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Evaluation of Compost Toilets

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EVALUATION OF COMPOST TOILETS

by

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Compost Toilet Evaluation

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INTRODUCTION

Human waste disposal from vault- and pit-type toilets has become a major recreation management problem. These toilets are used at certain recreation sites because of water shortages, ground water problems, remoteness of site and/or type of recreational experience designed for. Most methods employed to deal with the problem include the handling and transporting of large amounts of wastes. This handling and transporting activity has resulted in accidental spills and is always an obnoxious task to clean up. Therefore, an attractive alternative is the reduction of the waste mass into a humas end product at the site through the composting method.

The objective of this project was to investigate presently installed compost toilets at selected sites and to determine whether the Forest Service should consider composting as a waste disposal method on a wide-scale basis. The investigation also considered the ecology, management, and cost effectiveness of these composters, which are classified as either continuous-type or bin units.

THE COMPOST PROCESS AND TYPES OF COMPOSTERS

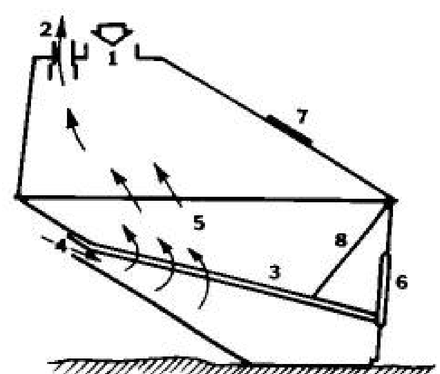
Composting is the controlled decomposition of organic material into a humas end product. Composting takes place by either of two processes: (a) Aerobic decomposition, or (b) anaerobic fermentation. In these processes, bacteria, fungi, molds, and other saprophytic organisms feed upon organic materials such as vegetable matter, animal manure, night-soil, and other organic refuse, and convert the wastes to a more stable form.

Aerobic composting (in presence of oxygen) is efficient, earthy smelling, and can generate high enough temperatures to kill its own microbial population, including enteric pathogens, and is favored over anaerobic composting. Anaerobic composting (in absence of oxygen) is slow, produces putrid odors such as sulfur and methane, and fails to eliminate all of the microbial population.

The Continuous Composting Toilet

Waste treatment by a continuous composting toilet relies on the natural process of decomposition, which requires 1 to 2 years for complete treatment. The process takes place in a large chamber (fig. 1) located beneath the toilet seat. This chamber is generally installed on a slope so that the waste slowly moves to a bottom removal area. Other chambers are heat assisted, some with built-in stirring devices. Wastes are combined with bark, or other compost material, to form a mass that can be reduced into humas, and continually undergoes decomposition until eventually disposed of.

Wastes are significantly reduced in volume during composting so that the final amount to be disposed of is relatively small. For example, only 8 cubic feet of compost is removed annually from a continuous composter serving 15 users daily throughout a summer season. Treatment of wastes in a properly maintained continuous composter has shown to effectively eliminate enteric pathogens, producing an aesthetically agreeable finished product. Since the process takes place in a closed system, there is usually no danger of untreated wastes reaching ground or surface water.



The arrows indicate air flow through the toilet.

KEY:
1. **Chute**
2. **Vent pipe with fan**
3. **Air duct**
4. **Air intake**
5. **Composting mass**
6. **Emptying hatch**
7. **Inspection hatch**
8. **Blocking plate.**

Width	**41.3 in (105 cm)**
Depth	**64.6 in (164 cm)**
Height	**51.2 in (130 cm)**
Vent pipe diameter	**4.3 in (11 cm)**

Figure 1. Diagram of a continuous composter.

The Bin Composter

Waste treatment by bin composting is a relatively new idea designed by the Northeastern Forest Experiment Station (Backcountry Research Project), Durham, New Hampshire. This approach (fig. 2) relies on trained personnel to provide conditions for rapid decomposition of the waste into humas. Ground hardwood bark or similar cellulose matter is combined with the waste in correct proportions to form an ideal mass for composting. Complete treatment requires approximately 2 weeks, at which time the finished compost is recycled through the process as a drying and bulking agent or shallow buried.

All wastes are collected in a leakproof container located under the seat of a conventional vault toilet. This containerized waste is removed from the toilet and transferred to an adjacent bin composter. During the transfer process, the waste is mixed with a suitable composting material in the collection container. When the mixed waste is deposited in the bin, a "compost run" begins, the addition of waste stops, the bin contents are mixed and mounded, and then left to compost for approximately 7 days. During this time, the temperature of the interior of the mound is monitored by a thermometer probe placed in the mound. Temperatures are recorded once or twice a day.

