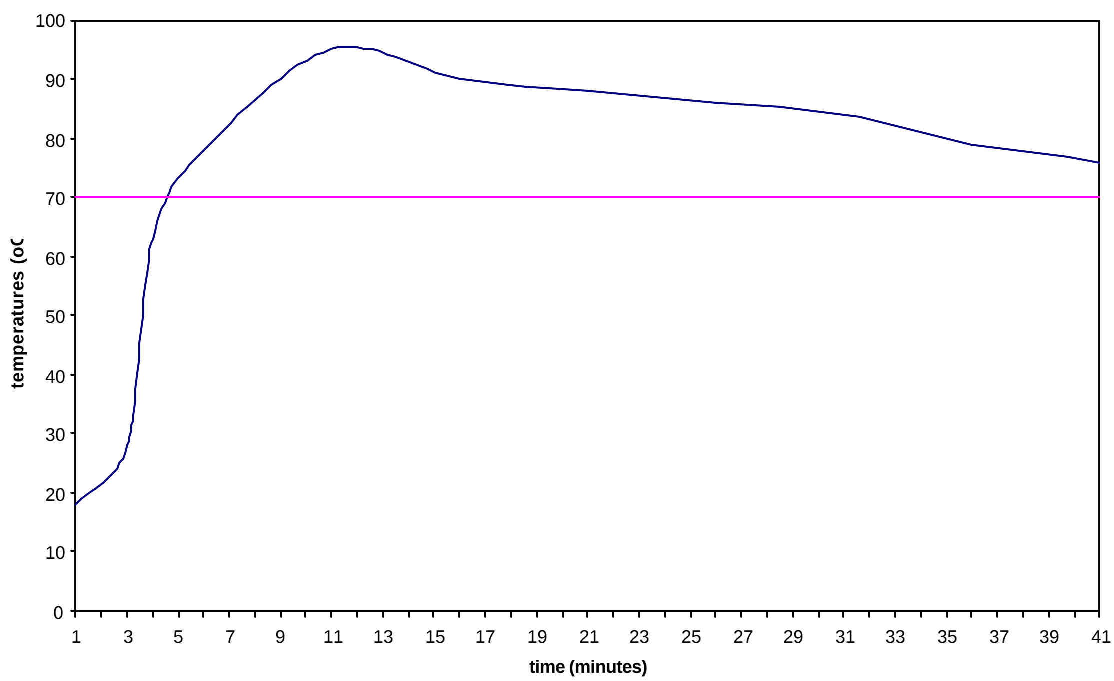
Table 8 - Market Value of Commercially Available Organic Fertilizer Products

Product	Description	State of product	N:P:K	Cost (retail)	Bottle size (oz.)	$/gallon (retail)
Compost runoff	Average of four facilities	Liquid	0.25 : 0.1 : 0.5	-	-	-
Foxfarm	Worm castings, bat guano, potash, kelp	Liquid	0.8 : 0.3 : 1	$ 9.98	32	$ 39.92
Alaska Fish	Fish emulsion, 4% chlorine	Emulsion	5 : 1 : 1	$ 7.99	Half gallon	$ 15.98
Alaska Fish	Fish emulsion, 4% chlorine	Emulsion	5 : 1 : 1	$ 4.98	16	$ 39.84
Maxicrop	Liquefied seaweed, 1% chlorine	Liquid	0.1 : 0 : 1	$ 4.49	8	$ 71.84
SeaSpray	Kelp concentrate	Liquid	0 : 0.3 : 0.5	$ 4.98	16	$ 39.84
Concern	Fish and kelp	Liquid	3 : 2 : 2	$ 6.98	24	$ 37.23
					Average	$ 40.77

7.2 Bench Scale Pasteurization Tests

A small pasteurization unit was used at the Zoo to demonstrate that pasteurization is a suitable alternative for treating runoff. In order to determine whether the system would accomplish pathogen destruction, a small bench scale pasteurization was conducted. Pasteurization, by EPA's definition, requires that a contaminated liquid be held at or above 70^{o} C for a period of at least 30 minutes. This small bench scale was conducted using a two-gallon kettle on a small natural gas stove. A five-gallon bucket of runoff was collected from the runoff containment basin at the zoo compost facility. Three sample jars were filled with this material and marked samples 1-raw, 2-raw, and 3-raw. These samples were placed in a cooler for delivery to the lab and marked 4-clean, 5-clean, and 6-clean. The two-gallon cooking pot was filled with runoff from the bucket and placed on the stove burner. Temperatures were recorded as the liquid heated up to ensure that 70^o C was exceeded for at least 30 minutes. The temperatures achieved and maintained are shown in Figure 1.

