The Compost Solution to Dockside Fish Wastes

UNIVERSITY OF WISCONSIN SEA GRANT INSTITUTE

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INTRODUCTION

Composting is a simple, inexpensive method of creating a valuable soil conditioner from everyday organic wastes. With composting, you can solve the distinctly messy problem of disposing of fish-cleaning waste by transforming it instead into a useful, potentially marketable product.

The composting of fish wastes has a long history in this country. Native Americans traditionally buried fish wastes with wood ashes as a fertilizer in their hills of corn. The first published recipe for composting fish wastes dates back to an 1859 book on organic manures and composts by S.W. Johnson.[1] In recent years, the increasingly unfavorable economics of sanitary landfills has led to a rapid increase in the use of composting as an alternative means of disposing of not only fish wastes but other organic municipal and industrial wastes in the United States.[2-8]

Most conventional commercial systems for disposing of fish wastes require large amounts of material as well as substantial construction and operation costs. However, small-scale composting can provide commercial fishermen, fish processors, charter fishing operations, resort and campground owners, and small coastal municipalities with an economical alternative.

This report is based on a series of laboratory tests and field trials conducted by University of Wisconsin Sea Grant scientists during 1985-87 of the feasibility and reliability of composting fish wastes with other readily available organic materials (wood chips, straw, bark and tree leaves) as a cost-effective and environmentally acceptable option for disposing of fish wastes.[9] The process described here is designed to accommodate varying amounts of fish waste, from less than a bucket to a truckload a day, making it equally suitable for backyard garden composting as well as for large-scale commercial operations.

THE INGREDIENTS

The only two ingredients needed for making fish compost are fish wastes and a bulking agent. The bulking agent serves two purposes: (1) it allows air to enter the pile so bacteria and fungi can work, and (2) it provides a proper carbon-to-nitrogen ratio so the material will compost efficiently without offensive odors. Shredded brush, shredded bark or wood chips satisfy both needs. An additional benefit of using wood waste is that it is abrasive and scratches the fish tissue, providing more exposed surface area and easier entry for the bacteria and fungi that decompose the fish.

Since composting is a recycling process designed to convert waste materials to a useful product, it is preferable that the ingredients be obtained at little or no cost. Some sources of free or low-cost wood-based bulking agents are tree trimmers, city leaf and chip dumping yards, lumber mills, bark from log peelers and planer shavings. Sawdust, leaves and grass clippings pack too tightly when used as the only bulking agent, and they can cause the pile to become anaerobic and foul-smelling. However, these materials also may be incorporated into the compost pile if wood chips or shredded brush are the primary bulking agent. Since this report is designed primarily for people with a fish waste disposal problem, obtaining adequate amounts of fish wastes is assumed not to be a problem. In Wisconsin, it is estimated that the wastes from commercial fish processing operations alone total as much as 3 million pounds per year.[10] A single representative Door County campground monitored for this study generated a minimum of 50 pounds of fish offal per day from May through September, with the volume peaking at 200-300 pounds per day during July and August.[9] Similarly, a private community boat ramp in the same county generated an average of 650 pounds of fish wastes per day during the same May-September period, peaking at 1,250 pounds per day during July.

LOCATING THE COMPOST PILE

The primary consideration for locating the compost pile is convenience. Home gardeners may want to locate the compost pile in a corner of their gardens where the finished compost is handy for use. For larger operations, the site should be accessible to the types of vehicles used to haul the fish waste and bulking agent. In either case, the site should have sufficient topsoil for draining precipitation and excess water in the fish wastes from the compost pile.

Composting operations involving large amounts of fish waste are best located in an isolated or agricultural area. While the purpose of composting is to dispose of fish waste without creating strong odors, large collections of fish offal may occasionally arrive in such a condition that odor may be a problem from the time the material is dumped and mixed until it is covered. The best way to avoid odor problems is to compost the fish waste immediately, carefully constructing the pile as described in this report. Other special considerations for large-scale composting operations include:

- Fish offal and the mixed composting layer are heavy. For small-scale composting by an angler/gardener (under 10 buckets of fish waste a day), the compost can be easily mixed and piled by one person with a shovel and garden fork. On a larger scale (more than 10 buckets or 150-200 pounds of fish offal a day), a tractor and loader (or several people with shovels) may be needed to do the mixing and piling quickly so as to avoid odor problems. In field trials on Washington Island, Wis., only one or two people were needed to handle 100,000 pounds of fish offal over a 6-week period, but the weight of that amount of composting material was too much for a small farm tractor, and the assistance of a payloader was required to pile the mixed offal and turn the compost pile.

