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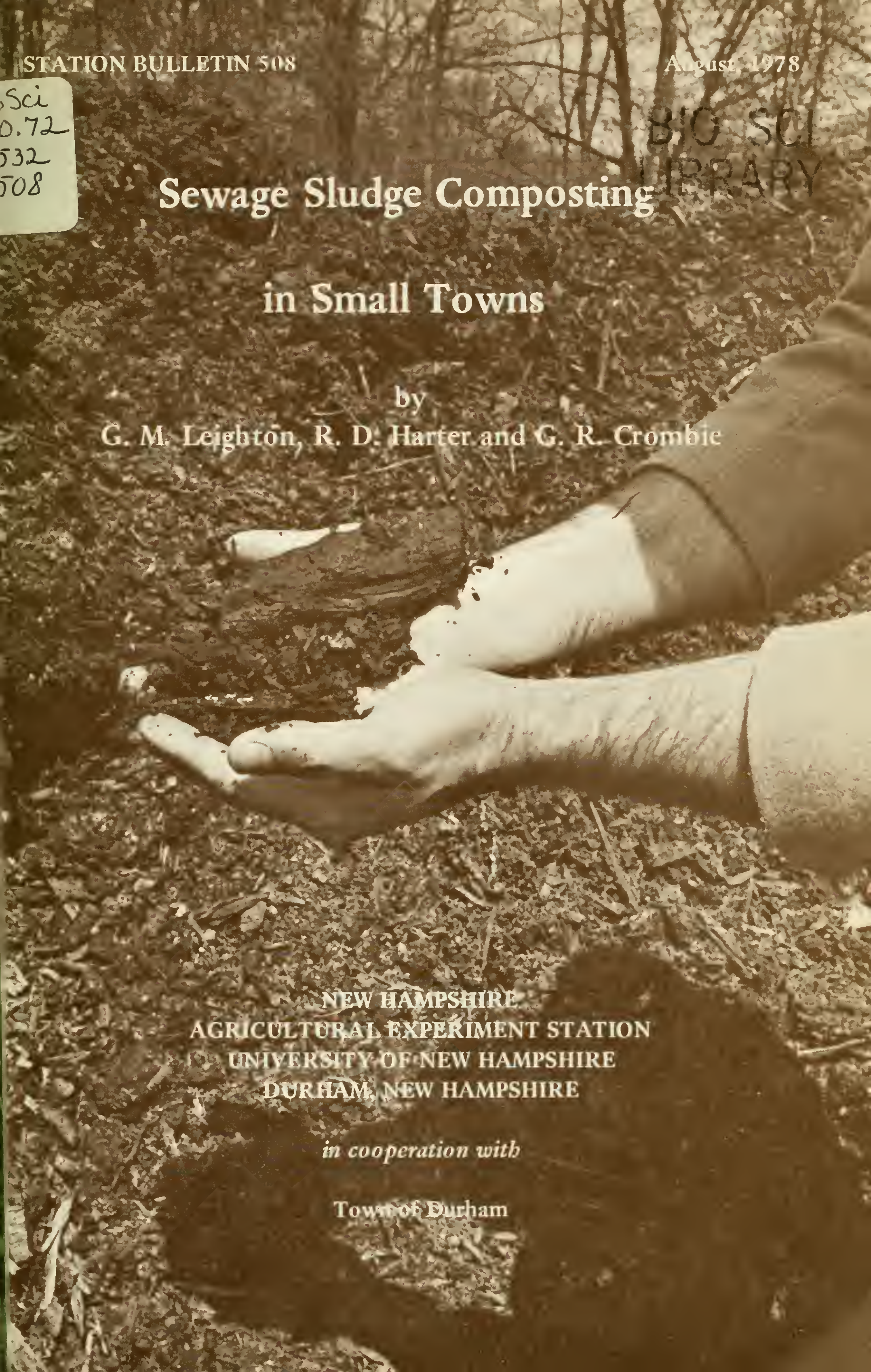

STATION BULLETIN 508

August, 1978

Sewage Sludge Composting in Small Towns

by
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in cooperation with

Town of Durham

PREFACE

This publication is a result of the research program of the Institute of Natural and Environmental Resources. The Institute is a multi-disciplinary group of scientists involved in a coordinated program of research, teaching, and extension. The research effort encompasses investigation of: problems affecting the quality of the environment, economics of agriculture, forest and wildlife resources, the efficient use and conservation of water and soil, and regional and community planning and development.

