Evaluation of Compost Facility Runoff for Beneficial Reuse
Phase 2

NIST MEP
Environmental Program

EVALUATION OF COMPOST FACILITY RUNOFF FOR BENEFICIAL REUSE
PHASE 2

FINAL REPORT

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INTRODUCTION

The Clean Washington Center (CWC) funded a two phase project to examine compost facility runoff. The runoff is a pollutant for many of the same qualities that would make it a plant nutrient. Nutrients in the runoff can have a detrimental effect on surrounding surface waters because of the increased plant growth caused by the presence of nitrogen, phosphorus, and potassium. These nutrients are all considered beneficial when added at correct rates to agriculture, gardens, and house plants. Runoff is a major problem for compost facilities. For these reasons, the CWC is interested in developing a marketable product from the runoff.

This report contains the findings of the second phase of the compost tea project. Phase 2 looked at implementing concentration techniques and market potential for a tea product. Phase 1 of the project consisted of characterizing the runoff by visiting four facilities, collecting samples during three storm events, and analyzing them for several constituents (BOD, TSS, pH, nutrients, salinity, fecal coliform, color, and a few metals). This report contains some data from Phase 1. The complete report for Phase 1 is available through CWC (*Report #CM-97-4, Evaluation of Compost Facility Runoff for Beneficial Reuse*). With the lab data from Phase 1, it was possible to determine if the material had nutrients in quantities that would be desirable in a commercial product. Comparisons were made to several commercial organic fertilizer products currently available on the market, and the runoff compared quite favorably. In addition, estimates of the nutrient content of a concentrated product and estimates for commercial value (based on the N:P:K of the products and the concentrated runoff) were made.

Growth trials were conducted to determine if the runoff had positive or detrimental effects on plants. Plants were grown and measured for bud/flower production and green mass (marigolds) and root and green mass (radishes). A summary of the results, as compared to MiracleGro and water, are shown in Section 3.5.

Table 1 - Runoff from Four Facilities (Range of Data)

Parameter	Range (mg/l*)
BOD_5	20 - 3,200
Total solids	1,100 - 19,600
Volatile solids	430 - 9,220
Color (color units)	1,000 - 70,000
Fecal (MPN/100ml)	200 - 24,000,000
Copper (ppb)	33 - 821
Zinc (ppb)	107 - 1,490
Nutrients:	
Ammonia N	32 - 1600
TKN	14 - 3,000
Nitrate+nitrite N	0 - 8
Total phosphorus	4 - 170
Ortho phosphate	0 - 90
pH (standard units)	6.7 - 9.5
Conductivity	887 - 16,500
Chloride	52 - 2,100
Potassium	167 - 4,640

* except where noted

Phase 2 of the project examined concentrating techniques to produce a thick and commercially viable product. These were conducted at a local large-scale yard debris compost facility. Techniques examined included using residual heat from the composting process and blending pond solids with blower condensate.

1.0 INVESTIGATION OF MARKET POTENTIAL

1.1 Nutrient Value Assessment

An assessment of the value for the runoff nutrient content is presented in this section. The nutrients in the runoff are considered a pollutant for the same reason that they can be considered a valuable asset. The nutrients are considered a pollutant in surface waters because they cause unnaturally high plant growth rates. Just as these nutrients promote the growth of plant life in surface water bodies, they can be used to promote the growth of agricultural crops, with proper attention to treatment and agronomic loading.

In order to assess the value of the nutrients in the compost tea, a comparison was made to the commercial value of nitrogen, phosphorus, and potassium. The pounds of each of these common fertilizers was calculated per 10,000 gallons of runoff based on the average analysis. Table 2 shows the cost of inorganic fertilizers based on the purchase of 50 lb. bags. These quotes were obtained from the Farm Supply Co-Op (Everett, WA).

Table 2 - Commercial Value of Nutrients in Runoff

Nutrient	Form	% dry weight	$/50 lb bag	$ dry/lb nutrient
Nitrogen	Ammonium	100%	$ 7.55	$0.15
Phosphorus	Phosphate	45%	$10.95	$0.48
Potassium	Potash	60%	$ 7.95	$0.26
Iron	Ferrous	55%	$19.95	$0.72
Copper	Copper sulfate	36%	$49.95	$2.77
Zinc		36%	$29.95	$1.66

This project examined the quantity of these elements available (on average) in the runoff from each of the four facilities. Table 3 shows the average values for the four facilities and the value of the nutrients available in the runoff. Dry pounds per 10,000 gallons of runoff was calculated for those elements present in the runoff. Dry pounds of each element was calculated as follows:

10,000 gallons x 8.34 lbs/gallon x % solids x ppm or mg/kg of element / 1,000,000

Based on the value presented in Table 3, a value in $/10,000 gallons of runoff was calculated. Using an average of runoff from four facilities, a value of $37 per 10,000 gallons was calculated. This was a hypothetical value and based solely on the nutrient value. Although difficult to quantify, the runoff also contained valuable organic material. The product will have no value unless consumers are educated about its value. Depending on the compost feedstocks, the product may need to be treated first to ensure safety (destruction of pathogens) and into a form consumers would want to purchase.

Table 3 - Runoff Value Assessment

Component	Average (ppm)	Commercial Value ($/lb)	Dry lb/10,000 gal	$/10,000 gal
Nitrogen available	585.1	$0.15	48.7	$ 7.30
Total phosphorus	67.0	$0.48	5.6	$ 2.69
Total potassium	1,211.0	$0.26	100.9	$ 26.23
Iron	6.1	$0.72	0.5	$ 0.36
Copper	0.2	$2.77	0.02	$ 0.05
Zinc	0.8	$1.66	0.07	$ 0.12
TOTAL				**$ 36.75**

1.2 Comparison to Other Commercially Available Organic Products

Many organic nutrient supplements are available on the market. Several of these products were examined and compared to the compost tea product from Cedar Grove. Cedar Grove is a large-scale composting facility which has large quantities of runoff to contend with. Currently, the material is collected in ponds and either reused on site or discharged into the King County sewer system for a fee. The comparison to Cedar Grove tea was made because the site produced large amounts of runoff, the organization was enthusiastic about the opportunity to develop a new product, and the facility handled primarily yard debris (and a small amount of other organics).

Commercially available products are either in a liquid form or in an emulsion (semi-liquid) state. Each product requires reconstitution in water to dilute it to an appropriate nutrient content, with doses ranging from 1 tablespoon per gallon to 1/2 cup per gallon. Foxfarm™ consists of worm castings, bat guano, mined potash, and kelp. Alaska Fish Fertilizer™ is an emulsion of fish industry by-products; Maxicrop™, SeaSpray™, and Concern ™ are all liquefied seaweed (kelp).

Table 4 represents a wide range of N:P:K ratios for these products, as well as the liquid from two sources at Cedar Grove. Most of the products also show analysis data for organic, water soluble nitrogen and ammonia nitrogen. Local retailers stated that the kelp products were “like magic” and often recommended them because of their high trace mineral and growth hormone content. None of the three kelp products included in this study had any printed information about these constituents on their labels. Since the sellers recognize that these are healthy for plant growth, it may be advantageous to analyze and label the compost tea product.