- A large amount of water is often present with the fish offal. The area used for mixing the fish waste with bulking agent can become saturated quickly, creating foul odors and handling problems. In a permanent composting operation, it is best if the mixing can be done on a concrete slab with a suitable location for catching leachate, which can be recycled into the pile. Sawdust is an excellent medium for catching leachate at a corner of the slab, and the leachate-soaked sawdust can then be used as if it were fish waste. If the mixing area in a temporary compost pile becomes saturated, cover it with fresh bulking material to prevent odor and fly problems.

- Animals and birds can be attracted to a large composting site, particularly if offal is dropped on the ground during dumping, mixing and piling. The creatures most likely to be attracted are skunks, dogs and gulls (notably, perhaps, cats were not observed at the field trial piles). Prompt and tidy mixing, piling and covering will minimize the attraction of scavengers. If pest problems persist, however, it may be necessary to cover the pile.

THE COMPOSTING PROCESS

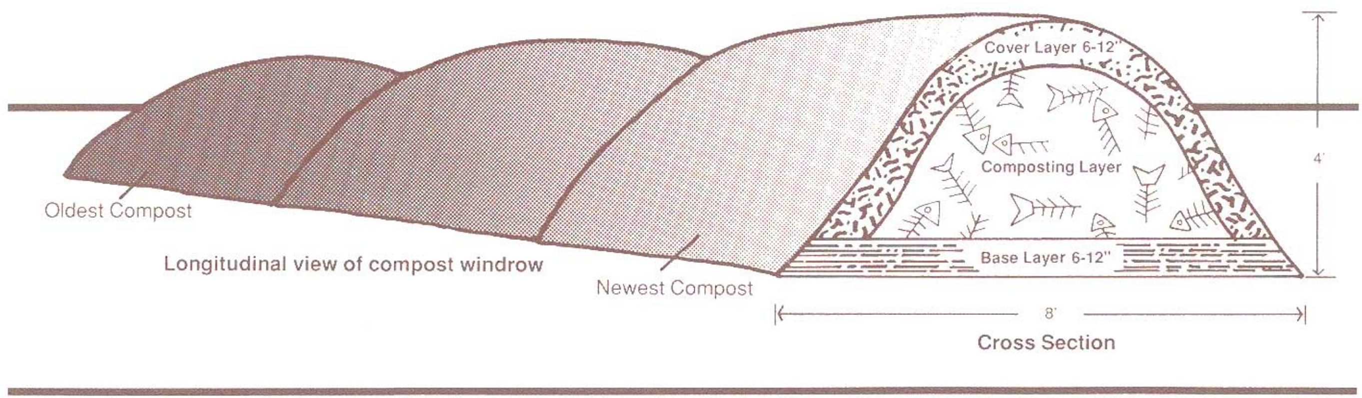
The compost pile is composed of three layers: a base layer, the composting layer and a cover layer (Figure 1). The functions of each layer are:

BASE LAYER

- Drains composting layer (prevents waterlogging)
- Intercepts leachates

COMPOSTING LAYER

- Generates high-temperature, aerobic microbial processes
- Rapidly stabilizes the fish offal (keeps it from becoming putrid) through decomposition and dehydration



Fish Composting Process

- Creates conditions unfavorable to maggots, flies and marauding animals

COVER LAYER
- Intercepts odors and ammonia from composting layer
- Retards heat loss from composting layer
- Allows air into composting layer
- Retards fly and animal entry into composting layer

The base layer is made of a bulking agent (wood waste) placed 6 to 12 inches thick on the ground or on a cement slab where the compost pile is to be located. The base layer should be no more than 6 to 8 feet wide but as long as necessary to accommodate the day's supply of compost material.

The composting layer is composed of fish waste, recycled compost (started or partially composted material, if available) and bulking agent. The recommended ratio is 1 volume of fish waste, 1 volume of recycled compost and 3 volumes of bulking agent (use 1 volume of fish waste and 4 volumes of bulking agent if recycled compost is unavailable). Mix the materials thoroughly. To accomplish this, lay down some bulking agent first, then add fish waste, recycled compost and additional bulking agent, and mix completely. Once the fish is coated with recycled compost and bulking agent, the problems of odors and flies are reduced. In a large-scale operation where machinery for mixing is unavailable, the bulking agent, fish waste and recycled compost may be placed in alternating layers without mixing. The composting layer is then piled on top of the base layer to form a trapezoid (see Figure 1).

