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WASTEWATER SLUDGE UTILIZATION AND DISPOSAL COSTS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Water Program Operations
Washington, D.C. 20460

MCD-12

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Methods of estimating costs and evaluating the cost-effectiveness of conventional wastewater treatment works have been developed in a separate document, entitled, A Guide to the Selection of COST-EFFECTIVE WASTEWATER TREATMENT SYSTEMS, NO. EPA-430/9-75-002, MCD-11.

Methods of estimating costs and evaluating the cost-effectiveness of land-application systems have been developed in a separate document, entitled, Technical Report, Costs of Wastewater Treatment by Land Application, No. EPA 430/9-75-003, MCD-10.

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WASTEWATER SLUDGE UTILIZATION AND DISPOSAL COSTS

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ABSTRACT

A flow sheet describing various sludge utilization and disposal alternatives is presented. Amortized capital and O&M costs are shown for plant capacities ranging from 1 - 1000 MGD. From this information preliminary comparisons of the cost-effectiveness of various sludge utilization and disposal alternatives can be made. The report provides supplementary information which when combined with the Technical Report: A Guide to the Selection of Cost-Effective Wastewater Treatment Systems, EPA-430/9-75-002 and Costs of Wastewater Treatment by land Application provides construction grant applicants with information for preliminary cost comparisons of various wastewater management alternatives.

ACKNOWLEDGEMENT

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SECTION I

INTRODUCTION

The purpose of this report is to present a series of cost relationships for sludge disposal alternatives and to describe briefly the process and type of information used in creating the cost relationships. In this context the term "sludge disposal alternative" is used to connote the combination of sludge treatment processes and sludge transport and ultimate disposal methodologies comprising a sludge management system.

The basic premises or conditions selected for development of the cost curves were as follows:

1. The variables to be considered in the relationships were:
   a. Sewage treatment plant flow rates varying from one to 1,000 MGD.
   b. Two levels of treatment, primary and (activated sludge) secondary.
   c. Sludge treatment processes incorporating incineration and anaerobic digestion.
   d. Transport to ocean disposal by barging and to land disposal by truck, rail, and pipeline.
   e. Land disposal by landfill and land spreading.

2. The range of transport distances for the ocean barging and land disposal methodologies were selected to reflect the transport distances likely to be considered by Eastern Seaboard cities, and were as follows:
   a. Barge transport to ocean disposal locations at distances of 15, 50, 80, 110, 150, and 180 miles from the barge loading station.
   b. Land transport over distances of 20, 50, 100, and 150 miles.

3. Barging transport costs were to be developed for two situations, viz,
   a. "Simple" case, wherein all sludge generated in a metropolitan area can be loaded at a single barge loading station.
   b. "Complex" case, where sludge is collected from a multiplicity of barge loading stations in a metropolitan area before the barge can be towed to sea.

4. All cost relationships were to be developed using March 1975 costs.

SECTION II

DESCRIPTION OF ALTERNATIVES

The sludge disposal alternatives for which cost relationships were developed are shown in Figure 1. The basic alternatives are as follows:

1. Alternative I: vacuum filtration of primary and thickened biological sludges to produce a sludge stream at 20% solids, followed by incineration and truck haul of the incinerator ash to a landfill site.

2. Alternative II: digestion of primary and thickened biological sludges followed by barging to an ocean disposal site under "simple" and "complex" barging conditions as defined in Section I.

3. Alternative III: digestion of primary and thickened biological sludges, vacuum filtration of a portion of the digested sludge stream and blending of this portion with undewatered digested sludge to produce a sludge at 10% solids, followed by barging to an ocean disposal site under "simple" and "complex" barging conditions.

4. Alternative IV: digestion of primary and thickened biological sludge, followed by tank truck or pipeline transport to a landspreading site.

5. Alternative V: digestion of primary and thickened biological sludge, followed by vacuum filtration to produce a sludge stream at 20% solids, and truck or rail transport to a landfill site.

Subalternatives were defined in each alternative to account for sludge handling and disposal associated with primary and activated sludge secondary treatment as follows:

1. The secondary treatment subalternatives within each alternative were cost-evaluated as shown in Figure 1 and described above, i.e., inclusive of the biological sludge stream and the thickening unit process for this stream.

