Composting Commercial Fish Processing Waste from Fish Caught in the Michigan Waters of the Great Lakes

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MICHIGAN STATE UNIVERSITY EXTENSION

Sea Grant

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Abstract

The disposal or reuse of fish processing waste has long been a challenge for Michigan's fish processing industry. Approximately 5 million pounds of waste from commercially processed lake whitefish, lake trout, and salmon are generated annually. In an effort to help the Michigan fish processing industry find better solutions to handle fish processing waste materials, a project was initiated to determine the viability of composting fish waste. The objectives of this project were to develop a compost marketing strategy, produce compost that met identified market specifications, and document the levels of mercury and halogenated hydrocarbons along the composting process to allay concerns in using composted fish waste.

Lake whitefish waste from fish caught in Lake Superior exceeded the USDA Food and Drug Administration's (FDA) chlordane and dieldrin action level of 0.3 ppm for food fish. Lake whitefish waste from fish caught in lakes Huron and Michigan were below the action level for chlordane and dieldrin. All lake whitefish waste, regardless of coming from Lakes Huron, Michigan or Superior, were below the FDA's action levels for food fish for toxaphene, dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyl (PCB) and mercury.

Lake trout waste from fish caught in lakes Superior and Huron exceeded the FDA action level of 0.3 ppm for chlordane and dieldrin. Chlordane and dieldrin were not detected in lake trout caught in Lake Michigan. Lake trout waste from fish caught in lakes Huron, Michigan and Superior were below the FDA's action levels for food fish for toxaphene, DDE, DDD, DDT, PCB and mercury.

Salmon waste from fish caught in Lake Michigan exceeded the FDA's PCB level of 2.0 ppm for food fish. Salmon waste from fish caught in Lake Huron was below the action level for PCB. All salmon waste, regardless of coming from Lake Michigan or Lake Huron, were below the FDA's action levels for food fish for chlordane, dieldrin, toxaphene, DDE, DDD, DDT and mercury.

No halogenated hydrocarbons were detected in compost made from white fish/lake trout waste while DDT levels in compost made from salmon waste were detected, but

were well below the FDA DDT action level of 5.0 ppm for food fish. Mercury levels were below both the FDA action level (1.0 ppm) and State of Michigan action level (0.5 ppm) in both white fish/lake trout waste compost and salmon waste compost. No chlordane, dieldrin, toxaphene, DDE, DDD, DDT, PCB or mercury was found in the leaf compost from the City of Kincheloe.

Mercury contaminant levels in basil plants grown in mixes with various amounts of white fish/lake trout and salmon compost in them were well below the FDA action level (1.0 ppm) and State of Michigan action level (0.5 ppm).

It is recommended that fish waste compost be a component of a growing mix that meets a more demanding specification and for which the consumer is accustomed to paying a higher price. Based on the trials in this study, growing mixes containing 20-25% compost in a professional peat based growing media are optimum. There is nothing in compost made from fish waste that would prohibit it from being used in an organic cropping system.

Introduction

The Great Lakes still support a sustainable commercial fishery. The activities of this commercial fishery vary among the states and the province of Ontario. In 2000, lake whitefish was the most harvested fish in both U.S. and Canadian waters of the Great Lakes, accounting for more than 21 million pounds and worth over $18 million in dockside value (Kinnunen, 2003). In 2000, 60 percent of the commercial harvest of Great Lakes whitefish was from Lake Huron, 25 percent from Lake Michigan and 10 percent from Lake Superior.

Lake whitefish, lake trout and salmon account for the largest share of commercial fish harvested from the Michigan waters of the Great Lakes (Kinnunen, 2003). In 2000, about 8 million pounds of lake whitefish, just over 1 million pounds of lake trout and over a half-million pounds of Pacific salmon were harvested from the Michigan waters of the Great Lakes. The lake whitefish commercial harvest in Michigan waters of the Great Lakes in 2000 was made up of fish from Lake Michigan (41 percent), Lake Huron (37 percent) and Lake Superior (22 percent).

In addition, about 1 million pounds of Pacific salmon are harvested each fall from weirs on rivers that flow into lakes Huron and Michigan. Kinnunen (2001) reported that, through the late 1990s, these weir-harvested Pacific salmon consisted of, by poundage, Lake Michigan coho salmon (38 percent), Lake Michigan chinook salmon (35 percent) and Lake Huron chinook salmon (27 percent). When these Michigan Great Lakes fish are processed, about half their weight is generated as waste byproducts. Thus about 5 million pounds of waste was generated from the harvest of lake whitefish, lake trout and salmon in Michigan in 2000.

The disposal or reuse of fish processing waste products has long been a challenge for Michigan's fish processing industry. This problem is especially acute in northern Michigan, where municipal sewage treatment systems are ill equipped to treat fish processing waste material and landfills are an expensive disposal solution. Some processors have developed markets in the liquid fertilizer industry that have helped alleviate disposal problems; however, the liquid fertilizer market is available only during the summer months, and it requires expensive refrigeration while material is accumulated. In an effort to help the Michigan fish processing industry find better ways to treat fish processing waste materials, a pilot project was initiated to determine the viability of composting fish processing waste material and identify markets for the composted material.

It was understood at the outset of this project that composting fish processing waste had been done before with varying amounts of success. Past fish waste composting pilot projects in Door County, Wis. (L. Frederick et al., 1989), Rogers City, Mich., and Michigan's Upper Peninsula (Logsden, 1991; Gould, 2004) provided a range of results. It is postulated that composting techniques, as well as the origin of fish and perhaps contaminants in feedstocks used as the carbon source, contributed to the wide range of test results.

Because contaminants in the fish waste were of concern, it was felt that analysis needed to be done all along the composting process. Accordingly, fish waste from various fish species from lakes Superior, Michigan and Huron; feedstocks used to provide carbon; the finished compost from two composting methods; and sensitive crops grown in a greenhouse in the finished compost were all analyzed for contaminants.

Objectives

The objectives of this project were to:

I. Produce compost that meets the specifications of the identified market.

II. Document the levels of mercury and halogenated hydrocarbons in the fish waste, the finished fish waste compost and plants grown in finished fish waste compost to allay any concerns about using composted fish waste.

III. Develop a compost marketing strategy.

Feedstock Descriptions

Lake whitefish and lake trout waste samples were collected from commercial fish processing facilities. Lake whitefish waste consisted of everything except the skin-on fillet portion of the fish. Lake trout waste consisted of everything except the skin-on fillet portion of the fish and the viscera. Pacific salmon waste consisted of the head and viscera minus the eggs (the fish were being processed for sale whole, and the eggs were sold as caviar). The carbon feedstocks used to make compost were sawmill bark wood chips, hardwood sawdust, cedar sawdust and industrial waste sawdust.

A composite sample of the fish waste (one-third lake whitefish, one-third lake trout and one-third Pacific salmon) plus the sawmill bark wood chips and hardwood sawdust were analyzed in preparation for developing a compost recipe. Analysis of these feedstocks was performed by Woods End Research Laboratories, Inc. (Mt. Vernon, Maine). Midwest BioSystems (Tampico, Ill.) performed the analysis on the industrial waste sawdust. (These analyses can be found in Appendix 1.)

In addition, a small amount of partially composted yard refuse (primarily leaves) was used to top off the pile at the Kincheloe site because additional carbon was needed beyond what was available as wood fiber materials. A feedstock analysis was not performed on the leaf compost. However, a halogenated hydrocarbon and mercury analysis was performed (Table 1).

Compost Production

Composting methods and locations

Two composting methods were used in this project — the rotating drum in-vessel composting method and the static pile method. The rotating drum in-vessel composter used was Model 408 manufactured by BW Organics (Sulfur Springs, Texas) (Figure 4). It has a capacity of 2.45 cubic yards and was located at Shady Side Farm (Holland, Mich.). The static pile was formed and located at the Kinross Charter Township Department of Public Works (Kincheloe, Mich.).

The sawdust, wood bark chips and fish waste analyses were used by Woods End Research Laboratories, Inc., to develop several compost recipes for this site (see Appendix 1). The compost recipe used was adjusted to compensate for higher than anticipated fish waste moisture content. The compost recipe was 13 cubic yards of sawdust (10 cubic yards of hardwood sawdust and 3 cubic yards of cedar sawdust), 10 cubic yards of hardwood bark and 9 cubic yards (1,800 gallons or 15,000 pounds) of fish waste. Cedar sawdust was used because of the difficulty in getting hardwood sawdust, but this is not recommended. Approximately 3 cubic yards of composted leaf material from the Kincheloe leaf collection facility were also incorporated in the pile. The fish waste, predominantly made up of lake whitefish and lake trout, came from three fish processors in the St. Ignace/Mackinaw City, Mich., area — Bell's Fishery, Clearwater Fish Cooperative and the Mackinac Straits Fish Company. About a third of the fish waste volume (4,100 pounds) came from Lake Superior fish; the rest came from fish from lakes Huron and Michigan.

Compost pile development

Because the compost pile was only to be on a pilot scale and the project was not designed to investigate actual compost production, no effort was made to replicate production techniques that might be used in a commercial-scale operation. The fish waste was delivered to the Kincheloe site in the same way that the processors typically deliver the material to the landfill — in 55-gallon or smaller barrels (Figure 1).

Figure 1.

To build the pile, an 8-inch-thick layer of sawdust and wood bark chips was spread over approximately 400 square feet.

Table 1. A summary of chemical contaminants found in fish waste, compost, leaf compost and tissue samples.

Sample Name	Chlordane ug/g	Dieldrin Total ug/g	Toxaphene Total ug/g	Sum DDTs ug/g	Sum PCBs ug/g	Mercury ug/g
LS-WF	2.00	1.00	0.03	0.18	0.72	0.020
LH-WF	0.00	0.28	0.16	1.46	1.10	0.030
LM-WF	0.00	0.00	0.11	0.00	1.58	0.030
LS-LT	0.60	2.10	0.00	0.00	0.00	0.130
LH-LT	0.41	1.27	0.00	0.20	1.02	0.090
LM-LT	0.00	0.00	0.53	0.00	1.07	0.060
LH-CHS	0.06	0.00	0.48	0.26	1.35	0.080
LM-CHS	0.00	0.00	4.20	0.05	2.97	0.250
Compost 1	ND	ND	ND	0.00	ND	0.170
Compost 2	ND	ND	ND	0.13	ND	0.040
Compost 3	ND	ND	ND	ND	ND	0.015
Plant 1	ND	ND	ND	ND	ND	0.001
Plant 2	ND	ND	ND	ND	ND	0.002
Plant 3	ND	ND	ND	ND	ND	0.002
Plant 4	ND	ND	ND	ND	ND	0.003
Plant 5	ND	ND	ND	ND	ND	0.003
Plant 6	ND	ND	ND	ND	ND	0.002
Plant 7	ND	ND	ND	ND	ND	0.004
Plant 8	ND	ND	ND	ND	ND	0.003
Plant 9	ND	ND	ND	ND	ND	0.003
Plant 10	ND	ND	ND	ND	ND	0.003
LOD	0.003	0.001	0.050	-	0.025	-
LOQ	0.010	0.003	0.165	-	0.825	-

KEY

LH-WF (Lake Huron lake whitefish)
LH-LT (Lake Huron lake trout)
LH-CHS (Lake Huron chinook salmon)

LM-WF (Lake Michigan lake whitefish)
LM-LT (Lake Michigan lake trout)
LM-CHS (Lake Michigan chinook salmon)

LS-WF (Lake Superior lake whitefish)
LS-LT (Lake Superior lake trout)

Compost 1 (Lake whitefish/lake trout compost)
Compost 2 (Chinook salmon compost)
Compost 3 (Leaf compost from Kincheloe)

Plant 1 (Trial 2-control),
Plant 2 (Trial 1-treatment 3-20% compost)
Plant 3 (Trial 2-30% salmon compost)
Plant 4 (Trial 3-control)
Plant 5 (Trial 3-treatment 4-25% compost)
Plant 6 (Trial 1-treatment 2-15% compost)
Plant 7 (Trial 1-control)
Plant 8 (Trial 1-treatment 4-25% compost)
Plant 9 (Trial 1-treatment 5-30% compost)
Plant 10 (Trial 1- treatment 1-10% compost)

LOD (Level of detection)
LOQ (Level of quantification)

Figure 2.

Barrels of fish waste were then tipped over by hand from a pallet on a forklift and evenly distributed over the wood bark chip/sawdust bed (Figure 2). Another layer of wood bark chips/sawdust approximately 6 inches thick was placed over the fish waste, and the process of alternating layers of fish waste and wood bark chips/sawdust was repeated. Fish waste was spread to the edges of the pile.

Once the pile reached 7 feet high, a front-end loader was used to thoroughly mix the pile. After this was completed, the pile was covered with a 12-inch layer of leaf compost to minimize odors and vermin attraction.

Managing the pile

The pile was in place for approximately 12 months. It was formed in the third week of June 2002 and was managed until we judged it to be mature enough for use in growing mixes in June of 2003. During most of the summer and fall, a fleece compost blanket was used to manage moisture and retain heat in the pile (Figure 3).

Figure 3.

A temperature probe was used to monitor the heat generated by the composting activity of the pile. The staff at the Kincheloe site monitored the pile, taking daily temperature readings most days. Temperature readings can be found in Table 2. They were asked to take three readings in random areas of the pile. Depending on the status of the pile, they were also asked to use their front-end loader to turn the pile.

The pile was within the working compound of the Kincheloe facility and within a few feet of a road used regularly by staff members. Odors were noticeable only when the pile was turned and then only in the immediate area. No animal problems were noticed around the pile because of a hurricane fence around the entire facility and the control of odors with an appropriate composting recipe.

Figure 4. BW Organics Model 408 rotating drum in-vessel composter.

In December 2002, a sample of the Kincheloe pile was tested by Woods End Laboratory for maturity. The analysis found the pile to be immature with high ammonium content. A subsequent test of the material in May 2003 using a Solvita test found the pile to be mature enough for use as a component of a growing mix.

Shady Side Farm site (Holland, Mich.)

