Composting Fish Waste

An Alternative for Minnesota Resorts

Minnesota Sea Grant Extension

Minnesota Extension Service
University of Minnesota
Natural Resources

COMPOSTING FISH WASTE
An Alternative for Minnesota Resorts

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INTRODUCTION

Minnesota's recreational fishing industry provides an estimated $788 million dollars annually to the state.[1] Sport anglers catch 30 to 35 million pounds of fish each year from the state's numerous lakes and rivers.[2] Cleaning those fish produces at least 15 million pounds of fish waste.[3]

Getting rid of the waste is a major problem. Throwing the waste into state waters is illegal[4]; tossing it into the woods attracts flies and animals. Although resort owners can pay to have the waste hauled to a landfill, many landfill operators now refuse to accept fish waste.

During 1990 the Minnesota Sea Grant Extension Program and the Minnesota Extension Service conducted five demonstration projects to determine the feasibility of composting at Minnesota resorts and marinas. Each site used a different design and mixture of sphagnum peat moss and wood chips. The information presented here is the best combination of design and materials for small scale composting of fish wastes from our 1990 demonstrations.

The four resorts and one marina that participated in the project are in the Minnesota counties of Lake, St. Louis, Itasca, and Cass. These resorts were chosen because they are the right size for this type of project. The composting system outlined in this manual is recommended for resorts with up to 25 or 30 cabins that produce no more than 25 five-gallon buckets of fish waste per week in a 14 to 16 week season. This volume of waste can be managed in one compost structure as described in this manual. Resorts that produce more waste will need additional structures.

BENEFITS OF COMPOSTING

Composting fish waste reduces odors, insect problems, and the amount of waste. Composting effectively stabilizes organic materials that can be returned to the soil.

Mature compost is an excellent soil conditioner. It contains both plant nutrients and essential trace elements. These nutrients are held in organic form and released slowly. Fish waste compost enriches soil for gardens, trees, and shrubs. When screened, it is also a choice top-dressing for lawns. Most compost improves soil conditions, but unfinished or improperly processed compost contains acids, ammonia, or alcohols that harm seedlings and sensitive plants. Consequently, it is important to compost carefully.

Adding compost improves the structure of most soils. When mixed with a sandy soil, compost holds moisture and inorganic minerals. Compost holds the soil together, and gives it a crumbly texture. The addition of compost makes it easier for plant roots to penetrate the soil.

In heavy clay soil, compost binds with clay particles to form larger particles. Surface water drains between the larger particles while the compost holds the moisture for plants. Soil conditioned with compost retains water better and resists surface crusting and erosion.

EFFECTIVE COMPOSTING

The goal of effective composting is to promote the growth of microorganisms that will decompose the fish waste. Six factors influence how effectively the waste turns to compost: the raw organic material(s), oxygen, temperature, moisture, pH, and time.

ORGANIC MATERIAL

The raw organic material–in this case, fish waste and sphagnum peat moss–to be composted must supply the nutrients the microorganisms need to grow.

The organic materials must also have the necessary microorganisms present to begin the process. The ratio of carbon to nitrogen is especially important. The optimum ratio for composting is 25 to 30 parts carbon to one part nitrogen.

Fish waste and sphagnum peat moss, mixed together according to the instructions in this manual, will be within the optimum range. When the carbon and nitrogen are balanced, all of the raw materials will be converted into compost. If there is an excess of nitrogen, odor problems will develop; if there is an excess of carbon, the materials will remain dormant until more nitrogen is added.

Sphagnum peat moss is used because it absorbs odors, especially ammonia. The sphagnum peat moss/wood chip combination allows air to move in and out of the pile.

OXYGEN

Aerobic microorganisms need at least a five percent oxygen level to grow. If there is not enough oxygen, the pile will begin to smell.[5] The pile recommended here has a structure and porosity that allows for adequate air movement. The interconnected airspace should account for 25 to 35 percent of the compost pile's initial volume.

TEMPERATURE

Heat is released during the decomposition process. In general, the ideal temperature range for composting is 113 to 150°F. Temperatures above 150°F slow the composting process. Temperatures above 170°F require immediate action to reduce temperatures. Use only non-mercury temperature meters. See the trouble shooting guide on page 13.

MOISTURE

Foul odors will develop with excess moisture. Too little moisture will significantly slow the composting process. In dry years it may be necessary to add water to keep the pile moist enough for good composting. However, in most years this will not be necessary because the combination of compressed bagged sphagnum peat moss, wood chips, and fish waste will naturally maintain the correct amount of moisture (45 to 55 percent by weight) when the pile is first built.

