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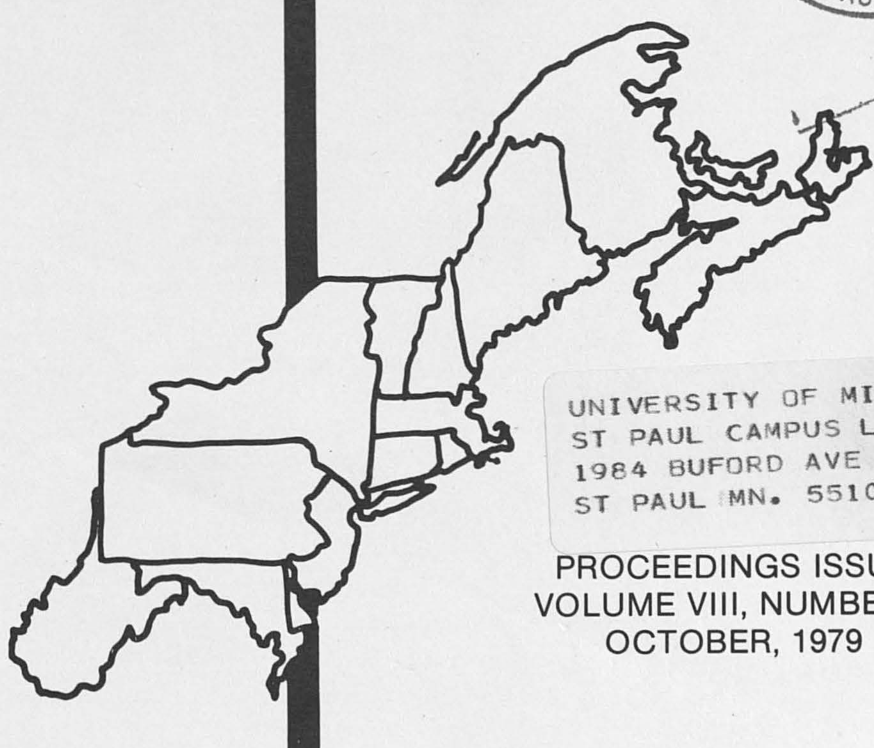



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# ECONOMIC ISSUES IN THE COMPOSTING OF SEWAGE SLUDGES

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In the northeast, communities have been faced with a variety of waste management problems brought about by population concentrations and higher consumption levels. One waste that has been receiving increased attention is sewage sludge generated by municipal waste treatment plants. Although alternative sludge treatment technologies are available, a number of municipalities have been ocean dumping. For example, in New Jersey it has been estimated that of the 230,000 dry tons of sludge produced annually, nearly two-thirds is being ocean dumped (Bolan et al.). Although ocean dumping is a relatively inexpensive method from the viewpoint of the municipality, it has become costly in terms of ocean and coastal resources (Colacicco et al., U.S. Department of Commerce). As a result of contaminated beaches, algae blooms, and fish kills (1976 and 1977) legislation was passed in 1977 to stop the ocean dumping of sludge by December 31, 1981 (U.S. Congress, 1977).

With the pending moratorium on ocean dumping, municipal authorities have been considering alternatives including land spreading, land filling, incineration and composting. Land spreading has been used successfully in a number of states, but it appears to have limited acceptance in densely populated areas (Bolan et al., Sevan, Smith, et al.). Efforts to land-apply wet sludges have met with strong public objection. In addition, landfill sites are operating at or near capacity and offer little or no long-term solution for sludge management. Incineration has three major drawbacks: (1) energy consumption, (2) meeting air quality standards, and (3) construction time to be brought on-line (McNulty and Sharpe, Kaercher, Neiswand and Pizor, Goldstein, U.S. Congress 1974, Blobaum et al.). Composting appears then to be the most viable for highly urban areas, given the prior constraints. Conversely, advantages often suggested include: (1) on-line time to meet the 1981 deadline, (2) and end product with a potentially wider range of uses, (3) ability to meet air and water quality standards, (4) costs comparable to other alternatives, and (5) public acceptance.