At the Shady Side Farm site, industrial waste sawdust replaced the sawdust used at the Kincheloe site. The in-vessel composter was charged in late October 2002 with 467 pounds (approximately 60 gallons) of fish waste, 147 pounds of hardwood bark, 393 pounds of industrial waste sawdust and 21 gallons of water. This mix had a C:N ratio of 29:1. The fish waste, generated at a Bear Lake, Mich., processing facility, came from salmon harvested from weirs for the collection of salmon roe and whole processed fish. After four days of continuous rotation, the composter was unloaded and the material was placed in a pile and allowed to mature until it was collected for testing in June of 2003.

Table 2. Temperature readings in the static pile at the Chippewa County Department of Public Works site.

Date	Daily temperature readings (°F)	Pile turned	Temperature readings after turning (°F)
June 2002			
19	56-60-58		
20	70-69-65		
21	72-84-75		
24	89-100-86		
25	86-100-106		
26	102-108-106		
27	106-114-108		
28	109-116-114		
July 2002			
1	116-120-118		
2	120-123-118		
3	120-122-120		
5	122-123-121	yes	114-124-116
6	122-150-122		
10	118-118-130-132		
11	130-132-140		
12	130-130-140		
16	132-140-136		
17	136-132-136		
18	138-134-142		
19	140-135-138		
22	136-130-142		
23	138-130-145	yes	116-122-120
24	120-122-120		
25	138-134-133		
26	138-140-138		
29	134-138-138-		
30	132-138-140		
31	132-134-128		

Date	Daily temperature readings (°F)	Pile turned	Temperature readings after turning (°F)
August 2002			
1	138-140-138		
2	134-136-136		
5	134-134-134		
6	140-138-136		
7	124-138-134		
8	132-138-134		
9	134-138-130		
12	130-130-128		
13	122-130-124		
14	122-130-128		
15	120-130-122		
16	122-130-124		
20	118-128-122		
21	120-130-124		
22	118-130-120		
23	120-130-122		
27	120-130-122		
28	122-128-120		
29	120-130-120		
30	120-125-120		
September 2002			
3	118-122-120		
4	118-120-120	yes	
5	90-110-110		
9	108-125-125		
10	100-124-124		
17	116-107-115		
March 2003			
27	48		
April 2003			
3	58		

Methods

Fish population samples

Lake whitefish and lake trout populations in the Great Lakes are made up of multiage year classes that can reproduce annually for many years after they reach maturity. In contrast, Pacific salmon in the Great Lakes reproduce once and then die, and thus each fishery comes through as one major year class.

To secure a valid sample of the fish waste stream, a length-frequency analysis was conducted on commercial fish harvest data collected in 2001 by the Chippewa Ottawa Resource Authority for lake whitefish and lake trout from lakes Superior, Michigan and Huron. A length-frequency analysis was also conducted on weir-caught Pacific salmon from lakes Huron and Michigan from 1995 through 2001 with data supplied by the Michigan Department of Natural Resources. With the developed length-frequencies, a sampling regime was developed to secure representative sizes of fish making up the fish waste stream from the commercial fishery (figures 5 - 12).

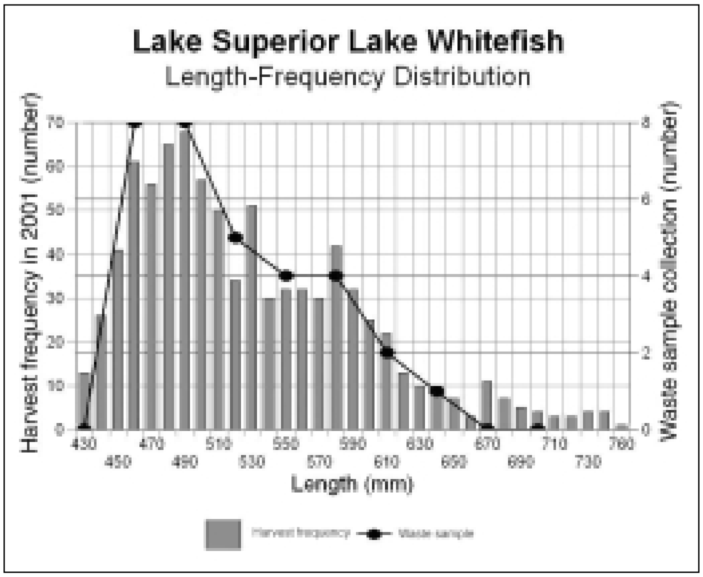

Figure 5. Lake Superior lake whitefish length-frequency distribution of the 2001 commercial harvest and the representative waste sample collected (number=32).

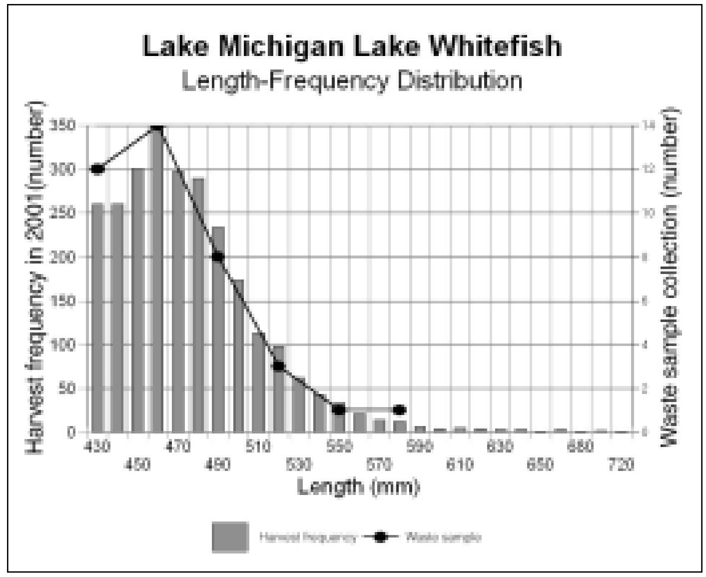

Figure 7. Lake Michigan lake whitefish length-frequency distribution of the 2001 commercial harvest and the representative waste sample collected (number=39).

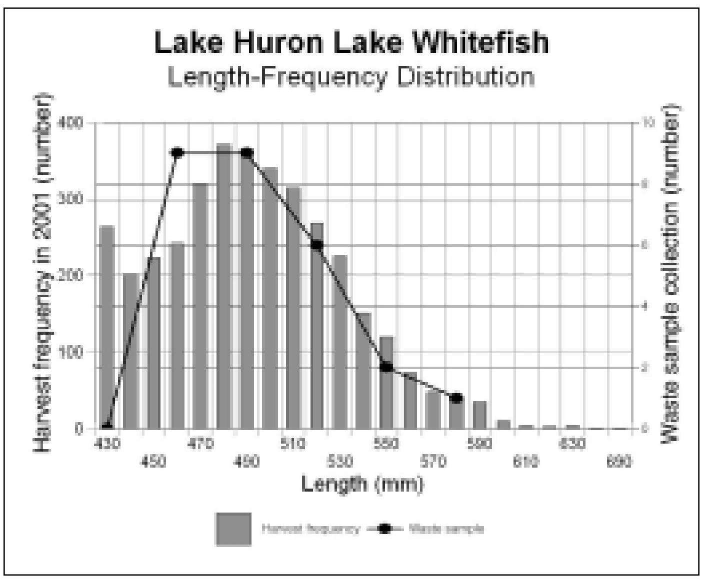

Figure 6. Lake Huron lake whitefish length-frequency distribution of the 2001 commercial harvest and the representative waste sample collected (number=27).

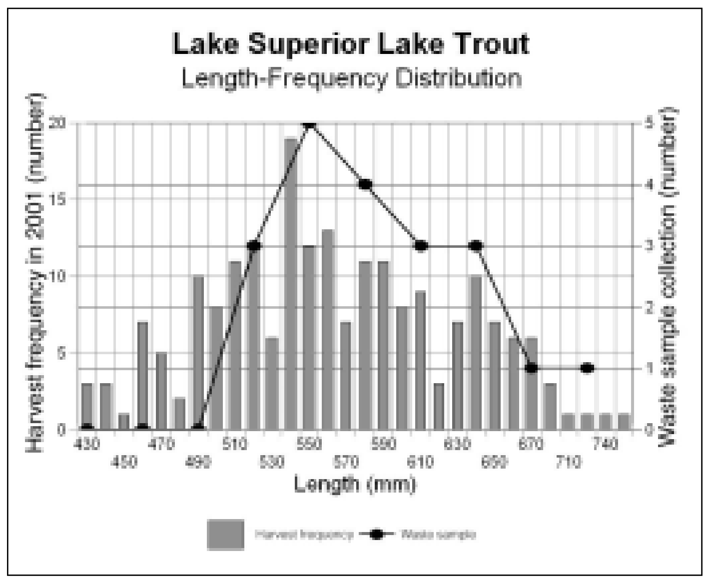

Figure 8. Lake Superior lake trout length-frequency distribution of the 2001 commercial harvest and the representative waste sample collected (number=20).

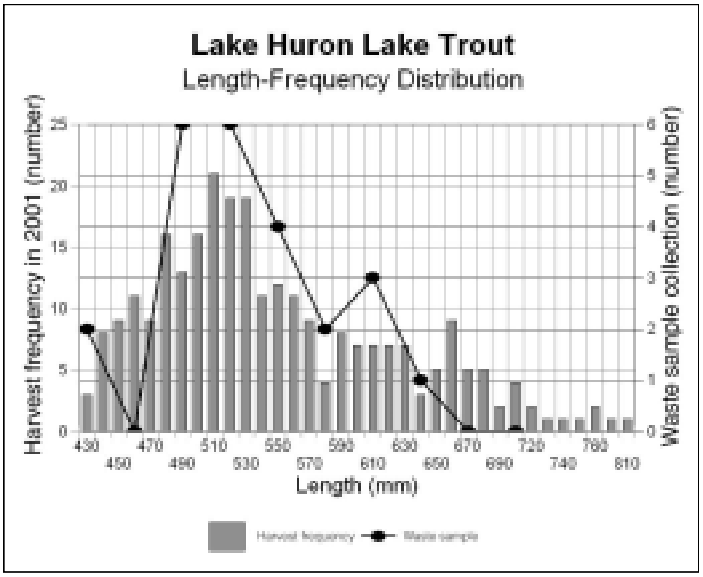

Figure 9. Lake Huron lake trout length-frequency distribution of the 2001 commercial harvest and the representative waste sample collected (number=24).

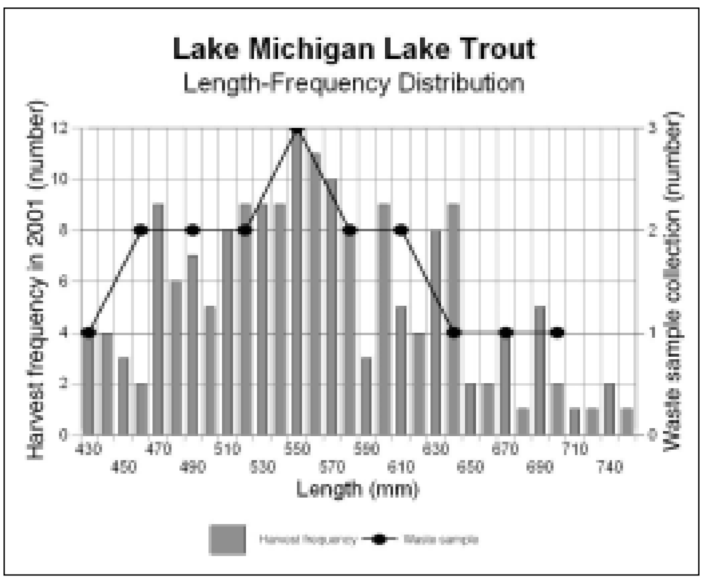

Figure 10. Lake Michigan lake trout length-frequency distribution of the 2001 commercial harvest and the representative waste sample collected (number=17).

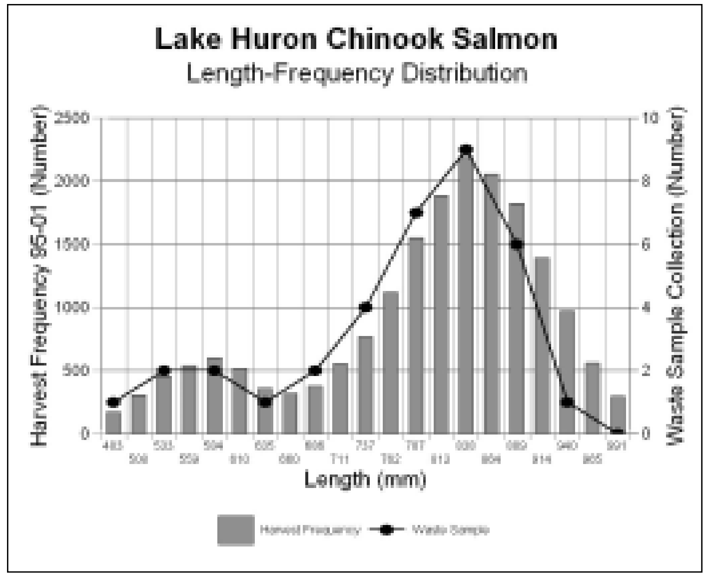

Figure 11. Lake Huron chinook salmon length-frequency distribution of the 1995-2001 weir harvests and the representative waste sample collected (number=35).

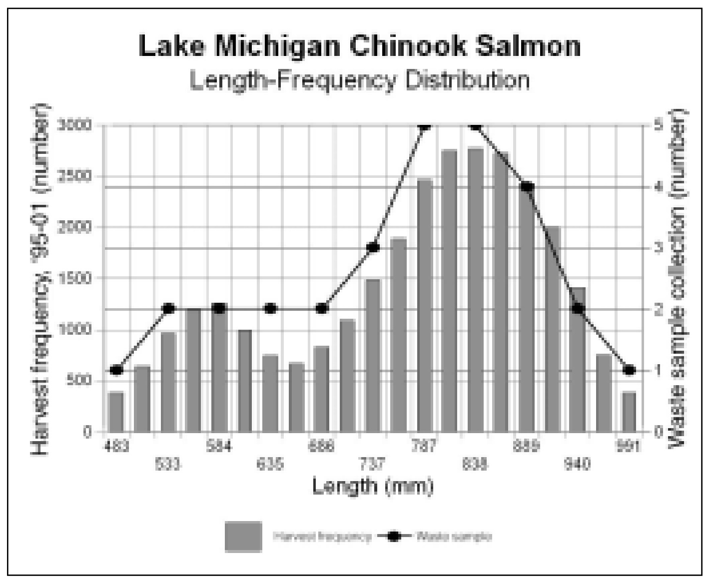

Figure 12. Lake Michigan chinook salmon length-frequency distribution of the 1995-2001 weir harvests and the representative waste sample collected (number=29).