ABSTRACT

The Town of Durham, New Hampshire, has been using a sewage sludge composting system since 1975 with considerable success. The process involves mixing wet sludge (about 22 percent solids) with wood chips at a ratio of three parts chips to one part sludge by volume, then covering the pile with about a foot of composted sludge for insulation purposes. Air is drawn through the pile for the first 10 to 14 days and exhausted into a small pile of composted sludge for odor absorption. After this period, the fans are reversed, and air is blown through the pile for another 10 days. The resulting compost is stable, practically odorless, and essentially devoid of pathogens. Negligible numbers of salmonellae and undectectable fecal coliforms remained after the composting period.

Composting costs were competitive with other methods of sludge disposal, about $72 per dry ton compared with $115 to $134 for trenching, $57 to $93 for incineration, and $62 to $115 for heat drying.

Composting appears to be a viable and highly satisfactory method of sludge disposal for towns without a high concentration of heavy metals in the sludge.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
DESCRIPTION OF SYSTEM	2
FIGURE I - Diagram of Forced Aeration System	4
COST OF OPERATION	6
Capital Costs	6
Table 1 - Capital Costs at Start of Composting (1975)	7
Table 2 - Costs Incurred, Each Pile (1975)	8
1977 Operations	8
Table 3 - Costs Incurred, Each Pile (1977)	9
DISCUSSION	9
FUTURE PLANS	10
IS COMPOSTING SAFE?	12
TABLE 4 - Estimated Town Costs per Pile for Future Semi-Mechanized System	13
TABLE 5 - Concentrations of Heavy Metals Through Composting Process, Durham, New Hampshire, 1973 to 1976	14
SUMMARY	15
LITERATURE CITED	17
ADDITIONAL READING	18

SEWAGE SLUDGE COMPOSTING IN SMALL TOWNS

by

G. M. Leighton, R. D. Harter and G. R. Crombie*

INTRODUCTION

Although waste-water treatment is a desirable method of protecting the environment, satisfactory disposal of the resultant sewage sludge has presented problems. Conventional solutions such as landfill, incineration, or dumping into water bodies often exchange one problem for another. Contamination of air, water, or land are frequent side effects of such activities. In addition, aesthetic questions can arise, centering around such issues as odor and "visual pollution." An increasingly important factor is economic; as energy costs rise, the costs for handling and transportation of sewage sludge rise as well.

Although New Hampshire towns produce relatively small quantities of sludge compared to large cities of the United States, disposal nevertheless presents significant problems to many communities. Several imaginative techniques for disposal of sewage sludge are being developed, but most are geared toward large quantities of sludge. Consequently, they are too expensive for use by small towns, many of which produce less sludge in a year than a medium-sized city produces in a day. Considering the amounts of sludge produced by most New Hampshire towns and the relatively large areas of undeveloped land in the state, land disposal of the sludge is an attractive alternative.

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In 1975 the Town of Durham, New Hampshire, initiated an experimental sludge composting project utilizing a forced aeration system, newly developed at Beltsville, Maryland, by U. S. D. A. Agricultural Research Service personnel (Epstein and Willson, 1975). The object of this report is to describe the forced aeration system, to present economic data relating to setting up and operating such a system, and to provide some basic guidelines for those who may be evaluating the feasibility of incorporating such a system in their town. Recent work regarding the potential for problems with heavy metals and/or pathogens will also be discussed.

DESCRIPTION OF THE SYSTEM

Several methods of sewage sludge composting have been developed in recent years. These range in complexity from simple compost piles to elaborate composting towers. Presently, two systems, windrowing and forced aeration, are most successful due to their simplicity, ease of operation, and adaptability. Both utilize an aerobic decomposition of the sludge, and a bulking agent such as paper shreds or wood chips to prevent compaction of the pile. In the windrow method, the sludge is mixed with a bulking agent and turned daily to provide aeration and to assure that all of the material is exposed to the higher temperatures that occur in the center of the pile. After two weeks, the pile is flattened to aid drying, and then moved to a curing area for 30 days. Several problems are associated with the windrow method; among them are odor and difficulty in maintaining desirable temperatures for aerobic decomposition, especially during rainy periods or during the winter months.