The ponds collect material from the entire site. Aerators in the ponds help to keep the liquid aerobic and help limit odors. Thick, settled material was taken off the pond bottom and analyzed. In addition, the liquid coming off the compost blowers (which draw ambient air through the piles) as condensate was sampled and analyzed. An extrapolation was made to show what the nutrient content would be if the liquid was concentrated.

Table 4 - Product Descriptions

Product	Description	Product State	N	P	K
Foxfarm	Worm castings, bat guano, mined potash, kelp	Liquid	0.8%	0.3%	1.0%
Alaska Fish	Fish emulsion, 4% chlorine	Emulsion	5.0%	1.0%	1.0%
Maxicrop	Liquefied seaweed, 1% chlorine	Liquid	0.1%	0.0%	1.0%
SeaSpray	Kelp concentrate	Liquid	0.0%	0.3%	0.5%
Concern	Fish and kelp	Liquid	3.0%	2.0%	2.0%
Cedar Grove	Solids drawn off of pond bottom	19.8% Solids	2.0%	0.3%	0.7%
Cedar Grove	Blower condensate	0.5% Solids	0.100%	0.060%	0.30%
		1% Solids	0.200%	0.004%	0.049%
		2% Solids	0.400%	0.007%	0.098%
		4% Solids	0.800%	0.014%	0.200%
		8% Solids	1.6%	0.028%	0.400%
		16% Solids	3.2%	0.056%	0.800%

The analysis for the solids drawn off of the bottom of the pond showed that the material was approximately 20% solids (a semi-solid state) with a N:P:K ratio of 2 : 0.3 : 0.7. This material may be suitable for sale as is, depending upon the pathogen content. The blower condensate, which was generally stronger than the runoff from the rest of the facility, also eventually ended up in the detention basin pond. This material added much of the BOD_5 content to the pond. This, in turn, increased the strength of the discharge to the sewer system. If the blower condensate could be diverted from reaching the pond, the strength of the discharge would go down. An analysis of the blower liquid showed that if it was concentrated to 16% solids, it had a N:P:K ratio of 3.2 : 0.1 : 1.

1.3 Results of Commercial Outlet Survey

A phone/fax survey was completed to investigate the potential for bringing a compost tea product to market. The participants were told that the CWC had a mission to expand markets for recycled goods, and organic residuals were a target waste. Participants were also informed that the tea product was a concentrated derivative of the rainfall runoff from compost facilities, which contained organics and nutrients from contact with the compost. Eight retail outlets were contacted for feedback (listed in Table 5), ranging from nurseries, garden stores, groceries, and home improvement stores.

The participants were told that the tea product would be marketed as a companion product to Cedar Grove Compost. The questions on the survey included the following:

- Would a liquid organic nutrient supplement as a companion product to Cedar Grove Compost be of interest to your retail market?
- Preliminary testing indicates that the product will have nutrient content (N:P:K) in the range of 2 : 0.5 : 1 in the bottle at approximately 20% solids (about the consistency of Alaska Fish Emulsion™). Is this a desirable nutrient content, or would a sweetened product be better? (Products are sweetened by adding bone meal or blood meal in order to raise nutrient percentages).
- What type of packaging would you like to see?
- What would be the optimum container size?

- Would several container sizes be desirable?
- Do you have a preference for container type (bucket vs. bottle)?
- If a compost tea product is developed and priced competitively or lower than similar organic supplements, would you make shelf space available?
- Any additional comments?

Table 5 - Retail Outlet Survey Participants

Retail Outlet	
City Peoples Mercantile	Furneys Nursery - Des Moines
Puget Consumer Coop	Furneys Nursery - Bellevue
QFC Grocery	Swansons Nursery
Eagle Hardware	Mohlbacks Garden Store

The majority of the participants had a great deal of interest in a product for sale in a bottle. All expressed more interest in a product which was tied to a proven product (the product that sells well has a proven track record and the companion product will likely have less to prove). The preferred container type was a half gallon or one gallon plastic jug with a handle, similar to a bleach bottle. Several retailers expressed interest in having the bottle recyclable or even made of recycled plastic.

Other concerns included the contaminant content in the tea, particularly pesticide content. The budget for this project did not allow for extensive contaminant testing, but any product produced should be tested for pesticides, coliforms, metals, etc. One retailer expressed concern about possible pesticide content in the Cedar Grove Tea. The nutrient content did not seem to be a primary concern to the retailers, although one participant thought it should be sweetened to raise nitrogen levels. In addition, there are several seaweed extracts that work extremely well that contain growth hormones and trace minerals but little N:P:K. Most retailers expressed that if the product works, N:P:K is fairly irrelevant. All participants stated interest in carrying the product.

1.4 Investigation of Horticultural and Agricultural Use

The use of this tea material in an agricultural setting is another possibility and would require loading the tea on the land at a rate which would not exceed the nutrient needs of the crop being grown. Loading to the nutrient needs of the plant is known as the agronomic loading rate. Agronomic loading for several crops is shown in Table 6. Agronomic loading is based on a limiting factor, or maximum pounds per acre of N, P, or K allowed per acre. This limiting factor allows for a calculation of maximum application rate in order to avoid surpassing the N, P, or K loading for the crop. These are general numbers and users should check with a local agricultural extension agent to account for site and soil specific conditions.

Table 6 - Agronomic Needs of Crops in lb/acre

Crop	N	P	K
Alfalfa hay	330	30	210
Corn	200	35	180
Wheat	125	22	90
Cottonseed	62	13	20

EPA, 1987

Table 7 shows the calculations made to determine the maximum loading rate of Cedar Grove compost tea to a hypothetical corn crop. These numbers are general loading assumptions, and any application rates should be checked with a local agricultural extension office. The pounds of N, P, and K per 10,000 gallons of tea, as calculated in Table 3, are shown in the second column of Table 7. The agronomic nutrient needs for corn are shown in column three. The maximum allowable gallons per acre without exceeding the nutrient needs are shown in column four. The lowest of these is the maximum allowable application rate. In this case, the limiting factor is the potassium content of the tea, and 17,900 gallons can be applied per acre. This is equal to an even distribution of 0.7 inches over the entire acre. The following is a sample of these calculations (using the available nitrogen from Table 3):

$$\frac{\text{1211 ppm N dry wt.}}{1{,}000{,}000} \times 8.34 \text{ lb/gal} \times 10{,}000 \text{ gallons} = 101 \text{ lb N/10,000 gallons}$$

$$\frac{10{,}000 \text{ gal}}{101 \text{ lb N}} \times \frac{180 \text{ lb N}}{\text{acre}} = 17{,}900 \text{ gallons/acre}$$

$$\frac{17{,}900 \text{ gallons}}{\text{acre}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{\text{acre}}{43{,}560 \text{ ft}^2} \times \frac{12 \text{ in}}{\text{ft}} = 0.7 \text{ inches}$$

Table 7 - Calculation of Maximum Agronomic Loading of Tea on Corn Crop

Nutrient	lb/10,000 gallons	Agronomic lb/acre	Gallons per acre
Nitrogen	48.7	200	41,100
Phosphorus	5.6	35	62,500
Potassium	100.7	180	17,900

