COSTS OF SLUDGE COMPOSTING

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ABSTRACT

The major sludge management methods are discussed and compared. A cost analysis of the aerated-pile process of composting sewage sludge is then presented. This process utilizes woodchips and other bulking agents to stabilize dewatered raw sludge. The operation as described is labor intensive, but subject to many modifications. The on-site cost of composting will range from $35 to $50, depending on the size of operation. This cost is insensitive to changes in capital costs but sensitive to changes in operating expenditures. A comparison of alternative sludge management processes may show composting to be cost-effective for some municipalities.

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COSTS OF SLUDGE COMPOSTING[1]

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INTRODUCTION

Concern about environmental degradation has intensified the search for environmentally acceptable and cost-effective sewage disposal techniques. The Water Pollution Control Act Amendments of 1972 implicitly established the goal of eliminating the conventional practice of sewage disposal by water dilution. Municipalities had practiced dilution because it was their cheapest, aesthetically acceptable disposal option. Dilution was inexpensive because fresh water was available and no one had to be compensated for its degradation. The 1972 legislation formally recognized that while our clean fresh water rivers and lakes had no price they yield considerable value to people. Congress likewise protected clean air in the Clean Air Act Amendments of 1970 and the ocean in the Marine Protection, Research, and Sanctuaries Act of 1972 (Ocean Dumping Act). These acts greatly intensified the search for non-water polluting, non--air polluting, and non-ocean dumping sewage disposal techniques.

The solids in sewage constitute one of its major, environmentally damaging ingredients. A large portion of these solids are removed in wastewater treatment and become sludge. Wastewater treatment operations are predicted to produce 40 percent more sludge in 1985 than in 1972 (9). About one-half of the increased sludge will be attributable to the mandated reduction of pollutants in wastewater effluent.

Since legislation now discourages the disposal of sludge by incineration and ocean dumping, a logical alternative is to apply the sludge to land. Unlike air and water, land is not a free resource. Municipalities must either buy land for sludge disposal or persuade private landowners to accept the material. For centuries, landowners have applied sludge on their land for its agricultural benefits (24). Relatively recent concerns for sludge's odor, heavy metal content, pathogen content, and social stigma, however, have made landowners and health authorities uneasy about putting sludge on land (10). This reluctance was enhanced by the development of inexpensive chemical nutrients and the increasing geographical separation between agricultural lands and sludge production.

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One important part of the long-term solution to the sludge management problem is to turn what is now perceived as a waste and potential pollutant into an economically valuable resource. Since the law makes no provision for the balancing of abatement benefits with treatments costs, the sludge issue is reduced to a cost minimization problem subject to the mandated regulations.

The Agricultural Research Service and Economic Research Service, U.S. Department of Agriculture, in cooperation with the Maryland Environmental Service, have been investigating the composting of sewage sludge as a technically feasible and economically viable method of sludge management by converting sludge into a valuable soil amendment and low grade fertilizer. The composting systems developed by ARS must be evaluated by comparison with other sludge disposal processes.

PRESENT SLUDGE DISPOSAL ALTERNATIVES

The major sludge disposal methods are landfilling, landspreading, incineration, and ocean dumping. Farrell (9) has estimated that in 1972 about 40 percent of U.S. sludge went into landfills, 20 percent was spread on land, 25 percent was incinerated, and 15 percent was disposed of in the ocean. If an ocean disposal ban is ever realized and if overall sludge production increases as predicted, then another 170,000 tons of sludge, or 80 percent of the current amount, will have to be disposed by the permissible sludge disposal processes. These trends have intensified the need for new, inexpensive, and reliable sludge disposal methods.

Table 1 is a compilation of the range of costs which have been reported for different sludge disposal processes. It also includes the cost of composting. The costs of the sludge disposal alternatives will vary between sites. The physical inputs necessary to dispose of sludge at any given site will be a function of the chemical and physical properties of the sludge, the geography, and the topography of site, as well as of the aesthetic sensibilities of the neighboring public, various institutional constraints, and Federal, State, and local legal restrictions. Prices of the physical inputs will also vary between localities, adding another variable to the cost and selection of a disposal method. Another source of variation lies in the fact that sludge processes are subject to economies of scale and size, so that per unit cost decreases as the size of operation increases.