The forced aeration system has several advantages over the windrow method. It requires less land and less manpower because the pile is left undistrubed for the first 21 days. In addition, higher and more uniform temperatures are maintained throughout the pile because a layer of finished compost acts as insulation. There is little odor production due to a mechanical aeration system (Hoyle, Tanner and Assoc., Inc., 1976).

In Durham's forced aeration process, four-inch diameter perforated plastic pipe is laid out on the ground in a 10 foot by 50 foot rectangle, then connected through a water trap to a 1/3 horsepower cage fan by a similar solid pipe (Figure 1). The perforated plastic pipe is then covered by an eight-inch pad of wood chips which extends five feet beyond the pipe on all sides. This pad acts as an air distribution system, prevents clogging of the pipe, and absorbs some moisture. The wet sludge (about 20 percent solids) is thoroughly mixed with wood chips at a ratio of three parts chips to one part sludge by volume. Several sludge to chip ratios have been used, but this ratio produced the best results. This mixture is then placed on the chip pad and covered with about a foot of screened compost for insulation purposes. The finished pile is about 20 feet wide by 60 feet long by 12 feet high and contains 60 cubic yards of wet sludge and 180 cubic yards of wood chips. During the first 12 to 14 days, air is drawn through the composting pile and exhausted into a small pile of finished compost for odor absorption. Durham has had good success by putting the fan on a timer so that the fan runs about five minutes every half hour. The optimum length of time for fan operation can be determined by noting the percent oxygen readings and adjusting the time accordingly. Temperatures are consistently between 60 and 85 degrees Celsius during this phase, even in winter. After