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In spite of this rather optimistic view of the process, a number of basic issues need to be considered to fully evaluate the process. They include: (1) adequate cost estimating procedures, (2) revenue potential, (3) private versus public production, (4) objectives of the composting process, and (5) capital intensive bias. These five issues were found to be important as the result of an intensive interdisciplinary study of an on-line composting system at the City of Camden, New Jersey. The purpose of this paper is to discuss the importance of each of these five issues in the economic evaluation of composting and to suggest ways to deal with them in the future.

## The Process

Composting is not a new technique; it has been used since ancient times to recycle vegetative and animal waste. Through biological action, organic material is broken down into a form that enhances crop production through increased availability of plant nutrients, increased water absorption and retention capacity and improved soil tilth. Composting sludge as developed thus far involves drawing air through a static pile containing a mixture of dewatered sludge and wood chips (this phase takes about 21 days). The wood chips create air voids so that there is greater contact between the sludge and the air flow. The air flow is important to maintain a time-temperature relationship for an adequate pathogen kill.

A flow of the various composting activities are portrayed in Figure 1. After the initial composting phase, the stack is broken down and moved to a storage area for curing (about 30 days). Once cured, the compost could be used either with or without the screening of the bulking agent (wood chips). If the compost is screened, the wood chips are returned to the initail composting phase. A wide range of uses is possible depending upon the characteristics of the sludges -- mainly the presence or absence of heavy metals.

Composting operations are highly divisible and generally labor intensive. That is, very small facilities (less than 3 dry tons/day which will serve a population of 30,000) consisting of a concrete pad, a conventional tractor w/front end loader and an air suction system (electric motor and fan) to highly automated systems handling an excess of 100 dry tons/day are being brought on line. Also, the same technology can be used over a wide range (sizes) of facilities since various sized equipment (dewatering, sludge/chip mixing, front end loaders, screening, conveyors, etc.) are available and divisible.

## The Issues

### Cost-Estimating Procedures

To date cost estimates of the composting process have varied substantially and are presented in Table 1. One major source of cost variation results from considering only the "add-on," or incremental costs which include, basically, contractual construction costs and operating costs such as labor, wood chips, equipment, etc. Thus, there has been a tendency to underestimate the total cost of the process. Research engineers and economists have also