The interior mound temperature must be maintained at 60^{0} to 70^{0} C for at least 36 hours. These temperatures occur at the thermalphilic stage of composting, which usually begins 3 to 4 days into the compost run and starts to decline after 7 or 8 days. These temperatures are high enough to scorch your hand and result in steaming vapors in the winter. The microorganisms in the mound generate the composting activity during the thermalphilic stage.

Figure 2.—The bin composter.

When the temperature begins to drop, the bin contents are turned inside out so that the outside parts are moved into the center of the mound. The mound then heats up to the thermalphilic levels again, and ideally, after another 7 or 8 days, the compost run will be over. The compost throughout the mound should appear somewhat dry, grayish in color, have an earthy smell, and possibly have evidence of fungus growth. Should there be any question as to whether the entire mound has composted, then a second turning may be advised.

Upon completion of a compost run, the end product may be shallow buried or may be used as a compost material in one or more runs. If used as compost material, the compost must be spread out, dried, and covered between runs. If shallow buried, a location should be selected at least 200 feet from the nearest water source to prevent nutrient loading.

TEST PROGRAM AND SITES

Sites were selected where observations and testing could be performed on composters in use for at least 2 consecutive years and at different geographical and climatic zones. With the above considerations, 33 installed systems at 5 sites were selected across the United States where ecological, managerial, and cost data might be obtained. Criteria for site selection included sites that could be found near sea level to 5,000 feet in all types of weather conditions, i.e., rain, snow, dry heat, sun, and foggy areas. Although these factors cannot be controlled, their presence can greatly influence the operation of both types of composters.

Selected compost sites and number and type of composters are as follows:

Site	*No. and type of composters*
Ottawa National Forest Sylvania Recreation Area Michigan	**19–bin**
Cleveland National Forest El Cariso Ranger District California	**2–continuous**
Angeles National Forest Mt. Baldy ***(private residence)*** **California**	**1–continuous**

—Continued

Appalachian Mountain Club Gorham, New Hampshire	6–bin 2–continuous
Farallones Institute Occidental, California	1–bin 2–continuous

Ecological Considerations

Ecological information involved the collection of compost samples that were considered to be as close to the end product of the composters as possible. These samples were chemically and biologically analyzed for those items contained in table 1.

Table 1. Test items

Coliform MPN/100 ml
Fecal Coliform MPN/100 ml
Total Coliforms, %
Total Solids, %
Moisture, %
Volatile Solids, %
Ash, %
COD (chemical oxygen demand), mg/1
PH
Temperature

Test methods and procedures were those outlined in the Environmental Protection Agency's "Manual of Methods for Chemical Analysis of Waste and Water." Coliform analysis was performed by the "most probable number"(MPN) method in a lauryl-sulphate medium. This method was preferred over the lactose media because lauryl inhibits the growth of other bacteria but not the development of coliform.

Pathogen tests were not performed because:

- It is not practical to test for all possible organisms and the National Sanitation Foundation maintains, in cooperation with compost toilet manufacturers, that if fecal coliform levels are low in the solid end product, then it is reasonable to expect that pathogen levels will also be low; and fecal coliform is an acceptable indicator organism.
- Previous studies indicate that if the desired temperature (60^{o}-70^{o} C) is reached during a compost run for 36 hours within a specific range of conditions, most of the pathogen content will be destroyed.
- Elaborate testing is required to identify all the human types and numbers of pathogen content within a sample, even if any existed.

In addition to gathering samples for analysis, observations were made on the condition of the compost mound. Such observations included deleterious materials, mounding, flies, odor, and liquid buildup.

Management Considerations

Proper management is perceived to be of the utmost importance, for no matter how well conceived, any system depends upon responsible management and administration to be successful. Management considerations involved the gathering of information on the amount of maintenance time invested annually, caretaker administration and operation (or lack of), quality control assurance, record keeping, and training.

Cost Analysis

The cost for effective disposal of waste can vary greatly depending on the location and method used. One method may be relatively inexpensive while another involves hundreds of dollars. Tables 2 and 3 are cost estimates for initial capital investments for the two types of compost systems (bin and continuous). The tables are not intended to be a comparison of the two systems, but rather as cost indicators.