Lake whitefish and lake trout waste samples were collected from commercial fish processing facilities in Marquette, Naubinway, St. Ignace and Mackinaw City, Mich. The lake whitefish waste samples consisted of everything except the skin-on fillet portion of the fish. The lake trout waste samples consisted of everything except the skin-on fillet portion of the fish and the viscera. (Lake trout are harvested by Native American fisheries, and this fish is delivered to processors with the viscera removed.) Pacific salmon waste samples were collected from a fish processing facility in Bear Lake that processed weir-caught salmon from lakes Huron and Michigan. The salmon waste consisted of the head and viscera minus the eggs — the fish were being processed for sale whole, and the eggs were sold as caviar.

Contaminant testing protocol

Fish waste, finished fish waste compost and plants grown in finished fish waste compost-amended growing mixes were analyzed by the Center for Integrated Plant Systems (Michigan State University, East Lansing, Mich.) for concentrations of chlordane, dieldrin, toxaphene, dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyl (PCB) and mercury. The action levels for these contaminants in food fish as established by the U.S. Food and Drug Administration (FDA) are:

Chlordane - 0.3 ppm

Dieldrin - 0.3 ppm

Toxaphene - 5.0 ppm

Dichlorodiphenyldichloroethylene (DDE) - 5.0 ppm

Dichlorodiphenyldichloroethane (DDD) - 5.0 ppm

Dichlorodiphenyltrichloroethane (DDT) - 5.0 ppm

Polychlorinated biphenyl (PCB) - 2.0 ppm

Mercury - 0.5 ppm (Michigan) and 1.0 ppm (FDA)

It was deemed important to understand the levels of microcontaminants that can be expected from fish waste materials by species and lake of origin. Different species of fish are known to accumulate microcontaminants at different rates, in part because of their position in the food chain. Although microcontamination levels are fairly well understood in edible portions of various fish, the levels that exist in fish carcasses is not well understood. Finally, lake contaminant levels differ between geographical areas, so determining fish waste contaminant levels by lake was felt to be important.

Fish waste contains most of the fatty tissue, so halogenated hydrocarbons would be concentrated in this material. Mercury is evenly distributed throughout the fish so we would not expect to see any major concentration of this in the fish waste. Research on contaminants present in the fish waste stream as well as the finished fish waste compost product has been lacking. To fill this void, representative fish waste streams as well as the finished fish waste compost product were examined for contaminants.

All fish waste samples for each species and lake were packed individually in plastic bags and transported in a cooler with ice to the Michigan State University Center for Integrated Plant Systems for contaminant analysis. The center used “modified multiresidue methodology for PCB, toxaphene, technical chlordane and other organochlorine pesticides in fish” as adopted from the Center for Environmental Health Sciences, Michigan Department of Public Health, Lansing, Mich. Samples were initially ground in a Hobart food processor. Fish waste and dry ice were ground in a blender to produce a powdered homogenate. The sample was mixed with 4x anhydrous sodium sulfate (Na_2SO_4) until dry and extracted in a chromatography column with diethyl ether/petroleum ether solvent. The solvent was then evaporated to dryness on a roto-vap. A Silica Gel 60 chromatography column with glass wool plug was used to get fractions. A gas chromatograph, Agilent 6890, equipped with mass selective detector, auto-samplers and HP Chem-Station, GC Column, DB-5 or equivalent, 30 meters, 0.530 mm diameter, was used. The residues were confirmed by the pattern of the peaks.

The mercury testing was conducted by the Animal Health Diagnostic Laboratory in East Lansing. The digestion was done on 1 gram (+/- 0.005) of fish waste material with 2 mL of concentrated nitric acid in a screw cap Teflon vessel at 95 degrees C overnight. The digest was transferred into a 100 mL VF containing 25 to 50 mL millipore polished water and 7 mL of concentrated hydrochloric acid. This was then treated with potassium permanganate ($KMnO_4$) until the solution remained slightly pink. This placed the mercury all into one valence state. The $KMnO_4$ was back titrated with hydroxylamine sulfate to a clear solution. This was then brought to the final 100 mL volume with water. The solution was then filtered through a 0.22 micron acrodisk prior to analysis. The cold vapor mercury unit was made by CETAC Inc. (Model m-6000). The standard curve was 25, 100 and 500 ppt and all solutions were diluted to fit inside the curve. The quality control used was a NIST Mussel SRM 2976 and the high calibration (500 ppt) solution was used prior to, at the middle and at the end of the run.

Plant growth trial methods

The use of finished compost made from lake whitefish and lake trout caught in lakes Huron, Michigan and Superior and salmon waste was evaluated as a component of a potting soil by Miller Horticultural Associates, Inc. (Portland, Ore.). The objectives of the plant growth trials were to:

1. Determine the appropriate amount of compost that can be added to a professional and retail growing mix that will result in acceptable plant growth.

2. Evaluate the nutritional status of plants grown in a compost-amended medium.

3. Determine the levels of mercury and halogenated hydrocarbons that are absorbed by plants grown in a compost-amended medium.

Trial 1

Trial 1 compared a standard professional growing medium (Premier ProMix BX amended with coir) with the same medium amended with fish waste (lake whitefish/lake trout) compost rates of 10 percent to 30 percent. The control medium consisted of 67 percent ProMix BX (Premier Horticulture, Quebec) and 33 percent short-fibered coir (Coco Palm Resources, Sri Lanka). The treatments were as follows:

Control	Premier ProMix BX amended with coir
Treatment 1	10% compost, 90% control
Treatment 2	15% compost, 85% control
Treatment 3	20% compost, 80% control
Treatment 4	25% compost, 75% control
Treatment 5	30% compost, 70% control

Sixty 1-gallon containers were filled with each treatment plus the control (a total of 360 containers). A medium sample from each treatment plus the control was taken and sent to Quality Analytical Labs (Panama City, Fla.) for analysis. Two basil (*Ocimum basilicum*) plants were planted in each 1-gallon container. The basil plants were obtained from Yoshitomi Brothers (West Linn, Ore.). Planting was done over a three-day period — June 23-25, 2003. Plants were randomized within the fertilization group and watered as needed (approximately every other day).

The control and each treatment were split in half, with the A group receiving no additional liquid fertilizer during the trial and the B group receiving fertilizer twice a week according to the following schedule:

Week 1-2	Gromore® 9-45-15 (nitrogen = 25 parts per million)
Week 3-12	Gromore® 20-20-20 (nitrogen = 100 parts per million)

Fertilizer was applied though a Dosatron® injector set at a 1:100 ratio.

Temperatures in the greenhouse ranged from 24 to 32 degrees C. The plants were grown until August 30, 2003. Ten plants per treatment and fertilization group were randomly selected to be measured for height, fresh weight and dry weight. Approximately 200 grams of fresh tissue from the most recently matured leaves were sent to Quality Analytical Labs for nutrient analysis. Two pounds (approximately 908 grams) of fresh plant material were shipped to the Center for Integrated Plant Systems (CIPS) at Michigan State University (East Lansing, Mich.) for halogenated hydrocarbon and mercury analysis following the same protocol used for the fish waste material analysis.

Trial 2

This trial evaluated the use of salmon compost as a component of a professional growing mix. The professional growing mix was the same mix used in Trial 1 (67 percent ProMix BX and 33 percent coir). Because of limited greenhouse space and a decision to grow only enough to conduct a halogenated hydrocarbon and mercury analysis, only one treatment of 30 percent salmon compost and 70 percent control medium was employed in this trial.

Two basil plugs were planted in each gallon container for a total of 60 pots (30 pots for the treatment and 30 pots for the control). Trial 2 was put on the same fertilization schedule, planted at the same time and kept at the same temperatures as Trial 1.

Plants were harvested at 12 weeks and shipped to CIPS for halogenated hydrocarbon and mercury analysis. No plant growth data were collected nor nutrient analysis conducted on these plants.

Trial 3

Trial 3 evaluated plant growth in the following mixes:

1. Lake whitefish/lake trout compost in a standard bark-based potting soil (Marigold 'Bonanza').

   The standard bark-based potting soil consisted of 55 percent composted pine bark, 35 percent peat moss, and 10 percent perlite. Dolomitic lime was added at a rate of 6 pounds per cubic yard to adjust the final pH to a range of 5.5 to 5.7. Fish waste compost was added in the same amounts as in Trial 1, beginning with 10 percent and ending with 30 percent compost.

   Forty pots were filled with each treatment plus the control. The control and each treatment were split in half, with the A group receiving no additional liquid fertilizer during the trial and the B group receiving fertilizer twice a week. Marigold 'Bonanza' was planted in each pot. Media samples were taken at the time of mixing and analyzed for nutritional levels by Quality Analytical Labs.

2. Lake whitefish/lake trout compost in a bark-based potting soil compared with a standard bark-based potting soil (basil).

   Forty pots were filled with treatment 1 (10 percent compost, 90 percent control). Half were fertilized, the other half were not. Basil was planted in these pots, two plugs per pot. Media samples were taken at the time of mixing and analyzed for nutritional levels by Quality Analytical Labs.

Planting occurred during June 25-26, 2003. All pots with bark-based potting soil, regardless of treatment, were topdressed with 6 grams of a 9-5-3 fish fertilizer to compensate for the microbial decomposition of the pine bark. Plants in group B received fertilizer twice a week using the same schedule as in Trial 1. Greenhouse temperatures ranged from 24 to 32 degrees C.

Plants were grown until August 30, 2003. Fresh and dry weights were recorded for 10 randomly selected marigold plants per treatment. Height and dry weights were recorded for 10 randomly selected basil plants.

Results

Fish waste sample test results

Lake Superior lake whitefish waste material exceeded the FDA action level of 0.3 ppm for both chlordane and dieldrin (Figure 13). Lake Huron lake whitefish waste material nearly reached the action level for dieldrin, but no chlordane was detected. These pesticides were not detected in Lake Michigan lake whitefish waste. Lake Superior lake whitefish waste contained almost seven times the FDA action level for chlordane and over three times the FDA action level for dieldrin. None of the lake whitefish waste material from lakes Superior, Huron and Michigan exceeded the FDA action level of 2.0 ppm for PCBs (Figure 14).

The lake whitefish waste material from lakes Superior, Huron and Michigan did not exceed the FDA action level of 5.0 ppm for toxaphene and DDT (Figure 15). Extremely low levels of toxaphene were found in lake whitefish waste from lakes Superior, Huron and Michigan. DDT was detected in lake whitefish waste from lakes Superior and Huron; none was detected in the Lake Michigan samples. None of the lake whitefish waste material from lakes Superior, Huron and Michigan exceeded the FDA action level of 1.0 ppm or the Michigan action level of 0.5 ppm for mercury (Figure 16).

Lakes Superior and Huron lake trout waste material exceeded the FDA action level of 0.3 ppm for chlordane and dieldrin (Figure 17). These pesticides were not detected in Lake Michigan lake trout waste. Lake Superior lake trout waste was double the FDA action level for chlordane and seven times the FDA action level for dieldrin. Although the Lake Huron lake trout waste just exceeded the FDA action level for chlordane, it contained over four times the action level for dieldrin. None of the lake trout waste material from lakes Superior, Huron and Michigan exceeded the FDA action level of 2.0 ppm for PCBs (Figure 18). Only Lake Superior lake trout waste had no detection of PCBs.

The lake trout waste material from lakes Superior, Huron and Michigan did not exceed the FDA action level of 5.0 ppm for toxaphene and DDTs (Figure 19). Low levels of toxaphene and DDT were found in lake trout waste from Lake Michigan and Lake Huron, respectively. Toxaphene was not detected in lake trout waste from lakes Superior and Huron. DDT was not detected in lake trout waste from lakes Superior and Michigan. None of the lake trout waste material from lakes Superior, Huron and Michigan exceeded the FDA action level of 1.0 ppm or the Michigan action level of 0.5 ppm for mercury (Figure 20).

Lakes Michigan and Huron chinook salmon waste did not exceed the FDA action level of 0.3 ppm for chlordane and dieldrin (Figure 21). These pesticides were not detected in Lake Michigan chinook salmon waste. Dieldrin was not detected in Lake Huron chinook salmon waste; a trace amount of chlordane was. Lake Michigan chinook salmon waste exceeded the FDA action level of 2.0 ppm for PCBs; chinook salmon waste from Lake Huron was below the action level (Figure 22).

Lakes Michigan and Huron chinook salmon waste did not exceed the FDA action level of 5.0 ppm for toxaphene and DDT (Figure 23). Chinook salmon waste from Lake Michigan nearly approached the FDA action level for toxaphene. None of the chinook salmon waste from Lakes Michigan and Huron exceeded the FDA action level of 1.0 ppm or the Michigan action level of 0.5 ppm for mercury (Figure 24).

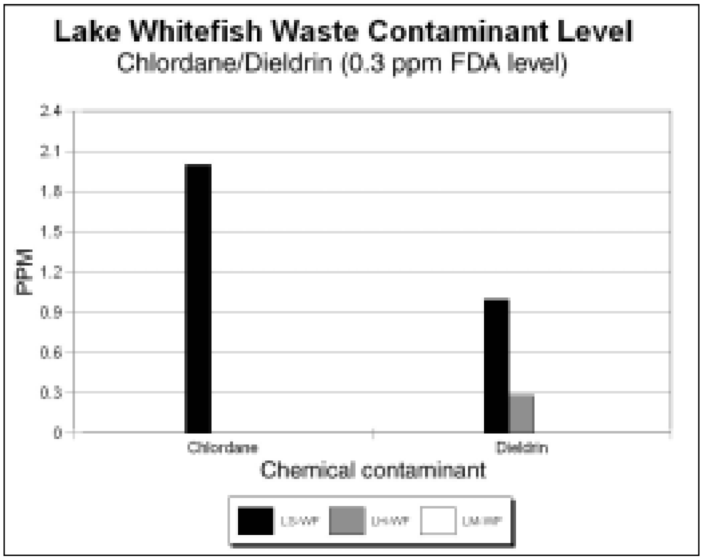

Figure 13. Lake whitefish waste contaminant levels for chlordane and dieldrin from lakes Superior (LS-WF), Huron (LH-WF) and Michigan (LM-WF). Chlordane and dieldrin each has an FDA action level of 0.3 ppm for food fish.