Figure 1. Flow Chart of Composting Activities and Product Uses

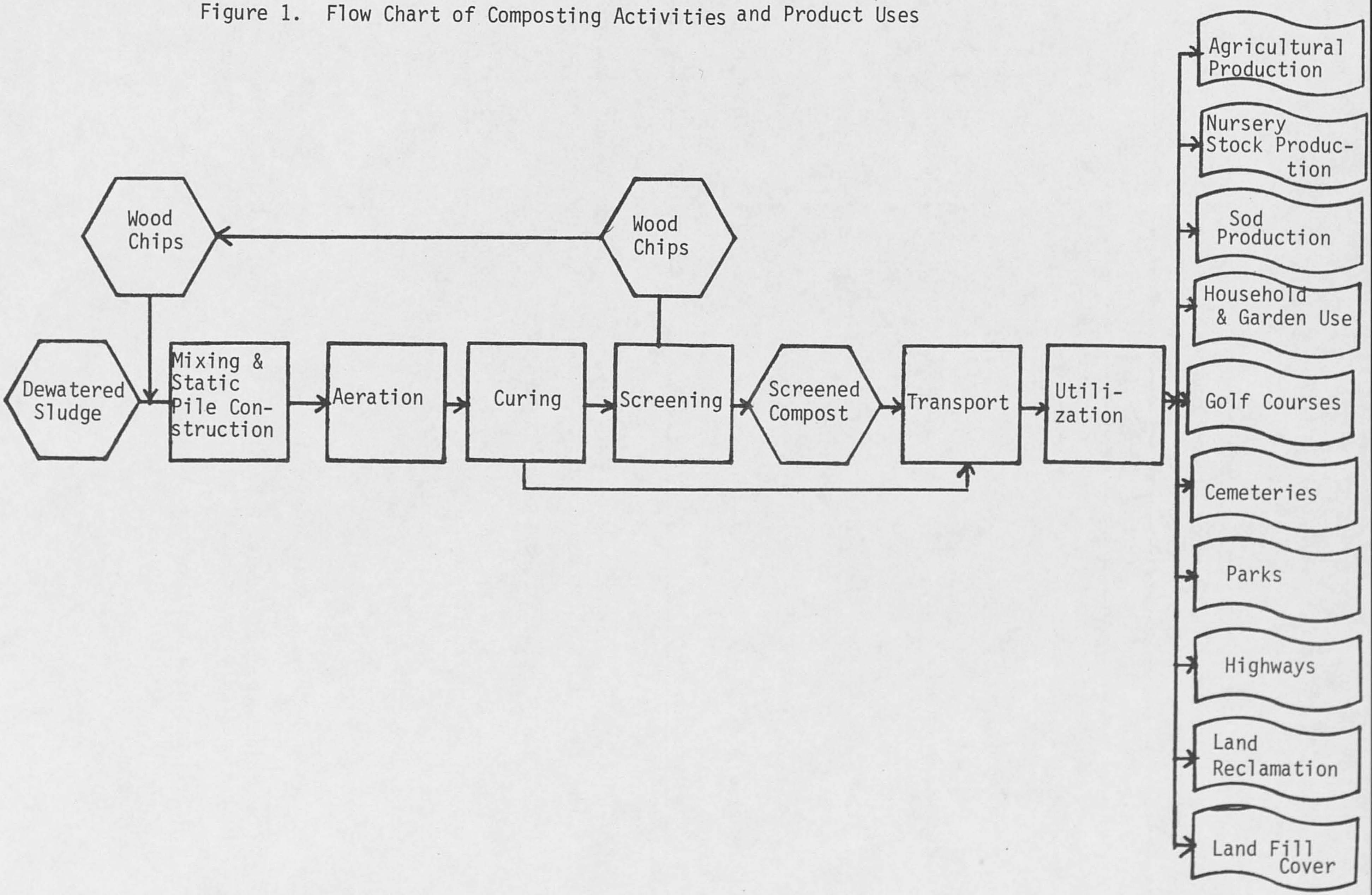

Table 1

Estimated Cost of Sludge Composting per Dry Ton

| Source | Cost/Dry Ton | Design Volume |
|---|---|---|
| | $ | dry tons/day |
| On-Line Estimate | | |
| Montgomery County[a/] | 92 | 280.0 |
| Blue Plains[b/] | 73 | 120.0 |
| Windsor, Ontario[c/] | 39 | 26.9 |
| Camden[d/] | 89 | 26.4 |
| Durham[e/] | 90-100 | 3.0 |
| Bangor[f/] | 56 | 2.0 |
| Experimental | | |
| Beltsville[g/] | 60 | 10 |
| Chicago[h/] | 311 | N.A. |

N.A. = Not Available

[a/] PRC Toups Corporation. Assumes LLT alternative used. The estimate excludes land costs which could add an additional $.20/dry ton.

[b/] J. Lenard Ignatowski and Kenneth L. Donnelly.

[c/] Louis S. Ramano, P.E. and John Faust. (Costs do not include interst on capital or opportunity cost of land, administration costs or engineering costs.)

[d/] Victor Kasper and Donn A. Derr.

[e/] George Crombie.

[f/] Dale Mosher and R. Kent Anderson.

[g/] D. Colacicco, E. Epstein, G.B. Wilson, T.F. Pane, and L.A. Christensen. Prices updated to December 1978.

[h/] Cecil Lue-Hing and George T. Kelly. Prices updated to December 1978.

been placed in the unenviable position of having to estimate the cost of bringing the process on-line without a prototype or blueprint from which to work. Thus, it is very easy to overlook such preconstruction expenditures as: (1) administration; (2) legal/contractual costs; (3) interest charges; and (4) engineering costs.[1/] In effect, major costs are incurred before the system is constructed. These costs can be important in cost effectiveness analysis where capital intensive and labor intensive systems are being considered.