TEST RESULTS AND OBSERVATIONS

Ecological Considerations

Table 4 presents a summary of the biological and chemical analysis test results. The following points are based on the results and observations of the sites. One particular observation of interest was the determination as to whether the mound was anaerobic or aerobic digesting. To establish a proper expression for the degree of composting is difficult, however, a subjective evaluation of odor and appearance of the final end product does constitute a valuable guide as to the condition of the materials in the compost process.

1. In 13 of the 19 bin composters examined at the Ottawa National Forest, Sylvania Recreation Area, the composters were anaerobic digesting. This is suggested by the putrid smell of sulfur and ammonia gasses emitting from the bins and in the surrounding area where compost

Table 2. Cost analysis considerations of bin composter

	Unit costs ($)	Cost ($) of site usage level: 50-150 Gal waste/season (or 330-1000 visitors)	150-300 Gal waste/season (or 1000-2000 visitors)	300-450 Gal waste/season (or 2000-3000 visitors)
I. INITIAL CAPITAL INVESTMENT				
Batch composter unit (including construction)	150.00/unit	150.00	150.00	150.00–300.00
Transportation/installation of above (1 four-mi round trip @ $2.65/hr)	5.30/unit	5.30	5.30	5.30–10.60
Outhouse with pit or vault (including stool assembly)	535.00–2,000/outhouse	535.00	535.00	535.00
TOTAL		690.30	690.30	690.30–845.60
II. OPERATIONAL EXPENSES				
Bark bulking agent (@ 7 lb bark–1 gal waste)	1.00/30 lb	11.70–35.00	35.00	35.00
Transportation of above to trailhead (50 mi @ 0.17/mi)	8.50/truckload	8.50	8.50	8.50
Packing bark into remote site (1 four-mi round trip @ $2.65/hr)	5.30/50 lb	32.90–98.70	98.70–197.40	197.40–296.10
Labor for composting operation (1 hr/10 gal waste)	2.65/hr	13.25–39.75	39.75–79.50	79.50–119.25
TOTAL		66.35–181.95	181.95–320.40	320.40–458.85

III. MANAGEMENT CONSTRAINTS

Labor-skill/intensive; system requiring frequent contact with raw wastes raising risk of possible contamination of personnel; managers may find the task of packing large volumes of bark unappealing.

IV. NONMONETARY BENEFITS

Batch unit can be visually inconspicuous; requires minimal site manipulation for installation; completion of compost cycle well defined; mixture of privy wastes with bark largely eliminates unpleasant odors; bark will be recycled, reducing the volume of fresh bark needed.

Table 3. Cost analysis considerations of continuous composter

	Unit costs ($)	Cost ($) by site usage level: 50-250 Gal waste/yr (or 330-1650 visitors)	250-500 Gal waste/yr (or 1650-3300 visitors)
I. INITIAL CAPITAL INVESTMENT			
Soltran unit (including construction)	3000.00/unit	3000.00	3000.00–6000.00
Transportation of above– Helicopter ferrying charge = $210.00 (150 mi round trip–1.9 hr @ $110/hr)	210.00/site	210.00	210.00
Four helicopter trips of 0.25 hr each @ $165/hr	165.00/unit	165.00	165.00–330.00
		TOTAL 3375.00	3375.00–6540.00
II. OPERATIONAL EXPENSES			
Bark bulking agent (02.5 lb bark–1 gal waste)	1.00/30 lb	4.20–16.70	16.70–33.30
Transportation of above to trailhead (50 mi @ 0.17/mi)	8.50/truckload	8.50	8.50
Packing bark into remote site (1 4-mi round trip @ $2.65/hr)	5.30/50 lb	12.20–48.80	48.80–97.60
Labor for composting operation (0.5 hr/wk @ $2.65/hr for 10-wk summer)	2.65/unit biweekly	13.25	13.25–26.50
		TOTAL 38.15–87.25	87.25–165.90

III. MANAGEMENT CONSTRAINTS–SOLTRAN

Site must have good sun exposure; point at which the continuous composting cycle is completed is not well defined, making it difficult to develop a schedule of disposal and to train the site manager; the compost chamber is flammable; the building is conspicuous.

IV. NONMONETARY BENEFITS

Little or no odor in outhouse, site manager does not handle raw wastes, little maintenance involved, vandal-proof building with rugged solar glazing.

NOTE: A Soltran is amortized at 20 yr.

Table 4. Test results.