Figure 1 - Bench Scale Pasteurization Temperatures



The energy (propane) and time required to produce a product for sale for the runoff was calculated. Table 9 shows the assumptions made regarding the runoff, the ambient temperatures, heat value of propane, and heat transfer efficiency. These assumptions allow for the calculation of propane use, in gallons per hour. Table 10 shows the demonstration container dimensions and R value of the materials.

Table 9- Runoff Assumptions

Initial temp	50 ^{o} F	10 ^{o} C
Heat to	158 ^{o} F	70 ^{o} C
Temp difference	108 ^{o} F	
Quantity of runoff	100 gallons	834 pounds
Energy required Propane heat value Heat value with efficiency	90,072 BTU's 90,000 BTU's/gallon 15.7 gallons/million BTU's considering efficiency	
	63,694 BTU's/gallon considering efficiency	
Heat transfer efficiency	60% efficiency of heat transfer - burner to tank	
Propane use	1.0 gallons/hour	

Table 10 - Container Dimensions

Height =	3.0 feet
Width =	3.0 feet
Depth =	3.0 feet
Corner height =	0.50 feet
R-value =	2

Table 11 shows the heat profile of the tank every 15 minutes, using the assumptions in Tables 9 and 10. This table shows how long it takes for the liquid to come up to 70^{o} C, and how many gallons of propane is required to do so. This, in turn, can be used to calculate cost per gallon of process runoff treated.

Table 11 - Heat Profile Every 15 Minutes

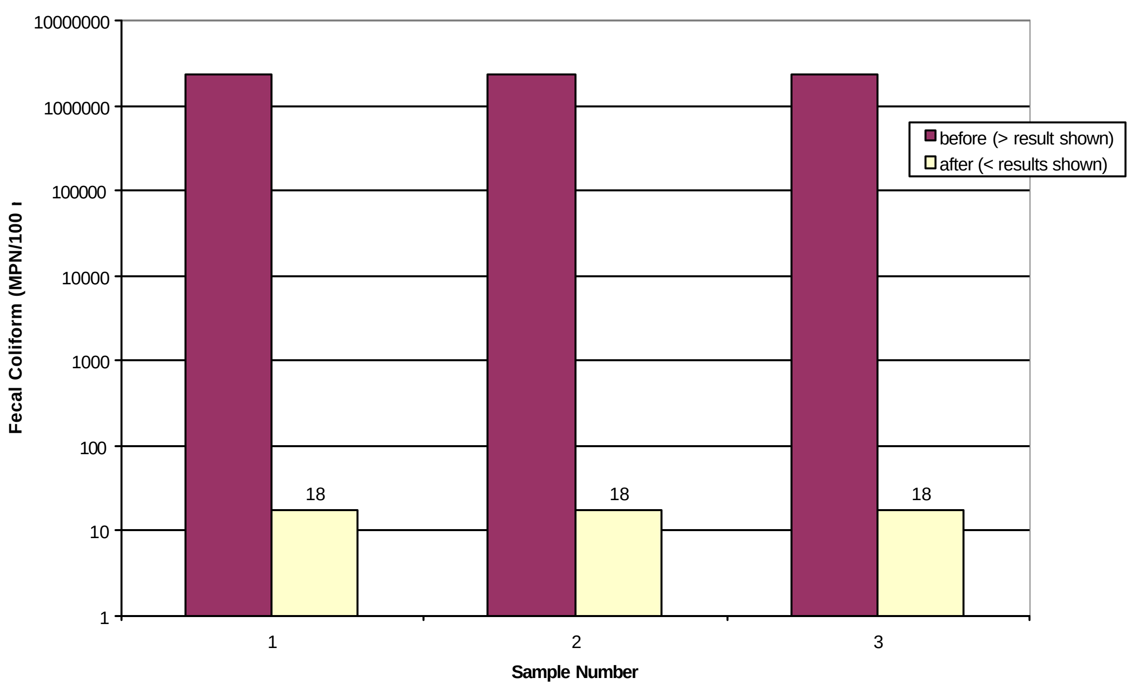
Hours	Ambient temp °C	Amb RH	Tea temp °C	BTU's released	BTU's transferred	Conductive heat loss[1] BTU's	Temp change delta BTU's	Temp change delta temp
0	10		10					
0.25	10	32%	13	15924	9554	24	9531	7.1
0.50	10	39%	20	15924	9554	110	9445	7.0
0.75	10	39%	27	15924	9554	195	9359	7.0
1.00	10	34%	34	15924	9554	279	9275	6.9
1.25	10	33%	40	15924	9554	363	9191	6.8
1.50	10	37%	47	15924	9554	446	9108	6.8
1.75	10	39%	54	15924	9554	528	9026	6.7
2.00	10	57%	61	15924	9554	610	8945	6.6
2.25	10	61%	67	3981	2389	690	1698	1.3
2.50	10	42%	69	3981	2389	706	1683	1.2
2.75	10	41%	70	3981	2389	721	1668	1.2
3.00	10	41%	71	3981	2389	736	1653	1.2
3.25	10	40%	72	0	0	751	-751	-0.6
3.50	10	42%	72	0	0	744	-744	-0.6
3.75	10	43%	71	0	0	737	-737	-0.5
4.00	10	45%	71	0	0	731	-731	-0.5
4.25	10	42%	70	0	0	724	-724	-0.5
4.50	10	42%	70	0	0	718	-718	-0.5
4.75	10	42%	69	0	0	711	-711	-0.5
5.00	10	42%	69	0	0	705	-705	-0.5
5.25	10	47%	68	0	0	698	-698	-0.5