The costs in table 1 have been inflated from the values found in the references to March 1976 levels using EPA's Sewage Treatment Plant Construction Cost Index. The costs presented are for the processes only and do not consider total system costs. The disposal processes are grouped by the different sludge processes that would precede them in a sludge handling system. Incineration, heat drying, and composting require ultimate disposal of their residues or products. With incineration, about 10 percent of the original weight of the dewatered sludge must be disposed of as ash. Heat drying and composting processes require a market to dispose of their products if the municipality does not need the products for its own use.

Table 1.--Comparative costs for various sludge disposal processes (1976 dollars).

Item	Range of costs, dollars per dry ton	References
Digested sludges:		
Ocean outfall	10 to 35	26
Liquid landspreading	20 to 54	5, 17, 20
Digested and dewatered sludges:		
Ocean barging	31 to 44	26
Landfilling	23 to 53	20, 26
Landspreading	26 to 96	4
Dewatered sludges:		
Trenching 1/	116 to 134	25
Incineration 2/	57 to 93	3, 4, 23
Heat drying 2/	62 to 115	4, 18
Composting 1,2/	35 to 50	

1/ Costs exclude transportation of sludge to site.

2/ Costs exclude cost of removal of residues and benefits from resource recovery.

Costs are presented on the basis of dry tons of solids settled during primary and secondary treatment. Assuming an average of 0.2 lb of settled solids per person per day from primary and secondary treatment (6, 9), a ton of dry sludge per day would be produced from the treated wastewater of 10,000 people. Further, if one assumes that 100 gallons of wastewater are produced per person per day (6), then a dry ton of settled solids per day corresponds to a flow of a million gallons per day. Suspended solids are then reduced by about 240 ppm in the treated wastewater. Dry ton cost figures must be used with care since some wastewater and sludge treatment processes can markedly change the quantity of solids that must be handled.

A major disadvantage of the sludge disposal methods in the first and second groups in table 1 is the digestion requirement. Anaerobic digestion costs have been estimated at $9 to $15 per dry ton of solids (23), while aerobic digestion is estimated at $10 to $18 per dry ton (26), for plants processing 10 to 50 dry tons per day. Anaerobic digestion has had a history of operational problems but reduces the quantity of solids to be handled.

Ocean disposal provides the least expensive sludge disposal system for communities that have this option. It is a reliable and unsophisticated disposal method that permits flexibility in plant operation. The greatest disadvantage in ocean dumping is the difficulty in monitoring and managing sludge in the marine ecosystem. Wyatt and White (26) listed the potential adverse effects of ocean disposal as: (1) Pathogen and heavy metal intake by fish and shellfish consumed by people, (2) pathogen contamination of ocean beach swimming areas, (3) disruption of marine fisheries, (4) aesthetic deterioration of ocean beach swimming areas, and (5) noxious gas production.

Spreading sludge on land is a centuries-old method of sludge management and nutrient recycling. Landspreading produces benefits by adding nutrients, water, and organic matter to the soil. While landspreading requires no sophisticated machinery to function successfully, certain disadvantages attend the operation. Galloway (10) discusses the social stigma attached to the idea of a municipality disposing of its sludge in a rural community. Moreover, the disposal of sludge by landspreading may conflict with the agricultural use of the land. Other disadvantages of landspreading are that many sludges are not suitable for agronomic use due to excessive levels of heavy metals or other industrial pollutants, possible ground water contamination, possible health hazards caused by pathogens and heavy metals in food crops, and operational problems involved in spreading sludge on frozen or wet soil.

The sludge disposal methods in the second and third groups in table 1 must be preceded by dewatering. Burd (2) found that dewatering costs ranged from under $10 per dry ton for some sandbed drying operations to nearly $100 per dry ton for some vacuum filtration operations.

Landfilling is one of the cheapest sludge disposal methods. It requires little capital investment and can be implemented in a relatively short time period. Landfilling is also flexible enough to handle sporadic sludge production. The major problem with landfilling is that of obtaining a suitable site. Residential communities often oppose landfilling of sludge because of the traffic, operation, and social considerations involved. Locating enough land for disposal can be difficult in urban areas. Completed landfills may not be suitable for construction because of settling and methane production. Also present is the potential for ground water contamination by heavy metals, nitrite, and industrial chemicals.