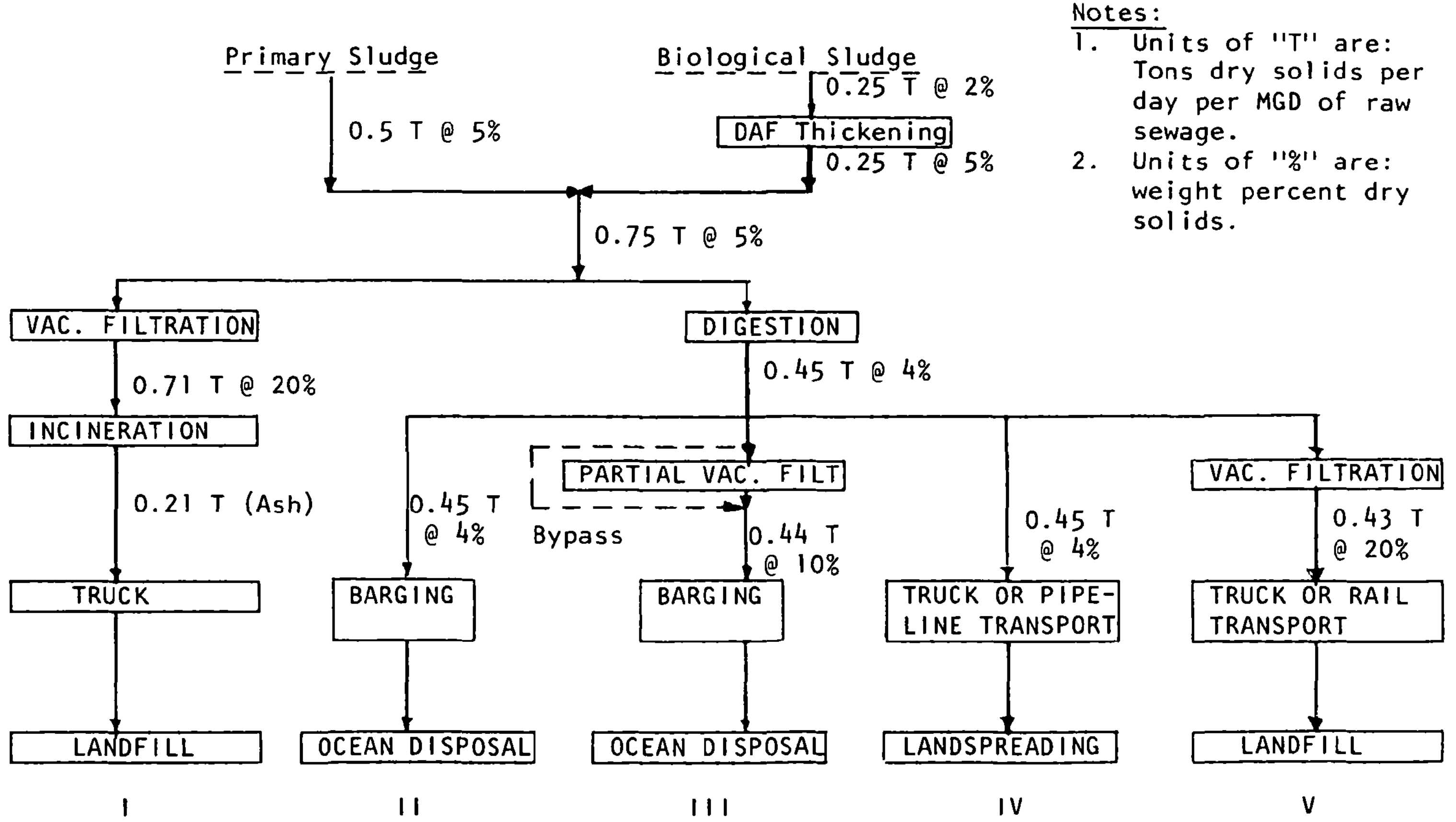
2. The primary treatment subalternatives were cost-evaluated exclusive of the biological sludge stream and the thickening unit process for this stream.