Conductive heat loss based on surface area, insulation, and ambient/compost temp difference
Btu release based on propane properties and burning efficiency
[1] ASHRAE Handbook 1985 Fundamentals

As can be seen in Table 11, 70° C is reached in just under three hours. This, plus an additional 30 minutes at 70° C, is the time required to pasteurize. As can be seen, 100 gallons of runoff can be pasteurized in under four hours by using approximately one gallon per hour of propane (approximately four gallons total).

After the desired temperatures were achieved, three samples of the pasteurized product were bottled and placed in the cooler for delivery to the lab. Lab results (Appendix B) indicate extremely high levels of fecal coliform in the raw feedstock (clean samples; >2,400,000 MPN/100 ml). The state limit for fecal coliform in fresh surface water used for water supply or recreation is 43 MPN/100 ml. After pasteurization, all samples tested out at < 18 MPN/100 ml (>99.999% removal), below the detection limit of 18 for the test dilution. These results indicate a complete removal of pathogen contamination in the runoff samples, rendering the product safe for use. Figure 2 shows the results, on a logarithmic scale. This detection limit can be lowered with a different test dilution, and in future tests the lower detection limit will be obtained.

Figure 2 - Fecal Coliform Reduction thru Pasteurization



All "after" results are below detection limit for the test.

Earlier calculations from Section 7 indicate that approximately 975 BTU's are required per gallon of runoff to raise the temperature from 10^{o} C to 75^{o} C and keep it there for 30 minutes to meet pathogen reduction requirements. Propane has 90,000 BTU's per gallon, so approximately 0.03 gallons of propane is required per gallon of runoff.

The test results for this task indicate that the product can be pasteurized to treat pathogen contamination. It also appears that the nutrient content is suitable for application either as it comes out of the pasteurization unit, or with a 3:1 dilution rate. These results are based on one grab sample. These results are quite encouraging, and it looks as if the product has good potential for reuse.

7.3 Pasteurization Process Alternatives for Woodland Park Zoo

The Woodland Park Zoo Compost Facility is a low tech composting operation. The system is essentially a static pile, which is turned with a front-end loader every two weeks. Zoo personnel are interested in developing a simple method of pasteurizing their runoff to produce a product for sale to the public. In an effort to help the Zoo achieve this goal, E&A recommended that two methods be tested for ease of operation and for reliability of pasteurization results. Samples were tested for pathogen reduction and for nutrient content. This report describes the two methods tested and the results of those tests.

In deciding what method to test, an effort was made to use some of the heat generated by the composting process. The Woodland Park Zoo Compost Facility uses a turned static pile system. The piles are built and turned every two weeks. This infrequent turning leaves heat undisturbed in the pile for two weeks straight. Since one of the byproducts of the process is waste heat, it would be desirable to tap this energy source to help heat the liquid for pasteurization. This excess heat can be utilized in one of two ways to meet EPA pathogen reduction criteria. The first way would be to disturb the piles during the two weeks of high temperature, place the barrels of process water in the piles, and monitor the water temperature. Once the water reaches the 70^{o} C required temperature for 30 minutes, the barrels can be removed. The second alternative would be to bury the process water barrels earlier in the process and allow the piles and the water to reach 55^{o} C for three days, when the barrels can be removed or left in position until the pile starts to cool down after two weeks or so.