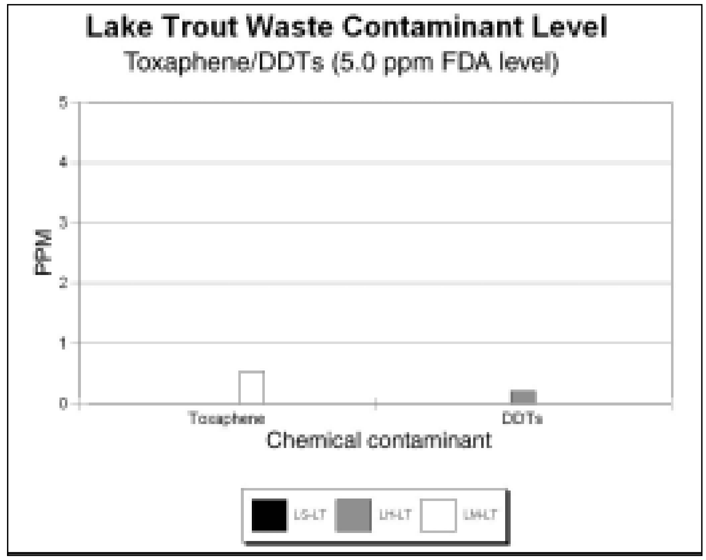

Figure 15. Lake whitefish waste contaminant levels for toxaphene and DDTs from lakes Superior (LS-WF), Huron (LH-WF) and Michigan (LM-WF). Toxaphene and DDTs each has an FDA action level of 5.0 ppm for food fish.

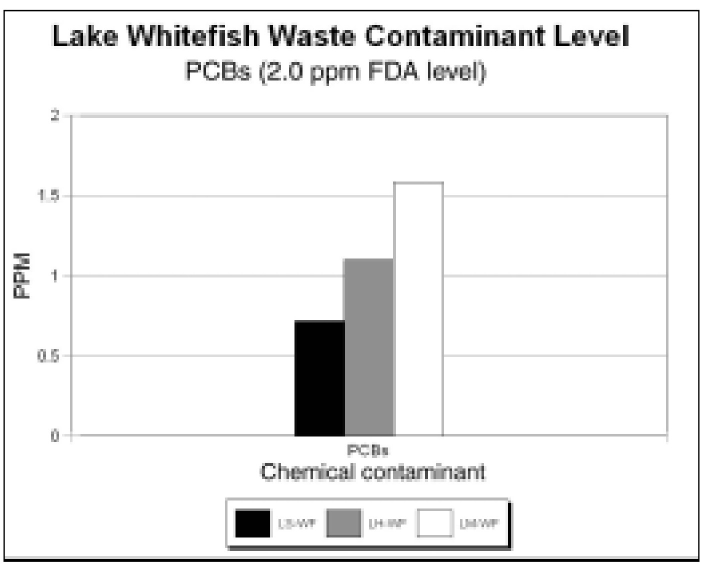

Figure 14. Lake whitefish waste contaminant levels for PCBs from lakes Superior (LS-WF), Huron (LH-WF) and Michigan (LM-WF). PCBs have an FDA action level of 2.0 ppm for food fish.

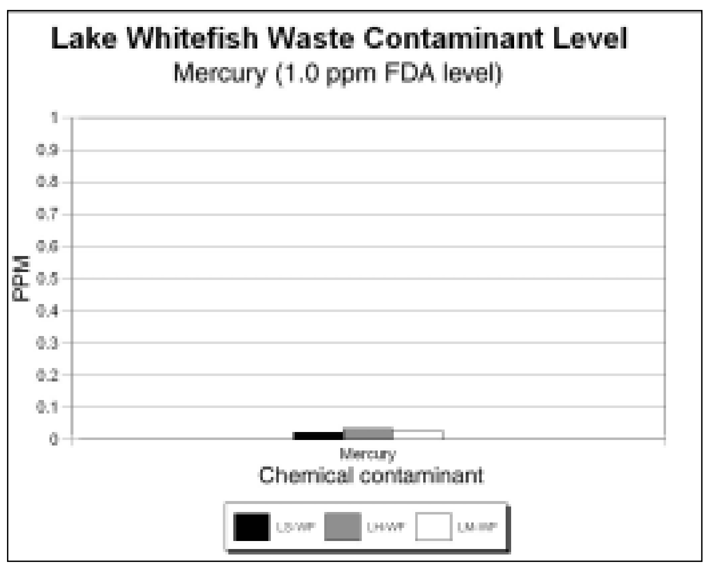

Figure 16. Lake whitefish waste contaminant levels for mercury from lakes Superior (LS-WF), Huron (LH-WF) and Michigan (LM-WF). Mercury has an FDA action level of 1.0 ppm and a Michigan action level of 0.5 for food fish.

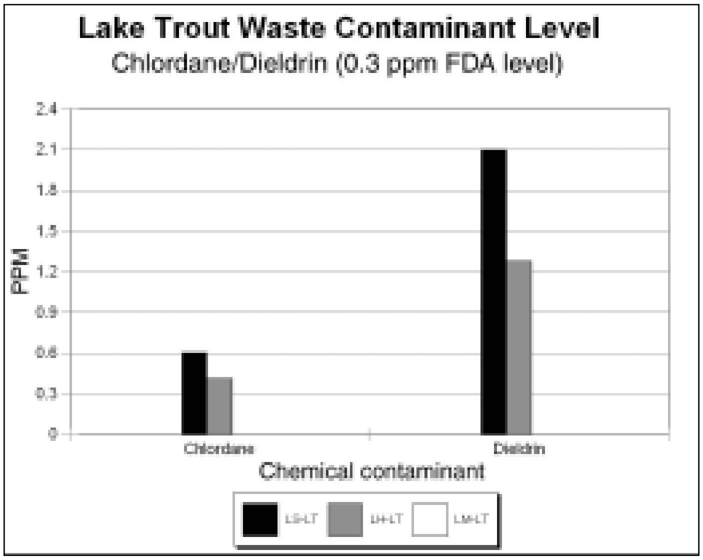

Figure 17. Lake trout waste contaminant levels for chlordane and dieldrin from lakes Superior (LS-LT), Huron (LH-LT) and Michigan (LM-LT). Chlordane and dieldrin each has an FDA action level of 0.3 ppm for food fish.

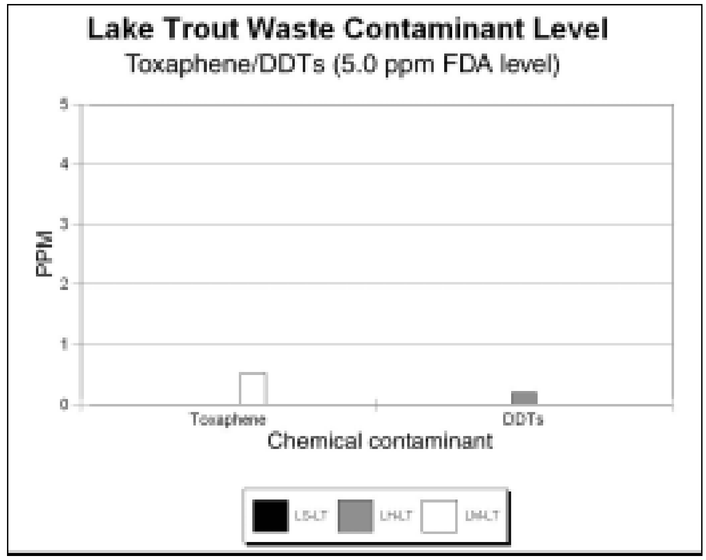

Figure 19. Lake trout waste contaminant levels for toxaphene and DDTs from lakes Superior (LS-LT), Huron (LH-LT) and Michigan (LM-LT). Toxaphene and DDTs each has an FDA action level of 5.0 ppm for food fish.

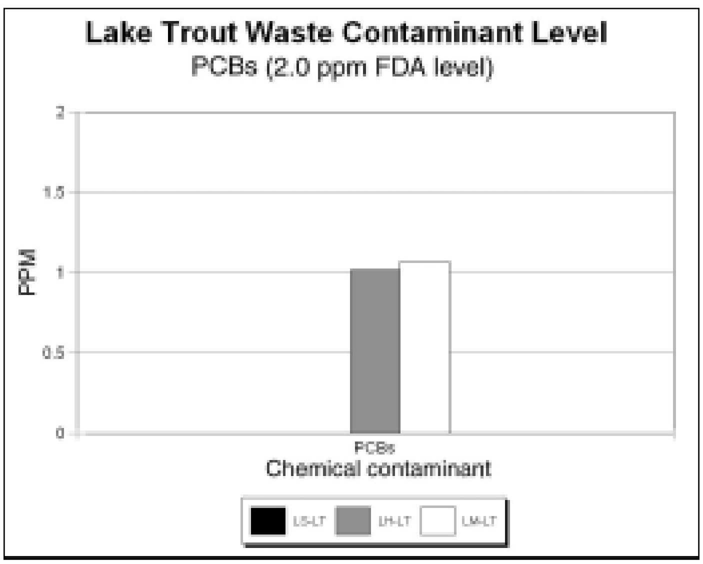

Figure 18. Lake trout waste contaminant levels for PCBs from lakes Superior (LS-LT), Huron (LH-LT) and Michigan (LM-LT). PCBs have an FDA action level of 2.0 ppm for food fish.

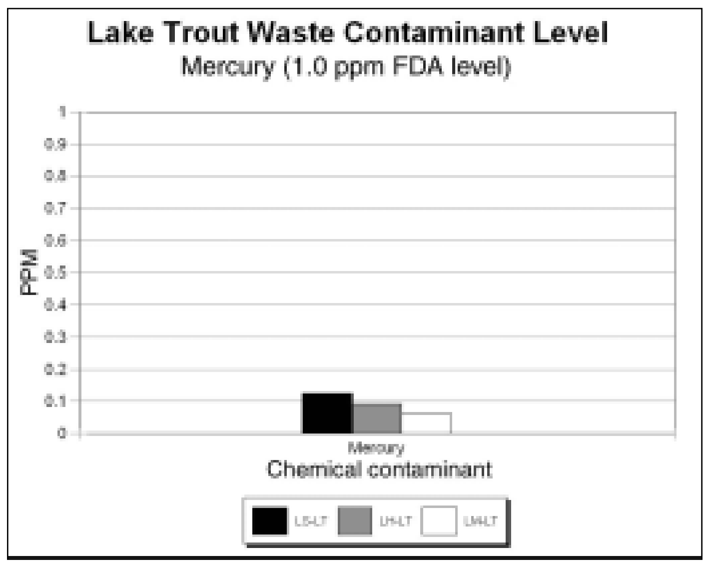

Figure 20. Lake trout waste contaminant levels for mercury from lakes Superior (LS-LT), Huron (LH-LT) and Michigan (LM-LT). Mercury has an FDA action level of 1.0 ppm and a Michigan action level of 0.5 for food fish.

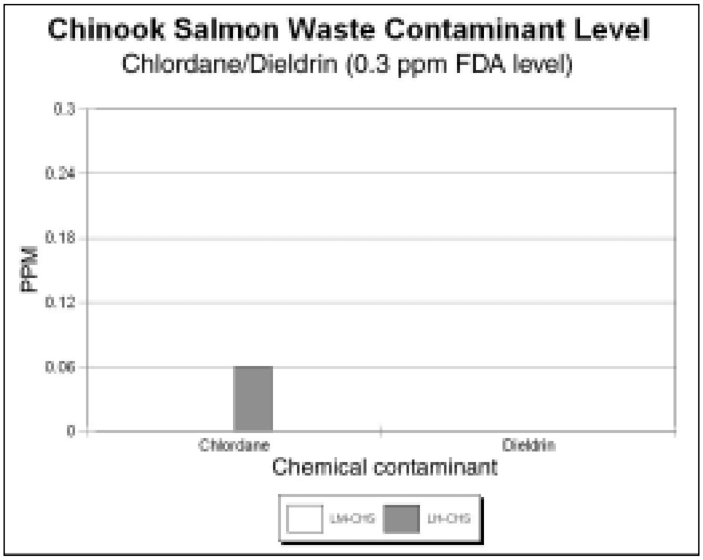

Figure 21. Chinook salmon waste contaminant levels for chlordane and dieldrin from lakes Superior (LS-CHS), Huron (LH-CHS) and Michigan (LM-CHS). Chlordane and dieldrin each has an FDA action level of 0.3 ppm for food fish.

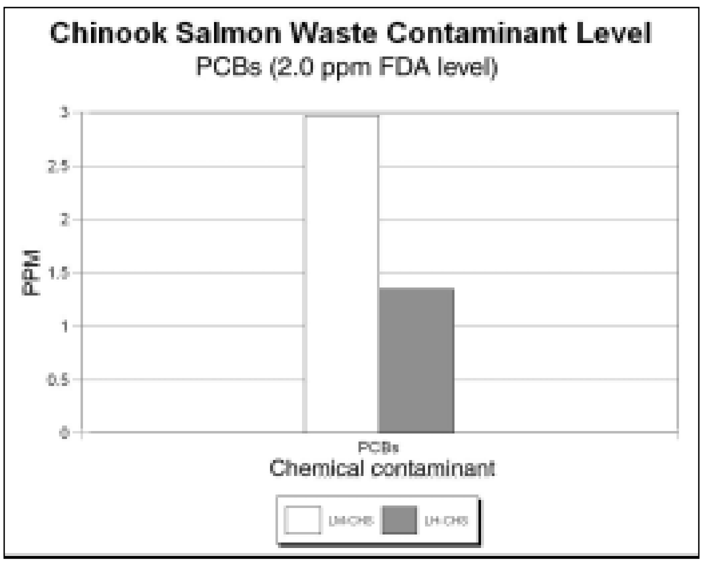

Figure 22. Chinook salmon waste contaminant levels for PCBs from lakes Superior (LS-CHS), Huron (LH-CHS) and Michigan (LM-CHS). PCBs have an FDA action level of 2.0 ppm for food fish.