Other variations in costs arise from: (1) using discount rates other than that suggested by the Water Resources Council (2) variation in length of the planning horizon, (3) salvage value at the end of the equipment life, (4) double counting for costs by using the capital recovery factor (principal and interest charge) and a sinking fund factor for cash flow and, (5) costs to the municipal authority with and without the federal cost sharing. One additional source of variation pertains to the design capacity of the facility. Though a plant may be designed to handle a given quantity of sludge (usually expressed on a dry ton per day basis of sludge to be composted) there will be built in reserve capacity. Where relatively new technology is being considered, reserve capacity may be in excess of that needed for variation in seasonal sludge flow primarily to hedge against unforeseen constraints. What is basically required for consistent cost estimation is full accounting of resources used (opportunity cost) whether previously owned or purchased just for composting, and secondly, a careful consideration of the design capacity.

## Revenue Potential

Once the process is brought on line and compost is produced, there remains the problem of how to "dispose" of it. Research to date indicates a full range of potential uses of compost; from landscaping purposes (wood ornamentals) using unscreened compost to sod production (screened compost) to land reclamation where loadings in excess of 50 dry tons/acre have been applied. The organic matter (about 50 percent on a dry weight basis) has generated benefits beyond those normally obtained from applying lime and inorganic fertilizers only. The slow release rate of the nitrogen provides a flow of plant nutrients over about a four-year period.[2/]

Major issues center on: (1) utilization versus marketing, (2) bulk versus bagging, (3) transport costs, (4) price or value. Little distinction has been made between utilizing compost (screened or unscreened) directly from the operation to the land and the entry into actual marketing channels. The latter may involve labeling the product, guaranteeing the minimum analysis, advertising, and a sales force. Although not presented here, data on the market potential of such products as compost indicate that the demand is quite inelastic, that the market is usually at or near its potential volume and that new product entries are risky (DiLalo, Born). Existing organic products are well established and people are reluctant to change product lines.

On a component basis (value of N, P, K, and the organic matter) compost would have an indicated value of about $12 per dry ton.[3/] Actual sales of compost at Bangor, Maine and Los Angeles, California indicate a value of about $15 per dry ton on a bulk basis (Table 2). Also, demonstration pro-

Table 2

Actual and Estimated Wholesale Value of Composted Sludge Marketed on a Bulk Basis

| Location and Use | $/Wet Ton | $/Dry Ton | $/Cubic Yard |
|---|---|---|---|
| Bangor, Maine | | | |
| Parks & Public[a] (actual) | 11.10 | 17.08 | 5.55 |
| Durham, New Hampshire | | | |
| Top Soil Substitute[b] (estimated) | 12.40 | * | 5.00 |
| Los Angeles, California | | | |
| Kellogg, Nitrohumus[c] (actual) | 11.00 | 15.71 | 5.50 |
| Windsor, Ontario | | | |
| Soil Conditioner[d] (actual) | 17.40 | 30.10 | 8.70 |

* $49.71 was the pre-dry-ton value reported; however, this implies compost of 25 percent solids. Since most compost is between 50-70 percent solids, this estimate is not included in the table.

a/ Dale Mosher and R. Kent Anderson. Price level updated to December 1978.

b/ George Crombie.

c/ Clay Kellogg. This price excludes transport costs to the user. It assumes material is 30 percent moisture and 1000 lbs per cubic yard.

d/ Louis S. Romano, P.E. and John Faust.

grams at Bangor and Durham have indicated wide public acceptance of compost.

Estimates of bagged compost portrayed in Table 3 reflected a wider range compared to the bulk basis. Again, using a dry weight basis, values range from $62.10 to $69 per ton. A part of this variation is explained by the type of bagging operation; Bangor uses burlap bags and compost is made available on an "as needed basis" whereas the upper values reflect commercial bagging. Bagging on a regular basis costs about $25 to $30 per ton, thus indicating a $32 to $44 per dry ton value on a bagged basis net of bagging cots.

## Private versus Public Production

Traditionally, the treatment of waste water has been limited to the public sector. Large initial investments with long planning/design periods and construction phases characterize waste treatment systems. The attractive economic aspect of composting is that it can be brought on line in less time and the initial investment is far less than incineration. But a major drawback is that it is a labor intensive system as shown in Table 4. Labor and annual administrative costs together constitute an estimated 32 percent of the total cost of composting. Labor costs account for 43 percent of the annual operating costs for the system brought on-line at the City of Camden.[4/] To handle 26.4 dry tons of sludge per day at Camden, two shifts are needed with three skilled and two unskilled laborers for the first shift and three skilled workers for the second shift. Also, since this plant must operate 260 days a year and the laborers will be off at least 26 days for vacation and holidays, part-time help is needed to meet the total time requirement. Because of the nature of the work, plants have reported a higher than average turnover rate.