Site	Sampling Date	Composter Type [1]	Total Coliforms/ml	Coliforms [3] MPN/100 ml	Fecal Coliforms MPN/100 ml	Total Solids (%)	Volatile Solids (%)	COD, mg /1	Ash (%)	Moisture Content % by weight	Highest Temperature of Mound (°C)	pH
APPLACHIAN MOUNTAIN CLUB												
Gentian Pond	7/20/79	(C)	$33(10)^2$	$\geq$ 2400	$\geq$ 2400	71.25	91.85	285,200	8.15	28.75	30.1	6.5
	8/21/80	(C)	$130(10)^2$	$>$ 2400	1600	50.57	84.42	360,000	15.58	49.43	38.0	7.8
Speck Pond	7/26/79	(B)	$34(10)^2$	$\geq$ 2400	$\geq$ 2400	67.52	87.44	317,800	12.56	32.48	62.0	7.9
	7/25/79	(B)	$210(10)^1$	$\geq$ 2400	$\geq$ 2400	72.73	86.53	213,500	13.67	27.27	62.0	7.1
Gale Head	8/21/80	(B)	60 [2]	46	46	33.26	81.16	212,000	18.84	66.74	12.8	8.0
	8/21/80	(B)	$31(10)^2$	$\geq$ 2400	$\geq$ 2400	25.25	60.06	67,000	39.94	74.72	53.5	7.3
Zealand Hut *(Site equipped with two bins)*	7/24/79	(B)	$41(10)^2$	$\geq$ 2400	$\geq$ 2400	60.40	76.85	678,400	13.15	39.60	55.0	7.5
	7/24/79	(B)	$110(10)^2$	$\geq$ 2400	$\geq$ 2400	64.42	89.0	373,400	11.0	37.58	29.4	7.0
Mizpah Spring	7/24/79	(B)	$260(10)^1$	$\geq$ 2400	$\geq$ 2400	61.95	90.55	189,680	9.45	38.05	44.0	6.6
	7/24/79	(C)	$140(10)^2$	$\geq$ 2400	$\geq$ 2400	78.46	83.66	223,700	16.34	21.54	36.0	6.5
	8/21/80	(C)	$110(10)^3$	$\geq$ 2400	$\geq$ 2400	49.63	78.40	210,000	21.60	50.37	20.0	7.2
	8/21/80	(B)	$130(10)^2$	$\geq$ 2400	$\geq$ 2400	35.79	89.21	98,900	10.79	54.21	18.0	6.8
Liberty Springs	7/20/79	(B)	$164(10)^2$	$\geq$ 2400	$\geq$ 2400	61.10	86.66	198,800	13.34	38.90	72.2	8.3
	8/21/80	(B)	$43(10)^4$	$\geq$ 2400	$\geq$ 2400	59.78	43.50	185,000	56.10	40.22	55.0	8.0
FARALLONES INSTITUTE												
Visitors Center	4/27/79	(C)	$110(10)^3$	$\geq$ 2400	$\geq$ 2400	31.97	83.97	360,400	16.11	68.03	21.1	7.5
House	4/27/79	(C)	$59(10)^2$	$\geq$ 2400	$\geq$ 2400	24.83	85.27	516,000	14.73	75.17	21.1	7.5
Kitchen	4/27/79	(B)	$130(10)^3$	$\geq$ 2400	$\geq$ 2400	32.78	82.14	314,000	17.86	67.22	37.78	6.9

[1] (B)—Batch; (C)—Continuous.

[2] Sample taken from drying rack.

[3] 2400 is the highest number obtainable using the lauryl-sulphate medium method; any numbers exceeding 2400 are recorded as 2400.