Trenching is similar to landfilling in that it can be quickly implemented and can dispose rapidly of large amounts of sludge. Trenching also has similar problems concerned with site selection, land acquisition, and potential ground water contamination. However, trenching does offer potential for improving marginal agricultural lands. Rather than a principal disposal method, trenching was developed more particularly as an emergency backup method for sludge disposal. Unfortunately, insufficient research has been conducted to determine conclusively the rate of dewatering and decomposition of entrenched sludges. Thus, the question of how soon sludge-entrenched land can be used for purposes other than agriculture remains unanswered.

Incineration would appear to be a logical solution to the sludge disposal problem because it provides about a 90-percent reduction in sludge volume, removing almost all the water and organic solids, and leaving only inert dry solids in the form of ash. Another advantage is that incineration requires little land area. While sludge ash is completely stabilized and free of pathogens, incineration is not an ultimate disposal method because the ash remains and it too must be disposed of. The ash is usually landfilled, although there are some economic uses for it (4). A distinct disadvantage to incineration is the energy requirement; that is, the cost of incineration rises with the escalating price of fuel. Techniques are available to recover some of the energy from incineration. Nevertheless, such considerations as initial capital costs, fuel costs, and problems of air pollution, odors, ash disposal, and potential explosion hazards tend to detract from incineration as an ultimate disposal method.

Heat drying is a process whereby excess moisture is removed from raw sludge. The dried sludge is easily handled, sterile, and can be used as a low grade fertilizer and soil conditioner. Successful marketing operations have been conducted with heat dried sludges from Houston, Chicago, and Milwaukee (18). Like incineration, heat drying is also energy-intensive and involves large initial capital costs. Heat drying also incurs some air pollution and odor problems and the complex machinery is subject to operational problems, including explosions.

The selection of a sludge disposal method for a municipality will depend on relative costs and environmental impacts. The economic and environmental impact of a particular sludge disposal method will vary with the chemical and physical nature of a municipality's sludge and with its geographical location. Therefore, it is expected that no one disposal method will be best for all cities. The sludge management system for a city which minimizes costs and environmental impact may incorporate several disposal methods.

COMPOSTING

Composting is an ancient technique developed to recycle organic wastes. Many types of organic materials have been composted in the past, but until recently the emphasis was on animal manures. In the 1920's, processes were developed for composting municipal refuse (14). In 1932, a refuse composting facility was established in Holland that is still operating (15). The Environmental Protection Agency estimated in 1971 that there were more than 2,600 composting facilities outside the United States (22). Of these operations, 95 percent were in India where the demand for compost is high. Composting operations also have been undertaken in the United States mainly for refuse, but few are still in existence. The major problems cited with composting as a disposal method for municipal refuse were the high operating costs and non-marketability of the product (11).

Sewage sludge frequently has been added to refuse before composting, but only recently has the composting of sludge alone been considered as a viable sludge management alternative. A mechanical sludge composting process was developed and tested by the Eimco Corporation in 1968 (16). The Agricultural Research Service at Beltsville, Md., has developed two processes for stabilizing sludges: (1) A windrow process that composts digested sludge and (2) a forced aeration process for composting raw or digested sludge.

The windrow process, developed in 1973, consisted of several operations (7). The sludge was mixed with woodchips at a volumetric ratio of 1:3 and placed in windrows about 6 feet high and 7 feet wide. The windrows were then turned daily for at least 2 weeks, after which they were flattened (spread out) to permit the compost to dry. The dried material was removed to a storage area, where the compost was further stabilized and the pathogens reduced to an acceptable level. After 30 days in storage, the material was screened and a portion of the woodchips was recovered for further use. The screened compost was an aesthetically acceptable product, easily handled and stored, and was used on civic projects in the Washington Metropolitan area.

The windrow process was successful for composting large quantities of digested sludge. However, when attempts were made to handle and process raw sludge in this manner, odor problems developed. All attempts to solve this problem in the windrows were unsuccessful. Ultimately, a mechanically aerated, stationary pile process was developed for composting raw or digested sludge which required less equipment and land than the windrow process without generating an odor problem.

The aerated pile process developed to handle raw or digested sludge differs from the windrow process in that the composting material is not turned. Aerobic composting conditions are maintained by drawing air through the pile at a predetermined rate. The effluent air stream is conducted into a small scrubber pile of cured screened compost, where odors are effectively removed. During composting, odors are also controlled by covering the pile with an insulating layer of cured compost.

The aerated pile process is currently being used at Beltsville to compost partly dewatered sludges (23 percent solids). While variations of the process have been employed, the following details provide the basis for the economic analysis reported here. Figure 1 presents a flow diagram of the aerated pile process.