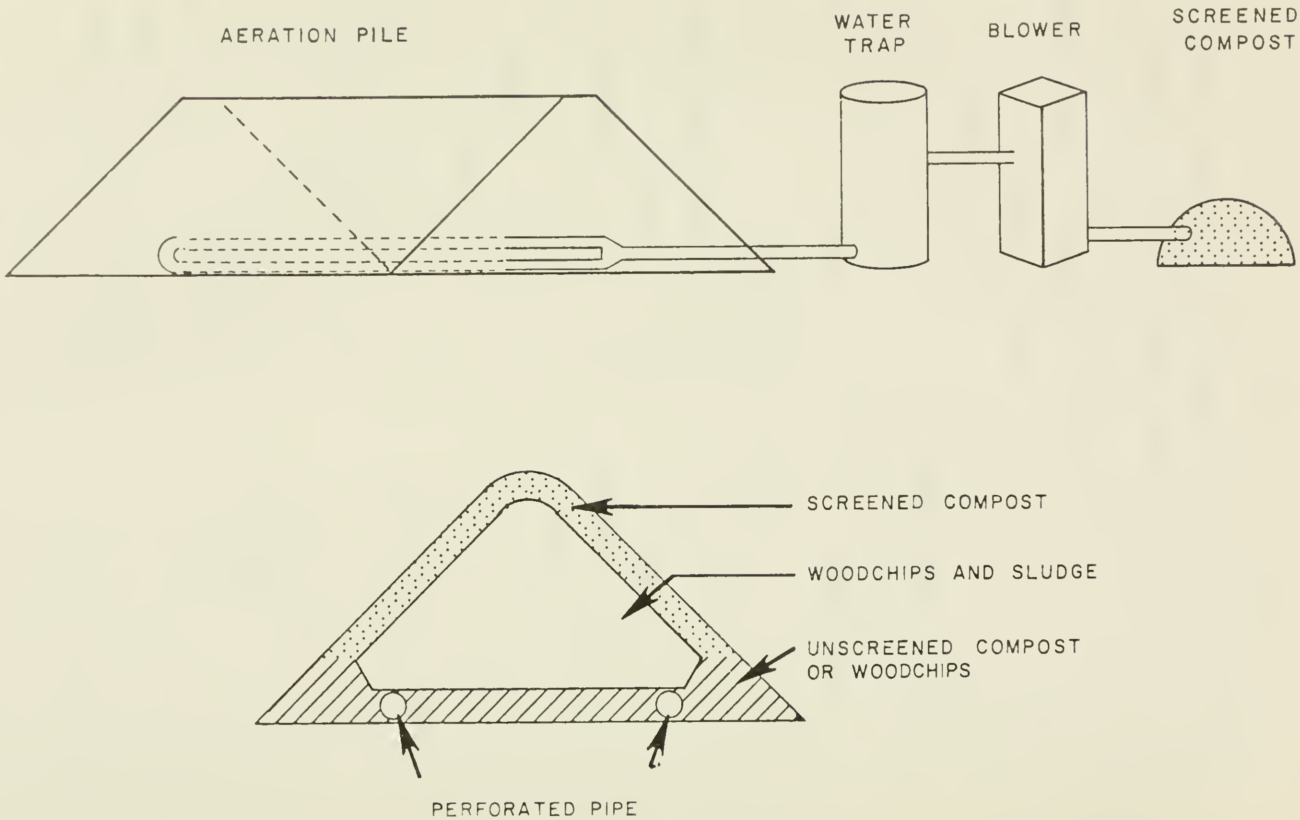

FIGURE I.

INDIVIDUAL PILE FORCED AERATION COMPOSTING SYSTEM this period, the sludge is dewatered and in good condition for screening. The compost pile can then be placed in a larger "curing" pile with no danger of anaerobic conditions developing. A problem may develop if the sludge is frozen when the pile is constructed. If this occurs, heating may be initiated by exhausting a working pile into the frozen pile.

Durham's present composting site is adjacent to the sewerage treatment plant and covers approximately 1-3/4 acres. The area has a gravel base and good drainage. It is recommended that any permanent site be paved, and include a drainage system to handle leachate from the piles and rain water falling on the pad. This should drain into a holding pond, or preferably back to the head of a treatment plant.

Mixing of the wood chips and sludge is done with a grader and loader in the following manner: The loader operator constructs a windrow of wood chips approximately 100 feet long. Sludge is piled on top of the wood chips, then covered with another layer of wood chips. This provides a "sandwich" of sludge between wood chips and aids in the mixing. The grader operator then mixes the material back and forth until an even consistency of wood chips and sludge is obtained. After the mixing is completed, the loader operator transfers the mixture onto the wood chip layer on the compost pad as previously described. When piling this mixture onto the aeration pad, it is important that the loader tires do not mat down the bedding and that the material is not packed into the pile. Air cannot properly move through an area that has been compacted, and the pile is likely to become anaerobic.

In mixing, the grader and loader work well together. However, mixing with the bucket of the loader only was tried and was found to be sufficient if a grader is not available. However, the mixing will not be as complete.

During the composting process, the piles should be monitored for temperature and internal air oxygen level. Temperatures should be recorded at least daily at several locations in the pile; oxygen values of the exhaust gasses should be measured in a like manner. Temperatures should be above 45^{o} C. and oxygen values between 5 and 15 percent (Epstein and Wilson, 1975). It usually takes two to three days for the temperature to reach 45^{o} C. If the temperature of the pile rises to over 60^{o} C., there is probably no need to monitor oxygen level. In the event that the temperature does not rise, the cause is usually insufficient oxygen to maintain aerobic decomposition, or excess cooling form too high an air flow. The required temperatures are usually attained when air flow is adjusted to maintain the air oxygen level at between 5 and 15 percent.

COSTS OF OPERATION

Capital Costs

There will, of course, be certain costs associated with start-up and operation of a forced aeration composting system. The initial costs incurred by the Town of Durham are summarized in Tables 1 and 2.

A graded and gravel-filled pad was already available near the Durham treatment plant, so no site preparation costs were incurred. However, the cost of preparing a mixing and composting pad would have to be included in most town's start-up costs.

For each fan box, a two-foot square platform was placed four feet above the ground on an old telephone pole to hold the aeration equipment. The fan motor and the timer were covered by a removable louvered top for weather protection. One 1/3 horsepower fan is sufficient to aerate two composting piles.