The composting layer is then blanketed with 6- to 12-inch-thick cover layer composed of a mixture of bulking agent and recycled compost (if available). The recommended ratio of bulking agent to recycled compost is 1:1. When the compost pile is first formed, various materials can be used in place of recycled compost, such as commercial garden compost, composted manure or soil. Once the pile is established, the first compost can be recycled after it has composted for at least 2 to 3 weeks and its temperature has dropped to air temperature.

Mixing started compost into the cover and composting layers will help the composting process to begin more quickly. The started compost introduces high populations of fungi and bacteria that are particularly good at breaking down the fish, brush and foul-smelling by-products of fish decomposition. Without started compost, these microorganisms will develop in the compost pile anyway, but it will take longer for optimal composting to get under way. If shredded brush is the bulking agent, the use of recycled compost is less important, because shredded brush contains a naturally high population of bacteria and fungi capable of decomposing fish. Harry Hoitink, a professor of plant pathology and soil microbiology at Ohio State University, suggests that, if recycled compost is unavailable for use in the cover layer, sawdust can be mixed with wood chips to create a denser cover to keep odors from escaping and flies from entering the pile.[11]

When preparing to compost fish waste, it is useful to obtain the bulking agent ahead of time. The approximate overall ratios of material needed for the various layers are as follows. If necessary, volumes of recycled compost can be replaced by bulking agents.

BASE LAYER

- Bulking agent—2 volumes

COMPOSTING LAYER

- Shredded or intact fish waste—1 volume

- Bulking agent—3 volumes
- Recycled compost (if available) or bulking agent—1 volume

COVER LAYER

- Bulking agent—2 volumes
- Recycled compost (if available) or bulking agent—2 volumes

This system uses a total of:

- 7-10 volumes of bulking agent
- 3 volumes of recycled compost (if available)
- 1 volume of fish waste

For those who are mixing by weight rather than volume, relatively dry wood-based bulking agents are about four times lighter than fish waste. To mix by weight, therefore, divide brush and compost volumetric ratios by a factor of four. This gives ratios of:

- 1¾ -2½ pounds bulking agent
- ¾ pound recycled compost (if available)
- 1 pound fish waste

PILE DIMENSIONS

Proper pile dimensions are absolutely essential to make the composting process work. If the pile is not layered and constructed according to these dimensions, the offal will not compost. The best compost pile shape is a trapezoidal windrow. The initial pile is constructed no more than 8 feet wide, (narrower if material is limited) by about 4 feet high, and as long as necessary. As more fish waste needs to be composted, the pile can be lengthened by laying new base, composting and cover layers against the previous pile. Of course, each time you add new material to the end of the pile, it must be covered with a cover layer of bulking agent and recycled compost. If gulls or other seabirds discover the pile, it may be necessary to cover the newest end of the pile with lightweight tarpaulins, chicken wire or filter cloth until composting begins.

With the windrow system, the oldest compost is located at one end and the newest material at the other end of the pile. After 2-3 weeks of undisturbed composting, the oldest material can be mixed and recycled as the volume of started compost needed for making new compost becomes larger.

Theoretically, the composting windrow can be extended indefinitely, but it is generally more convenient to form a series of windrows rather than one long windrow when composting large amounts of material. A windrow also should be closed off if the mixing area becomes saturated from the large amount of water often present with fish offal. If that happens, cover the mixing area with sawdust or wood chips, and start a new windrow and mixing area.

COMPOSTING TEMPERATURES

Decomposition of the composting material generates heat. This hastens the composting process, drives off moisture and discourages flies, rodents and gulls. For fish composting, the rapid establishment of high temperatures in the composting layer is particularly important for stabilizing the fish by dehydration and for encouraging the development of nonputrifying fungi. The temperature range that generates the highest quality compost is 140-165 degrees Fahrenheit (°F). This ideal temperature range should be self-maintaining for about 2 weeks while the material is actively composting. As the fish stabilization phase of the composting process nears completion, the temperature of the composting layer will drop.