Initially, a load of sludge, which contains about 10 wet tons or 14 yd^3, is dumped onto a bed of 25 yd^3 of woodchips, which have been spread to a depth of about 15 inches. A front-end loader with a 4-yard bucket turns the material over until thorough mixing is attained. Mixing a 14 yd^3 load of sludge with woodchips takes from 10 to 15 minutes.

Concurrently with the mixing, the forced-aeration system is laid out. A front-end loader and a laborer spread a 6-inch layer of unscreened compost on the ground to form the base for the compost pile. A loop of 4-inch perforated plastic drainage pipe is laid on the unscreened compost and then covered with a 6-inch layer of unscreened compost. For a 10-dry-ton-per-day (43 wet tons) operation, this layer consists of 28 yd^3 of unscreened compost. About 94 feet of perforated pipe is required for a 43-wet-ton-pile having dimensions of 53 feet long, 12 feet wide, and 8 feet high. The loop of perforated pipe is connected to a 1/3-hp blower by 14 feet of solid pipe fitted with a water trap to collect the condensate. In the case of a 10-dry-ton pile, the blower is controlled by a timer set for a cycle of 4 minutes on and 16 minutes off. The blower has a housing to protect it from the weather. Sixteen feet of solid plastic pipe connect the blower to a conical scrubber pile consisting of a 6-inch layer of woodchips (2 yd^3) covered with 10 yd^3 of screened compost.

The sludge and woodchip mixture, in a volumetric ratio of 3:5, is placed on the prepared base. In accounting for the chips comprising the base, the adjusted volumetric ratio is about 1:2. After the pile has been constructed,

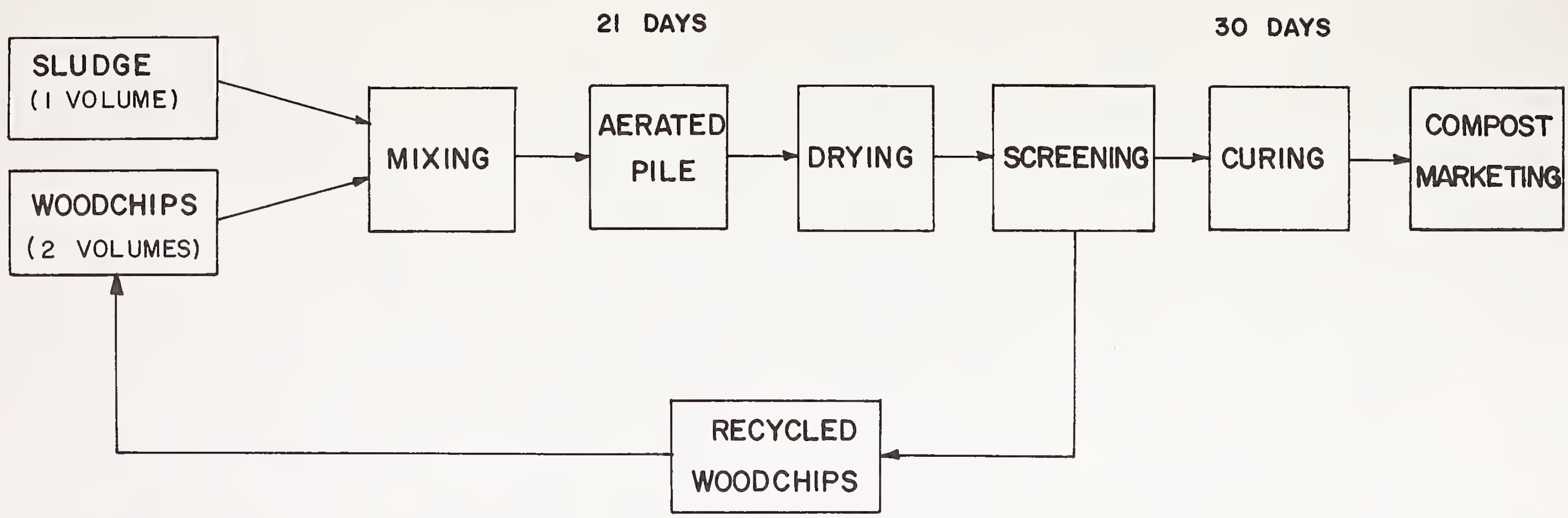

Figure 1.--Flow diagram of the Beltsville aerated pile method for composting raw sludge.

it is covered with a 12-inch layer of screened compost for insulation and odor control. The blower cycle is initiated and the 3-week composting period begins. Within a week, the mean pile temperature should exceed 140° F.