In developing material balances for the sludge "flow" through the unit process trains in each alternative, the normalized parameter selected was "tons of dry solids per day per MGD of flow." The values of this parameter for the sludge stream at each point in the unit process trains, and the corresponding solids concentrations of the sludge stream, are shown in Figure 1. These data were developed using the assumptions that:

1. Primary treatment generates 0.5 ton dry solids/day/MGD at 5% solids in the sludge flow from the primary clarifiers.

2. Secondary treatment generates 0.5 ton dry solids/day/MGD at 5% solids in the sludge flow from the primary clarifiers and 0.25 ton dry solids/day/MGD at 2% solids in the biological sludge flow from the secondary clarifiers.

FIGURE 1. SLUDGE DISPOSAL ALTERNATIVES



3. Thickening by dissolved air flotation (DAF) increases the solids concentration in biological sludges from 2 to 5%.

4. Incineration results in destruction of 70% of the dry solids content of the sludge flow.

5. Digestion (anaerobic) results in destruction of 40% of the dry solids content of the sludge flow.

6. Dewatering to 20% solids can be achieved with vacuum filtration.

7. The maximum solids concentration of which sludge can be discharged (pumped) from a barge is 10%.

SECTION III

DEVELOPMENT OF COST RELATIONSHIPS

APPROACH

The steps used in the development of the cost estimates were as follows:

1. Cost data were developed for each unit process, transport method, and ultimate disposal method specified in the sludge disposal alternatives presented in Figure 1, taking into consideration the variables of:
   a. Plant flow rate (1, 10, 100 and 1,000 mgd).
   b. Type of treatment (primary and secondary).
   c. Type of transport (truck, rail, pipeline, and barging) and one way transport distance (land, at 20, 50, 100, and 150 miles; and ocean, at 15, 50, 80, 110, 150, and 180 miles).
   d. Type of barging (simple or complex).

2. The above cost data were used in compiling costs by alternative for each combination of variables within each alternative, to obtain the desired sludge disposal alternative cost data; because of the number of variables considered in each alternative, the sets of cost data developed in each alternative were as follows:
   a. Alternative I - 32
   b. Alternative II- 96
   c. Alternative III- 96
   d. Alternative IV- 32
   e. Alternative V - 32

3. The selection of which transport mode was to be used in Alternatives IV and V (truck or pipeline in Alternative IV and truck or rail in Alternative V) was based on least cost.

4. The 288 sets of cost data obtained in the preceding steps were utilized in the development of a graphical presentation of capital cost and total annual (amortization plus operation/maintenance) costs as a function of flow rate, treatment level, transport distance, etc., as the end product.

The cost relationships developed in Step 4 above are presented and described in Section IV, and the development of the cost data for the individual unit treatment processes and transport and ultimate disposal cost relationships is presented below.

GENERAL COST ESTIMATING CONDITIONS

The cost estimating conditions that were applied generally in the development and/or updating of cost curves for individual unit treatment processes and the transport and ultimate disposal methodologies are as follows:

1. Economic factors:

a. Interest rate - 5 7/8% and project life = 20 years, for which the value of the Present Worth Factor is 11.59 and the value of the Capital Recovery Factor is 0.0863.
b. Labor rate (including fringe benefits) = $6.50 per man hour.
c. Service and Interest Factor = 27%.
d. STP Index (Environmental Protection Agency) = 232.1 (March 1975).
e. Wholesale Price Index (Department of Commerce) = 170.4 (March 1975).
f. CCI (Engineering News Record) = 2200.

2. Land Unit Costs:
   a. Treatment plant sites:

Q(MGD)	Land Cost ($/Acre)
1	3,000
10	4,000
100	5,500
1,000	8,000

   b. Landfill or landspreading sites:

Q (MGD)	Land Cost ($/Acre) at Haul Distances of 20 mi.	50 mi.	100 mi.	150 mi.
1	2,000	1,000	500	500
10	2,500	1,500	1,000	1,000
100	3,000	2,000	1,000	1,000
1,000	3,500	2,500	1,000	1,000

3. Sludge generation quantities: the assumption used is that secondary treatment results in generation of 0.75 ton dry solids/day/MGD, and primary treatment in 0.5 tons dry solids/day/MGD; thus for any given flow rate, the sludge quantity generated for primary treatment is assumed to be equal to two thirds of the quantities generated for secondary treatment.