The second method of pasteurization consisted of setting up a propane burner under a 55-gallon drum filled with runoff. The temperature of the containerized liquid was monitored to reach greater than 70^{o} C for 30 minutes. This method is a field test of the bench scale pasteurization described in the previous section of this report.

7.3.1 Pasteurization Method 1 – Buried Containers

Five barrels (two 15 gallon plastic barrels and three 5-gallon glass jugs) were filled with liquid runoff from the site. Each container was sampled for pathogen analysis. The two plastic barrels were rigged with an air-bleeding valve, which was vented out the top of the pile. One glass jar had a bleeder valve which was routed to a 5-gallon bucket of water, to create a seal but allow air to bleed up through the water. Two of the glass jars were simply sealed tight.

Each container had a thermocouple wire feeding through the top into the liquid. The opposite end came out of the barrel through a compression fitting and out through the top of the pile. This end of the wire has a two-pronged plug, which is plugged into a digital temperature meter, allowing for monitoring of the liquid temperatures. Please see the photos below.

Runoff from Paved Surfaces to Drain

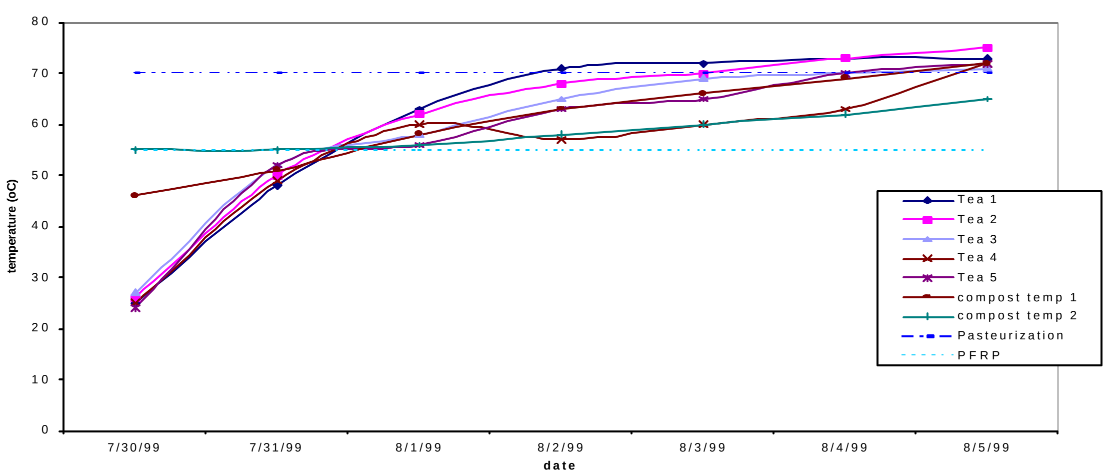
Pasteurization Containers Filled w/Runoff

Containers Placed in the Pile

Covering the Containers while Turning

The front-end loader operator placed a one-foot deep layer of feedstocks on the pavement. The five containers were placed on the layer of feedstock, and covered with additional feedstock to a height of five to six feet. The thermocouple wire was fed through a pressure fitting and out the top of the pile. Pile temperatures were monitored along with the temperatures of the liquid in the container. It was hoped that the temperature of the liquid would exceed 55^{o} C for three consecutive days. As can be seen in Figure 3, all five jugs exceeded this time and temperature relationship, and in fact exceeded 70^{o} C for the thirty minutes required for pasteurization.