For example, if a crop of corn is grown, an agronomic load of 200 lb/acre of nitrogen, 35 lb/acre of phosphorus, and 180 lb/acre potassium is needed. The runoff contains 48.7 lb N per 10,000 gallons, and therefore to achieve 200 lb N per acre, 200/48.7 x 10,000 gallons of runoff would be applied. To achieve the maximum potassium loading rate, 180/100.7 x 10,000 gallons of runoff, or 17,900 gallons would be applied. For this example, a farmer could apply 17,900 gallons of runoff per acre without exceeding agronomic loading rates. This 17,900 gallons per acre equals 0.65 inches of runoff per acre per year (17,900 gallons / 7.48 gallons/cubic feet / 43,560 sq. ft. / acre x 12 inches/ft = 0.65 inches/acre/year). Again, this loading rate can only be applied with DOE approval of pretreatment practices and with Washington State University (WSU) agricultural extension approval. The approval process should begin by contacting the local DOE office to discuss plans for runoff generated at a site. If treatment and discharge to surface water is planned, the DOE would require an NPDES stormwater permit, which regulates quantity and quality of discharge. Applications to contain all of the runoff and reuse it for agricultural use must comply with the Washington Administrative Code (WAC 16-200-7063), four-year cumulative total nutrient loading limits, or with agronomic loading for the chosen crop. Limits for metals loading per acre per year are contained in WAC 16-200-7-64.

1.5 Investigation of Potential Commercial Value

The following section describes the retail value of commercially available products and derives a conceptual retail value for the Cedar Grove tea. This conceptual market value for the tea product was compared to the cost of concentrating, handling, and bottling to determine the feasibility of such a product. Table 8 shows the market value of the five products, as well as nutrient and value comparisons. One product was specifically chosen for comparison (half-gallon size, Alaska Fish Emulsion™). The emulsion was sold in a concentrated form and had instructions for dilution in order to properly apply nutrients. Side panel information stated that the product contained an N:P:K ratio of 5:l:l, with a solids content of approximately 18%. The half-gallon plastic jugs sold at the retail level for $7.99.

Table 8 - Market Value of Commercially Available Organic Fertilizer Products

Product	Description	Product State	N:P:K	Cost (retail)	Bottle size (oz.)	$/gallon (retail)
Foxfarm	Worm castings, bat guano, mined 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**

A tea product can be sold in many container sizes and types. The example shown in Table 9 assumes that it will be sold in gallon jugs. The closest comparison to this was the Alaska Fish Emulsion™ product, which sold at $7.99 per half-gallon plastic bottle. This was equal to a retail price of $15.98. This example assumes a wholesale value of $5 per gallon for the Cedar Grove tea. The N:P:K ratio of the materials drawn off the pond bottom was 2:0.3:0.7, with a total solids of 20%. With proper disinfection (to eliminate fecal coliform and other pathogens), this material may be adequate for sale. It had a comparable N:P:K and had a similar consistency to the Alaska Fish Emulsion™. The blower condensate material was, as mentioned earlier, stronger than the runoff from the rest of the site. Table 9 shows how many gallons of blower condensate were needed to produce 2000 gallons of concentrated tea at 16% solids. The calculation shows that 64,000 gallons would be required to produce the 2000 gallons of tea from the blower condensate. The site had a storage capacity of approximately 8.5 million gallons of runoff, with the blowers generating between 0 and 5000 gallons of condensate per day.

Table 9 - Value Estimate for Cedar Grove Tea

Product		Comment	N : P : K	Cost	Size	Value
Retail Product For Comparison:					**Retail:**	
Fish Emulsion		Half gallon	5 : 1 : 1	$ 7.99	1/2 gallon	$ 15.98
Tea Product Wholesale Value:					**Wholesale:**	
				$/gallon	**Gallons**	**value ($)**
Cedar Grove	Solids drawn off pond bottom	19.8%	2 : 0.3 : 0.7	$ 5.00	2000	$10,000
Cedar Grove	Condensate from blowers	0.5% solids	0.1 : 0.002 : 0.025		64,000	
		1% solids	0.2 : 0.004 : 0.05		32,000	
		2% solids	0.4 : 0.007 : 0.1		16,000	
		4% solids	0.8 : 0.014 : 0.2		8,000	
		8% solids	1.6 : 0.028 : 0.4	$ 5.00	4,000	$ 20,000
		16% solids	3.2 : 0.1 : 1	$ 5.00	2,000	$ 10,000

Table 9 shows that the nitrogen content of the runoff was very close to that of the emulsion product. The phosphorus average was slightly less, and the potassium was much higher. As mentioned in the previous section, potassium encourages root growth and improves plant resistance to disease. Potassium also increases the size and quality of fruit and increases winter hardiness. Potassium should not be applied at greater than the agronomic rates for the same reasons that it is not wise to over apply nitrogen (potential runoff to surface water). Phosphorus is also present in the runoff. The role of phosphorus in plant growth is important to several processes, including photosynthesis, respiration, and fatty acid synthesis. Heavy concentrations of phosphorus are found in regions of the plant involved in the synthesis of nucleoproteins. Plants lacking in phosphorus may develop dead areas on the leaves or fruit, have a general stunted appearance, and may have leaves with a dark blue-green coloration.

Addition of other nutrients can sweeten the tea as well. Nitrogen can be sweetened with the addition of bloodmeal (N:P:K of 14:0:0), and phosphorus can be raised using bonemeal (N:P:K of 2:11:0). A 100 lb bag of bonemeal will add 14 lbs of nitrogen to the mix, and a 100 lb bag of bonemeal will add 11 lbs of phosphorus. This is an inexpensive and easy way to change the N:P:K ratio of the runoff to suit the needs of retailers or farmers.

1.6 Preliminary Investigation of Transportation Costs

Costs associated with the transport of the liquid can be estimated by comparison to the transport of biosolids to agricultural sites. Biosolids are transported at approximately 20% solids, and their density is similar to that of water (since they are 80% liquid). These costs can be compared to the cost for disposal to the sewer and to the value of the product to determine if the economics favor transportation to a site.

A major metropolitan area in the United States estimates that a 100 mile round trip costs approximately $3.50/wet ton, or approximately 1.3 cents per gallon, or 0.013 cents per gallon/mile. This cost accounts for labor, fuel, operations, and maintenance. This is an approximation for the costs associated with the transport of the runoff from a compost facility in a tanker truck.

King County charges a fee for discharge to the sewer of high strength runoff. The 1998 fees are $0.124125/lb of Biochemical Oxygen Demand (BOD) and $0.181032/lb of total suspended solids (TSS). Assuming that a facility discharges a runoff with 2500 ppm of BOD and 2500 ppm TSS (0.25% solids), the fee for discharge is 0.114 cents per gallon.

Using this estimate of 0.114 cents per gallon discharge fee and the estimate of 0.013 cents per gallon/mile for transport, an estimate for a break-even distance for transport of the liquid can be calculated. The distance to which the liquid can be hauled without incurring costs above what it would cost to discharge to the sewer in King County is 10 miles (0.114 cents per gallon divided by 0.013 cents per gallon/mile). These estimates are examples only, and all calculations should be based on a sites operating and actual discharge costs. The discharge costs for a facility depends upon the strength of the runoff. This example uses an average runoff strength. Other facilities may have much stronger or much weaker liquid, which could dramatically change these calculations. The sample calculations are summarized in Table 10.