The additional assumptions, specific to cost evaluating each unit process and sludge transport and disposal methodology, are discussed below.

UNIT TREATMENT PROCESSES

Dissolved Air Flotation

Capital, O/M and total annual costs for the DAF (dissolved air flotation) thickening of biological sludges were estimated using cost relationships developed by McMichael (Reference 1), updated to March 1975. The parameters used in developing the DAF cost data were as follows:

1. Dry solids loading rate of 48 lb/day/sq ft.

2. Polymer dose at 10 lb/ton dry solids and polymer cost at $1 per lb.

Vacuum Filtration

Estimates of capital, O/M, and total annual costs for the vacuum filtration process were developed using the following Bechtel cost relationships, updated to March 1975:

1. Alternative I: vacuum filtration of raw primary and biological sludge (Reference 2).

2. Alternatives II and V: vacuum filtration of digested primary and biological sludge (Reference 3).

Incineration

Estimates of capital, O/M, and total annual costs for the incineration process were developed using Bechtel cost relationships (Reference 4), updated to March 1975.

Digestion

Estimates of capital, O/M, and total annual costs for the anaerobic digestion process were developed using Bechtel cost relationships (Reference 5), updated to March 1975.

TRANSPORT METHODOLOGIES

Pipeline

Estimates of capital, O/M, and total annual costs for pipeline transport of sludge slurries were developed using cost relationships presented by Thompson *et al* (Reference 6), updated to March 1975. The updated cost relationships were applied using the assumptions that:

1. "Downtown" construction cost curves apply for pipeline installations from zero to 10 miles from the treatment plant.

2. "Suburban" construction cost curves apply for pipeline installations between distances of 10 and 20 miles from the plant.

3. "Rural" construction cost curves apply for pipeline installations at distances greater than 20 miles from the plant.

Truck and Rail

The primary source of information used in developing truck and rail haul total annual cost curves were unpublished cost relationships developed in the James River Comprehensive Water Quality Management Study (1971 - 1973), updated to March 1975. These unpublished cost relationships were developed by obtaining sludge haul bid costs from tank truck and rail haul carriers as a function of wet tonnage hauled and haul distance, and were updated by direct contact with the haulers to obtain cost escalation factors.

Barging

Barging costs were developed using the barging economics model developed by Clark *et al* (Reference 7). The steps used in updating the parameters in this model were as follows:

1. Barging capacity was assumed to cost $340/ton (Reference 8), and towing

costs (at eight knots) were estimated as follows, using updates of data from References 9 and 10:

Barge Capacity (Tons)	Towing Cost ($/hr)
8,000	300
5,000	225
2,000	150

2. Total annual barging cost curves were constructed as a function of annual wet tonnage hauled, barge size, and haul distance.

3. From the above curves, the least total annual cost was defined as a function of annual tonnage and haul distance, and a second set of cost curves defining least annual cost as a function of annual tonnage and haul distance were constructed.

4. The resultant cost curves were compared with cost projections for sludge barging (Reference 9) from Philadelphia and DuPont (exemplary of the "simple" case) and New York (representative of the "complex" case).

5. Excellent comparison was found between the Philadelphia cost projections and estimates for the Philadelphia and DuPont cases developed using the updated economic model; however, it was found that unit sludge barging costs ($/wet ton) for New York were about twice those estimated using the updated economic model.

6. Based on the preceding comparisons, two sets of barging cost curves were developed, one each for the:
   a. "Simple" case, using the cost curves constructed with the updated economic model.
   b. "Complex" case, constructed by escalation of the cost curves for the "simple" case by 100%.

ULTIMATE DISPOSAL METHODOLOGIES

Landfilling

Landfill capital, O/M and total annual costs were estimated as follows:

1. Landfill construction cost (excluding land) and O/M costs were developed using cost relationships presented by Wyatt and White (Reference 11).

2. Land costs were estimated using the unit land costs presented earlier in this section and a land requirement rate of 3.75×10^{-3} acre/ton of sludge (wet or dry)/year (Reference 12).