Table 4. —Continued

Site	Sampling Date	Composter [1] Type	Total Coliforms/ml	Coliforms [2] MPN/100 ml	Fecal Coliforms MPN/100 ml	Total Solids (%)	Volatile Solids (%)	COD, mg/1	Ash (%)	Moisture Content % by weight	Highest Temperature of Mound (°C)	pH
CLEVELAND NATIONAL FOREST												
Elsinore—Street Site	1/18/79	(C)	$71(10)^4$	⩾ 2400	⩾ 2400	17.37	76.88	1,280	23.12	82.63	20	7.5
	8/24/79	(C)	$280(10)^4$	⩾ 2400	⩾ 2400	21.28	69.10	84,520	30.90	78.72	20	7.1
	7/18/80	(C)	$35(10)^3$	⩾ 2400	⩾ 2400	28.70	87.76	15,620	12.24	71.30	20	6.4
Blue Jay	8/24/79	(C)	$19(10)^2$	⩾ 2400	⩾ 2400	10.90	68.30	207,460	31.70	89.10	21.1	7.1
	7/18/80	(C)	$160(10)^2$	⩾ 2400	⩾ 2400	17.4	51.30	12,300	48.70	82.60	21.1	7.1
OTTAWA NATIONAL FOREST *(NOTE: Of the 13 sites examined, only 3 were tested. See the test results for an explanation.)*												
Clark Lake	8/2/79	(B)	$35(10)^4$	⩾ 2400	⩾ 2400	54.44	87.86	406,700	12.14	45.56	25	7.1
Pine Campground	8/16/80	(B)	$64(10)^3$	⩾ 2400	⩾ 2400	10.83	84.36	180,000	15.64	89.17	20	7.5
Balsam Campground	8/16/80	(B)	$110(10)^5$	⩾ 2400	⩾ 2400	9.33	83.60	230,000	16.40	90.67	16.7	8.4
ANGELES NATIONAL FOREST												
Mt. Baldy	4/5/79	(C)	$64(10)^5$	⩾ 2400	⩾ 2400	27.78	88.34	242,500	11.86	72.22	21.1	7.6
	9/12/80	(C)	$44(10)^3$	⩾ 2400	⩾ 2400	44.62	73.51	261,400	26.49	55.38	21.1	6.9

1/ (B)—Batch; (C)—Continuous.

2/ 2400 is the highest number obtainable using the lauryl-sulphate medium method; any numbers exceeding 2400 are recorded as 2400.

had been disposed of. Within the bins, maggots and other parasites propagated throughout the mounds. In some bins, the compost material was fizzing and bubbling sulfur gasses on the top layer when disturbed. The material in the bins was not mounded but flat and was cold to the touch or at ambient temperature. The material consisted of a solid compact top layer with a liquid layer on the bottom and gasses in-between. Because all the composters appeared to be anaerobic digesting, only three samples were gathered for evaluation.

Interviews with the caretakers indicated that their training as a compost caretaker was based on reading a Forest Service manual and oral instruction.

2. All continuous compost sites examined were both anaerobic and aerobic digesting. Aerobic digestion was noted at the top and middle of the mounds and was indicated by the texture of the mound, earthy aroma, and warmth of the mound. Anaerobic digestion was observed at the bottom of the mound and in the liquid accumulator of the composter. Anaerobic digestion was noted due to the sulfur odors emitted and uncomposted material.

All continuous compost sites had mounds at, or within 12 inches of, the riser and had a covering of various fungi, mold, and in some cases mushroom growth. There were indications that blackwater had been, or was, leaking from the access door of the composter or where sections of the composter had been bolted together (fig. 3). In addition, all sites had blackwater accumulation at or near the capacity of the system. Caretakers indicated liquid was being removed from the composters every 2 to 3 months during a season (fig. 4).

One continuous composter had indications that a channel had been molded through the mound from top to bottom causing fresh deposits to slide from the top to the bottom into the liquid accumulator. The mound surrounding the channel appeared dry, compacted, and cold. In addition, the caretaker stated the composter was accumulating over 80 gallons of blackwater every 2 months (the liquid accumulator capacity is approximately 80 gallons).

3. With exception of one bin composter, all composters had coliform counts above that recommended for end products. The National Sanitation Foundation Joint Committee on Wastewater Technology established that the end product should contain 200 fecal coliform per gram or less with a moisture content not to exceed 75 percent by weight. This indicates that regardless of the condition of the composter (aerobic or anaerobic) the composting process had not eliminated the fecal and total coliform to a safe level and therefore may not be eliminating the dangerous pathogens.

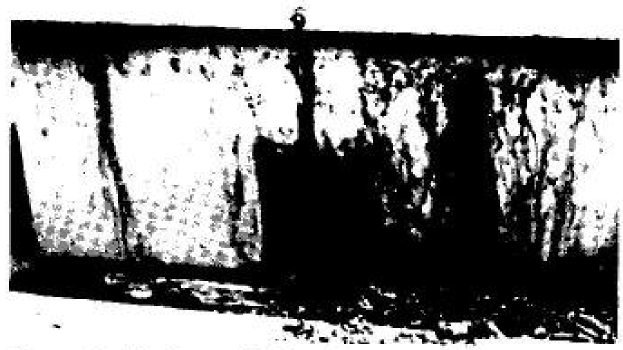


Figure 3.—Blackwater leaking from continuous composter.

Figure 4.—Sample of blackwater removed from continuous composter.