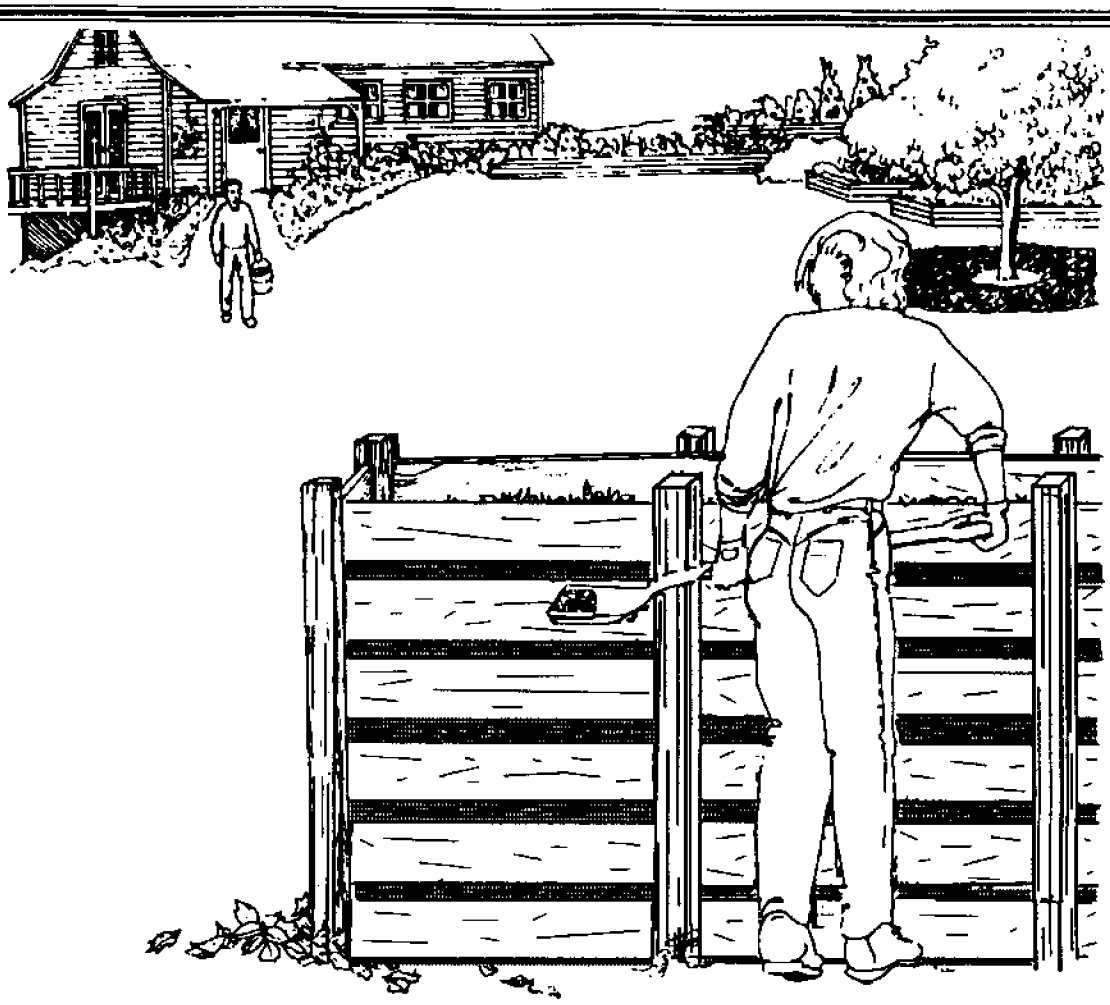

Photo Credit: Northeast Regional Agricultural Engineering Service

PH

Proper pH is necessary for composting to take place. By following the recipe in this manual, the finished compost should be slightly acidic to neutral with a pH in the range of 6.0 to 7.1.

TIME

Most organic materials must be composted and aged for one year before they are considered mature. There are chemical, physical, and biological tests that can determine the maturity of compost.[6] If larger or more durable wood chips are used, the material will take longer to mature.

If you have questions about composting, read the troubleshooting guide on page 13 for problems and solutions.

SUGGESTIONS FOR SUCCESSFUL COMPOSTING

The composting process should become a regular part of the fish cleaning operation. When the composting site is located near your fish cleaning area, it is easier to include it in your daily operation. It also helps when only one individual manages the compost pile.

Add the fish waste to the pile within 24 hours after cleaning the fish. Adding the waste immediately reduces odors. If you cannot put the fish waste into the compost pile within 24 hours, it should be kept cold (not frozen) and covered with a three to four inch layer of sphagnum peat moss. Do not leave fish waste exposed to air. It will smell and attract flies and animals.

COMPOST COSTS

Estimated costs for building and starting a composting pile are $300 to $900. This includes building materials, sphagnum peat moss, and wood chips for one structure. Costs after the first year will be substantially less, because the enclosure will last for several seasons. If this sounds expensive, compare it to your current and future costs for disposal of fish wastes.

Table 1. Fish Compost Building Materials

Materials	Quantity
Gravel	1-3 inch base layer
8 inch diameter fence poles (8-10 feet long)	8 poles
2 inch x 6 inch x 8 foot boards	32 boards
2 inch x 6 inch x 6 foot boards	6-12 boards
5 foot x 60 foot netting (3/4 inch or 1 inch mesh)	1 roll
6 foot x 20 foot plastic netting (3/4 inch or 1 inch mesh)	1 piece
8 foot x 4 inch diameter pre-drilled PVC drain pipes	6-7 pipes
Sphagnum peat moss (4 cubic foot bales)	55-65 bales

Labor

Once the materials are at the site, it takes two people approximately one day to build the enclosure. Digging the holes and setting the posts into the ground requires the most time. Proper planning makes the job easier.