The most convenient way to measure the temperature within the compost pile is to use a battery-powered digital thermometer with a probe, like those used in deep fryers at fast-food restaurants. If this type of thermometer is unavailable, a long metal thermometer that can be

Table 1: Comparative Fertilizer Value of Representative Fish Waste Composts, Commercial Composts and Commercial Organic Fertilizers †

Organic Soil Conditioner Components	*Composting Time (Months)*	Nitrogen *Total (%)*	Nitrogen *Water Insoluble (%)*	Nitrogen *Water Soluble (%)*	*Available Phosphorus (%)*	*Available Potassium (%)*
Fish Waste Composts						
New Lisbon wood chips	3	1.2	1.1	0.1	0.5	0.5
	7	0.8	0.7	0.1	0.2	0.2
	12	1.3	1.3	0.04	0.3	0.2
Shredded brush / Door County (Wis.) fish waste	7	1.2	1.2	0.03	0.5	0.3
Door County shredded brush / Door County salmon	5	0.6	0.5	0.1	0.1	0.2
Door County shredded bark / Door County salmon	5	0.9	0.8	0.1	0.1	0.2
Commercial Composts						
Wood chips / raw sewage (Beltsville)	≥ 2	1.0	1.0	0.01	—	0.2
Wood chips / digested sewage sludge (Beltsville)	≥ 2	0.6	0.6	0.01	—	0.1
Municipal waste / digested sewage sludge (Lodi)	—	0.8	0.8	0.00	0.03	0.4
Shredded bark / sewage sludge (Paygro™)	—	0.9	0.8	0.1	—	—
Bedding material / cow manure (Fertlife™)	—	1.0	0.8	0.2	1.0	1.0
Worm castings	—	1.6	1.2	0.4	0.1	0.02
Commercial Organic Fertilizers						
Bone meal / dried blood (Garden Food™)	not applicable	5.0	4.0	1.0	5.0	5.0
Dried sewage sludge (Milorganite™)	not applicable	6.0	5.5	0.5	2.0	0.0

†Percentage weight of bagged material; fish waste and municipal waste composts were assumed to contain 50% water.

— Unknown

Table 2: Comparative Heavy Metal and PCB Composition of Representative Fish Waste and Sewage Sludge Composts[1]

Compost Code[2]	Heavy Metals							PCBs[4]
	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	
Fish Waste Composts								
A10–1 (3)	5	0.5	3.8	16	1.8	21	810	< 0.01
A10–3 (7)	4	0.2	1.9	13	1.1	22	120	< 0.01
A10–4 (12)	16	0.4	7.5	34	2.1	11	190	—
A13–1 (7)	9	0.5	3.4	14	2.4	23	300	—
S2–1 (5)	21	1.3	5.4	14	4.8	> 10	60	—
S3–1 (5)	16	0.4	2.3	8	2.4	13	320	—
Sewage Sludge Composts								
BR	—	8	—	300	55	290	770	0.17
BD	—	9	—	250	—	320	1,000	0.25
LD	—	4	—	510	36	600	1,500	—
Sewage Sludge Organic Fertilizer								
Milorganite™	< 33	35	5,000	390	141	276	1,000	—
U.S. EPA Limits[3]	—	10	1,000	1,000	200	700	2,000	10

[1] All measurements in parts per million (micrograms per gram oven-dried weight of compost).

[2] See Table 3 for code amplification. Numbers in parentheses are composting times in months.

[3] Rules for Land Application of Sludge and Residuals, chap. 367, Department of Environmental Protection, April 1985, p. 13.

[4] Polychlorinated Biphenyls

— Not tested or not applicable

Table 3: Compost Comparison Code Descriptions and Ratios of Constituents

Compost Code	*Age (months)*	*Constituents*	*Appx. Ratio (w/w)**
A10–1	3	aspen & birch chips / fish waste	1.4:1
A10–3	7	aspen & birch chips / fish waste	1:1
A10–4	12	aspen & birch chips / fish waste	1:1
A13–1	7	shredded brush / commercial fish waste	1:1
S2–1	5	shredded brush / salmon waste	1:1
S3–1	5	shredded bark / salmon waste	1:1
BR	>2	wood chips / raw sewage sludge (Beltsville)	—
BD	>2	wood chips / digested sewage sludge (Beltsville)	—
LD	—	municipal waste / digested sewage sludge (Lodi)	—

* A weight–to–weight (w/w) ratio of 1:1 relates approximately to a volume ratio of 4:1 (v/v).
— not available

inserted into the composting layer and the temperature read with a dial on the end also works well. Regardless of the type of thermometer used, it should have a temperature range of 70-180°F.

The temperature of the composting layer is related to the size and shape of the pile. If the pile is too flat, the temperature in the composting layer will not get high enough for the material to compost properly; the fish will ferment instead, resulting in foul odors and leachates. If this occurs, remake the compost pile according to the dimensions described earlier. Construct a new base layer of fresh bulking agent, use the entire old pile as the composting layer, and form a new cover of bulking agent and recycled compost.