Figure 3 - Temperature Profile for In-Pile Pasteurization Test

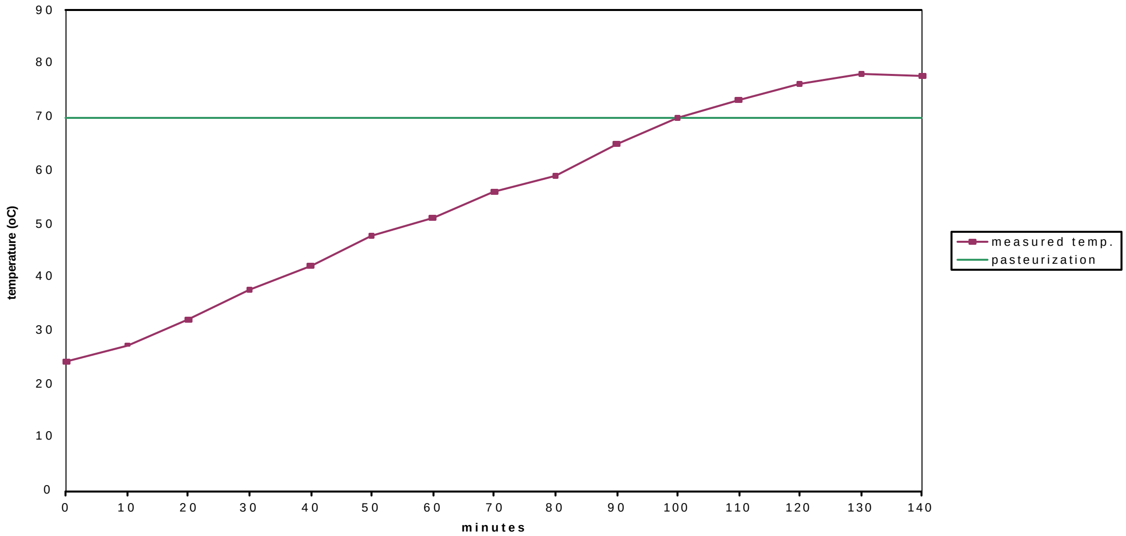


7.3.2 Pasteurization Method 2 - Propane Heater

The second method of pasteurization used is a field test of the bench scale test performed earlier in the project. A heavy-duty propane burner was set up with a 55-gallon drum of runoff over it. A thermocouple wire was inserted into the liquid through the top, and temperatures were monitored over the course of the heating. The heating data, volume of liquid, and thermodynamics calculations were used to estimate large scale propane needs and heat transfer estimates. Please see the photos of this pilot process below. The temperature profile is shown in Figure 4.

Propane Pilot Test Setup	Thermocouple and Digital Temp Meter
	

Figure 4 - Temperature Profile for Propane Pasteurization Test



The propane burner chosen is rated at 36,000 BTU's per hour. Propane provides approximately 90,000 BTU's per gallon. The runoff started at approximately 75^o F (24^{o}C), and was heated to 70^o C (approximately 158^o F). One BTU will heat one pound of water one-degree Fahrenheit. The 55 gallons of water weighs approximately 458 pounds. In order to heat 458 pounds of water from 75 to 158^o F, approximately 38,000 BTU's are required. The length of time that the liquid took to heat to 70^o C was approximately 100 minutes. This means that the heat transfer and loss efficiency (based on the burner rating of 36,000 BTU's per hour, 38,000 BTU's required to heat the water, and 100 minutes to do so) was 60%. A 60% transfer and loss efficiency means that for this system, 40% more propane is required than the amount calculated without considering efficiency or loss. The 38,000 BTU's required to heat the liquid means that with losses and transfer efficiency, approximately 53,000 BTU's are required. Again, propane provides 90,000 BTU's per gallon, so this test required 0.6 gallons of propane. The transfer efficiency could be maximized and losses minimized with shielding of the burner and insulation of the container. This test was performed without insulation or shielding. After 70^o C was reached, the propane was cut back substantially.

Table 12 – Propane BTU Calculations

	Temp °C	Temp °F	Delta temp °F	Lbs of water	BTU's required to heat	Losses	BTU's required total
0 minutes	24	75					
100 minutes	70	158	83	458.7	37,900	40%	53,060

Using these assumptions, the propane required to pasteurize 100 gallons of runoff using this method would be approximately 1.1 gallons of propane. These results are essentially identical to the pilot study discussed in Section 7.1.1. Industrial quantities of propane sell for approximately one dollar per gallon. Therefore, fuel costs for pasteurizing 100 gallons of runoff would be approximately $1.10. This is a very small cost when considering the potential revenues generated from 100 gallons of product. Survey results (see Section 7.6) indicate that the product could easily sell for $6 per gallon.

7.3.3 Results of Two Pasteurization Tests

Both pasteurization tests yielded results showing complete reduction of pathogens. The tests showed that levels of fecal coliform (the indicator organism) were very high in the water running off the site. The results were orders of magnitude higher than the allowable limit for the surface waters of the state (the state limit for fecal coliform in fresh surface water used for water supply or recreation is 43 MPN/100 ml).