Sphagnum Peat Moss and Wood Chips

This project used only sphagnum peat moss. We used sphagnum peat moss because it is curly and porous, and not as easily crushed as other types of peat. This characteristic helps keep the compost pile from becoming too wet. We cannot recommend the use of any other type or grade of peat.

The cost of sphagnum peat moss varies. Baled seconds of sphagnum peat moss are the most economical choice. A standard five by five by 16 foot structure will require 55 to 65 four cubic feet bales. To get current prices in your area, contact Ted Tower, executive vice president of the Minnesota Peat Association, Route 1, Box 216, Wright, MN 55798. Phone: 218-644-3993.

LOCATION

Water should always drain away from the compost structure and away from wells. The structure should be at least 50 feet away from your fish cleaning station, 150 feet away from any shoreline, and 100 feet away from any well. The site should also be at least 100 feet away from buildings where people are housed or work for more than four hours per day.

A site with regular human activity worked better in the demonstration projects than a site with minimal human activity. For easier maintenance, all brush, trees, and tall grass should be cut for 20 to 30 feet from the compost structure. (See Figure 1)

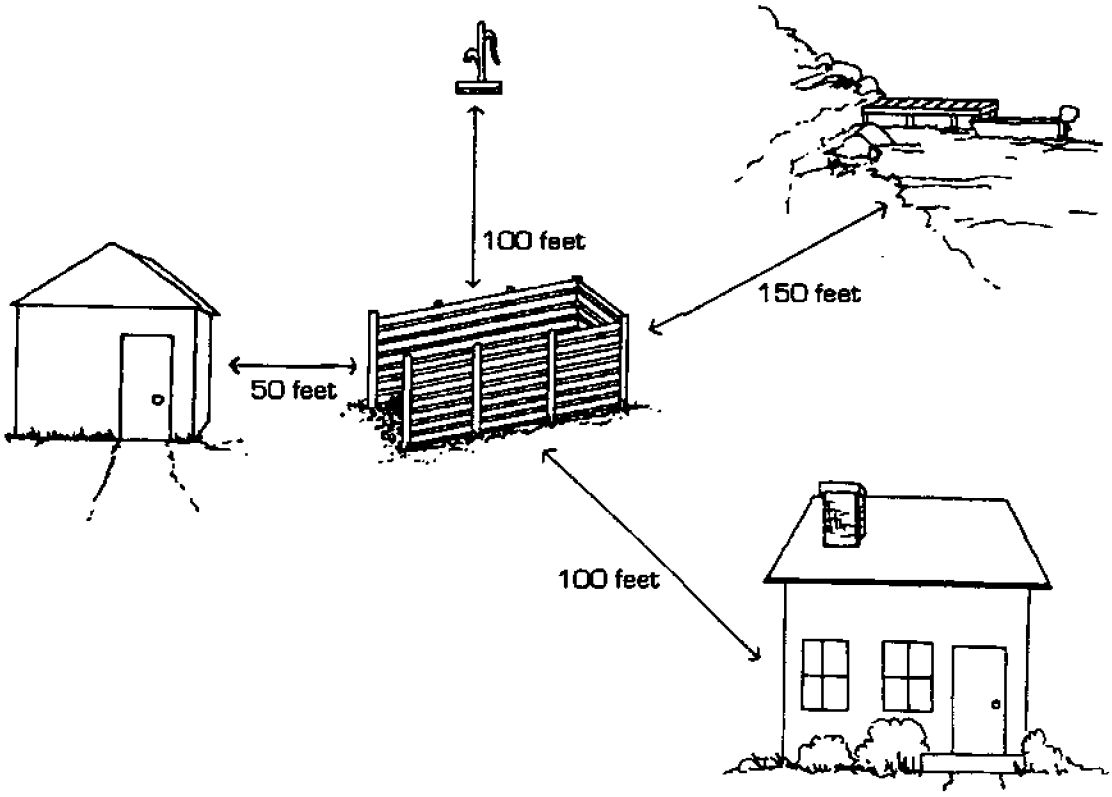

Figure 1. Place structure at least 50 feet from fish cleaning station, 150 feet from shore, 100 feet from buildings where people are housed or work more than four hours per day, and 100 feet from wells.

STRUCTURE

The confinement structure for fish waste composting should be five feet wide by five feet high by 16 feet long (the length can vary depending on fish waste load). A structure of this size can handle 5,000 to 10,000 pounds of fish waste over one summer season. Do not make the structure wider than five feet. In wider piles, it is difficult to maintain proper temperature and oxygen levels. Two or more structures of the recommended size are easier to manage.

Building a Permanent Structure

The most common design places the posts three to four feet into the ground. Nail the boards to the inside of the posts to create a smooth interior wall. The end gates need to be securely fastened (by bolts or equivalent) to hold the end gates in place. Nails alone are not strong enough.

If you can dig post holes and you know where you want the structure permanently located, it is to your advantage to build a permanent structure. It requires fewer building materials and is easier to design and construct.