If the pile is too wide and too high, the temperatures may rise and stay well above 165°F. Prolonged periods of such high temperatures kill bacteria and fungi, which are beneficial for compost maturation and the suppression of plant diseases when the compost is used. Also, sustained temperatures above 165°F will tend to drive off moisture too rapidly, and the compost may have to be watered so that the material can finish composting. Turning and mixing the pile after it has composted about 2 weeks will usually cure this problem. If the pile is made much higher than 4 feet and wider than 8 feet, the entry of air into the center of the pile will be a problem, and the bacteria and fungi won't get enough air to decompose the fish properly.

USE OF FILTER CLOTH IN COMPOSTING

In the trial compost piles constructed at University of Wisconsin experimental farms at Arlington and Sturgeon Bay, gardener's filter cloth was used between the layers of the pile. The original purpose of the filter cloth was to separate the various layers for study purposes. However, filter cloth can also serve several useful functions in small composting operations. Filter cloth between the layers helps maintain the shape and structure of the pile and prevents the material from being scattered about. It also retards the entry of flies and animals, provided the filter cloth is weighted with rocks around the edges to prevent animals from digging under it. Chicken wire placed over the entire pile further discourages the entry of animals.

In larger composting operations where the pile will be turned with a tractor and bucket or a payloader, filter cloth should not be used between layers. The weight of the cover and composting layers makes it difficult to remove the filter cloth when the pile needs to be turned, and the filter cloth will become entangled in the machinery.

TURNING THE COMPOST PILE

After the layered compost pile has been built, it should be allowed to compost undisturbed until the temperature in the composting layer approaches that of the surrounding air (at least 2-3 weeks). By this time, the fish offal will be stabilized and even the large bones will be partially decomposed, although the bulking agent will not be broken down yet.

After this first stage, which essentially makes the fish offal inoffensive, the pile can be opened safely. If compost is needed for recycling in the composting layer of a new compost pile, the old material can be turned, mixed and used. The recycled compost used in the cover layer should be at least a month old, however.

With small amounts of material, the compost maturation process can be hastened by placing the 2- to 3-week-old compost in a rotating drum where it can be moistened and turned 2-3 times a week. Rotating drums are available from gardening supply centers, or they can be constructed from 55-gallon metal drums. The entire composting operation can be performed successfully using a rotating drum, but it is important to retain the three-layer approach for the initial composting phase, including leaving the compost undisturbed during that phase. The cover layer should be separated from the composting layer with cover cloth to allow reuse of the cover until odor suppression is no longer an issue. If you have plenty of started compost for cover, don't need to use the started compost and have enough space available, the pile can be allowed to sit until fall, at which time the pile should be turned and mixed so the nutrient content will be uniform and the composting bacteria and fungi are redistributed. Depending on the amount of material, the pile can be turned with a garden fork, a tractor and loader, or a payloader. After the material has been turned, it should be repiled in windrows and allowed to compost until spring.

In the spring, the material can be used as enriched mulch, shredded through a compost or soil shredder to be used as compost, or allowed to sit until the remaining brush has broken down, depending upon the need for compost and the amount of space available. The amount of time necessary for the wood chips to decompose varies with the type of wood used and the size of the chips. In a compost prepared from mixed hardwood and softwood brush at the Sturgeon Bay Experimental Farm, it took 18 months to completely compost the wood. If the material is allowed to compost another year, the 2-year-old compost can be shredded, screened and used as a potting mix in greenhouses, for houseplants or as seed starter.

USING THE COMPOST

Composts are used generally as soil conditioners to promote soil aggregation, improve the soil water retention capacity and encourage the more extensive development of root systems. Compost also improves soil structure by adding organic matter, which encourages the growth of microorganisms and earthworms important to healthy plant growth. The breakdown of organic matter results in the slow release of phosphorus and nitrogen, making these elements available at a rate that can be used by plants.

Used as a mulch, compost is applied to the soil surface to conserve moisture, hold down weeds and ultimately improve the soil structure. A mulch acts as an insulating blanket, keeping the soil temperature cooler in the summer and preventing the loss of soil moisture from winds and the hot, drying sun. Compost mulch placed around plants before winter can prevent frost heaving and/or winter kill.

CHEMICAL ANALYSES OF FISH COMPOST

The experimental fish compost was made from Lake Michigan fish offal according to the process described in this report by UW Sea Grant scientists during the summers of 1985 and 1986. It was tested under both greenhouse and field conditions on lettuce, beets and tomatoes to be certain that nutrients and trace minerals were absorbed and incorporated into the plants.