Table 10 - Transportation Cost Estimate

Item	Cost
Transportation Cost Estimate	0.013 cents per gallon/mile
Discharge Fee per lb pollutant	$0.124125 per lb BOD $0.181032 per lb TSS
Discharge Fee $/gallon (2500 ppm BOD, 2500 ppm TSS)	0.57 cents per gallon
Round Trip Miles to Break Even	10 miles

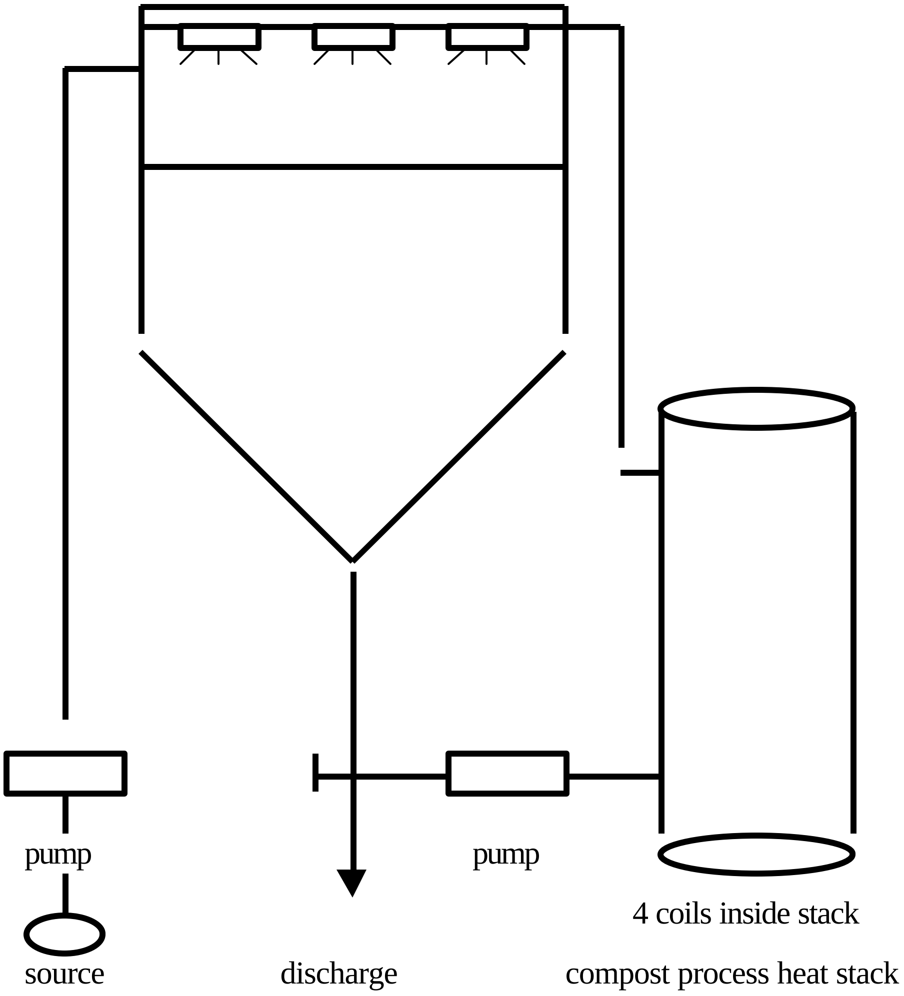
These estimates did not include any fee gathered from the farmer. Value of the liquid has been estimated and based solely on nutritional content in an earlier section. This value was approximately $37/10,000 gallons or $0.37 cents per gallon. If this fee could be obtained from a farmer, the break even distance would increase to approximately 40 miles round trip. This distance would include delivery to the site only, not application to the field.

2.0 DEWARTING DEMONSTRATON

2.1 Dewatering Description

The dewatering demonstration portion of this project employed a concentration technology using the residual heat from the compost process. Cedar Grove used an aerated static pile composting system, which drew ambient air through the hot pile to provide oxygen to the microbes and strip heat out of the process. The hot, saturated exhaust air was sent through a condensate trap chamber and then through a biofilter for odor control. In order for the biofilter to operate correctly, the exhaust air (approximately 140-150^{o} F) had to be cooled to below 130^{o} F. At Cedar Grove, two methods were employed to cool the exhaust. First, a chamber with a greatly increased diameter existed between the fans and the biofilter, allowing for the flow to slow and heat to dissipate through the walls of the chamber. This chamber was approximately 100 feet long and was surrounded by a greenhouse, which used the residual heat. This method has not always been adequate to sufficiently cool the exhaust, and a tower has been installed to divert a portion of the hottest air to the atmosphere. This hot air stream was used to heat the pondwater to improve the thermodynamics of the concentration apparatus.

Figure 1 - Pilot Dewatering System Description



Steps for concentrating pond liquid:

1. Fill evaporation tower to fill line from blower condensate drain.
2. Start circulation pump to heat liquid and spray into tower.
3. Continue to circulate until desired consistency is achieved.
4. Air flow is heated to 200 °F with heater (this did not occur at our site test - equipment was not available - this would have improved the transpiration of the water to the atmosphere).
5. Fill bottles with Compost Tea.
6. Heat can disinfect tea - would have to monitor temperatures and retention times (see time and temperature relationship equations below).

The time and temperature relationships for destruction of pathogens in sewage sludge are shown below. Equation 1 is for sludge with a solids content greater than 7% solids, and Equation 2 is for sewage sludge with a solids content less than 7% solids. This material had a solids content less than 7% solids and Equation 2 was used in estimating pathogen destruction in the pond liquid. Detention time (D) is in days, and temperature (t) is in °C. Temperatures had to be at least 50° C and a minimum time of 20 minutes to ensure proper mixing. Using Equation 2, the required detention times for several temperatures were calculated and are shown in Table 11. As can be seen, there is a wide range of detention times required over a relatively small increase in temperature.

Equation 1 - Sewage sludge at least 7% solids:

$$D = 131{,}700{,}000/10^{0.1400t}$$

$$t >= 50^{o}\ C\ (122^{o}\ F)$$

Equation 2 - Sewage sludge less than 7% solids:

$$D = 131{,}700{,}000/10^{0.1400t}$$

$$t >= 50^{o}\ C\ (122^{o}\ F)$$

Table 11 - Time and Temperature Relationships for Pathogen Destruction

Temperature (^{o}C)	**50**	**55**	**60**	**65**	**70**
Detention time	13 days	2.6 days	12.5 hours	2.5 hours	30 minutes

The design and operation of this setup did not generate enough heat to concentrate the liquid. Supplemental heat needed to be added in order to accomplish the goals originally set. The four loops inside of the exhaust tower did not allow for enough residence time to transfer sufficient heat. Future trials should employ more loops and longer detention time to allow for better heat transfer. The process will work if heat is transferred from the exhaust to the water; the hotter the exhaust, the shorter the detention time. Additional design time should be spent to further investigate the time and temperature relationships required to drive off the water.