A wooden structure made of naturally rot resistant lumber (such as cedar), or pressure treated rot resistant wood, is strong and durable and should last for at least ten years. Wooden structures are also aesthetically pleasing to resort owners and their guests. (See Figure 2)

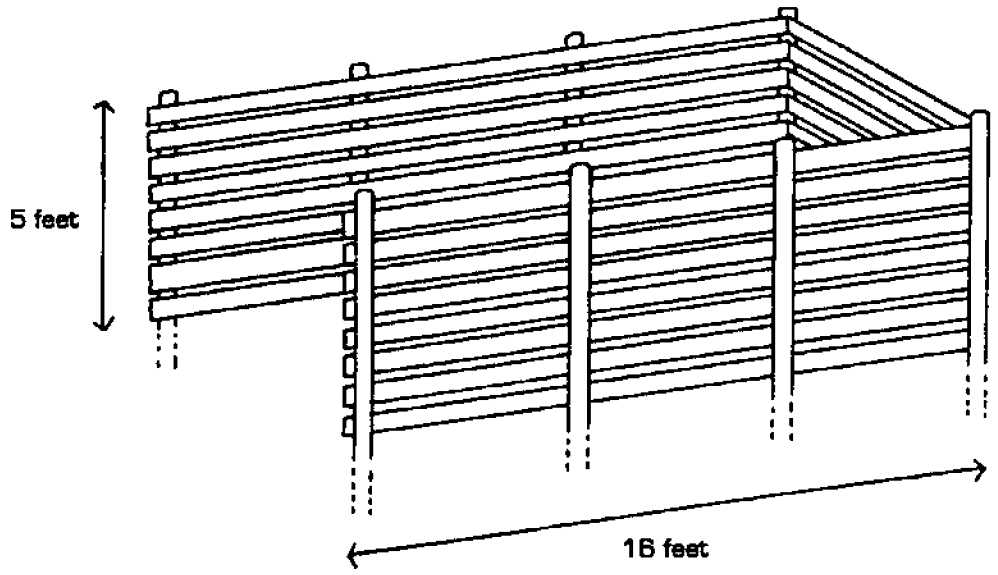

Figure 2. Permanent wooden structure. Back end is removable. Posts are set three to four feet into ground.

Some lighter weight structures lasted only a single fishing season because of the weight of the compost pushing against the sides. The cost of building a durable structure will be lower than the cost of rebuilding a flimsy structure each year.

Building a Moveable Enclosure

In the demonstration project, one resort used a self-standing box structure that did not set the posts in the ground. Although this structure takes more design work and is more expensive, it works better in rocky areas and can be more easily moved. (See Figure 3)

For added versatility, the compost structure can also be made in four foot modular sections that can be attached and detached as necessary. This makes lengthening or shortening the structure easier as your needs vary. It also makes removal of the finished compost easier.

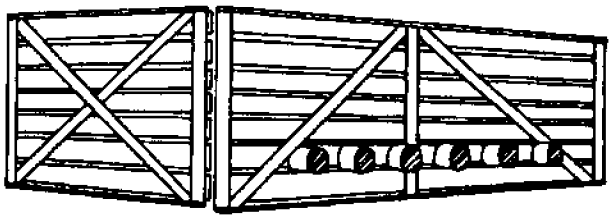

Figure 3. A self-standing structure can be used in rocky areas where in-ground posts are not possible.

Netting

With either type of structure, wire or plastic netting needs to be attached to and cover the interior surfaces of the boards. Wire netting is also used to build the internal divisions that stretch widthwise across the enclosure. A 3/4 inch or one inch mesh size works best. Sixty linear feet of five foot wide mesh will cover the inside surfaces and make the three internal divisions necessary to build the four vertical cells of the pile. (See Figure 4)

These internal mesh walls allow for better composting and prevent slumping . The netting should extend from below the gravel base to above the bottom of the top board. Chicken wire, hardware cloth, and extruded square mesh plastic netting have all been used successfully.

A lightweight plastic netting should be placed over the top of the enclosure to keep the compost materials in the structure and to keep out birds and small animals.

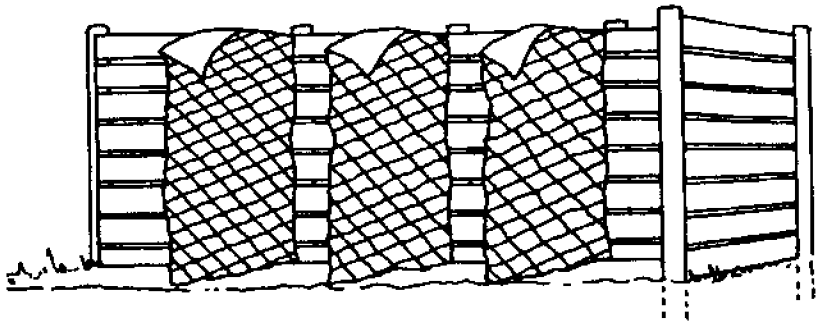

Figure 4. Cut away side view of compost structure shows three internal walls made of wire or plastic mesh. The mesh is stapled or nailed to the walls of the structure. The three walls provide four separate cells to fill with compost

DEVELOPING THE SITE

With supplies in hand, you can begin building the compost structure. For a structure that uses posts set into the ground, lay a one to three inch gravel or course wood chip base after the posts have been set.

If your site is located on rock with no topsoil, and you will not use posts set into the ground, double the depth of the base layer to provide adequate surface drainage. Lay the base layer first, then add the structure.

To develop the first section of your compost pile, add a four to six inch layer of wood chips to the base layer. Push two of the PVC drainage pipes down into the top of the layer of wood chips.