Table 13 – Fecal Coliform Reduction for Pasteurization Tests

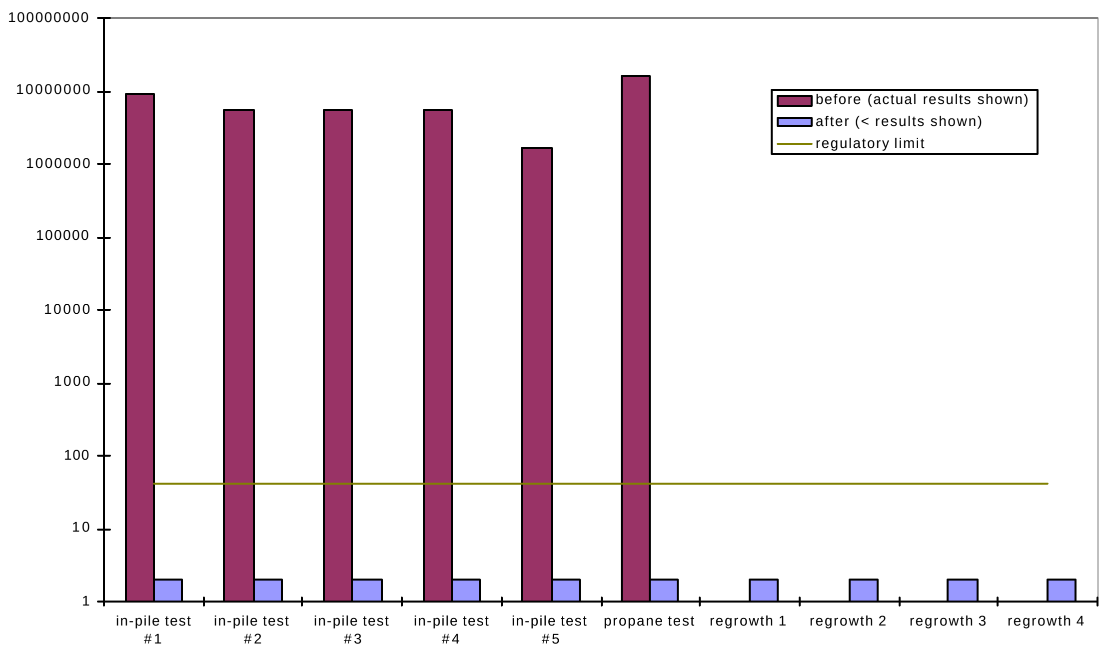
	Pile Test #1 (MPN/ 100 ml)	**Pile Test #2 (MPN/ 100 ml)**	**Pile Test #3 (MPN/ 100 ml)**	**Pile Test #4 (MPN/ 100 ml)**	**Pile Test #5 (MPN/ 100 ml)**	**Propane Test (MPN/ 100 ml)**
Before (actual results)	9,200,000	5,400,000	5,400,000	5,400,000	1,700,000	5,420,000
After (< results shown)	2	2	2	2	2	2

After the desired temperatures were achieved, three samples of the pasteurized product were bottled and placed in the cooler for delivery to the lab. Lab results (Appendix B) indicate extremely high levels of fecal coliform in the raw feedstock (as high as

9,200,000 MPN/100 ml). After pasteurization, all samples tested out at < 2 MPN/100 ml (>99.99998% removal), below the detection limit of two for the test dilution. These results indicate a complete removal of pathogen contamination in the runoff samples, rendering the product safe for use.

At the time of the propane testing, four samples were taken from the containers with the product of the in-pile pasteurization test. The liquid had been sitting for three weeks, and no re-growth was seen (all samples were < 2 MPN/100 ml). Figure 5 shows the results, on a logarithmic scale, of the in-pile pasteurization test, the propane pasteurization test, and re-growth samples.

Figure 5 - Fecal Coliform Reduction Results



Both of the methods of pasteurization yielded results indicating that pathogens can be reduced to a level acceptable for use by the public. The lack of re-growth indicates complete destruction of the pathogens, despite a detection limit above zero.

7.4 Zoo Broo Product Nutrient Testing Characteristics

The product from each of the containers from the in-pile pasteurization test was sampled and analyzed for nutrients in order to determine a recommended dosage for use on household and garden plants. Table 14 contains the nutrient data from the samples.