Table 1. - Capital Costs at Start of Composting (1975)

Item	
Aeration equipment	
Dayton Model 7C-504 Centrifical Blower, 1/3 Horsepower	$ 73.00
Paragon Model JW30-0, 120v Timer	25.00
Fan Box	
Plywood	10.00
Louver	3.00
Paint	2.00
Labor	25.00
Double 120v receptacle	1.00
Wire and plastic conduit (150 ft.)	75.00
Main breaker box and breaker	10.00
Total for each blower	224.00
Monitoring equipment - temperature	
YSI Telethermometer, Model 42SC	200.00
Thermistor Probe, YSI#403	30.00
Total	230.00
Monitoring equipment - oxygen	
Dynapump portable vacuum pump, Model 12	75.00
IBC single sensor oxygen meter	235.00
IBC #210-002 oxygen sensor (10 ft. lead)	85.00
Construction of probe[1]	50.00
Total	445.00
TOTAL CAPITAL COSTS	$899.00

[1] Probe housed in 1/2 inch diameter galvanized pipe to reach center of pile.

Fig. 2. Raw sludge is mixed with wood chips in the ratio of three parts wood chips to one part sludge.

Fig. 3. A 20' x 60' bed of wood chips is laid down for good distribution of air.

Fig. 4. Four inch perforated pipe is placed on the bed and covered with four inches of wood chips.

Fig. 5. The chip/sludge mixture is piled on the bed and is covered with approximately one foot of composted material for insulation.

Fig. 6. A small cage fan draws air through the pile for 21 days. Temperatures of up to 82° C. (180°F.) have been measured in the piles.

Fig. 7. After the 21 day composting period, the piles are broken down and new piles constructed.

Fig. 8. The composted material is completely decomposed and is safe for use. It is a stable material, the odor of which bears little indication of its origin.

Fig. 9. The compost has been very useful in landscape plantings and other beautification projects throughout Durham.

Table 2. - Costs Incurred, Each Pile (1975)

Item	Cost
ADS flexible plastic pipe (37¢/foot)	$ 56.00
Wood chips ($3.25/cubic yd.)	585.00
Mixing equipment and labor	210.00
Monitoring of pile	52.00
Electric power	3.00
Capital Costs[1]	6.00
Total	$912.00
Cost per wet ton of sludge[2]	21.70

[1]Capital expenditures spread over the life of the project; does not include construction of compost pad.

[2]One wet ton equals approximately 1.4 cubic yards.

1977 Operations

Since initiation of the composting project, the cost of composting in Durham has been reduced considerably. Part of this reduction in cost has been realized by re-using the wood chips, so it must be determined whether the savings gained by re-using the chips offset the cost of screening. Durham had purchased a chipper at a cost of $7,180 to chip wood products that come to the town's incinerator site, but suspended operation of the machine when it was determined to be dangerous to operate. It has a tendency to snap branches when they are fed into the mechanism, and occasionally to kick back the material that is fed in. At this writing, Durham is purchasing wood chips for the composting process at a cost of $3.15 per cubic yard.

Table 3. - Costs Incurred, Each Pile (1977)

Item	Cost
Perforated plastic pipe (48¢/foot)	$ 62.00
Wood chips ($1.50/cubic yard)	270.00
Equipment and labor	280.00
Monitoring of piles	52.00
Electricity	3.00
Capital Costs[1]	6.00
Total	$673.00
Cost per wet ton of sludge	16.00

[1]Capital expenditures spread over the life of the project; does not include construction of compost pad.

DISCUSSION

The largest single nonlabor cost in composting is for wood chips. The costs quoted (Table 2) may be slightly high, since the chips can be used more than once. The chips have been satisfactorily reused by simply mixing the compost with more sludge; but to use the chips in more than two or three cycles, fine particles need to be removed by screening. To do this, a rotary screen is necessary, thus adding to the fixed costs. (Rotary screens can be rented, but the cost is prohibitive.) Additional handling costs and the need for extra equipment may offset the savings gained by re-using the chips, unless the handling facilities are capitalized with a new plant as in Durham's new system. (See Future Plans.) Chip costs can also be decreased by purchasing a chipper, providing the town has an adequate supply of wood to be chipped (Table 3).

The second largest cost is for manpower and equipment to handle the materials before and after composting (Tables 2, 3). Included in this figure is depreciation on the front-end loader and the grader; both are written off at $10 per hour. Approximately five hours for the loader and four hours for the grader are required to remove one pile and build another. Two operators and an additional person usually spend eight hours each to build one pile. The third person sets the pipe and direct the loader operator so that he does not run over the pipe or the uncomposted sludge-chip mixture. The equipment wash-down time is also included. Labor is charged off at $5 per hour. These costs may vary somewhat from town to town, depending upon equipment available as well as the local wage and fringe-benefit package.