The piles can be located separately on the pad or in an extended pile configuration. In the extended pile configuration, the pile is constructed by using the shoulder of slope of the 50-foot side of the previous day's pile and so on, forming a continuous or extended pile. Results indicate that composting raw sludge in this fashion is not only feasible but also offers certain advantages. For example, the extended pile configuration decreases the required operating area by at least 50 percent. Moreover, the amount of blanket material required to prevent the escape of odors is also decreased by 50 percent, as is the woodchips requirement for the pile base. However, small municipalities that do not produce sludge everyday would probably prefer the isolation of the separated piles, so that they could be sure each batch was in the pile the specified number of days. The extended pile method was assumed in the analysis because it describes a 7-day-per-week operation.

After 21 days in the pile, the composted sludge is essentially pathogen free and stabilized (8). The blower is disconnected and the pile taken down. At this time, if weather conditions permit, the compost may be dried (in windrows or spread out in thin layers) and screened. In case of inclement weather, the compost may be placed directly in a curing pile for 3 to 4 weeks before screening. Drying is essential to facilitate clean separation of compost from chips. The recovery of the plastic pipe is not economical because of the time and labor involved; therefore, it is discarded.

For drying, the unscreened compost is spread out with a front-end loader to a depth of 12 inches. Periodically, a tractor-drawn harrow is employed to facilitate drying of the compost. If rains occur, the drying material will be wetter than in the aerated piles; hence, drying can only commence when 2 days of dry weather are forecast.

Screening is performed with a rotary screen, a front-end loader to feed the screen and to remove the separated chips and compost, and two equipment operators. The chips are recycled by mixing with incoming sludge. The compost is stored in piles for 30 days to remove any remaining offensive odors. The compost is then ready for utilization as a low grade fertilizer, as a soil amendment, or as a substitute for topsoil in land reclamation projects.

The site development and preparation for composting are not extensive. The land area requirement is 1 acre for every 3 dry tons (12 wet tons) of sludge processed daily. A 10-dry-ton-per-day site would require 3.5 acres. Of this area, a half acre would be required for a runoff collection pond to accommodate drainage from the site; about 2 acres would be surfaced for roads, mixing, composting, and drying; and the remaining acre would be for administration and storage. More land may be necessary to isolate the site from its neighbors, depending on their aesthetic sensitivities. The land area required for runoff collection and drying will depend on the climatic conditions of the area.

A pond and collection ditches are necessary to collect runoff from the compost site that would otherwise pollute surface waters. A sewer line should then conduct the pond water to a sewage treatment plant. The pond should have sufficient capacity to receive all the runoff during major storms because this is the time when most treatment plants are overtaxed. Maximum capacity can be assured by draining the pond during dry periods.

All that is needed in the administration area is an office, a covered storage area, and a parking area. The composting pad should be constructed of asphalt with a good underlying foundation to support the heavy machinery.

COST ANALYSIS OF COMPOSTING

A complete economic analysis of composting requires an examination of the cost of processing the sludge into compost and an analysis of the costs or revenues from distribution to consumers. This discussion will not include an analysis of the market for compost. The compost produced from the 70 dry tons of sludge per week processed at Beltsville is hauled away by bulk users at their own expense. For this reason, a sensible assumption in the absence of a market survey may be that the compost distribution operation will realize no net revenues or costs to the municipality.

The capital costs for the 10-dry-ton-per-day site were estimated at $376,200 (table 2). Capital investment is about one-fifth of that for comparable incineration capacity (23). About one-half the investment is in site development and one-third is in equipment. A land price of $10,000 per acre was assumed and land costs were included for completeness.

Amortized equipment costs account for more than $5.00 of the cost per dry ton of sludge processed. The cost of the front-end loaders is the largest capital expenditure of the composting operation. The cost analysis is based on a front-end loader fitted with a 3.5 yd^3 bucket. Compost and raw sludge are relatively light, weighing 1,000 lb per yd^3 and 1,400 lb per yd^3, respectively. Rototillers, rotoshredders, and composters have also been used and will adequately mix the sludge and woodchips. These machines can also facilitate the drying of unscreened compost in either a thin layer or windrow configuration.