2.2 Thermodynamics Discussion

The thermodynamics of the system set up at Cedar Grove did not allow for enough water to be driven off to concentrate the liquid very much. The system did not transfer as much heat to the water as was necessary. The air leaving the exhaust stack ranged from 100-115^{o} F, and the black flexible PVC used to run the water through the stack did not transfer heat well. Future projects should use more loops inside the stack. This project used 4 loops, and a minimum of 12-15 should be used. In addition, the hose could be directed through a duct closer to the piles to maximize heat transfer. The piles are generally in the range of 140-150^{o} F.

Supplemental heat could also be used to induce evaporation of liquid and therefore increase the solids content of the liquid. A propane steam generator with a heat exchanger in the tank could accomplish this. The addition of supplemental heat would also serve (as high temperatures are achieved) to destroy pathogens in the runoff. Pathogens are not always present, but if the runoff contains organisms which are considered health hazards, treatment with a disinfectant or with heat is necessary. If the runoff has very high solids (i.e. 10% or greater), a disinfectant may not be suitable, since the solids also contain a large percentage of organic material. Disinfectant in the form of chlorine is available in industrial grade by the barrel or by the gallon. When purchased in a small container, a gallon costs about four to five dollars. At the highest recommended dosage of chlorine for disinfection, a gallon of sodium hypochlorite would disinfect approximately 150 gallons of raw sewage. Using this conservative estimate, the cost would be approximately $0.03/ gallon of treated runoff. Supplemental heat would serve this purpose, while also concentrating the solids.

Calculations show that, if supplemental heat is used, the solids of the runoff could be raised from approximately 1% to 10% in less than a day. The cost to achieve this would be related to the cost of the propane to drive the heat exchanger. Using a cost for propane of $1.25 per gallon, the cost to achieve this concentration is approximately $0.05 per gallon of product produced. This is fairly insignificant when considering that a conservative estimate for wholesale value places the product in the $3 - $5/gallon range.

2.3 Product Testing Results

The product was tested for several pollutants and for nutrient content. Each of the various types of runoff were tested before the concentration demonstration began. The three types of Cedar Grove runoff tested were the liquid flowing to the collection pond, the solids settled to the bottom of the collection pond, and the condensate collected from the blowers which draw air through the compost piles. The results of this testing is shown in Table 12.

Table 12 - Test Results for Runoff Sources

Parameter	Runoff	Pond Solids	Blower Condensate
Total solids (%)	0.52	19.8	0.22
Volatile solids (%)	0.31	49.7	0.14
BOD_5 (ppm)	1100	17,000	1400
TKN (ppm)	2200	20,000	3400
Ammonia N (ppm)	34	820	44
Nitrate+Nitrite N (ppm)	ND	ND	ND
Total phosphorus (ppm)	180	2700	18
pH	6.7	6.8	6.64
Potassium (ppm)	7650	6550	24500

Copper (ppm)	50	40	102
Zinc (ppm)	445	371	702

As can be seen, the pond solids were much thicker than the other materials. Later in the demonstration, when a sample was taken off the bottom for blending in the concentration tank, it appeared to be far less solid. The blower condensate was stronger than the runoff from the rest of the facility. This liquid was collected from the blowers and diverted by pipe to the ponds. Since the ponds are eventually pumped to the King County sewer system, and the facility is assessed a fee according to the strength of the water discharged, a method to divert the blower condensate from the collection pond should be developed. An effort was made to divert this material to the concentration unit.

The batch of material tested in the concentration unit consisted of 300 gallons of solids from the collection pond, 300 gallons of blower condensate, 90 lbs of bloodmeal (to sweeten the nitrogen content), and 113 lbs of bonemeal (to sweeten the phosphorus content). The pond solids were considerably more wet than those tested earlier. The concentrator unit ran for 15 days, and the materials were tested for nutrient content. The thermodynamics of the system did not allow for a large increase in solids content. The residual heat from the compost was not hot enough to drive off water or transpire water vapor from the spray nozzles. Additional heat was required to concentrate the solids of the compost tea. However, since it was not in the scope of this particular project and more pressing issues at the site took precedence, the additional testing was not accomplished. An evaluation of the additional heat required is included in a section which follows. The total solids and nutrient content of the runoff before and after treatment are shown in Table 13.

Table 13 - Results of Concentration Test

Parameter	Input	Output
Total solids (%)	0.5	1.1
TKN (ppm)	12,250	26,500
Total phosphorus (ppm)	3580	7850
Potassium (ppm)	18500	35400
N:P:K	1.2 : 0.4 : 1.8	2.6 : 0.8 : 3.5

3.0 BENCH SCALE GROWTH TRIAL

3.1 Growth Trial Description

The bench scale growth study was designed to examine the effects of applying three strengths of runoff and a standard fertilizer use against the growth of a control group that used only water. All plants were grown in four-inch pots with professional potting mix as a medium. Potential effects were unknown at the start of the project, and measurements were designed to examine whether the runoff had a positive or detrimental impact on the growth of the plants.

The purpose of the test was to perform an initial assessment to see if there was any potential for product development. The results were used as the basis of a field trial design performed at the Love Israel Commune in Arlington, WA. The results of this test were inconclusive because of inconsistent watering by the Love Israel staff. The test was designed to compare the performance of the runoff to the performance of water.

Two types of plants were chosen for study. Radishes were chosen in order to measure the effects on root growth, and marigolds for examination of flower production. Five plants from each of the two species were treated with three different strengths of runoff, one treatment of recommended fertilizer loading, and one treatment of water only. These plants were grown to maturity and then measured for several factors. These factors are included in Table 14. A description of the treatment schedule is shown in Table 17.

Table 14 - Growth Study Summary

	Radishes	Marigolds
Days to maturity	30	60
Parameters measured	root weight green wet weight green dry weight	# flowers # buds (unopened flowers) green dry weight
Application 1, 100% runoff	5 plants	5 plants
Application 2, 50% runoff	5 plants	5 plants
Application 3, 20% runoff	5 plants	5 plants

Fertilizer	5 plants	5 plants
Control	5 plants	5 plants

3.2 Growth Trial Details

Measurements for the parameters of the marigolds and radishes were taken to determine which method of fertilization had the best or least detrimental effect on the plants. This was accomplished by growing the target species in four-inch pots with potting soil and under grow lights. Watering was done on the same day and in the same quantity for each plant group, using the runoff and fertilizer (liquid form) in place of water for the corresponding plant groups.

The radishes and marigolds were started in a flat container, and after one or two weeks of growth (after sufficient germination with water only), they were sorted (small and large plants eliminated) and transplanted into four-inch pots. At this point, fertilizer, runoff, and water dosing began.