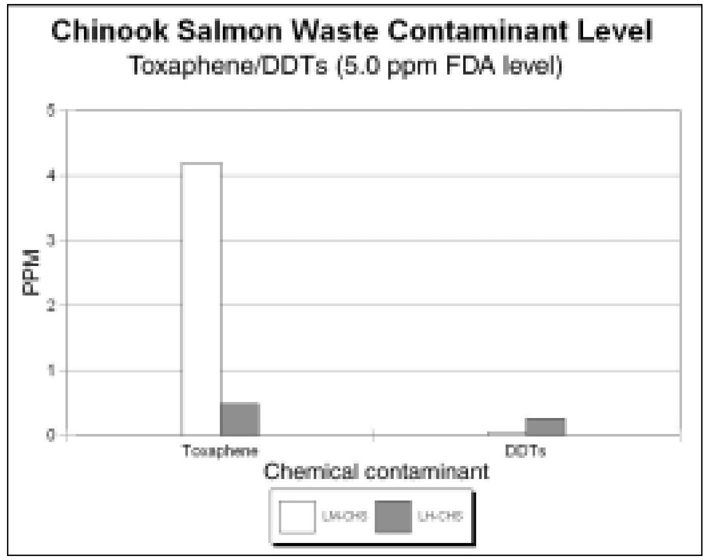

Figure 23. Chinook salmon waste contaminant levels for toxaphene and DDTs from lakes Huron (LH-CHS) and Michigan (LM-CHS). Toxaphene and DDTs each has an FDA action level of 5.0 ppm for food fish.

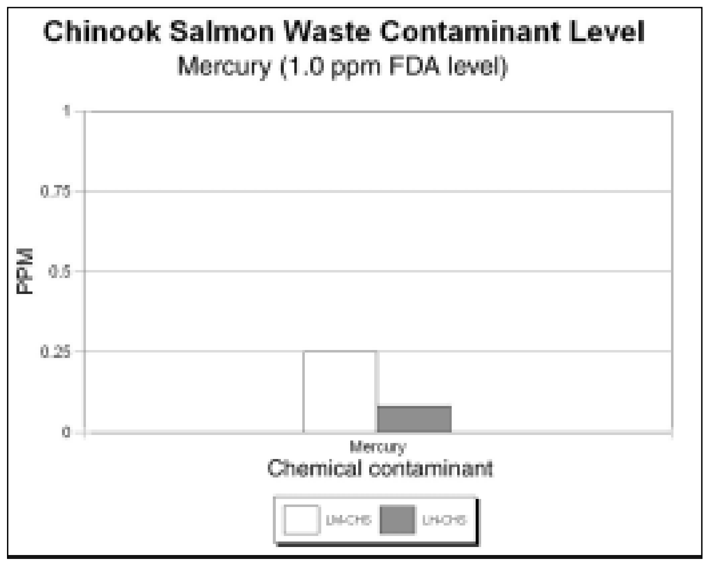

Figure 24. Chinook salmon waste contaminant levels for mercury from lakes Huron (LH-CHS) and Michigan (LM-CHS). Mercury has an FDA action level of 1.0 ppm and a Michigan action level of 0.5 ppm for food fish.

Plant growth results

Trial 1

Statistical analysis was applied using multiple regression and analysis of variance with Statgraphics 3.0 (Manugistics). Plants in the fertilized treatments were significantly taller than those in corresponding non-fertilized treatments (Table 3). Non-fertilized treatment 5, was significantly taller than the other plants in the group.

No significant differences were noted in dry weights and fresh weights of the plants within and between treatments.

Tissue analysis of the basil plants showed similar fertility levels between non-fertilized and fertilized treatments (tables 4-5).

It was observed at the end of week 6, in the 30 percent compost level only, that some senescing of the foliage and stems occurred on the uppermost 4 to 5 inches of the basil plants. The cause of the distortion was not obvious from the symptoms.

Table 3. Trial 1 basil plant heights, fresh weights and dry weights.

	Plant heights		Plant fresh weights		Plant dry weights	
	Non-fertilized, average (cm)	Fertilized, average (cm)	Non-fertilized, average (grams)	Fertilized, average (grams)	Non-fertilized, average (grams)	Fertilized, average (grams)
Control	66.40a	81.80c	119.24a	170.56a	28.82a	35.65a
Trt 1 (10% compost)	67.45a	84.10c	103.10a	162.00a	26.90a	33.92a
Trt 2 (15% compost)	63.10a	85.20c	108.20a	159.82a	26.99a	36.75a
Trt 3 (20% compost)	65.55a	82.20c	136.83a	153.56a	34.71a	36.92a
Trt 4 (25% compost)	68.40a	81.40c	127.54a	164.94a	33.18a	35.22a
Trt 5 (30% compost)	71.70b	80.60c	117.72a	188.67a	34.00a	38.81a

P<0.05 for least significant difference.

Table 4. Trial 1 — tissue analysis of fertilized basil.

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
Macronutrients (%)						
N	1.33	1.28	1.17	1.03	1.19	1.12
P	0.58	0.61	0.47	0.46	0.46	0.58
K	2.16	2.18	1.52	1.78	1.65	1.62
Ca	2.16	2.44	2.15	1.81	1.85	1.88
Mg	0.46	0.57	0.51	0.41	0.46	0.46
S	0.09	0.07	0.05	0.06	0.07	0.10
Micronutrients (ppm)						
Fe	142.53	156.44	123.68	139.23	119.25	125.91
Mn	116.47	92.03	94.81	78.04	82.16	93.16
B	31.35	33.00	28.24	26.27	27.25	26.62
Cu	2.92	2.88	2.18	2.08	2.39	1.74
Zn	89.32	94.63	84.32	66.38	86.40	60.20
Mo	1.00	1.33	1.41	1.04	1.22	0.96
Na	70.91	54.53	52.32	64.82	82.23	52.19
Al	94.31	94.99	80.23	89.92	71.50	72.81

Table 5. Trial 1 — tissue analysis of non-fertilized basil.

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
Macronutrients (%)						
N	0.94	1.21	0.92	1.31	1.47	0.84
P	0.25	0.48	0.36	0.49	0.52	0.43
K	1.46	2.82	1.68	2.67	2.20	1.63
Ca	2.15	2.61	2.35	2.69	2.57	2.12
Mg	0.39	0.44	0.43	0.47	0.51	0.40
S	0.08	0.09	0.08	0.12	0.15	0.11
Micronutrients (ppm)						
Fe	101.63	116.03	112.30	140.58	160.07	114.06
Mn	61.99	32.83	28.75	37.97	54.45	47.12
B	24.86	34.26	27.33	36.04	34.50	26.97
Cu	2.18	3.18	2.26	3.89	4.47	2.56
Zn	86.44	116.40	81.57	109.38	111.36	85.26
Mo	0.70	0.89	0.89	1.07	0.92	0.74
Na	103.77	88.83	127.30	96.63	158.81	67.94
Al	68.23	77.29	76.95	89.30	84.28	64.71

Results — Trial 2

No plant growth data were gathered for this trial. However, it was observed at the end of week 3 that the salmon compost-amended plants were a darker green than the other plants grown in Trials 1 and 3.

Results — Trial 3

There were two experiments in Trial 3.

Basil (Experiment 1)

Height and dry weight of basil grown in a 90 percent bark-based potting medium/10 percent lake whitefish/lake trout compost mix were compared with the height and dry weight of basil grown in a 90 percent professional growing medium/10 percent lake whitefish/lake trout compost mix (this mix is treatment 1 of Trial 1).

The height and dry weight in the basil plants were less when the bark/compost potting soil was used (Table 6). This was observed within two weeks of planting and was consistent throughout the trial. This may have been due to the activity of microorganisms in the bark/compost potting soil mix that use nitrogen to break down the bark and therefore competed with the plants for the available nitrogen. After the plants in Trial 3 were top-dressed with pelletized fish fertilizer, two weeks passed before there was noticeable plant response. This delay in plant response might have been responsible for the final differences in height and dry weight noted between the basil in Trial 1 and Trial 3.

Table 6. Trial 3 basil plant heights and dry weights.

	Basil height		Basil dry weight	
	Non-fertilized, average (cm)	Fertilized, average (cm)	Non-fertilized, average (grams)	Fertilized, average (grams)
Premier ProMix BX amended with coir/ compost	67.45a	84.10b	26.90a	33.92b
Bark-based potting mix /compost	N/A*	57.20c	16.95c	28.79a

P<0.05 for least significant difference.
*Data was not collected.

Tissue analysis of the basil plants showed similar fertility levels between the two fertilization treatments (Table 7). Potassium was notably lower in the plants grown in Trial 3 than those in Trial 1 treatment 1 (tables 4 and 5). Nitrogen and phosphorus were similar between the two trials.

Table 7. Tissue analysis comparison between fertilized and non-fertilized basil grown in 90% bark-based potting mix and 10% lake whitefish/lake trout compost mix..

	fertilized basil	non-fertilized basil
	Macronutrients (%)	
N	1.22	1.54
P	0.46	0.45
K	1.16	.98
Ca	2.04	1.64
Mg	0.74	0.62
S	0.12	0.12
	Micronutrients (ppm)	
Fe	104.30	100.75
Mn	85.12	76.21
B	25.27	22.49
Cu	3.11	2.08
Zn	158.17	103.16
Mo	1.37	1.26
Na	58.01	48.12
Al	74.69	64.75

Marigolds (Experiment 2)

Marigolds were grown in six treatments — control plus the five variations of compost. In both the fertilized group and the non-fertilized group, the greatest dry weight was noted in the 20 and 25 percent compost-amended soils (Table 8). At 30 percent, a decrease in dry weight was noted. The non-fertilized plants in treatments 3 and 4 were not significantly different from those grown in the fertilized group, with the exception of treatment 5.

Subjectively, the plants grown in the 30 percent compost-amended medium were smaller throughout the sample, and several plants succumbed to disease over the course of the study.

By the end of week 4, treatments 3 and 4 in Trial 3 were showing improved color and growth in comparison with

Table 8. Trial 3 marigold dry weights.

	Non-fertilized, average (grams)	Fertilized, average (grams)
Control	8.51a	14.10c
Trt 1 (10% compost)	12.23b	14.24c
Trt 2 (15% compost)	11.89b	13.75c
Trt 3 (20% compost)	15.34c	17.79c
Trt 4 (25% compost)	17.74c	17.15c
Trt 5 (30% compost)	8.72a	13.25b

$P<0.05$ for least significant difference.

other treatments in that trial. The foliar levels of nitrogen in the marigold plants were higher in the fertilized group than in the unfertilized plants (tables 9 and 10). Phosphorus and potassium, however, were similar between the two groups. It was noted that all plants had elevated levels of zinc in the foliage. Zinc was elevated in some of the plants from Trial 1, but were not as high as in those grown in the bark-based compost in Trial 2.

A review of the lab results from the initial media samples indicated that available zinc was not excessive in either medium (tables 11 and 12). Subsequent trials of compost-amended media should continue to review the zinc levels to determine their origin.

Table 9. Tissue analysis of fertilized marigolds.

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
			Macronutrients (%)			
N	4.56	4.43	4.81	4.70	4.73	4.19
P	0.55	0.82	0.78	0.76	0.75	0.63
K	4.00	3.95	3.64	3.19	2.97	4.11
Ca	1.41	1.98	1.94	1.70	1.80	1.64
Mg	0.63	0.78	0.77	0.74	0.68	0.78
S	0.62	0.57	0.59	0.44	0.44	0.62
			Micronutrients (ppm)			
Fe	124.13	128.67	134.63	130.20	118.64	137.13
Mn	286.77	183.10	200.12	183.43	157.23	189.85
B	43.45	55.09	50.72	48.46	53.98	43.07
Cu	6.05	5.80	5.50	4.55	5.59	4.85
Zn	276.90	271.51	233.01	201.57	175.92	225.29
Mo	1.92	2.11	2.07	1.89	2.07	2.03
Na	101.99	114.80	103.35	77.79	183.94	106.98
Al	49.57	49.04	52.94	47.44	54.19	62.44

Table 10. Tissue analysis of non-fertilized marigolds.

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
			Macronutrients (%)			
N	*	3.97	4.22	3.81	3.27	*
P	0.51	0.67	0.64	0.56	0.57	0.39
K	4.26	3.63	3.32	3.32	2.61	4.35
Ca	1.88	1.84	2.02	2.09	2.24	1.75
Mg	0.80	0.98	1.02	0.97	0.93	0.82
S	0.79	0.78	0.75	0.72	0.65	0.59
			Micronutrients (ppm)			
Fe	130.68	134.36	122.63	128.23	111.52	140.12
Mn	367.75	152.03	135.55	104.60	99.83	313.64
B	52.95	48.85	34.57	38.83	35.74	37.62
Cu	8.44	8.07	5.59	5.84	4.47	5.45
Zn	355.79	311.32	198.28	182.43	134.83	258.53
Mo	2.13	2.66	2.00	2.15	2.03	1.97
Na	110.64	122.12	65.90	94.66	73.68	108.07
Al	83.80	69.53	53.23	66.59	53.04	65.52

* The lab did not receive enough tissue to determine nitrogen content.

Contaminant concentrations in compost and basil plants

The fish waste compost generated from the lake whitefish and lake trout waste stream did not have any reportable levels of halogenated hydrocarbons. Only very low levels of DDT showed up in the fish waste compost that was generated from the chinook salmon waste stream (Figure 25).

Mercury levels in fish waste compost from lake whitefish/lake trout waste showed a slight increase when compared with the original waste stream. Fish waste compost generated from chinook salmon waste showed a decrease in mercury levels compared with the original waste stream. None of the finished fish waste compost exceeded the FDA action level of 1.0 ppm or the Michigan action level of 0.5 ppm for mercury (Figure 26).

Chlordane, dieldrin, toxaphene, DDE, DDD, DDT and PCB were not detected in the basil plant tissue. Mercury levels were well below the FDA action level of 1.0 ppm and the Michigan action level of 0.5 ppm for food fish (Figure 27).