For composting to operate effectively, close technical supervision and monitoring is required. Correct mixing and static pile construction is important for aeration systems to work properly. Time-temperature relationship is important for proper and complete composting (Goluke). Several different types of machinery (front end loaders, aeration systems, dump trucks, mixing/blending equipment, screen/separators, elevators, etc.) must be operated, repaired, and maintained daily. Without close management, subsystems can fail and eventually affect the whole system.

Thus, given these characteristics, composting by private vendors should be given consideration. The best entry point would be after the dewatering of sludge. Sludge could be transported to the private vendor's site, composted and then utilized in some way (direct land application or marketed). Since the water content in dewatered sludge is higher than in compost, off-site composting may be more costly due to additional transport costs.[5/] Private vendors could, through public bidding, indicate the price they would be willing to charge to compost and the volume they would handle.

From society's point-of-view, some advantages and disadvantages are indicated. The profit motive would: (1) encourage cost minimization, (2) adopt the latest technology, (3) serve the waste disposal objective of the municipality, and (4) produce a composted product meeting the needs of users. In general, greater control and flexibility is possible via

Table 3

Wholesale Value of Composted Sludge, Bagged Basis

| Estimates | Package Size | Package | Wet Ton | Dry Ton | Cubic Yard |
|---|---|---|---|---|---|
| | $ | $ | $ | $ | $ |
| Los Angeles, Calif. | 50 lb | 1.20 | 48.20 | 69.00 | 24.10 |
| Kellogg, Nitrohumus[a/] | 50 lb | 1.20 | 48.20 | 69.00 | 24.10 |
| Bangor, Maine[b/] | .11 cu yd | 2.22 | 40.36 | 62.10 | 20.11 |

a/ Kellogg, Clay. A 30-percent moisture content was assumed.

b/ Dale Mosher and R. Kent Anderson. Price level updated to December 1978.

Table 4

Composting Cost per Dry Ton, 26.4 Dry Ton Capacity, Camden County Municipal Utility Authority, 1978

| | Annual Total $ | $/Dry Ton | Percent |
|---|---|---|---|
| Variable Costs | | | |
| 1. Labor | 153,800 | 22.41 | 25 |
| 2. Bulking Agent | 132,300 | 19.27 | 21 |
| 3. Repair & Maintenance | 29,800 | 4.34 | 5 |
| 4. Fuel, oil & electric | 30,800 | 4.49 | 5 |
| 5. Piping | 10,000 | 1.46 | 2 |
| Subtotal | 356,700 | 51.97 | 58 |
| Fixed Costs | | | |
| 1. Site Development | 94,500 | 13.77 | 15 |
| 2. Equipment | 83,600 | 12.18 | 14 |
| 3. Administration | 40,600 | 5.92 | 7 |
| 4. Building & Land | 18,600 | 2.71 | 3 |
| 5. Engineering | 12,100 | 1.76 | 2 |
| 6. Monitoring | 4,700 | .68 | 1 |
| Subtotal | 254,100 | 37.02 | 42 |
| Total | 610,800 | 88.99 | 100 |

private vending.

Disadvantages of the private vendor alternative include (1) higher transactions costs, (2) constraints on use if concentrations of heavy metals are present, (3) site availability, (4) higher transport costs, and (5) higher opportunity cost of capital. Transactions costs would be enhanced by use of several vendors because of negotiations, contracts and monitoring/quality control. The Contstruction Grants Program would have to be modified to accommodate vendors. Thus, the use of private vendors would tend to be contained to smaller treatment systems (less than 10 dry tons per day). The presence of heavy metals would limit the uses of composted sludge and the interest of vendors. Limited sites and increased distances from the treatment plant could offset any cost reductions along with higher expected costs of capital. Current EPA guidelines call for an interest of 6 7/8 percent compared to at least 12 percent for vendors. In sum, the potential for composting via vendors would have to be done on a case-by-case basis.