Plant quantities for each species and treatment consisted of five plants per treatment, five treatments per species, and two species. This totaled 50 plants, or 25 plants per species. In summary:

- **Radishes from seed:**
  - 5 plants per treatment
  - 5 treatments
    - 3 dilutions of runoff
    - traditional fertilizer
    - water only
- **Marigolds from seed:**
  - 5 plants per treatment
  - 5 treatments
    - 3 dilutions of runoff
    - traditional fertilizer
    - water only
- Total 50 plants, 25 per species

3.3 Runoff Strengths/Dilutions

Fertilizer strength for the F group plants (those watered with commercial fertilizer) was determined by the nutrient needs of the target species. A typical fertilization regiment for the target plants was a liquefied solution derived from a dry fertilizer with an N:P:K ratio of 15:30:15. This fertilizer could be applied in two strengths, depending on whether addition occurred monthly or at each watering. The protocol for this project was to fertilize during each watering period. For this application rate, the recommended dosage was 1.25 grams of dry fertilizer per gallon (330 mg/liter). At this rate, the liquid solution had a N:P:K ratio of 0.005:0.01:0.005 (% of wet weight). The runoff mixtures/dilutions used for the growth trial were most closely matched and bracketed these fertilizer characteristics. Table 15 shows the comparison of this ratio to the ratios of each runoff mixture. The ratios of each were determined by using the nitrogen, phosphorus, and potassium concentrations from the lab analyses.

Table 15 - Runoff and Fertilizer Nutrient Comparison

Solution	N (ppm)	P (ppm)	K (ppm)	N (%)	P (%)	K (%)
Fertilizer (liquid)	50	100	50	0.005	0.010	0.005
Cedar Grove	98	140	275	0.010	0.014	0.028
Phoenix	1760	48	3740	0.176	0.005	0.374
Woodland Park	263	3230	828	0.026	0.323	0.083
WSU	161	33	495	0.016	0.003	0.049

Similarly, the runoff dilutions to be used for application were determined from the recommended nitrogen application for the plants. Of the three dilutions, the first had a higher N dosage, the second was close to the recommended dosage, and the third was lower. The runoff best suited for the potted plant growth trial was from Cedar Grove Compost facility. This material had a higher percentage of the three target recommended nutrients than the fertilizer, so it could be applied straight and with two dilutions in order to compare dosage response. The dilutions and corresponding nutrient contents are listed in Table 16. The watering and fertilization schedule is presented in Table 17. As can be seen in Table 16, the nitrogen and phosphorus content of Application 2 and the potassium content of Application 3 are similar to that of the fertilizer.

Table 16 - Determination of Runoff Dilution Rates

Treatment	Dilution	N	P	K
F	330 mg/liter	0.005	0.010	0.005
1	1 runoff:0 water	0.010	0.014	0.028
2	1 runoff:1 water	0.005	0.008	0.014
3	1 runoff:4 water	0.002	0.003	0.006
C	Water only	0	0	0

Table 17 - Nutrient and Water Loading Rates

Treatment	N:P:K	Volume/plant*	Frequency
F	0.005 to 0.0100 to 0.005	30 ml.	every other day
1	0.010 to 0.014 to 0.028	30 ml.	every other day
2	0.005 to 0.008 to 0.014	30 ml.	every other day
3	0.002 to 0.003 to 0.006	30 ml.	every other day
C	0 to 0 to 0	30 ml.	every other day

***** Watering needs were evaluated and adjusted as needed during the growth trial

3.4 Nutrients Applied

The total mass of nutrients applied to each plant group is calculated below. This calculation is useful to compare when evaluating growth data. Table 18 contains the nutrients applied to each group. The nitrogen loading of the three application rates were designed to bracket that of the fertilizer application, which was based on the recommended loading rate. In other words, the fertilizer application matches the nutrient uptake of the plants, and Application 2 was designed to closely match the fertilizer application. As can be seen in Table 18, the nitrogen loading of Application 2 is close to that of the fertilizer group. The phosphorus loading for Application 2 is 30% lower than that of the fertilizer, and potassium is 2.7 times higher.

Table 18 - Total N, P, and K applied (mg/plant)

	Radishes (30 days)			Marigolds (60 days)		
	N	P	K	N	P	K
Fertilizer (plant need)	14.5	29	14.5	43	86	43
Application 1	28.4	40.6	79.8	84.3	120.4	236.5
Application 2	14.2	20.3	39.9	42.1	60.2	118.3

Application 3	5.7	8.1	16.0	16.9	24.1	47.3
Control	0	0	0	0	0	0

3.5 Growth Trial Results

The following figures show the data gathered for analysis. For each plant type, the results of the average growth measurements are shown. The average of each parameter is compared to the average for the corresponding parameter in the control group. A percent difference from the control is calculated for each test group, and these results are presented in Figures 2 and 3.

A statistical analysis was performed on the data in order to determine if the differences seen in the averages were statistically significant. T-tests were performed on each group against the control to determine the probability of significant difference. The t-test looked at the mean, the variance, and the number of observations to determine the probability (in percent) that the two groups came from distinct populations. In all cases the probabilities of significant difference were high. The highest significance was for Application 2 of the runoff.

For the radish group, the results showed that in all cases, the root weight was greater for applications of nitrogen than for the control. In addition, the green weight was lower, indicating that the nitrogen energy was used in the root growth of the plant. For the case of growing radishes and other root crops (tubers possibly), this was considered a positive effect. In all cases, the runoff outperformed the fertilizer and the best results were seen from Application 2. There were no detrimental effects in quality for any of the treatments (i.e. woody or split radishes).

For the marigolds, each group showed an average increase in flower and bud (unopened flowers) production over that of the control plants. Figure 3 shows the total production (buds and flowers) and dry plant mass. The total production for each of the runoff applications was greater than that of the fertilizer, while for the flower production only, Application 2 alone showed greater production than the fertilizer. Again, the statistically significant difference was substantial between Application 2 and the control and fertilizer groups.