Table 11. Trial 1 — Media analysis.

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
pH	5.16	5.34	5.09	5.05	4.99	5.05
EC	1.23	1.40	1.72	1.53	1.63	1.40
Macronutrients (ppm)						
NO_3-N	61.70	51.50	115.30	100.80	113.80	94.70
NH_4-N	ND	ND	ND	ND	ND	ND
P	20.22	19.16	25.42	20.36	20.73	20.82
K	123.72	200.93	179.87	147.48	170.30	149.03
Ca	90.81	66.52	131.74	116.64	119.88	101.07
Mg	34.16	27.25	49.11	42.82	42.59	36.88
SO_4-S	75.77	82.05	83.52	69.54	59.52	53.62
Micronutrients (ppm)						
Fe	0.89	0.86	0.92	0.81	0.76	0.66
Mn	0.21	0.43	0.07	0.14	0.29	0.09
B	0.19	0.18	0.24	0.23	0.24	0.22
Cu	0.07	0.08	0.07	0.07	0.08	0.07
Zn	0.30	0.40	0.18	0.14	0.11	0.09
Mo	0.03	0.03	0.02	0.02	0.02	0.03
Na	35.59	62.13	51.47	44.34	52.15	45.06
Al	0.46	0.41	0.48	0.48	0.54	0.48
Cl	32.00	86.00	45.00	39.00	46.00	42.00
Si	6.51	4.67	9.51	7.33	7.95	7.68

Table 12. Trial 3 — Media analysis.

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
pH	4.76	5.13	5.09	4.55	4.63	4.50
EC	0.19	0.30	0.23	0.75	0.81	1.33
Macronutrients (ppm)						
NO_3-N	ND	ND	ND	45.20	46.50	99.90
NH_4-N	ND	ND	ND	ND	ND	0.40
P	2.21	9.88	5.87	18.74	19.18	25.25
K	23.08	42.03	30.18	94.73	104.05	147.32
Ca	7.08	13.53	8.70	46.20	47.62	85.94
Mg	4.78	9.55	6.27	27.81	27.14	44.61
SO_4-S	7.79	14.11	8.75	11.59	12.45	18.39
Micronutrients (ppm)						
Fe	0.64	0.41	0.34	0.27	0.33	0.26
Mn	0.19	0.16	0.14	1.17	1.01	1.61
B	0.12	0.13	0.12	0.25	0.25	0.29
Cu	0.08	0.07	0.07	0.07	0.07	0.05
Zn	ND	0.02	0.01	0.06	0.05	0.06
Mo	0.02	0.03	0.02	0.02	0.03	0.02
Na	16.47	21.46	20.25	29.89	35.36	44.98
Al	1.84	1.24	1.20	1.65	1.62	1.43
Cl	12.00	30.00	30.00	29.00	35.00	43.00
Si	12.06	10.53	9.94	5.56	6.50	5.84

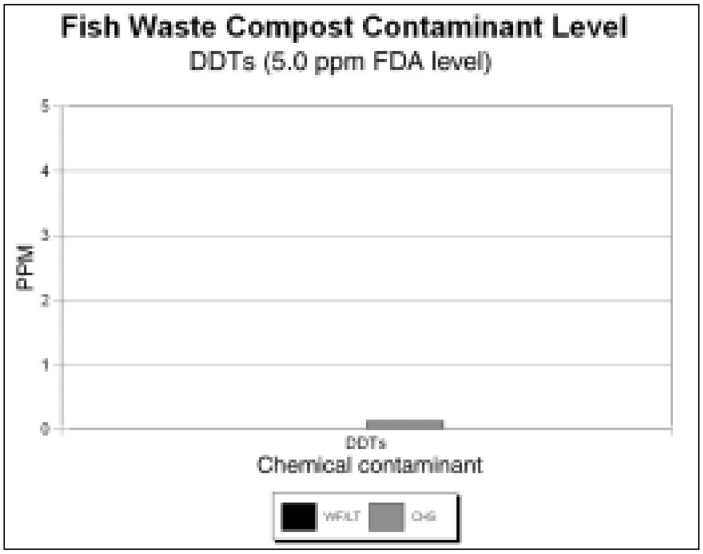

Figure 25. Fish waste compost contaminant level for DDTs from lake whitefish/lake trout waste (WF/LT) and chinook salmon waste (CHS). DDTS have an FDA action level of 5.0 PPM for food fish.

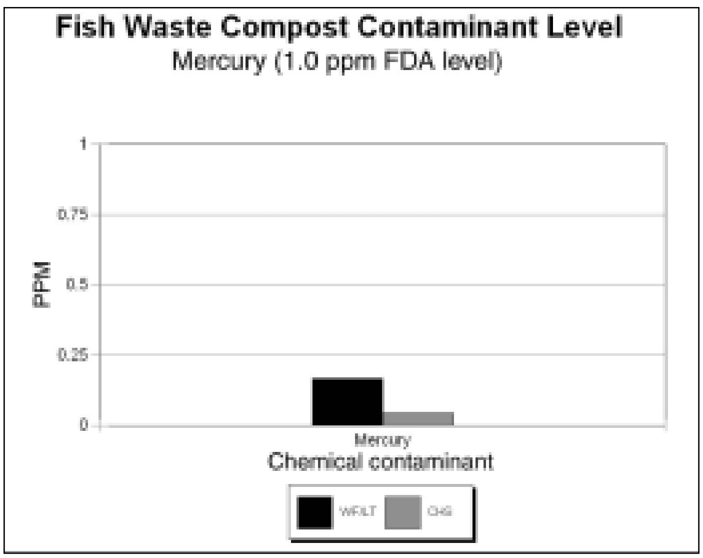

Figure 26. Fish waste compost contaminant level for mercury from lake whitefish/lake trout waste (WF/LT) and chinook salmon waste (CHS). Mercury has an FDA action level of 1.0 ppm and a Michigan action level of 0.5 ppm for food fish.

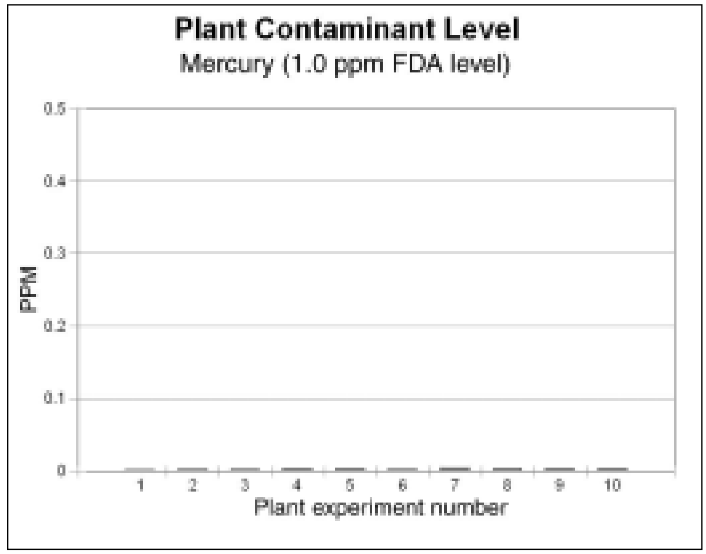

Figure 27. Contaminant levels for mercury from plants grown in various amounts of fish waste compost. Mercury has an FDA action level of 1.0 ppm and a Michigan action level of 0.5 ppm for food fish.

Markets for Composted Fish Waste

Market information sources

The market information reflected in this section was gathered through a variety of methods. Both telephone and in-person interviews were conducted with a number of consultants and university people active in the field. Two trade shows (the Great Lakes Fruit, Vegetable and Farm Market Expo and the Great Lakes Trade Expo of the Michigan Nursery and Landscape Association) were attended to complete interviews with suppliers to the industry and users of some of its products, especially orchard growers and organic farmers. Limited store survey work was done. Much of the information concerning products available in the market was obtained from Web searches. This work also builds on a report on compost markets completed by Northern Initiatives in November 2000 (Cambier and Rector, 2000).

Project history

The disposal or reuse of fish processing waste has long been a challenge for the fish processing industry in Michigan. These problems have been especially acute in northern Michigan in recent years because landfills and municipal sewage treatment systems have been ill equipped or otherwise inappropriate solutions for this disposal. Some processors have recently developed markets in the liquid fertilizer industry that have helped alleviate these problems. These markets, however, require fish processors to incur the costs of storage, especially refrigeration costs, as waste is accumulated for transport. In the off-season, fish waste is generally taken to a landfill for lack of any better solution. In 2004, fish processors in Michigan's eastern Upper Peninsula (U.P.) paid landfills $60 per ton to take fish waste.

Potential markets

The opportunity to market fish waste/wood residue compost presents some unique challenges as well as opportunities. The limited amount of fish waste available to compost could restrain the size of a composting operation and thus its economic viability. One way around this problem is to make the fish compost product a component of a larger waste refining and/or composting operation. That is a possibility, given the interest in making better use of wood residues in the U.P. as well as interest in farm and food residue composting.

On the other hand, limiting one's thinking about a compost product derived from specific, well-defined feedstocks (i.e., fish and wood) rather than a compost product that might be produced from a waste stream that would be less well characterized (such as a municipal solid waste stream) provides an advantage — the characteristics and quality of such a compost product can be very predictable and thus suitable for some market niches. The challenge of this current market research is to find the most valuable potential market niche for such a product.

In a report on compost opportunities produced by Northern Initiatives (Rector and Cambier, 2000), it was clear that marketing a simple compost product would be a challenging task. Although the National Bark and Soil Producers Association state the annual growth of the soil market (including compost, topsoil and growing media) is between 8 and 10 percent, most products labeled as compost are not highly regarded in the market. Such products sold by mass merchandisers are usually of low quality and sold on price, and discussions with people in the market confirm this evaluation. Without exception the advice has been to use compost in combination with other materials to produce a growing mix or potting soil that meets the more demanding specifications of those uses and for which the consumer is accustomed to paying a higher price.

Volume estimates

To get a handle on the volume limits of a fish compost product, rough estimates were prepared of the quantities of fish waste compost that could be generated and the volume demands of at least one specific market. These estimates start out with the volumes of fish residues currently available in the Straits of Mackinac area. No effort has been made to suggest how much of this volume might be available to a composter. There is very little known about compost markets that generate any cash flow for the processors. This residue is all disposed of at some cost. A business model built on the ability to pay even a minimal amount for this material or at least provide a no-cost disposal option should be able to compete effectively for the available supply.

Estimates of the volume of fish residue that might be diverted to a composting operation in the Straits of Mackinac area (between the Upper Peninsula and the Lower Peninsula, connecting Lake Michigan and Lake Huron) run from 3 million to 5 million pounds annually. Charles Gould with MSU Extension (personal communication, 2002) estimates that 3 million pounds of fish waste would produce approximately 1,650 to 3,300 tons of compost. At 800 to 1,000 pounds per cubic yard of compost at 40 percent moisture, the available residue could produce at most perhaps 8,250 cubic yards of finished compost annually.

Compost industry trends

In early 2000, 32 compost manufacturing facility operators participating in the U.S. Composting Council's Seal of Testing Assurance (STA) program were surveyed to get a sense of marketing trends in the industry. These compost operations were some of the largest in the country, producing approximately 1 million cubic yards of compost annually. The operators were not representative of the whole industry but rather represented the more experienced compost marketers across the nation.

The survey revealed some interesting and perhaps logical trends (Alexander, 2000). Forty-two percent of these operators were bagging a product; the rest sold in bulk only. The largest volume market segments were landscapers and homeowners. Retailers and nurseries made up 23 percent and 19 percent of the respondents, respectively. By far the largest application for this compost was as a soil amendment in turf or garden applications. Uses as mulch and as a growing medium were second and third in the list of most frequent applications. A small but fast growing use of compost in erosion control was identified. After this small but growing trend for use in erosion control, the next most prominent trends identified were agricultural uses and blending uses, especially "high quality" blends.

Of most interest in the survey for the purposes of marketing fish waste compost were responses to questions about market trends. The two most common answers were that the operators had noticed greater market acceptance of compost (both retail and wholesale) and that operators were increasingly customizing their products to increase sales or value.

The use of composts in growing mixes

The idea of using composts in potting mixes and greenhouse substrates has been around for some time. Typically the use of composts has been driven by the economic value of substituting low-value compost for a higher value peat or coir product. Compost traditionally has been viewed as a low-cost filler material. However, high quality compost can add to the value of a mix, through either its physical, chemical or biological properties. Of these various properties, the biological values are probably the greatest. The disease suppression and other benefits it brings to plant health and growth are substantial, although not widely appreciated. As demonstrated by the results reported in other sections of this report, compost can also replace the use of fertilizer and thus reduce costs in the greenhouse.

Greenhouse substrate markets

Many of the research people interviewed, including John Biernbaum (Michigan State University) and John Bouwkamp (University of Maryland), both of whom have been active in the use of composts for substrates, have strongly recommended looking at compost as a component of a substrate mix for the greenhouse industry. The amount of compost used in a mix depends in part on which of these properties — physical, chemical or biological — is being influenced. Typical mixes used today rely heavily on peat products and/or rock wool augmented with micronutrients, perlite and vermiculite. Those mixes constitute a soil-less mix that is used simply to hold the plant and provide an appropriate environment for the provision of both moisture and air to the plant.

Those in the private sector and close to the market caution that compost use, although good in theory, has been very difficult to sell to the industry. Although compost use has been tested a number of times, the industry has been very reluctant to adopt its use. The industry is very conservative on this point and reluctant to take risks with its production. Changes in the substrate for these operations are a big deal, generally requiring changes in the watering and fertilizing regimes of the greenhouse. Such changes are not made lightly.

Miller looked at the specific needs of nurseries and greenhouses trying to use compost in potting media (Miller, 2001). She suggests that soil-less media should have a pH between 5.5 and 6.5. Most composts are neutral to alkaline (7.0 to 9.0 pH), a factor that may limit the volume of compost that can be used in a greenhouse mix. Total soluble salts should not exceed 3.0 ds/m for nursery use and 2.0 ds/m for greenhouse use. The percent of dust particles (less than 0.5 mm) should be kept below 20 percent of the compost. Moisture content should be kept between 40 and 50 percent for ease of mixing. The compost should be screened to minus ½ inch for the smaller containers used in typical greenhouse facilities. The carbon to nitrogen ratio should be below 25:1 to avoid nitrogen tie-up. Bioassays or Solvita® tests (6 or above) are commonly accepted. General guidelines for microflora used by labs that specialize in such testing should be used. Labs that analyze compost can be found in Appendix 2.