The PVC pipes bring air into the center of the pile. To allow extra ventilation, drill an additional set of 1/2 inch holes (about 2 1/2 to 3 1/2 inches apart) in each of the PVC drainage pipes. The additional holes should be face up between the two rows of pre-drilled holes (See Figure 5). To draw additional air into the pile, drill the holes closer together toward the middle of the pipe.

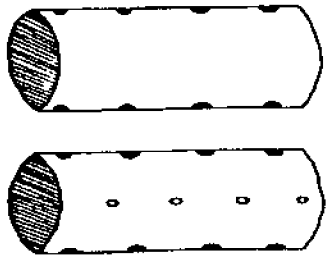

Figure 5. Pre-drilled PVC pipe comes with a row of holes down each side (top). Add another set of holes between the pre-drilled rows at 2 l/2 to 3 1/2 inch intervals (bottom). Add additional holes closer to the center of the pile to improve aeration.

You will need at least six PVC drain pipes for the entire structure (See Figure 6). The pipes should be placed widthwise across the enclosure with the ends sticking out between the two bottom boards. Cut a half circle out of the top or bottom board for the pipe to fit through. The ends of the pipes should extend one foot beyond the structure on both sides. Cover both ends of the pipes with netting (held on by duct tape) to keep flies and small animals out of the pile. Add more wood chips until both pipes are covered. Then add a five to six inch layer of well fluffed sphagnum peat on top of the wood chips.

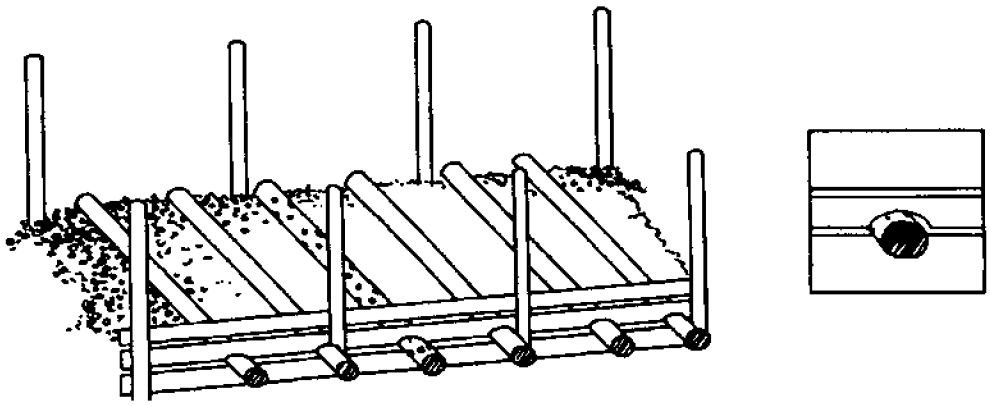

Figure 6. Cut a semi-circle in the top or bottom board for the pipe to fit through. Press the pipes down into the layer of wood chips, then cover with more wood chips and sphagnum peat moss.

To create the first vertical cell, staple or nail a five foot x five foot piece of netting widthwise across the structure about four feet from the back end. Attach the wire only half way up so you can fill it with fish waste (See Figure 7). This piece of netting forms the fourth "wall" of the first cell. The netting will eventually attach to the top boards on both sides of the structure.

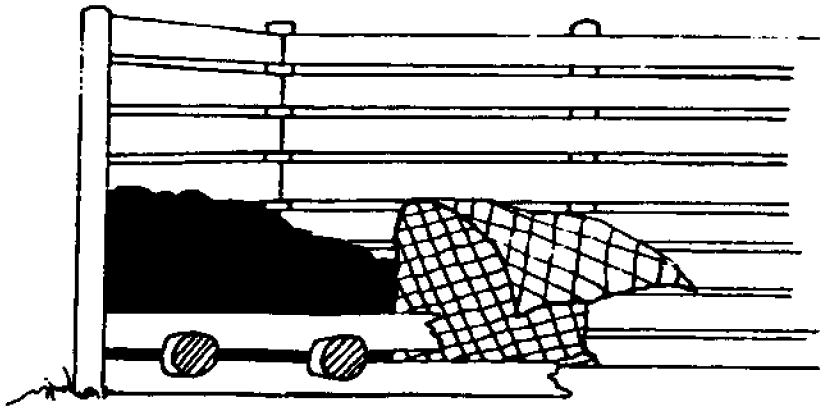

Figure 7. Add waste in two foot sections, working from the back of the structure. (Divide your four foot section in half). Staple or nail the wire mesh to the insides of the boards to form the internal "walls." As the height of the pile increases, increase the height of the netting accordingly.

DEVELOPING THE PILE

Your enclosure is now ready for the fish waste. Work in two foot sections beginning from the back. Fill each cell in a stair-step fashion. Add a six inch layer of compost material to the back two feet of the cell, then a six inch layer of compost to the front two feet of the cell. Return to the back half of the cell and add a six inch layer on top of the original back layer. Add the next six inch layer on top of the original front layer. Rotate back and forth between the two sections until the cell is full. (See Figure 7). As you fill the first cell with compost, nail or staple the netting higher up on the boards to hold the compost materials in. When the cell is full (five feet high) and the netting is fully attached, begin the second cell. Fill the second and subsequent cells in the same stair-step fashion.