Little attempt has been made to salvage the aeration pipe used under the pile. At the current cost of 38¢ per foot, or $62 per pile (approximately 150 ft. needed), it simply is not economically feasible to take the time necessary to tear down the pile carefully and recover the pipe. At present it is difficult to estimate how long the equipment will last. Assuming that it will last at least two to three years, fixed costs should be in the same range as for electric power.

Monitoring can be done by one person and costs about $53 per pile over a 21-day period. The actual monitoring requires about 10 minutes per pile per day plus the time required to prepare and put away equipment and record data. Durham's Treatment Plant operator performs these tasks.

The cost of $15 per yard (Table 2) to compost sludge into a useful product compares favorably with the cost of other methods, approximately $12 per yard for incineration and $8 per yard to landfill sludge.

Furthermore, reduction of chip cost by re-using chips and/or by a town supplying its own chips decreases this cost to some extent (Table 3). According to Epstein (personal communication), a one-inch chip can be re-used about five times before it is completely disintegrated. This extent of re-use requires screening, which adds an estimated $1 per yard to the overall cost. When all factors are considered, it is not inconceivable that the cost of composting could be reduced to less than that of landfill simply by initiating economies in obtaining and handling the chips.

FUTURE PLANS

The Town of Durham is now sufficiently satisfied with the composting process that it has been incorporated into the design for a new secondary treatment plant as the sole sludge handling system. So far as possible, operating costs will be lowered by incorporating more permanent facilities in the new plant. For example, the aeration system will be embedded in a concrete pad so new pipe will not be required for each new pile. Mixing of the chips and sludge will be done by a pugmill to reduce equipment and labor costs. Finally, a front-end loader will be purchased for the composting system. Thus, town equipment purchsed for other purposes will not have to be used and charged off to the composting on an hourly basis. In total, the estimated capital cost for the semi-mechanized system will be $500,000. Ninety-five percent of this amount will be covered by Federal and State funds. This leaves only $25,000 to be funded by the town. (In comparison, establishment of a landfill site in Durham was estimated to cost $600,000.) The estimated lifetime of the new treatment plant is 20 years, with an average sludge production of 43 wet tons per week over the period. Thus, the per wet ton capital costs will be $23. However, the

Town's share of this will be only five percent, or $1.15 per wet ton. The Town's estimated cost per pile is itemized in Table 4.

Although total cost of the system will be about $28.50 per wet ton, spreading the cost across the State and United States tax bases means that actual cost to the town is quite low. Obviously, the actual costs depend upon location and conditions, so not every town could depend upon being able to compost at this cost, nor upon receiving such a large percentage of Federal and State Funds. Durham's costs will also increase over the lifetime of the plant, since the largest variable cost is labor, which will undoubtedly increase over the period.

Durham's plans for the new system include purchase of a wood chipper with an automatic feed. This is felt to be a safer design, eliminating the hazards encountered with the older chipper. This chipper should hold the cost of wood chips to about $1.50 per yard.

Finally, indications are that there might be a market for the screened compost, and a nominal charge for the material might further decrease the composting costs. This is particularly true if current University of New Hampshire experiments using compost for production of turf and ornamentals prove feasible on a commercial basis.

IS COMPOSTING SAFE?

The primary areas of concern associated with sludge composting are heavy metal concentrations and the potential for pathogen survival. Both of these areas have been the subject of much study in the past few years.

The major subjects of concern among the metals are cadmium, copper, zinc, lead, nickel, chromium, and boron. Once such metals are added to

Table 4. - Estimated Town Costs per Pile for Planned Semi-Mechanized System

Item	Cost
Capital Costs	$ 48.00
Wood Chips	270.00
Labor	80.00
Electricity	4.00
Monitoring Piles	55.00
Total	$457.00
Cost per wet ton of sludge	7.15

soils, they remain there unless taken up by harvestable vegetation. Thus, even if the amount of heavy metals in the sludge is modest, toxicity problems can develop over time. It is therefore important to determine concentrations of heavy metals in the composted sludge to determine safe application rates. Heavy metal content of Durham's compost at several stages of the process are provided in Table 5. For residential towns such as Durham, there is little problem in this regard. However, for some industrialized towns, land disposal of composted sludge may not be an acceptable alternative due to the presence of heavy metals. Harter (1975) surveyed the heavy metal content of sludges in New Hampshire and found, with a few exceptions, that the metal content is low compared with most sludges on the industrial Northeast. He also provided a means of determining the amount of sludge that can be safely applied with little likelihood of toxic build-up of heavy metals.