There has been concern in some quarters about the industry reliance on peat products and the effect on the environment of peat mining operations. Unlike peat, compost is a renewable resource and its use does not involve the environmental impacts associated with mining peat bogs.

Regional substrate markets

Because transportation is an important element in the cost of bringing a substrate product to market in the U.P., regional market opportunities were investigated. They included the use of abandoned mines as high-security growing chambers for the pharmaceutical industry and the market for flower bed amendments in residential and resort industry markets, especially on Mackinac Island.

A pilot project underway at SubTerra's White Pine facility is investigating the use of compost as a component of a greenhouse mix to grow specialty crops in an underground growth chamber (i.e., high-tech greenhouse) for the pharmaceutical industry. Recent changes in state regulations that make it easier to access mines and market interest in SubTerra's growing services make it much more likely that the White Pine facility will be expanded to a commercial scale in 2005. Very rough early estimates of the demand for compost at the White Pine facility suggest that, at full development, 3-gallon containers cycled four times a year would use 45,170 cubic yards of material. If that material were 20 percent compost, the potential use of compost at that facility would be in the vicinity of 9,000 cubic yards annually.

An interview with the SubTerra parent company in Saskatoon, Sask., reveals that it currently uses a mix that is 50 percent BX peat and 50 percent coconut coir. The BX peat product is a mix of peat, vermiculite, lime and micronutrients supplied by Premiere. This mix, once expanded, costs $57 a cubic yard (Canadian dollars) or $43.60 (U.S. dollars). A web survey found that the retail price for expanded Premier Pro BX for garden use was as high as $134.81/cy.

In addition to the costs of peat and coir, a large operator must add the cost of labor, space, energy and equipment to prepare the mix. As the Canadian facility has expanded in the past year, it has found it increasingly difficult to keep up with the substrate demand. This is likely to be a problem at SubTerra within the next year, creating a market opportunity for either compost as a component of a mix or for a custom mix prepared off site. The company will likely be very interested in better material-handling methods than those being used at this time as it grows in size. The use of appropriate reusable containers and perhaps automated growing container preparation will be important considerations for a supplier of substrate.

Currently, the Canadian operation pasteurizes some of the mix it uses to assist in pest management. The material is taken to 70 degrees C for a period of 15 minutes. Their intent is not to sterilize the mix. Interviews suggest that the price range for greenhouse substrate in the United States ranges from around $35 per cubic yard at the low end to more than $100 per cubic yard for the more demanding users.

Organic substrate markets

In interviews with researchers in the field, including Bouwkamp and Biernbaum, the idea of using compost in a substrate mix for the organic industry has been enthusiastically promoted. The new USDA compost standards require vegetable growers to use vegetable starts produced with organic materials if they are available. There is a widely held expectation that the organic greenhouse industry is on the cusp of substantial growth to meet market demand.

Most commercial starter mixes contain both synthetic fertilizers and wetting agents to help regulate moisture, improve aeration and increase nutrient availability. Synthetic fertilizers and, in most cases, wetting agents are not allowed in the production of organic vegetable starts. Composts are being touted for this use because they can provide superior wetting qualities to peat-based mixes and they supply nutrients. Because of the beneficial microorganisms they contain, composts can also provide protection from diseases and encourage plant growth.

However, lists of organic suppliers do not indicate much commercial production of organic starts in the Midwest at this time. Further interviews with the major organic vegetable growers in Michigan indicate that growers are producing their own starts, usually with substrate prepared on the farm. Michigan Grower's Products does produce a special mix for these growers, but the market for U.S. product seems to be limited. The desire to grow their own starts is driven partly by a desire to produce unusual varieties that are generally not available except as seed. Thus selling to this market segment would probably require selling directly to farmers and also overcoming the farmers' reluctance to purchase a prepared substrate mix.

The production of a compost product that can meet the USDA Organic Standards §205 (http://www.ams.usda.gov/nop/NOP/standards/FullRegTextOnly.html) may present a challenge, but only because the standards are not finalized. Thus far no standards have been set for mercury in compost. Halogenated hydrocarbon content must be below the FDA's action level, which this project has clearly demonstrated to be the case.

Consumer Potting Mixes

Several of the people interviewed in this effort suggested that a high-end, well-merchandised "boutique" potting soil for the consumer market could be very profitable. A look at the market shows that a wide range of products are available both in quality and price.

The Cooperative Extension horticulturists at Colorado State University recently completed a trial of a number of potting media that they found available from mass merchandisers, garden centers and nurseries. They found some of the most popular brands resulted in poor or mixed plant growth. They also tried products that were labeled "compost" and found them to be poor performers.

In the market these products are available in many prices and sizes. "Sam's Choice Continuous Feeding Potting Mix" is sold for $2.50 for a 0.39-cubic-foot (10-quart) bag. This product was advertised with a fertilizer value of 0.16-0.1-0.1. Another example, "Garden-Ville Potting Soil," was found advertised as the best-selling premium potting soil in Texas. It was priced at $5.99 for 0.50 cubic foot.

A typical price point for a bagged product out of a mass merchandiser of this nature would be about $3 to $3.50 for a 0.62-cubic-foot (16-quart) bag delivered to the retailer. Of this price, about $1 would go to the producer, or about $27 per cubic yard; about $1 would go into the bagging and about another $1 into transportation. This margin should be improved upon through the merchandising of a high quality "boutique" brand through nurseries and garden centers rather than mass merchandisers.

A composting operation run by the Department of Public Works (DPW) on Mackinac Island provides an example of a regional market in the eastern Upper Peninsula. The DPW composts a mix of wastes, especially horse manure, and sells the product in bulk to the public on the island. It produces 2,000 to 3,000 cubic yards a year, and all of it is sold for $8 to $10 a cubic yard. The production is managed as a system to dispose of waste rather than an operation to maximize profits. All transportation costs are borne by the user within a small geographic area.

The production of a bagged high value product could utilize a distributor on a regional basis. The Cisco Companies of Indianapolis are one example of a distributor that handles both bulk quantities as well as small volumes of high-value products to garden centers. The latter are often distributed in a small geographic region to manage transportation costs. One distributor has speculated that a small-volume high quality product could probably be marketed in an area bordered by Traverse City, Sault Ste. Marie and Marquette, Mich., and Green Bay, Wis.

Conclusions

Contaminants in fish waste, compost and basil plants

The level of halogenated hydrocarbons in lake whitefish and lake trout waste depended on the lake of origin. Some lake whitefish waste and lake trout waste exceeded the FDA action level for food fish for a particular contaminant. Contaminant levels for mercury from lake whitefish waste, lake trout waste and chinook salmon waste did not exceed the FDA action level of 1.0 ppm or the Michigan action level of 0.5 ppm for mercury.

The compost generated from the lake whitefish and lake trout waste did not have any reportable levels of halogenated hydrocarbons. Only very low levels of DDT showed up in the compost made from the chinook salmon waste. Contaminant levels for mercury from lake whitefish/lake trout waste compost and chinook salmon waste compost did not exceed the FDA action level of 1.0 ppm or the Michigan action level of 0.5 ppm for mercury. Leaf compost from the city of Kincheloe did not have any reportable levels of halogenated hydrocarbons or mercury.

Because halogenated hydrocarbons were known to be present in the fish waste, the absence or reduced levels of these contaminants in both the lake whitefish/lake trout and chinook salmon composts suggest that microorganisms active in the composting process break down the halogenated hydrocarbons. The same cannot be said for mercury. Because it is a heavy metal and in its elemental form, the low levels in the compost are most likely due to the fact that levels of mercury in the fish waste were low and then were diluted when the fish waste was mixed with other feedstocks used to make the compost. Mercury can not be reduced through biological activity.

Basil plants did not contain any halogenated hydrocarbons and only very low levels of mercury. This stands to reason, considering halogenated hydrocarbons and mercury levels were either non-detected or at very low levels in the compost mixes. A summary of the halogenated hydrocarbon and mercury contaminant levels found in the fish waste, fish waste compost, leaf compost and basil plant tissue analysis, is found in Table 1.

Plant growth

Trial 1

Basil plants grown in the professional growing substrate of peat, coir and perlite had increased height at the 30 percent compost level without any additional liquid fertilizer. However, height did not improve in the fertilized plants with increasing levels of compost. Faster growth and better color were observed in the 20 percent and 25 percent compost-amended mixes compared with plants in the control and 10 percent and 15 percent compost-amended mixes during the first six weeks of the trial. Additionally, the results show that non-fertilized plants in the 20 percent and 25 percent compost-amended mixes were similar in dry mass to those grown with the addition of fertilizer. The use of fertilizer negates the impact of increasing compost levels in the media. Tissue analysis of the basil plants showed similar fertility levels between non-fertilized and fertilized treatments.

It was observed at the end of week 6 at the 30 percent compost level only that some senescing of the foliage and stems occurred on the uppermost 4 to 5 inches of the basil plants. The cause of the distortion was not obvious from the symptoms.

Trial 2

No plant growth data were collected for Trial 2.

Trial 3

Basil plants in the bark-based mix did not perform as well as those in the professional mix when both were amended with 10 percent compost. Incorporation of a starter fertilizer into the bark-based mix is suggested for subsequent trials to determine if this addition overcomes the slow initial growth. It should be noted that this comparison between a peat-based mix and a bark-based mix was included in the project to encourage the use of bark as a locally available and more sustainable material.

The bark-based mix showed a drop in dry weight and health of marigolds grown in the highest treatment level, of 30 percent compost. It was observed that in both the fertilized and the non-fertilized groups, the plants grown in the 20 and 25 percent compost treatments were fuller, had more branching and flower development, and were a deeper green color. For a bark-based medium, either of these two levels would enhance the performance of the retail potting soil.

Barrel use in static pile composting

The barrels typically used to collect fish waste in the fish processing operations would present a problem for a production compost operation — they were difficult to tip by hand. An on-going composting operation would need to investigate safer and less labor-intensive tipping methods, perhaps involving different collection containers in the fish processor facility that could be more easily moved on and off trucks and tipped over.

Fish Waste Compost Markets

The opportunity to market fish waste/wood residue compost presents some unique challenges as well as opportunities.

- The challenges include having a finite volume of fish waste, overcoming fears about contaminants in the compost and finding the most valuable potential market niche for fish waste compost.
- The opportunities include receiving a fair price for compost that meets market specifications and eliminating dependence on landfills for disposal of fish waste.

The profitability of a composting operation will depend on:

- The tipping fee that can be charged processors.
- The ability of an operator to manage production costs (possibly by integrating the composting with other operations).
- Developing a market for a high quality product, either as a niche consumer product or as a high quality bulk product that meets the needs of the greenhouse industry. In other words, manufacturing a growing mix to meet a more demanding specification for which the consumer willingly pays a higher price.

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Appendix 1-a

Woods End Research Laboratory, Inc.

20 Old Rome Road - Mt Vernon ME 04352

207-293-2457 — lab@woodsend.org

Client:
Pete Gambier
Northern Initiatives
228 West Washington Street
Marquette MI 49855

Date: 18-Jun-02
Project:
Acct# 2182
Initials EE
Ref: **fish recipe** HIGH SAWDUST w. water

Compost Mix Ratio Analysis

SAMPLE IDENTITY	fish offal composite	bark	sawdust		water
LAB #	5410.0-.2	5425.0	5425.1		

LAB TEST TRAITS	1	2	3	4	5
Moisture, % as is	69.4	33.5	36.5	0.0	100.0
Organic Matter, % of TS	80.2	60.0	98.9	0.0	0.0
Total-Nitrogen, % ofTS	7.40	0.36	0.09	0.00	0.00
P, % of TS	n/a	n/a	n/a	0.001	0.001
K, % of TS	n/a	n/a	n/a	0.001	0.001
C:N Ratio	5.9	91.3	628.3	0.5	0.5
Other: [Na]	n/a	n/a	n/a	0.001	0.001
Other: [nitrate]	n/a	n/a	n/a	0.001	0.001
Density, lbs/cu.yd.	1870	590	506	1	1680
Compressibility Factor	1.0	1.5	1.2	0.0	1.0

PROPORTIONS:						TOTAL:
Wet Weight Ratios	1.000	0.900	1.300	0.000	0.900	4.1
Example Wet Tons	100	90	130	0	90.0	410
Dry Weight Ratios	0.3	0.6	0.8	0.0	0.0	1.7
Example Volume cu.yds.	107	305	514	0	107	1033
% of Total Wet Weight	24.4%	22.0%	31.7%	0.0%	22.0%	100%
% of Total Volume	10.4%	29.5%	49.7%	0.0%	10.4%	100%
Compressed Vol, cu.yd.	107	203	428	0	107	846
Compressed Volume, %	12.6%	24.1%	50.6%	0.0%	12.7%	100.0%

PROJECTED RECIPE ANALYSIS

Moisture	OM, % of TS	N, % of TS	C:N	P, % of TS	K, % of TS	Density, #/yd
57.80%	82.13%	1.47%	30.1	0.00%	0.00%	970

% Moisture @ Saturation		
	n/a	n/a
71.5%	n/a	n/a

NOTES: ¤

Appendix 1-b

Woods End Research Laboratory, Inc.