The center of the pile in the first cell should be filled with a mixture of one part fish waste, two parts sphagnum peat moss and one part wood chips. Piles with a mixture of wood chips and peat moss allow better ventilation and oxygen flow than those with peat moss alone. Some types of shredded wood bark can be used in place of wood chips; aspen bark works very well.

You can develop your pile by using separate layers of the fish waste and the bulking material or by mixing the fish waste with the bulking material before you put it in the center of the pile. With either method, you need to cover all of the fish waste with four to six inches of bulking material at the end of each day.

When you start the pile, adding an additional shovel of mature compost (fish waste compost is ideal) or top soil and one cup of 10-10-10 fertilizer to the first five to ten layers will make the raw materials compost faster.

When the fish waste/bulking materials in the first cell are a full five feet high, the cell is full. Blanket the pile with a layer of four to six inches of sphagnum peat moss to absorb odor and a layer of four to six inches of wood chips to absorb moisture and to reduce blowing and drying of the pile.

Next, build the second cell. Fill all four vertical cells until the structure is full. Some reduction in volume (up to 40 percent) is normal as the composting process continues. **Do not add fish waste after a cell is completed.** Leave it alone for one year to let it compost. (See Figure 8)

TEMPERATURE

Depending on the outside temperature, the pile should begin to heat in seven to 21 days. It will peak at 130°F to 150°F and then slowly decline to a level where the internal pile temperature is approximately the same as the outside air temperature. The pile will stay warm well into the fall and early winter. You may experience fly problems before the pile begins to heat. See Trouble Shooting Guide.

If the temperature rises above 170°F the pile needs to be cooled. A compost pile can be cooled by dividing the pile or by increasing the internal air flow. Without a thermocouple and a temperature meter, it will be difficult for you to monitor temperatures. A non-mercury thermometer that is long enough to reach into the center of the compost pile can be purchased at most hardware stores. A pile built as described here should compost in the correct temperature range. **Do not use a mercury kitchen or household thermometer in the compost pile.**

The pile should be left unturned and allowed to age for at least 12 months before the compost is used. After 12 months, the appearance of the final compost will be improved by mixing the material to break up bones. The mixed material should stand for an additional four to six weeks before it is used as a soil amendment or mulch.