Table 14 – Nutrient Content of Woodland Park Compost Facility Runoff

	Tea 1	Tea 2	Tea 3	Tea 4	Tea 5	Average
% solids	0.30%	0.30%	0.20%	0.30%	0.30%	0.28%
N (ug/g)*	160	120	100	120	110	122
P (ug/g)*	26	29	26	26	27	26.8
K (ug/g)	120000	130000	190000	120000	130000	138000
N (%) dry weight basis	5.3%	4.0%	3.3%	4.0%	3.7%	4.1%
P (%) dry weight basis	0.9%	1.0%	0.9%	0.9%	0.9%	0.9%
K (%) dry weight basis	12.0%	13.0%	19.0%	12.0%	13.0%	13.8%

*wet weight analysis

The lab results indicate that the liquid has an average solids content of approximately 0.3% solids, nitrogen of 0.01%, 0.00% phosphorus, and 0.01% potassium. These percentages are calculated on a wet weight basis, or as the material appears in the container. Considering the percent solids content, Table 14 also shows the dry weight solids content for N, P, and K.

Several organic material liquid plant food products are available for sale to the public. Table 15 shows the nutrient content of the runoff and of each of the organic plant supplements. The supplements report N:P:K levels. It is assumed that these N:P:K levels are for the material as it sits in the bottle (the labels do not indicate whether this is the case). The labels also do not indicate a % solids content, so it is not possible to calculate the nutrient content on a dry weight basis, which would allow for an accurate even comparison. The recommended dosages for use on household plants and gardens are also shown in Table 15.

Table 15 – Nutrient Comparison

	N	P	K	Recommended dosage
Zoo Tea	0.01%	0.00%	0.01%	1/2 cup per gallon
Sea Spray	0.00%	0.30%	0.50%	1 oz/gal
Alaska Fish Emulsion	5.00%	1.00%	1.00%	1 tbsp/gal
Maxi Crop	0.10%	0.00%	1.00%	1 tbsp/gal
Fox Farm	0.80%	3.00%	1.00%	4 tbsp/gal
Concern	3.00%	2.00%	2.00%	3 tbsp/gal

Based on a comparison to the Maxi Crop, which requires one tablespoon per gallon of water, the recommended dosage for the Zoo Tea will be approximately one-half cup per gallon of water. This dilution is less than some of the other products (such as Alaska Fish Emulsion) but will provide nutrients and organics for plant growth.

7.5 Product Bottling and Distribution

After completion of the two pasteurization tests and review of the lab test results, the product was bottled for distribution to the public. A label was developed for the pilot project in order to ensure that consumers knew what the bottles contained after bringing them home. The label incorporates graphics currently used in Zoo Doo marketing materials, and also contains dilution instructions for the user.

The majority of the product produced in the two pasteurization tests was bottled for distribution during the fall Fecal Fest (Zoo Doo sale). Eighty gallons were bottled, leaving about fifteen gallons for use on zoo grounds and other projects. Bottles were filled by hand for this test, using a double action barrel pump (available at any hardware stores for $15). Once filled, the bottles were placed back in their boxes and stacked under the Fecal Fest canopy, ready for distribution.

Zoo Broo Label	Bottling the Zoo Broo for Fecal Fest
	

Ready for Distribution at Fecal Fest	Bottled Product
	

7.6 Zoo Broo Customer Survey

During the fall Fecal Fest at the zoo, the quarterly compost sale of Zoo Doo, the purchasers had the opportunity to take home a one gallon jug of Zoo Broo. Approximately 80 gallons of the product were given away, along with a survey form and a self addressed stamped envelope. The survey was designed to gain information about the consumers impression of the product. There was no attempt to gather plant growth information. It was felt that if we required this information, the surveys would not be returned. The survey form, informational sheet, and a sheet filled out with the average responses are all contained in Appendix C. Overall, the results indicated a very favorable response to the product. Nearly everyone indicated that they would pay $6 per gallon for the product. A few people indicated that the smell was quite bad, but it didn't seem to diminish their overall opinion of the product. At this printing, 35% of the surveys have been returned.

7.7 Zoo Broo Economics

The test product was produced on a small scale. Still, with the small economy of scale, the product would produce a large gross profit. Outlined below are the economics of the two methods of pasteurization. Capital costs are neglected for this particular test, because they were insignificant and would be paid for with the first 100 gallon batch. The propane burner and tank were approximately $75, the barrels for burying in the pile were approximately $100. A one hundred gallon batch of Zoo Broo could yield $600 gross sales.

Table 16: Economics of the Two Methods of Pasteurization

	Buried Containers	**Propane Method**
Quantity	45 gallons	55 gallons
Time spent for pasteurization ($25/hr)	$25	$25
Time spent for bottling	$25	$25
Container/sticker costs*	$28.35	$34.65
Total $	$78.35	$84.65
$ per gallon (cost)	$1.74	$1.54
$ per gallon (gross sale)	$6	$6

*bottle - $0.58, sticker - $0.05

7.8 Zoo Broo Marketing

Zoo Doo, Woodland Park's compost product, already has good product visibility from several years of product marketing. This name recognition will allow Woodland Park to rapidly introduce a related product. Because of this, the cost of product marketing would be very minor as compared to other facilities that might have to spend significant resources to launch a new product. Any and all product marketing costs would reduce the revenue generated by the product producer.