Table 5. - Concentrations of Heavy Metals Through Composting Process, Durham, New Hampshire, 1973 to 1976*

Sample	Collection Date	Cu	Zn	Cr	Cd ppm	Pb	Co	Ni	Hg
Fresh Sludge	9/27/73	179	350	33	1.3	84	7.1	20	1.5
	9/29/75	197	200	31	1.5	92	5.0	15	1.3
New composting Pile	9/29/75	119	150	26	0.6	61	0.5	15	0.9
Comp. Pile at mid-process	3/9/76	155	300	24	0.8	70	5.0	14	1.5
	3/9/76	155	240	41	1.1	88	5.0	15	0.7
	3/9/76	85	250	31	1.3	65	2.5	15	0.6
Composting Completed	9/29/75	75	198	16	1.0	54	2.5	10	0.4
Curing Pile	3/9/76	55	110	17	0.5	68	2.5	10	1.1

*Samples dired, passed through 2 mm sieve, and sent to Technological Resources, Camden, N. J., for analysis.

A much more emotional concern, perhaps, is the potential for pathogen survival, which could conceivably create a health hazard. The major pathogens present in human wastes fall into four broad categories: 1) ova of helminths (intestinal worms), 2) protozoans, of which the dysentery-causing organism Entamoeba histolytica is an example, 3) bacteria, which include salmonella, and 4) viruses, which cause a variety of diseases including flus, colds and polio (Burge, Cramer and Epstein, 1976). All of these organisms can be destroyed by the heat generated in composting, making monitoring of temperatures within the pile vital.

Berge, Cramer, and Epstein (1976) state: "Of all treatments, composting is the only one that greatly reduces pathogen levels and also stabilizes sludges sufficiently so that they can be utilized without the generation of malodors." Pasteurization, ionizing radiation, and heat treatment can eliminate pathogens, but leave the sludge in an unstabilized state—it will quickly putrify when applied to land.

Current research indicates that the health hazard from pathogens is minimal. Tests using indicator viruses have shown excellent pathogen kill, even though higher temperatures are needed to kill the indicator organism than to kill organisms responsible for the diseases of concern to man. Negligible numbers of salmonellae and undectable fecal coliforms remained after the composting period (Epstein and Willson, 1975).

These results have been borne out in Durham. Sampling conducted in 1975, for example, showed no measurable numbers of Salmonella sp. in fully composted sludge. Despite the apparent lack of pathogenicity of the compost, its use on food crops, particularly root crops, is not recommended. To avoid any possibility of legal repercussions, town personnel should have a firm and consistent policy of recommending the use of compost only on turf and ornamentals.

SUMMARY

The sludge composting process developed at Beltsville, Maryland, and presently in use by the Town of Durham has proven desirable from a number of standpoints. The process results in a useable, stable product with little odor problem and excellent pathogen kill. In addition, the cost is competitive with other methods. Total fixed costs to start the Durham project were $899. Total costs for operating equipment were $224 (excludes equipment already owned by the town for other purposes). Composting costs for the first few piles were $912. This works out to approximately $72 per

dry ton, compared to $116 to $134 for trenching, $57 to $93 for incineration, and $62 to $115 for heat drying (Colacicco et al., Feb. 1977). Efficiencies developed with experience have further reduced the cost.

The sludge composting project has been well received by town residents. There are no odor problems unless anaerobic conditions have developed, and requests for the finished product have been exceeding production. The Town of Durham Public Works Department has itself been using substantial quantities of the finished product for town beautification, roadside stabilization, turf improvement, etc. Any compost not utilized by the town is quickly removed by residents.

It appears that composting is a good and viable sludge disposal method for towns such as Durham with low concentrations of heavy metals in the sludge.

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