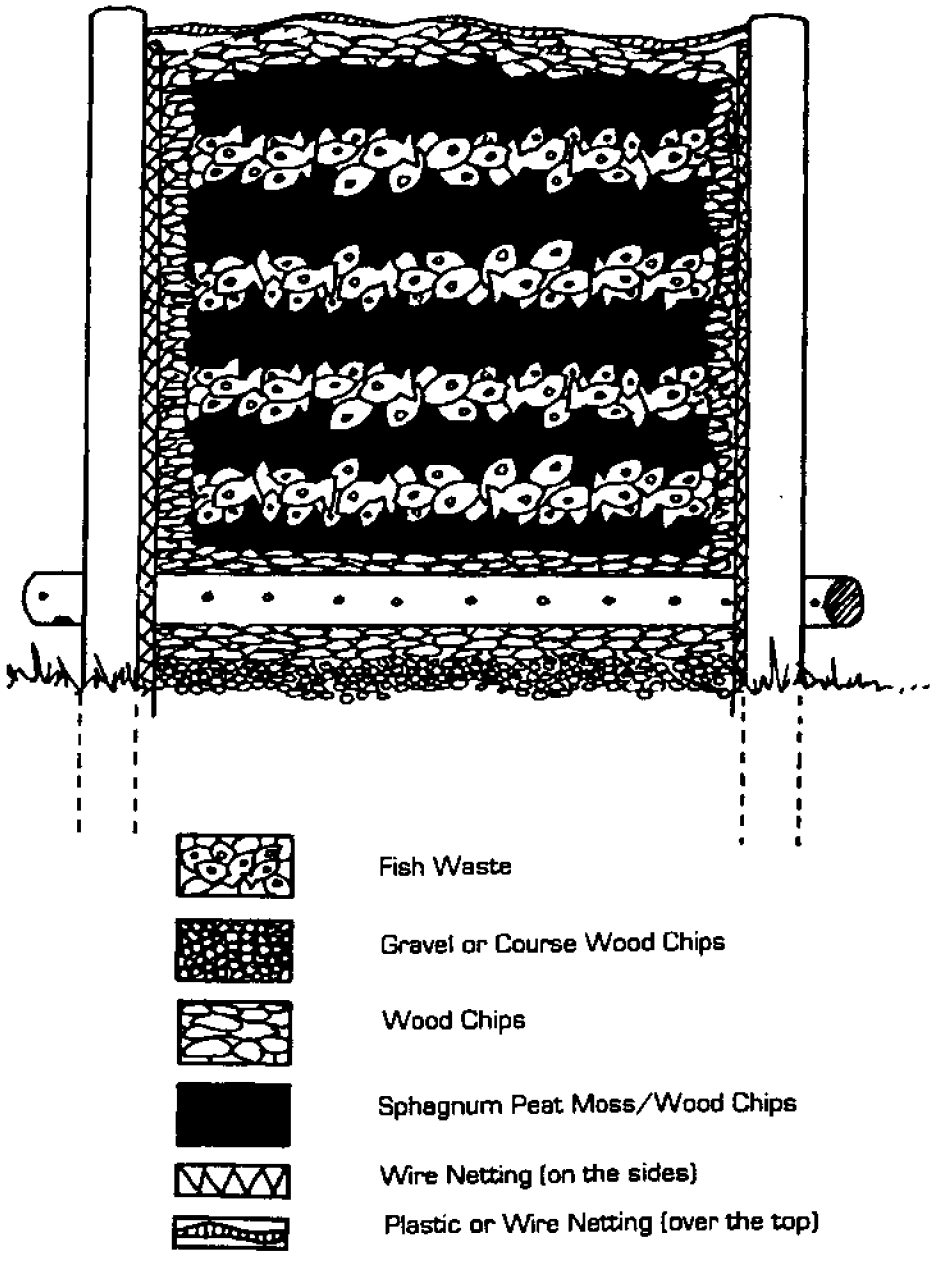

Figure 8. Cross section of a completed compost pile. Note that wood chips surround the pile to improve aeration.

PROBLEMS AND SOLUTIONS

Odor

One part wood chips to two parts sphagnum peat moss controlled odors and increased the pore space and oxygen levels better than peat moss alone. At the only resort where we used sphagnum peat moss alone, the pile filled with water after a major rain, and oxygen levels were near zero.

Low Oxygen Levels

Low oxygen levels can encourage insect problems on the pile surface. If insects are a problem, spray the pile with an EPA labeled fly spray. The most effective sprays are those with pyretheran based active ingredient(s). Contact your local county extension agent for current fly control recommendations.

Birds

Birds are not a problem when the enclosure is covered with light-weight plastic netting. In uncovered piles, ravens, gulls, and robins may visit, especially if fresh fish wastes are not completely covered with peat.

Small Animals

To avoid small animal problems, make sure the fish wastes are completely covered with peat and try not to spill liquids around the pile. If fish waste liquids are spilled on the ground, dig up all of the wet soil and put it into the pile. The wire mesh attached to the inside of the enclosure will help keep small animals from digging into the pile.

Bears

A compost pile should not be located near sites where bears or other wild animals have been trained to feed on fish wastes. At one resort, a bear had eaten fish wastes dumped on the site for a number of years. When the bear found the compost pile located on the same site, he continued to raid the pile every night until it was finally buried. Other resorts reported that bears crossed next to the compost pile without digging in it.

Snakes

In two of the remote sites, snakes attracted to the warmth of the pile nested in the wood chip blanket. A compost site with regular human activity will be less likely to attract snakes. Snakes may occasionally startle people, but they do not interfere with the compost process.

All the composting problems we encountered were resolved with better pile maintenance procedures or the use of additional sphagnum peat moss.

FISH WASTE COMPOST TROUBLESHOOTING GUIDE

PROBLEM	POSSIBLE CAUSES	SOLUTIONS
Rotten odor	• Not enough bulking material	• Add sphagnum peat and wood chips
	• Excess moisture (anaerobic conditions)	• Add sphagnum peat and wood chips
	• Compaction (anaerobic conditions)	• Loosen pile by turning, add wood chips, and sphagnum peat
Ammonia odor	• Too much nitrogen (lack of carbon)	• Add sphagnum peat and wood chips
Low pile temperature	• Pile too small	• Make pile bigger or insulate sides
	• Insufficient moisture	• Add water to pile
	• Poor aeration	• Loosen pile and add wood chips
	• Lack of nitrogen	• Add fish waste or nitrogen fertilizer
	• Cold weather	• Increase pile size or insulate pile with extra layer of wood chips
	• Inadequate microbial activity	• Add mature compost or soil
High pile temp (150°F)	• Pile too high or wide	• Reduce pile size
	• Poor ventilation	• Loosen pile, add wood chips and PVC pipe
Pests: snakes raccoons skunks birds	• Fish waste not covered	• Cover pile with netting; make sure fish waste is covered with 3 to 4 inches of sphagnum peat each day

HEALTH CONSIDERATIONS

When handling peat, protective clothing and good personal hygiene are important. Always wear gloves, a long-sleeved shirt, and long pants. Try not to inhale peat. Follow these suggestions when working the pile: 1) spray a light mist of water on the compost pile a day or two before turning it, 2) choose a calm day to turn the pile, 3) wear a dust mask, and 4) wash thoroughly with soap and water after working with peat.

If you have a cut, puncture, or scrape that does not heal or becomes blistered, swollen, or sore, tell your physician you have worked with sphagnum peat moss.

Two rare diseases are associated with composting: Sporotrichosis[7] and Aspergillus fumigatus.[8] Read more about these diseases in the footnotes.

Contact your physician or your local Department of Health representative for additional information.

LEGAL CONSIDERATIONS

Legal obligations are the composter's responsibility. Contact your local units of government for the legal requirements of composting fish waste in your area.

The Minnesota Pollution Control Agency (MPCA) has set standards for compost produced at a solid waste compost facility. Fish composting is exempt from these rules because the MPCA classifies it as backyard composting.[9] However, when compared to the solid waste compost levels, fish compost samples are of higher quality than the MPCA standards of Class I compost, which means they contain even fewer heavy metals and PCBs.