Figure 2 - Runoff Treatments vs. Control Plants for Radish Plant Group

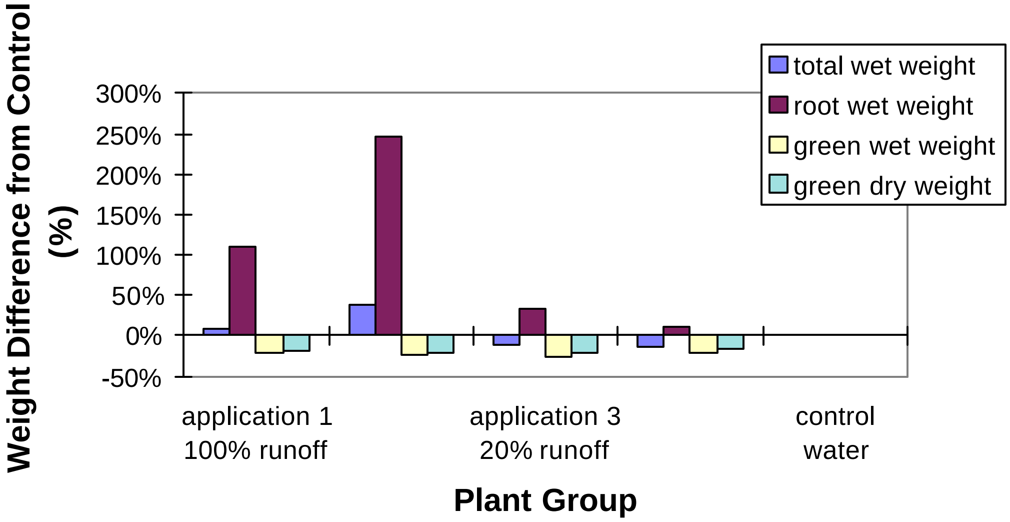
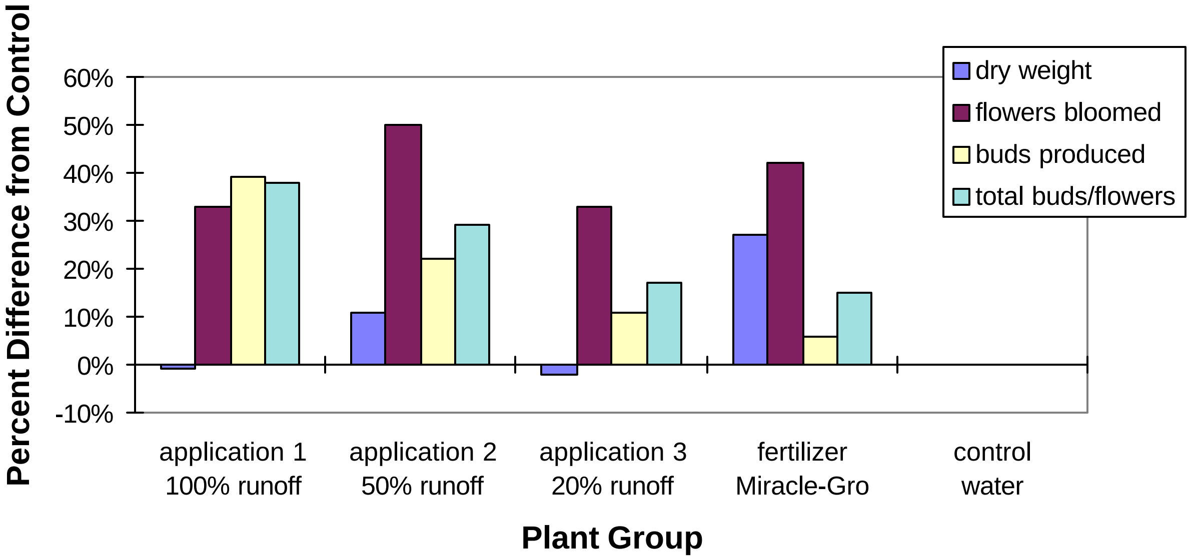


Figure 3 - Dry Weight, Flowers, and Buds - Treatments vs. Control Plants



One goal of the study was to examine the potential toxic constraints of applying the runoff dilutions to the plant groups. The results of the plant mass measurement and the flowering did not indicate any adverse toxic effects. Toxic effects would likely have manifested in smaller plant growth or flowers, or possibly plant mortality; no mortality was observed.

3.6 Love Israel Field Trial Results

Treatment of broccoli at the time of transplantation with a fairly strong concentration of compost runoff appeared to diminish eventual crop yield by 29 - 48%; early production appeared more affected than late. Also, a higher percentage of treated plants succumbed to root rot than did the control (untreated) plants. No quantifiable data was obtained from the experimental plots which used potatoes. The potatoes were harvested without being weighed or counted. Some qualitative results were observed, including the observation that the potatoes grown in the treated plots were healthier and larger than those grown in the control plots. This coincided with the bench scale results, which showed better results in root crops with the application of the runoff as compared to commercial fertilizer and control plots. Observations of the plants revealed that the treated plots appeared to have survived the summer flea beetle infestation better than the control plots.

The growing season in which this experiment was conducted was highly variable and unusual compared to normal growing seasons. A representative from the farm stated that, when it was hot, it should have been cool, cool when it should have been hot, dry when it should have been wet, and wet when it should have been dry. This emphasized the fact that the experiment endured highly variable conditions, and results should be studied with these conditions in mind.

3.7 Data Interpretation

The data presented above shows an increase in root growth and flowering of test plants with the addition of compost runoff, as compared to those plants treated with traditional fertilizer and plants treated with only water. These results were statistically significant, and did not show any detrimental effects from the application of the runoff material (a pre-study concern). Study of the lab analyses revealed some clues as to why this increased growth occurred.

Potassium levels in runoff Applications 1 and 2 (straight and 1:1 dilution) were 5.5 and 2.7 times higher than that of the fertilizer solution. Table 19 shows the differences between the growth and the potassium application of the runoff plant groups and the fertilizer plant group. Potassium encourages root growth and increases plant resistance to disease. It produces larger, more uniformly distributed xylem vessels throughout the root system. Potassium increases size and
quality of fruit and vegetables and increases winter hardiness (Western Horticulture Handbook).

Table 19 - Growth and Potassium Application Differences

Plant Group	**Root Growth**		**Flowers and Buds**		**Potassium Applied**	
	Weight (g) Average	Percent Difference	Number	Percent Difference	mg/plant	Percent Difference
Fertilizer	2.8	0%	11	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%

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 which use compost as a medium have shown strong flower production when compared to other potting mixes, and this has been determined to be an effect of the micronutrients present in the compost (Gouin). Since the runoff is from a compost facility, it is likely that there are balanced micronutrients present. Due to budget constraints, the lab analyses performed for this project did not include full micronutrient analysis. Historical data from Cedar Grove Composting gathered before this project indicated the presence of many micronutrients in the 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 showed that in all of the radish groups on which nutrients were applied, the average root growth and the average green weights were lower than those for the control. Furthermore, the plant groups applied with runoff showed increased root growth over the fertilized group. This indicated that the nutrient balance was more appropriate for root growth in the runoff groups than for the fertilized group. The better balance was most likely due to the presence of the micronutrients in the runoff.

In addition to higher levels of potassium and the potential presence of micronutrients, the runoff may have had 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 which are difficult to breakdown. Humic acids are likely to be present in any runoff which 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).

3.8 Growth Trial Conclusions

These conclusions were drawn from the examination of the data generated by the two growth studies (bench trial and field trial).

1. Yard debris compost facility runoff application resulted in larger radish roots and more buds and flowers on marigold plants.
2. There was no evidence of plant toxicity from application.
3. Growth energy appears to go to roots and flower production. Fertilizer produced more green mass.
4. The best responses were found from the applications of this runoff diluted with 50% water, with approximately 50 ppm N, 70 ppm P, and 140 ppm K.
5. Increases in growth may be attributed to the high levels of potassium, the presence of micronutrients, or the potential presence of humic acids.

3.9 Strawberry Growth Trial

An additional test was conducted with several products collected from sources at Cedar Grove. The test consisted of growing strawberries in the greenhouse next to the compost piles. Seven different applications were applied to groups of four plants (28 plants total). Blower condensate was applied straight and three dilutions of pond solids were applied. These four applications were compared with a control (water only), an application of Alaska Fish Emulsion™ (as prescribed on the bottle), and one application of pond solids treated with chlorine to disinfect. These sets of plants were treated equally and watered evenly with the different liquids. The berries from each of the four plants from each group were harvested and weighed. The results of the harvest are presented in Table 20.