8 Management Practice Case Study: Soos Creek Organics Composting Facility Water Management Evaluation

8.1 Calibrating the Energy and Water Balance Model

The spreadsheet model developed for this evaluation uses expected typical values for degradation energy and energy release rates during the composting process. Specific operating data from Soos Creek was used to calibrate the model for the currently used composting process. The calibrated model was then used to evaluate potential benefits from using water and energy management techniques.

The model calibration period is October 1998 through May 1999. During this period, Soos Creek hauled approximately 2.8 million gallons of process water from the site at a considerable expense. During this time, the facility had approximately 15,000 cubic yards of composting materials on site. The composting was done in 24 loader turned windrows that were approximately 30 feet at the base, 150 feet long, and 12 feet high.

The composting energy spreadsheet model (Appendix D) used to compare the moisture management characteristics of several composting configurations was adapted for use in evaluating alternatives for Soos Creek. The nearby Landsburg station was used as the estimate of rainfall at the site during the evaluation period. During the period of interest (October 1998 through May 1999) the Landsburg rainfall was 56.92 inches. This compares to 43.65 inches for the same period at Sea-Tac Airport. The peak three-month rainfall period was December 1998 through February 1999. During this period 33.5 inches of rain fell at Landsburg. About 60 percent of the wet season rainfall fell between December 1, 1998 and February 28, 1999. Assuming that runoff is consistent during the period of interest, it is estimated that 1,650,000 gallons of process water was generated and hauled by Soos Creek during December through February, 1999. Using the model to back calculate the energy utilization that would result in that much process water runoff, it was estimated that 65% of the energy available from the composting process was utilized by Soos Creek for evaporation during this period.

8.2 Comparison of Rainfall Management Alternatives

Several variations in compost processing and site management were compared for impact on the quantity of process water runoff that would need to be managed by Soos Creek. The intent of this evaluation is that Soos Creek would modify their composting process on a seasonal basis to minimize the generation of process water runoff. The alternatives compared include:

- *Separation of Process Water and Stormwater on the Composting Pad* – Since winter time yard debris quantities are generally reduced significantly, the option of reducing the operating size of the pad becomes available. A simple curb across the pad would be used to divert runoff away from the composting area. The seasonally separated part of the pad would need to be cleared and swept by late September in preparation for the rainy season.
- *Larger compost piles* – Larger composting piles will do a better job of capturing water because of reduced slope area. Larger piles will also do a better job of retaining generated heat. Heat retention will increase the utilization of available energy. This alternative may reduce movement of oxygen into the center of the pile and thereby increase the odor potential.
- *Larger piles with low rate aeration* – Optimum heat utilization can be achieved by adding a minimal aeration system to the larger composting piles. The aeration will provide a continuous supply of air to capture and carry away the evaporated moisture. The aeration rate must be sufficient to carry the majority of the moisture out of the pile without re-condensing. This alternative will also help to control odors. Low rate aeration will likely result in high temperatures in the piles.

- *Extended Aerated Static Pile* – This established composting process generates far more energy than needed to evaporate all rain falling on the surface. It is provided as a comparison baseline.
- *Structural Cover* – A structural method of reducing process water is to cover the composting area. This prevents the rainfall from contacting the composting material except as desired by the operator. This gives a high level of moisture control. Storage facilities may be necessary to allow utilization of rainfall for composting moisture control.

The results of the modeling evaluation indicate that significant reduction in process water runoff can be accomplished by seasonally modifying the composting process. The results of the alternative comparison for the Soos Creek Facility are provided on Table 17. All alternatives have assumed volumes of 15,000 cubic yards and a depth of 12 feet.

Table 17 - Composting Process Water Management Alternatives

	Current[1]	*Pad isolation*	*Larger piles*	*Low rate air*	*EASP*[2]
Pad area (ac)	3.0	2.1	1.6	1.6	1.0
Pile runoff (%)	28	28	5	0	0
Runoff (gal)	1,650,000	780,000	315,000	255,000	145,000
% reduction		53	81	85	91
Avg. depth (ft)	5.5	5.5	7.0	7.0	10.5

[1]large static pile (no aeration)
[2]extended aerated static pile composting