## Objectives of Composting

The composting process basically has two objectives: (1) to reduce the volume of sludge and/or, (2) to maximize the plant nutrient/soil structure properties. The sewage authority views composting as a way to solve its "sludge disposal problem" -- when the material is moved off-site and disposed of. But the composting process can be adjusted (time-temperature relationship, size and amount of screening, moisture content) to produce varying materials to serve a myriad of uses. These uses are enhanced if the plant nutrient/soil structure properties are maximized. The time-temperature relationship can also be used to minimize volume, thereby reducing labor, equipment and space required. The purpose of composting, then, depends on whether it is veiwed primarily as a sludge disposal alternative or a process geared to utilization. Use of private vendors would tend to internalize any externalities created by public production and private use.

## Capital Investment Bias

As mentioned earlier, the basic composting process has been used since ancient times. How large scale composting is to be best brought on-line is still open to debate. Since few relatively large systems (10 tons or more) have been brought on-line, there is a tendency to hedge against unforeseen problems by overinvesting in the site design and equipment. This results from engineering preferences and also federal/state cost sharing programs. Engineers favor a capital intensive design because of: (1) system reliability, and (2) proven equipment/processes. Labor intensive designs are viewed as less reliable because the use of more people results in greater management needs and lower skill levels and poses a greater potential for labor-management disputes.

Overinvestment in site design and equipment is used by engineers to guarantee the system's reliability and to avoid legal problems created by equipment not meeting contractual specifications. Also, there is a tendency to employ proven industrial equipment that is custom designed when more conventional assembly line agricultural equipment appears to be suitable. A case in point is the lack of adoption of conventional agricultural equipment, e.g., field tractors w/front-end loaders, feed mixing equipment, screens, etc. which, as yet have not received adequate consideration.

There is the tendency to select the more captial-intensive designs because of federal and state cost sharing programs (Marshall and Ruegg, 1974, 1975). Cost sharing applies to the initial construction costs and not to operating costs (EPA). Thus, there is a bias toward shifting as much of the cost to the cost sharing program (construction costs) which may be more costly in terms of the total social resources used.

## Summary

Initially, composting was viewed as a process that could potentially solve the sludge waste probelm and generate a product that could offset most, if not all, of the cost. Estimates to date, however, indicate a cost range of $70 to $90 per dry ton of sludge processed (exclusive of dewatering costs) with a potential revenue offset of $15 per dry ton of compost sludge on a bulk basis and $37 on a bagged basis.[6/] These estimates indicate that there are some economies of size associated with varying plant sizes.

When examining the potential value of compost, direct utilization through land application to soil for a variety of purposes (mulching, crop production, parks and recreation maintenance, land reclamation, etc.) should be analyzed differently from "marketing." There has been a tendency to view any form of utilization as "marketing."

An important issue raised here concerns the use of private vendors. This is suggested in light of the manpower needed to operate the facility plus the close day-to-day monitoring and supervision of the process. A private vendor could orient the process toward maximum volume reduction, direct land application or marketing outlets, depending on weather conditions and market demand. Greater control over cost could also be exerted by adopting more conventional, readily accessible and less expensive equipment than that currently being used.

## FOOTNOTES

[1]These costs were estimated to be $272,900 or 13.2 percent of total initial cost for a 26.4 dry ton/day design facility at the City of Camden.

[2]See footnote 3 for the physical and chemical properties of compost.

[3]Based on compost containing: (1) 1.5 percent N released over a 4-year period, (2) .5 percent $P_2O_5$ and .5 percent $K_2O$, (3) 50 percent organic matter and 65 percent moisture, (4) a bulk weight of 1000 lbs/cu yd, (5) N, $P_2O_5$ and $K_2O$ value at $.28, $.22, and $.12/lb, respectively, (6) organic matter valued at $12.20 per dry ton. The time distribution of N availability

was as follows: 20 percent the first year, 5 percent the second year, .5 percent each year in the third and fourth years. The value of N in years 2 - 4 was discounted to the present using 6 7/8 percent.

[4] Estimates have placed the figure at 52 percent for other systems (see Colacicco et al.).

[5] This off-site transport may be required regardless of whether composting is done by the authority or a private vendor due to periodic odor problems.

[6] One dry ton of sludge yields between .57 - 1.02 dry tons of compost (Higgins et al.).

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