Site development costs for a 10 dry ton-per-day-operation will approximate $198,000, but will vary considerably with the site's location. The cost analysis assumed that 400 feet of 8-inch sewer line was installed at $35.00 per foot. If a sewer line is not cost-effective, the pond can be drained by an irrigation system adjacent to the site. The cost of treating the runoff was not included in this analysis. The electrical estimate is derived from the composting site at Beltsville and engineering was assumed to be 25 percent of the other site development costs.

Cost of the asphalt composting pad includes grading, 12 inches of crushed stone, and 4 inches of asphalt. While a crushed stone pad is adequate for composting, the experience at Beltsville has shown it to require heavy maintenance.

Table 2.--Capital costs for a composting facility processing 10 dry tons of sludge per day (1976 dollars).

Item	Capital costs, dollars per year
Site development:	
Asphalt pad (1.5 acre)	83,800
Roads, administration	13,000
Electrical work	20,000
Sewer	14,000
Pond, drainage	28,000
Engineering	39,700
Total	198,500
Equipment:	
Office trailer	5,000
Storage	1,500
Front end loaders (2 pieces)	106,000
Screen	16,300
Tractor	4,700
Pickup	4,700
Blowers (33 pieces)	2,500
Total	140,700
Land (3.5 acre)	37,000
Capital investment	376,200

The annual costs of a compost site that processes 10 dry tons per day is presented in table 3. A 10-dry-ton-per-day site will handle the sludge from a community of about 100,000 people. This site is assumed to be operating 8 hours per day, 7 days per week. As can be seen, the cost of composting is about $51 per dry ton of sludge for the 10-ton-per-day operation.

About 80 percent of the annual costs are attributable to operating costs. Over 50 percent of the operating costs are spent on labor, making composting a labor intensive operation. The 10-dry-ton-per-day composting operation requires four men on the site 5 days per week and two men during the weekend. The total work force for a 7-day operation consists of a superintendent and four equipment operators. The cost analysis assumes that a payroll of five people can handle the job. It was also assumed that each person would take 5 weeks off for paid sick leave, vacations, and holidays, and that 0.3 man-years of overtime would be necessary. The superintendent receives $7.50 per hour and the operators receive $6 per hour. Labor costs include $400 per man for health insurance and 6 percent for the employer's Federal Insurance Contribution Act share.

The second most expensive item in composting is the bulking material. The woodchips used in the Beltsville process cost $9.60 per dry ton of sludge

Table 3.--Annual costs for a composting facility processing 10 dry tons of sludge per day (1976 dollars).

	Annual costs Dollars per year	Dollars per dry ton	Percentage of annual cost
Operating Costs:			
Woodchips	35,000	9.60	19
Plastic pipe	12,200	3.34	7
Gasoline	2,300	.63	1
Diesel	5,300	1.45	3
Electricity	1,500	.41	1
Equipment maintenance	8,400	2.30	5
Equipment insurance	1,400	.44	1
Pad, road maintenance	1,200	.33	1
Water/sewer	500	.14	1
Labor	77,500	21.23	43
Miscellaneous supplies	4,400	1.20	2
Total	149,700	41.01	81
Capital costs:			
Site development 1/	14,600	4.00	8
Equipment 2/	19,200	5.26	10
Land 3/	2,300	.63	1
Total annual costs	185,800	50.90	100

1/ Capital recovery factor (6.125 percent, 30 yr) = 0.0736

2/ Capital recovery factor (6.125 percent, 10 yr) = 0.1367

3/ Capital recovery factor (6.125 percent, infinite) = 0.06125

processed, which is 19 percent of the annual costs. The cost analysis assumes a cost of $3.50 per yd^3 for woodchips. Depending on cost and availability, bark and sawdust are acceptable substitutes for woodchips. Current research involves investigation of the potential usefulness of air classified refuse paper, leaves, bagasse, cotton gin trash, peanut hulls, and other organic wastes as bulking materials for sewage sludge composting. Availability of a large storage area for the woodchips makes them cheaper for two reasons: (1) The chips can be transported more economically in large bulk carriers, that is, 40 yd^3 trucks; and (2) the chips can be purchased when their availability is high and their price is low. They can be stored indefinitely before use. For the cost analysis, it was assumed that the woodchips could be recycled four times.