4. For all sites, both bin and continuous composters, the low ash content suggests that the waste was not fully digested and that the material should be allowed to continue composting or should be dried and reused in another compost run.

5. All bin composters examined under the jurisdiction of the Appalachian Mountain Club appeared to be aerobic. This was evident by good mounding; its texture having a uniform grayish color, earthy smell, no liquid accumulation or puddling, and excellent temperature profiles. Caretakers interviewed stated that their duties adhered to

a strict outlined procedure and record keeping based on a labor-skill training program.

6. Very little deleterious material was found in any of the composters; the most predominant being small plastic bags and tampon inserts.

7. Flying insects were observed at all sites, but were not in abundance to be disturbing. At all composters on the Ottawa National Forest, the lids to the bins were not sealed and it was not surprising that most mounds had maggots and breeding insects. Interviews with the caretakers indicated that the abundance of flying insects was dependent on weather, season, and condition of the mounds. Insects were usually more abundant during initial mixing, anaerobic digesting, and because bin lids were not sealed or left uncovered and continuous composter riser lids left open.

Management Considerations

With exception of the Appalachian Mountain Club, no administering agency had any records concerning the management and administration of the composters. Further, there was no evidence that there was a program for training, checks and balances for compost consistency, nor quality control. In brief, it appeared that the total responsibility of composting was left entirely to technicians, usually a one to two person crew, who had received some oral instructions and had been provided with a manual on composting. In one case, the entire compost process was left to one individual who had no prior experience in sanitation.

No records existed concerning individual composters for such items as temperature profile, amount of bark or similar compost material used for each run, visitor usage, and the amount of time for individual compost runs. Further, all composters managed under the above poor administration were identified as anaerobic digesting and the caretakers were unaware that such a condition existed. The caretakers were performing "so-called" composting for 1 to 2 weeks without the benefit of a temperature profile and were merely disposing of the blackwater and waste when it "appeared" composted. Without proper records they could not know that the compost was ready for turning, removal, or disposal.

In the case of the continuous composters, all managers indicated that they had little experience in administering such an operation. None seemed to be aware that aerobic and anaerobic digestion was occurring, why the excess liquid accumulation, nor that liquid accumulation raised the odor problem. Such conditions could cause water nutrient loading, transfer contagion by animals, and health risks to an operator.

Cost Analysis

Tables 2 and 3 contain cost estimates for the investment and operation of composters. As to an actual cost analysis, no such analysis has been undertaken by the administrators of the composters examined. Managers did have previous reports and associated costs of composting, but nothing current. Therefore, it is impossible to comment as to whether these composters are being cost-effective compared to other waste disposal methods.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. This limited study showed that bin composting produced higher temperatures that resulted in a greater reduction of organic material than continuous composting.

2. Neither bin nor continuous composting was capable of reducing the fecal coliform down to recommended limits.

3. Responsible administration is usually consistent with aerobic composting and the absence of (or poor) administration resulted in anaerobic composting.

4. Most ash contents and COD were high which indicates that more composting could be achieved.

Even though none of the important parameters were met in the two types of composters, the practical side of the method should be discussed. If the waste after composting can be shallow buried at or near the site then the manager has resolved the waste disposal problem. If all this results in no detrimental health effects to the public then perhaps the system of composting can be considered in selected areas.

Recommendations

If compost toilets are considered as the best alternative to a given situation, then the following guidelines are recommended:

1. For bin composters, implement a program according to the 1978 publication, "A Manual for Bin Composting," USDA Forest Service, Northeastern Forest Experiment Station, Broomall, PA.

2. For continuous composters adhere strictly to the

manufacturer's operation manual paying particular attention to troubleshooting of liquid accumulation, compacting, channeling, drying, flying insects, mixing, and odors.

3. Apply stringent, consistent administration within defined parameters for monitoring, quality control, training, and record keeping of individual composters as outlined in the above-mentioned manual or the 1978 operation manual, "The Composting Alternative," Appalachian Mountain Club, Gorham, N.H.

4. Periodic laboratory tests should be performed on items as listed in table 1 with specific attention being given to fecal coliform, moisture, pH, and ash content. Records should be kept on all parameters so that background data are accumulated.

Further information on compost toilets is being published in January or February 1981 on a study, "Rural Wastewater Disposal Alternatives," prepared by the Department of Health Services, Office of Appropriate Technology, State of California. This 18-month study involved 39 active systems and will be available from:

Steven Hathaway
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26 West St. Clair
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