MINNESOTA STATE AGENCIES:

For the office nearest to you check your local phone directory. Contact your local Minnesota Extension service county agents if you have specific technical questions about composting.

Department of Agriculture
90 West Plato Blvd
St. Paul, MN 55107
612) 297-2200
Regulates sale of fertilizers and soil amendments in Minnesota. See Minnesota Statutes, section 17.713.

Department of Health
717 SE Delaware Street
Minneapolis, MN 55440
(612) 623-5000
Regulates public food preparation, waste disposal methods, and public accommodations.

Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55155
(612) 296-6157
Regulates fish and game and public water/land use in Minnesota.

Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155
(612) 296-6300
Regulates pollution, including solid waste and composting.

FOR MORE INFORMATION

Contact your local county extension office.

This is the first report of the Sea Grant/MES fish waste compost demonstration project in Minnesota. Additional information will be developed and made available in the future. Your comments and suggestions are encouraged.

Sea Grant programs in other states have set up demonstration projects using shredded bark, brush, or wood chips to compost fish wastes. The Minnesota project built on that experience and used applied research to come up with a system that can work well under Minnesota conditions. Research projects in the U.S. and Canada show that composting fish waste can be successful.[10,11,12]

This project was funded by Minnesota Sea Grant Extension, the Minnesota Extension Service, Minnesota Tourism Center, and St. Louis and Itasca Counties.

The authors would like to express their appreciation to the cooperators, county extension staff, funders, and advisors. Technical assistance and advice came from the Minnesota Pollution Control Agency and the Natural Resources Research Institute. The Minnesota State Department of Health and the Minnesota Department of Natural Resources also reviewed the results of this project. Listed below are the names of the project participants.

Knife River Marina
Knife River, MN

Little Sweden Resort
Cook, MN

Northland Lodge
Deer River, MN

Mal Bay Resort
Cohasset, MN

Stoney Point Resort-Leech Lake
Walker, MN

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1. *U.S. Department of the Interior, U.S. Fish and Wildlife Service, March 1989. National Survey of Fishing, Hunting and Wildlife Associated with Recreation. 1985.*

2. *Minnesota Department of Natural Resources Files, Personal Communication, R.Payer, 1991.*

3. *Minnesota Sea Grant Extension Program, Personal Communication, J.Gunderson, fisheries agent. 1991.*

4. *1991 Fishing Regulations, Minnesota Department of Natural Resources.*

5. *Derikx, PJL, et.al. 1990. Odorous Sulfur Compounds Emitted During Production of Compost, Applied and Environmental Microbiology. 56:176-180. The ten most offensive odorous sulfur compounds commonly produced during composting are dimethyl trisulfide, dimethyl disulfide, methanethiol, dimethyl sulfide, carbon disulfide, hydrogen sulfide, 3-methylbutanone, butanone, 2-pentanone, and ammonia.*

6. *Other methods of measuring compost maturity include a C:N ratio reduction from 30:1 or more to 15:1 or less, a +60 percent decomposition as measured by ignition-loss analysis, an earthworm bio-assay, seed germination techniques and nuclear magnetic resonance imagery.*

7. *Emmons, CW, et.al. 1970. Medical Mycology. Philadelphia: Lea and Febiger. 508 pp. and D'Alessio, DJ, et.al. 1965. An Outbreak of Sporotrichosis in Vermont. New England Journal of Medicine 272:1054-1058.*

   Sporotrichosis is a lymphatic disease that can develop in horses, humans, and other mammals. It is caused by the fungus Sporothrix (Sporotrichum) schenckii. This fungus has been found in soil, flowers, shrubs, decaying wood, and bales of sphagnum peat moss. Spores of the fungus are introduced through small wounds. A small painless blister develops at the point of entry and slowly becomes inflamed and enlarged. Lymph glands in the armpits or elbows may become sore as the fungus spreads. With early diagnosis, this disease can be treated. If left untreated, the disease infects bones, abdominal organs, and unblemished skin. This disease occurs so infrequently that many physicians are unfamiliar with it and occasionally misdiagnose it.

8. *Aspergillus fumigatus is common to most environments. It is found in soil, leaves, grass, and decaying wood. For most people Aspergillus fumigatus is not a problem. The fungus enters the lungs of people with immune system impairments (chemo-therapy, radiation therapy, organ transplant anti-rejection drugs, HIV/AIDs, etc). In very rare cases it causes death. People with immune system impairments should avoid composting fish because the concentration of spores in the air is higher near compost piles.*

9. *Minnesota Pollution Control Agency Solid Waste Management Rules, Parts 7001.0010 through 7035.2875 (primarily 7035.0300 subp. 7. definitions. backyard compost site. and 7035.2835 subp. 1. scope.*

10. *Mathur, SP, et.al. 1982. The Feasibility of Preparing High Quality Composts from Fish Scrap/Peat with Seaweeds or Crab Scraps. Bio Agriculture/Horticulture V. 4. pp 27-38.*

11. *Frederick, L, et.al. 1989. The Compost Solution to Dockside Fish Wastes, Project No. R/NI-12, A/AS-1, A/AS-2. Madison: University of Wisconsin Sea Grant Institute.*

12. *White, DG, et.al. 1989. Composting Salmonid Fish Waste: A Waste Disposal Alternative. Cornell Cooperative Extension Program, Ithaca NY.*