The experimental fish compost was also tested for its fertilizer value and found to be comparable to commercial composts currently on the market, all of which had considerably lower nitrogen, phosphorus and potassium values than commercial organic fertilizers (Table 1). Heavy metals were not present in the experimental compost in concentrations harmful to plants, and the heavy metal concentrations were significantly lower than in sewage sludge composts and fertilizers (Table 2).

Lake Michigan fish are contaminated with varying amounts of polychlorinated biphenyls (PCBs), and this caused concern that PCBs might be transferred from the fish to the compost and, consequently, to plants grown in the compost. In the fall of 1986, compost was made from salmon carcasses obtained from the Wisconsin Department of Natural Resources' egg-gathering facility near Sturgeon Bay, Wis. Edible-portion PCB levels in the fish ranged from 0.8 to 5 parts per million (ppm), though whole-fish PCB levels are generally slightly higher. PCBs were not detectable (detection level: 0.01 ppm) in either the compost made from these fish or the plants grown in that compost (Table 2).

GREENHOUSE APPLICATIONS

When incorporated in the soil, a 1-inch to 3-inch compost layer is added once or twice a year and turned into the top 4 inches of soil. Fish compost makes an excellent potting mixture for greenhouse or houseplant use because it releases nutrients slowly, making them available to plants for an extended period of time. In greenhouse experiments at the University of Wisconsin-Madison, lettuce, beets and tomatoes were grown in various mixtures of fish compost and sand. Mixtures ranging from 25 percent compost and 75 percent sand up to 75 percent compost and 25 percent sand proved most satisfactory. Experiments with chrysanthemums showed that fish waste composts also can be used as a replacement for organic bulking agents in potting soil mixtures.

REFERENCES

1. S.W. Johnson. 1859. *Essays on Peat, Muck, and Commercial Manures.* Hartford: Brown and Gross Publishers.

2. S.P. Mathur, J.-Y. Daigle, J.L. Brooks, M. Lévesque and J. Arsenault. 1988. "Avoiding Disposal Problems: Composting Seafood Wastes." *BioCycle* 29(8):44-49.

3. N. Goldstein. 1985. "Sewage Sludge Composting Facilities on the Rise." *BioCycle* 26(8):19-20.

4. J.C. Hay, J.C. Caballero, J.R. Livingston and R.W. Horvath. 1985. "Two-Step Composting in L.A. County." *BioCycle* 26(8):38-40, 42-44.

5. G. Vallini, M.L. Bianchin, A. Pera and M. DeBertoldi. 1984. "Composting Agro-Industrial By-Products." *BioCycle* 25(4):43-46.

6. R. Jodice, R. Barberis, M. Consiglio and E. Roletto. 1984. "Composting Bark and Agro-Industrial Sludges." *BioCycle* 25(2):36-38.

7. L.F. Diaz and C.G. Golueke. 1984. "Co-Composting Refuse and Sludge." *BioCycle* 25(1):21-25.

8. J.E. Alpert, E. Epstein and R.J. Veillette. 1984. "Keeping the Peace with Neighbors." *BioCycle* 23(5):50-53.

9. R.F. Harris, L.A. Peterson and L.L. Frederick. 1986. "Composting Fishery Waste," project no. R/NI-12. *In: UW Sea Grant Institute 1986-88 Proposal to the National Sea Grant College Program for Continuing Sea Grant Support,* vol. 2, pp. 399-408.

10. D.A. Stuiber, R.L. Lindsay, S. Smith, J. Sommercorn, R. Vilstrup and M. Kummerow. 1977. *Handling Fishery Wastes and By-Products*. Madison: UW Sea Grant Institute.

11. H.A.J. Hoitink and G.A. Kuter. 1986. "Effects of composts in growth media on soil-borne pathogens." In: *The Role of Organic Matter in Modern Agriculture*, Y. Chen and Y. Avnimelech, eds., pp. 289-306. Dordrecht, Netherlands: Martilnus Nijhoff Publishers.

12. C.G. Golueke. 1977. *Biological Reclamation of Solid Waste*. Emmanus: Rodale Press.

13. J. Minnich. 1982. *The Wisconsin Garden Guide*. Madison: Staton and Lee Publishers, Inc.

14. "Organic Gardening" magazine staff. 1982. *The Encyclopedia of Organic Gardening*. Emmanus: Rodale Press.

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