3. Land costs were estimated to provide land for five years of operation, and no salvage value was assumed for the land.

Landspreading

Landspreading capital, O/M, and total annual costs were estimated as follows:

1. An application rate of 10 tons dry solids/acre/year (Reference 13).

2. Distribution costs at $20/day/ton dry solids (Reference 14) and land preparation costs of $2,000/acre (Reference 12).

3. The purchase and salvage value of the land required were assumed to be equal; the net annual cost of the land was estimated as equal to the annual interest cost on the purchase price of the land.

COST RELATIONSHIPS

The initial objective in the assessment of the 288 sets of cost data developed for Alternatives I to V was to develop a single-page graphical presentation allowing the user to:

1. Estimate graphically the following types of costs, by alternative, type of treatment, flow rate, and type and distance of residuals transport:
   a. Capital costs.
   b. O/M costs, in units of cents per 1,000 gallons, and dollars per year.
   c. Total annual costs, as the sum of amortization and O/M costs, in units of cents per 1,000 gallons and dollars per year.

In the processes of evaluating the sets of cost data and exploring ways to develop the presentation, it was observed that:

1. Because of the lack of ready information on capital costs for acquiring truck, rail, and barging systems, estimates could be obtained only for contract hauling (i.e., for total annual costs), and no breakdown could be developed for amortization and/or O/M costs for these transport methodologies.

2. While barging costs were found to be variable with respect to distance at a given flow rate and treatment level, such was not the case for the land disposal alternatives (Alternatives I, IV, and V). The total annual costs for Alternatives I and V were found to be distance independent, and those for Alternative IV were found to vary ± 20 percent at each haul distance with respect to the average value for all distances at a given flow rate and treatment level.

3. The latter circumstance, i.e., the absence of a trend of increasing total annual cost with increasing land haul distance, at a given flow rate and treatment level, was fortuitous in that it reflects the values of unit land costs selected for the analysis (see subsection entitled GENERAL COST ESTIMATING CONDITIONS).

4. That is, for the schedule of unit land costs selected for the evaluation, the sum of transport and land disposal costs on a total annual basis was nearly equal at each haul distance, for all haul distances, in each land disposal based alternative at the same flow rate and treatment level.

Because of the preceding circumstances, it was necessary/possible to adjust the framework of the graphical presentation as follows:

1. Capital costs are presented graphically only for the sludge processing and land disposal related elements of each alternative; no capital costs are included in any alternative for the transport element, such that the capital costs for each alternative are distance independent.

2. Total annual costs for the land based alternatives are presented graphically for the sludge processing land disposal related, and transport elements on a distance independent basis.

SECTION IV

SLUDGE DISPOSAL COST CURVES

A graphical presentation of the sludge disposal cost curves is presented in Figure 2. The elements of the cost curves are as follows:

1. A flow rate scale ranging from 1 to 1,000 MGD.

2. Capital cost scales for the primary and secondary treatment subalternatives within each alternative, wherein capital costs are included for the sludge processing and land disposal elements within each subalternative.

3. Unit cost scales (in units of cents per 1,000 gallons) for each subalternative; "unit cost" is defined as the normalized total annual cost, inclusive of amortization and O/M costs, for the sludge processing, transport, and disposal elements of each alternative.

4. "Slant lines" for determining unit costs for barging disposal at one way ocean haul distances of 15, 50, 80, 110, and 150 miles.

5. A "slant" line for determining unit costs for the land disposal alternatives as a function of haul distances between 20 and 150 miles.

6. A nomograph for determining total annual cost (dollars per year) as a function of flow rate and the unit cost for a given subalternative at that flow rate.

The procedure for using the diagram is as follows:

1. Select flow rate, treatment level, alternative, and haul distance (haul distance if an ocean disposal alternative is selected).

2. Enter flow rate on the "Q, MGD" scale in the upper left hand corner of the graph.

3. Read capital cost by moving rightward horizontally across the capital cost scales; guide scales are provided at either side of the capital cost scales to assist lineup of the straight edge.

4. Read unit cost by reading horizontally from the "Q, MGD" scale to the deflector line; proceed vertically downward to the appropriate slant line; then read unit cost by moving rightward horizontally across the unit cost scales; guide scales are provided to assist lineup of the edge at each step.

5. Using the selected flow rate, the unit cost as determined above, and a straight edge, enter the "Nomograph for Determining Total Annual Cost" and read total annual cost directly.

PAGE NOT

AVAILABLE

DIGITALLY

SECTION V

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