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207-293-2457 — lab@woodsend.org

Client:
Pete Gambier
Northern Initiatives
228 West Washington Street
Marquette MI 49855

Date: 18-Jun-02
Project:
Acct# 2182
Initials EE
Ref: fish recipe HIGH BARK w. water

Compost Mix Ratio Analysis

SAMPLE IDENTITY	fish offal composite	bark	sawdust		water
LAB #	5410.0-.2	5425.0	5425.1		

LAB TEST TRAITS	1	2	3	4	5
Moisture, % as is	69.4	33.5	36.5	0.0	100.0
Organic Matter, % of TS	80.2	60.0	98.9	0.0	0.0
Total-Nitrogen, % ofTS	7.40	0.36	0.09	0.00	0.00
P, % of TS	n/a	n/a	n/a	0.001	0.001
K, % of TS	n/a	n/a	n/a	0.001	0.001
C:N Ratio	5.9	91.3	628.3	0.5	0.5
Other: [Na]	n/a	n/a	n/a	0.001	0.001
Other: [nitrate]	n/a	n/a	n/a	0.001	0.001
Density, lbs/cu.yd.	1870	590	506	1	1680
Compressibility Factor	1.0	1.5	1.2	0.0	1.0

PROPORTIONS:						TOTAL:
Wet Weight Ratios	1.000	1.500	1.020	0.000	0.900	4.4
Example Wet Tons	100	150	102	0	90.0	442
Dry Weight Ratios	0.3	1.0	0.6	0.0	0.0	2.0
Example Volume cu.yds.	107	508	403	0	107	1126
% of Total Wet Weight	22.6%	33.9%	23.1%	0.0%	20.4%	100%
% of Total Volume	9.5%	45.2%	35.8%	0.0%	9.5%	100%
Compressed Vol, cu.yd.	107	339	336	0	107	889
Compressed Volume, %	12.0%	38.1%	37.8%	0.0%	12.1%	100.0%

PROJECTED RECIPE ANALYSIS

Moisture	OM, % of TS	N, % of TS	C:N	P, % of TS	K, % of TS	Density, #/yd
55.86%	76.08%	1.37%	30.0	0.00%	0.00%	994

% Moisture @ Saturation		
	n/a	n/a
70.1%	n/a	n/a

NOTES: ¤

Appendix 1-c

Woods End Research Laboratory, Inc.
20 Old Rome Road - Mt Vernon ME 04352
207-293-2457 — lab@woodsend.org

Client:
Pete Gambier
Northern Initiatives
228 West Washington Street
Marquette MI 49855

Date: 18-Jun-02
Project:
Acct# 2182
Initials EE
Ref: **fish recipe** HIGH BARK

Compost Mix Ratio Analysis

SAMPLE IDENTITY	fish offal composite	bark	sawdust		water
LAB #	5410.0-.2	5425.0	5425.1		

LAB TEST TRAITS	1	2	3	4	5
Moisture, % as is	69.4	33.5	36.5	0.0	100.0
Organic Matter, % of TS	80.2	60.0	98.9	0.0	0.0
Total-Nitrogen, % ofTS	7.40	0.36	0.09	0.00	0.00
P, % of TS	n/a	n/a	n/a	0.001	0.001
K, % of TS	n/a	n/a	n/a	0.001	0.001
C:N Ratio	5.9	91.3	628.3	0.5	0.5
Other: [Na]	n/a	n/a	n/a	0.001	0.001
Other: [nitrate]	n/a	n/a	n/a	0.001	0.001
Density, lbs/cu.yd.	1870	590	506	1	1680
Compressibility Factor	1.0	1.5	1.2	0.0	1.0

PROPORTIONS:						TOTAL:
Wet Weight Ratios	1.000	1.500	1.020	0.000	0.000	3.5
Example Wet Tons	100	150	102	0	0.0	352
Dry Weight Ratios	0.3	1.0	0.6	0.0	0.0	2.0
Example Volume cu.yds.	107	508	403	0	0	1019
% of Total Wet Weight	28.4%	42.6%	29.0%	0.0%	0.0%	100%
% of Total Volume	10.5%	49.9%	39.6%	0.0%	0.0%	100%
Compressed Vol, cu.yd.	107	339	336	0	0	782
Compressed Volume, %	13.7%	43.4%	43.0%	0.0%	0.0%	100.0%

PROJECTED RECIPE ANALYSIS

Moisture	OM, % of TS	N, % of TS	C:N	P, % of TS	K, % of TS	Density, #/yd
44.57%	76.08%	1.37%	30.0	0.00%	0.00%	900

% Moisture @ Saturation	n/a	n/a
70.1%	n/a	n/a

NOTES: ¤

Appendix 1-d

Woods End Research Laboratory, Inc.
Old Rome Road. P.O. Box 297
Mount Vernon, ME 04352/USA
207-293-2457 FAX: 207-293-2488 www.woodsend.org

Account: 2182	Code: smn Project: n/a
· Pete Gambier	Date Received : 12/30/1902
· Northern Initiatives	Date Reported : 01/16/2003
· 228 West Washington Street	Lab ID Number : 5631.0
· Marquette MI 49855	Quality Checked : WD 1/16/0

COMPOSITION ANALYSIS

Sample Identification: **Compost: Fish Processing Residue, Woodchips, Bark**

VARIABLE MEASURED	Unit	dry basis	as is basis	Notations †
DENSITY	$lbs \cdot ft^3$	-	32	876 lbs/yd^3
Solids	%	100.0	50.1	1002 lbs/ton
Moisture	%	0.0	49.9	120 gals/ton
est. water holding capacity	%	167	63	150 gals/ton
Inert and Oversize Matter	%	~	8.6	172.0 lbs/ton
pH (paste, H_2O)	$-logH^+$	~	6.33	V Low
Free Carbonates (CO_3)	Rating	~	2	Med-High
Organic Matter	%	51.7	25.9	518 lbs/ton
Conductivity	$mmhos \cdot cm^{-1}$	~	2.6	Med-Low
Carbon:Nitrogen (C:N) Ratio	w:w	12.8	12.8	M. Low
Solvita CO_2 Rate	(see chart)	~	3	High
Solvita NH_3 Rate	(see chart)	~	5	Absent
Maturity Index	(see chart)	~	3	Immature

Notes: ppm = mg/kg < = less than MLD (minimum level of detection); nd = none detected

†For explanation of data, see Woods End Laboratory Interpretation Sheet

Appendix 1-e

Page 2 of 2

Woods End Research Laboratory, Inc.
Old Rome Road, P.O. Box 297
Mount Vernon, ME 04352/USA
207-293-2457 FAX: 207-293-2488 www.woodsend.org

Account: 2182	Code: smn--Project: n/a
Pete Gambier	
Northern Initiatives	Date Received : 12/30/1902
228 West Washington Street	Date Reported : 01/16/2003
Marquette MI 49855	Lab ID Number : 5631.0

MINERALS ANALYSIS

Sample Identification: **Compost: Fish Processing Residue, Woodchips, Bark**

VARIABLE MEASURED	Unit	dry basis	as is basis	pounds/ton *as is*
Total Mineral Nutrients				
Total Nitrogen	%	2.175	1.090	21.8
Organic-Nitrogen	%	1.882	0.943	18.9
Phosphorus (P)	%	0.522	0.261	5.2
Potassium (K)	%	0.192	0.096	1.9
Sodium (Na)	%	0.061	0.031	0.6
Calcium (Ca)	%	1.922	0.963	19.3
Magnesium (Mg)	%	0.123	0.062	1.2
Soluble Nutrients				
Ammonium-N (NH_4-N)	ppm	2373	1189	2.4
Nitrate-N	ppm	560	281	0.6
Nitrite-N	ppm	<2	< 1	nd
Chloride (Cl)	ppm	959	481	0.96
Sulfate (SO_4-S)	ppm	<4	< 2	

Notes: ppm = mg/kg < = less than MLD (minimum level of detection); nd = none detected

Appendix 1-f

Woods End Research Laboratory, Inc.
Old Rome Road, P.O. Box 297
Mount Vernon, ME 04352/USA
207-293-2457 FAX: 207-293-2488 www.woodsend.org

Account: 2182
· Pete Gambier
· Northern Initiatives
· 228 West Washington Street
· Marquette MI 49855

Code: Project: n/a
Date Received : 06/06/2002
Date Reported : 06/19/2002
Lab ID Number : 5410.3
Quality Checked : WD 6/19/02

COMPOSITION ANALYSIS

Sample Identification: **Fish Offal: Composite of 5410.0, .1, and .2**

VARIABLE MEASURED	Unit	dry basis	as is basis	Notations †
DENSITY	lbs·ft^3	-	69	1870 lbs/yd^3
Solids	%	100.0	30.6	612 lbs/ton
Moisture	%	0.0	69.4	166 gals/ton
est. water holding capacity	%	245	71	170 gals/ton
pH (paste, H_2O)	-logH$^+$	~	6.48	V Low
Free Carbonates (CO_3)	Rating	~	1	None
Organic Matter	%	80.2	24.5	491 lbs/ton
Conductivity	*mmhos*·cm^{-1}	~	6.8	Med-High
Carbon:Nitrogen (C:N) Ratio	w:w	5.9	5.9	Ext. Low
Total Mineral Nutrients				
Total Nitrogen	%	7.392	2.262	45.2

Notes: ppm = mg/kg < = less than MLD (minimum level of detection); nd = none detected

Appendix 1-g

Woods End Research Laboratory, Inc.

Old Rome Road, P.O. Box 297
Mount Vernon, ME 04352/USA
207-293-2457 FAX: 207-293-2488 www.woodsend.org

Account: 2182
· **Pete Gambier**
· **Northern Initiatives**
· **228 West Washington Street**
· **Marquette MI 49855**

Code: sr Project: n/a
Date Received : **06/14/2002**
Date Reported : **06/19/2002**
Lab ID Number : **5425.1**
Quality Checked : WO 6/19/02

COMPOSITION ANALYSIS

Sample Identification: **Sawdust**

VARIABLE MEASURED	Unit	dry basis	as is basis	Notations †
DENSITY	$lbs{\cdot}ft^3$	-	19	506 lbs/yd^3
Solids	%	100.0	63.5	1270 lbs/ton
Moisture	%	0.0	36.5	88 gals/ton
est. water holding capacity	%	297	75	179 gals/ton
pH (paste, H_2O)$^-$	$-logH^+$	~	7.58	MedHigh
Free Carbonates (CO_3)	Rating	~	1	None
Organic Matter	%	98.9	62.8	1256 lbs/ton
Conductivity	$mmhos{\cdot}cm^{-1}$	~	0.2	Ext Low
Carbon:Nitrogen (C:N) Ratio	w:w	628.3	628.3	Ext. H
Solvita CO_2 Rate	(see chart)	~	6	Med-Low
Solvita NH_3 Rate	(see chart)	~	5	Absent
Maturity Index	(see chart)	~	6	Active-Curing
Total Mineral Nutrients				
Total Nitrogen	%	0.085	0.054	1.1

Notes: ppm = mg/kg < = less than MLD (minimum level of detection); nd = none detected

Appendix 1-h

Woods End Research Laboratory, Inc.
Old Rome Road, P.O. Box 297
Mount Vernon, ME 04352/USA
207-293-2457 FAX: 207-293-2488 www.woodsend.org

Account: 2182
Pete Gambier
Northern Initiatives
228 West Washington Street
Marquette MI 49855

Code: sr Project: n/a
Date Received : 06/14/2002
Date Reported : 06/19/2002
Lab ID Number : 5425.0
Quality Checked : WO 6/19/02

COMPOSITION ANALYSIS

Sample Identification: **Bark**

VARIABLE MEASURED	Unit	dry basis	as is basis	Notations †
DENSITY	lbs·ft^3	-	22	590 lbs/yd^3
Solids	%	100.0	66.5	1330 lbs/ton
Moisture	%	0.0	33.5	80 gals/ton
est. water holding capacity	%	276	73	176 gals/ton
Inert and Oversize Matter	%	~	2.6	52.0 lbs/ton
pH (paste, H_2O)	-logH$^+$	~	5.95	ExLow
Free Carbonates (CO_3)	Rating	~	1	None
Organic Matter	%	91.2	60.6	1213 lbs/ton
Conductivity	mmhos·cm^{-1}	~	0.6	V Low
Carbon:Nitrogen (C:N) Ratio	w:w	121.0	121.0	Ext. H
Solvita CO_2 Rate	(see chart)	~	4	Med-High
Solvita NH_3 Rate	(see chart)	~	5	Absent
Maturity Index	(see chart)	~	4	Med-Active
Total Mineral Nutrients				
Total Nitrogen	%	0.407	0.271	5.4

Notes: ppm = mg/kg < = less than MLD (minimum level of detection); nd = none detected

Appendix 2

To maximize the benefits of compost for an intended use, the quality of the compost must be analyzed. Listed below are labs that perform compost analysis. It is recognized that this is not an all-inclusive list. This list should not be interpreted as an endorsement by Michigan State University Extension or any other private or public institution identified in this publication to the exclusion of other labs. This list is simply meant to be a starting point in identifying a lab to work with. Contact information for other labs can be obtained through a web search.

Ag Analytical Services Lab
Contact: Ann Wolf
Penn State University
Tower Road
University Park, PA 16802

TEL: 814-863-0841

FAX: 814-863-4540

EMAIL: amw2@psu.edu

WEB: http://www.aasl.psu.edu

A&L Great Lakes Labs
Contact: Lois Parker
3505 Conestoga Drive
Fort Wayne, IN 46808

TEL: 260-483-4759

FAX: 260-483-5274

EMAIL: lparker@algreatlakes.com

WEB: http://www.algreatlakes.com/main.asp

BBC Laboratories, Inc.
Contact: Vicki Bess
1217 N. Stadem Drive
Tempe, AZ 85281

TEL: 480-967-5931

FAX: 480-967-5036

EMAIL: info@bbclabs.com

WEB: http://www.bbclabs.com/

Minnesota Valley Testing Labs
1126 North Front Street
New Ulm, MN 56073

TEL: 507-354-8517 or 800-782-3557

FAX: 507-359-1231

EMAIL: crcmvtl@newulmtel.net
WEB: http://www.mvtl.com

Soil Foodweb, Inc.
1128 NE 2nd Street, Ste 120
Corvallis, OR 97330

TEL: 541-752 - 5066

FAX: 541-752-5142

EMAIL: info@soilfoodweb.com

WEB: http://www.soilfoodweb.com

Woods End Research Laboratory, Inc.
Contact: Anthony Underwood or Will Brinton
20 Old Rome Road
Mt. Vernon, ME 04352

TEL: 207-293-2457

FAX: 207-293-2488

EMAIL: compost@woodsend.org

WEB: http://www.woodsend.org

For more materials available online, visit the MSU Extension Web site at:
http://web2.msue.msu.edu/bulletins/intro.cfm