Table 20 - Results of Strawberry Growth Trial

Test Description	Grams	% Difference from Control
Test 1 - Control (water)	7.96	0%
Test 2 - Test 6 + chlorine	0	-100%
Test 3 - Alaska Fish Emulsion (3 tbls/gal)	10.56	33%
Test 4 - Blower Condensate[1]	7.46	-6%
Test 5 - Pond Solids[2] (2 tbls/gal)	28.69	260%
Test 6 - Pond Solids (4 tbls/gal)	13.07	64%

Test 7 - Pond Solids (8 tbls/gal)	4.29	-46%

[1] blower condensate applied without dilution

[2] pond solids are approximately 20% solids

The results show that the plants responded well to the pond solids. The dilutions of this semisolid material allowed for application of the nutrients at agronomic levels in a water solution. The nitrogen content of the dilution used in Test 5 closely matched the nitrogen content of that in Test 3 (Alaska Fish). Both the dilutions in Test 5 and Test 6 outperformed the Fish Emulsion™ and the control. The blower condensate had a response similar to that of the control. The four plants watered with the sample dosed with chlorine did not produce any fruit.

4.0 ECONOMIC ANALYSIS SUMMARY AND WORKSHEET

This section summarizes and consolidates the economic information described in this report. In addition, a worksheet is described which allows the user to calculate the nutrient and solids content of the runoff from a specific facility. This worksheet can assist users in determining if their runoff is suitable for sale as a commercial product, and how its characteristics will change as it is concentrated.

The runoff value assessment presented in Section 1.1 applies the commercial agricultural value of the nutrients found in the runoff to quantity of each, and calculates a conservative value estimate in $/10,000 gallons. Based on the average nutrient content for each of the facilities, a value of approximately $37/10,000 gallons was calculated. This would vary depending upon the nutrient content of the runoff.

Considering the nutrient content of several commercially available products for home and horticulture use, the runoff compared very favorably. An investigation of five commercially available products containing fish emulsion, bat guano, worm castings, potash, and seaweed revealed that on average, the products sold for over $40 per gallon and were packaged in small containers meant for dilution. These values are shown in Table 8 in Section 1.5. Table 9 shows the value of 2000 gallons of the Cedar Grove runoff in different states of concentration when sold at a wholesale price of $5 per gallon. This example is used to show how to calculate the value of a runoff for comparison to the cost for processing.

Transportation costs to agricultural fields were compared to the King County sewer discharge fees in order to estimate a break-even round trip distance. If a fee could be collected for the nutrient value in the water, a break even round-trip distance would be 40 miles. This distance is dependent upon the nutrient content of a specific runoff.

In order to better understand the nutrient content of the runoff, this section provides a worksheet with instructions on how to calculate N:P:K percentages. Nutrient content is generally reported on a dry weight basis as a percentage. An N:P:K of 1:2:1 indicates 1% nitrogen, 2% phosphorus, and 1% potassium. Reporting on a dry weight basis allows for the calculation of agronomic application rates for different crops. In addition, the nutrient content and the solids content should be reported. This allows the user to determine the nutrient content as it sits in the bottle, thereby allowing for calculation of dilutions. These calculations can be made ahead of time and placed on the label by the producer. This can aid the consumer in making an educated purchase.

1. **Nitrogen calculation (dry weight basis)**

   % N = _______ mg/kg / 1,000,000 x 100

2. **Phosphorus calculation (dry weight basis)**

   % P = _______ mg/kg / 1,000,000 x 100

3. **Potassium calculation (dry weight basis)**

   % K = _______ mg/kg / 1,000,000 x 100

- **Calculation of percentage of nutrients percentage as in bottle**

% dry weight N / % total solids/100 = % N in bottle

- **Calculation of gallons of tea per acre for crop X** gallons/acre = required lb N/acre for crop X / (8.34 lb/gal * %N in bottle)

These numbers allow the user to calculate the required dilution rate for any crop which may be fertilized (tomatoes in a garden, corn in a farmers field, or a suburban lawn).

SUMMARY AND CONCLUSIONS

The project did not yield a thickened tea product, as was initially anticipated. However, a product can be made that would be marketable to the public. A product marketed in association with a compost product would most likely share shelf space with other available organic products. If a product was produced using supplemental heat (cost $0.05 per gallon of product for propane), bottled for approximately $0.25 per bottle, and the material was transported in a truck to retail outlets in 1000 bottle lots (to several outlets over the course of the day), there is the potential to make a substantial profit.

In addition to the potential profit, there exists the possibility to reduce the cost to discharge the material to the sewer system. In wet months, a large scale composting facility is charged as much as $5000 per month to discharge to the sewer. Every gallon of runoff that is diverted from the sewer would save a tenth of a cent. When considering the rainfall in western Washington, this could accumulate quickly.

Steps to be taken if considering reuse of compost runoff include the following:

- Test the runoff for nutrients (nitrogen, phosphorus, potassium);
- Test the runoff for pollutants (BOD_5, fecal coliform, chloride, pH); and
- Test the runoff for total solids content and volatile solids content (organic content).

If the runoff has low pollutant content (less than limits established by DOE for land application - consult local DOE office) and high nutrient content (greater than 0.5% of N, P, or K), it may have a high potential for reuse. Any application of this material to the land would require the consent of the local health departments. Bottling or land application of the product may require disinfection through the addition of chlorine or heat to reduce the pathogen content of the liquid. The Washington State Department of Agriculture has established limits on nutrient and metals accumulation on agricultural lands. These limits cannot be exceeded when applying fertilizer products to the land. These limits are listed in Table 21.

Table 21 - Department of Agriculture Cumulative Nutrient Loading Limits

Nutrient	4 Year Cumulative Total (lbs/acre)
Nitrogen (N)	1600
Phosphorus (as P_2O_5)	700
Potassium (as K_20)	1600
Boron (B)	12
Calcium (Ca)	800
Chlorine (Cl)	300
Copper (Cu)	10
Iron (Fe)	80
Magnesium (Mg)	400
Manganese (Mn)	40
Molybdenum (Mo)	4
Sulfur (S)	300
Zinc (Zn)	30
Lime ($CaCO_3$ equivalent)	12000
Gypsum ($CaSO_4$)	12000

Table 22 - Washington State Standards for Metals

Metals	lbs/acre/year
Arsenic (As)	0.297
Cadmium (Cd)	0.079
Cobalt (Co)	0.594
Mercury (Hg)	0.019
Molybdenum (Mo)	0.079
Nickel (Ni)	0.713
Lead (Pb)	1.981
Selenium (Se)	0.055
Zinc (Zn)	7.329

Further study of the subject may yield better and more concrete findings. This report finds that the material has a high nutrient content and has a high potential for reuse. The development of a reliable unit to disinfect and concentrate the material would provide an additional source of income for a compost facility. The product could be a good companion to the sale of bagged or bulk compost.

ACKNOWLEDGMENTS

The author would like to acknowledge the commitment of the ReTAP program to expanding the market for recycled goods. 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.

In addition, the author would like to acknowledge the assistance of:

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INFORMATION DISSEMINATION EFFORT

The following efforts were undertaken by E&A in order to disseminate information to the public regarding the information contained in the two phases of this project. A presentation was given at the Washington State Recycling Association annual conference. The topic of the presentation was "Innovations in the Composting Industry." The talk consisted of a discussion of the feasibility of producing a tea product and the results of Phase 1 of the project, along with discussion of composting gypsum wall board and using compost in bioswales for treating runoff. Also, an article appeared in Biocycle Magazine (September 1997) outlining the results of Phase 1 of the project.