All of the other items in the operating costs add up to less than 20 percent of the annual cost. Reusable steel pipe could be used to replace the plastic pipe in the aeration system. While the operating time is increased slightly by removing the pipe from a pile before it is taken down, the cost of supplies is reduced. The cost of equipment maintenance, which is based on the repair record of machines at the composting site, is assumed to be 6 percent of the purchase price of the machines. Insurance is estimated at 1 percent of the equipment purchase price. The following input quantities per dry ton of sludge are assumed in this cost analysis and are based on the experience at Beltsville:

Woodchips	2.75 yd^3/dry ton
Plastic pipe	12.3 ft/dry ton
Gasoline	1.1 gal/dry ton
Diesel	3.5 gal/dry ton
Electricity	17.3 kwh/dry ton

On the basis of the experience gained at Beltsville for a 10-dry-ton-per-day operation, costs were estimated for a 50-dry-ton-per-day facility. The on-site cost per dry ton of sludge processed decreased from $51 to $36 as the operation was scaled up from 10 to 50 dry tons per day. Accordingly, operating costs decreased from $41 to $28 per dry ton. The greatest economy of size was in the cost of labor, which only doubled as the amount of sludge processed more than quadrupled. The capital cost requirement per dry ton per day capacity diminished from $40,000 to $30,000.

Capital may be substituted for labor as the forced aeration process becomes refined. The small capital input in the defined process adds to the attraction of composting as an interim process. The composting operation can be implemented quickly and does not require specialized equipment. If a community is undecided on how best to resolve their sludge problem, or wishes to wait for further development of feasible disposal alternatives, it may wish to consider the process of composting as defined here. There is, however, a potential to reduce labor and operational costs by modification of the materials handling aspects of this process. With specialized equipment, total and operating costs would be reduced while the fixed investment would have to be increased. Costs could be reduced, especially for small towns, by utilizing available labor or equipment for part-time composting operations.

The cost per dry ton is sensitive to changes in operating costs, but insensitive to equipment, land, and site development costs. The per dry ton costs will increase by $1 if operating expenses increase by 4 percent. The cost of equipment must rise by 19 percent and cost of site development by 25 percent to increase the cost per dry ton by $1. If operating costs increased by $10,000, total cost per dry ton would increase by $2.70. If the cost of equipment, site development, and land were increased by $10,000 each, the dry ton cost would only increase $0.32, $0.17, and $0.15, respectively.

Transporting the sludge from the treatment plant to a composting site can be expensive. For example, sludge transportation to the Beltsville Research Facility costs about $1.50 per dry ton per mile. Thus, it is recommended that large-scale composting sites be placed in close proximity to the associated wastewater treatment plant.

A final economic consideration in composting is that the current guidelines for the cost sharing of facilities for pollution abatement of municipal wastewater are biased toward construction-intensive projects (12). Composting and other noncapital-intensive sludge disposal techniques will be more expensive to a municipality than to the nation. Unfortunately, this encourages the selection of waste disposal techniques that are not cost-effective for some municipalities.

SUMMARY

Concerns about environmental degradation as evidenced in the Water Pollution Control Act, The Clean Air Act, and The Ocean Dumping Act have intensified the search for environmentally acceptable, cost-effective sludge disposal techniques. The cheapest sludge disposal methods, fresh and salt water dilution, are no longer acceptable. The major concern now is the form the sludge will be in when it is applied to the land.

In landspreading and landfilling, digested sludge is applied directly to the land. Under most circumstances, landfilling is less expensive than landspreading but the benefits are also considerably less. Trenching is an expensive sludge disposal method but can dispose of large quantities of sludge quickly with some benefit to the soil. Heat drying, incineration, and composting convert sludge into inoffensive and easily handled materials that require final disposition. These three methods can yield benefits to partly offset their high cost. Incineration has the potential for heat recovery and the economic use of its residue. Composting and heat drying yield a product that can improve the productivity of soil and the growth of crops.

Composting is receiving increased attention as a sludge management alternative. The research at Beltsville involves investigation of the technical and economic feasibility of composting. Two processes have been developed: (1) The windrow process for composting digested sludge and (2) the aerated pile process for composting undigested or raw sludge.

The aerated pile process of composting can be a cost-effective sludge disposal process. The composting process is subject to economies of scale ranging from $51 per dry ton for a municipality of 100,000 to about $35 per dry ton for a city of 500,000. Composting is land-intensive, requiring an acre for every 3 dry tons of sludge processed, or for about every 30,000 people. Composting is also labor intensive because 40 percent of the costs are for labor expenses. Composting may be a cost-effective alternative for some community sludge management problems.

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