SLUDGE HANDLING AND DISPOSAL PRACTICES AT SELECTED MUNICIPAL WASTEWATER TREATMENT PLANTS

APRIL 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PROGRAM OPERATIONS
MUNICIPAL CONSTRUCTION DIVISION
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SLUDGE HANDLING AND DISPOSAL PRACTICES AT SELECTED MUNICIPAL WASTEWATER TREATMENT PLANTS

by
Sverdrup & Parcel and Associates, Inc.
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OFFICE OF WATER PROGRAM OPERATIONS
WASHINGTON, D.C. 20460

FOREWORD

This report was prepared for the Municipal Construction Division of the Environmental Protection Agency as fulfillment of Task Order No. 9 dated August 3, 1976 under continuing Contract No. 68-01-3289 dated June 26, 1975. It reviews current practices in managing the sludge produced at certain municipal wastewater treatment plants.

SUMMARY

This report describes the sludge handling practices employed by members of the Association of Metropolitan Sewerage Agencies (AMSA). Dewatering and disposal methods are evaluated with respect to the prevalence of various types of equipment and systems, sludge handling costs, and other factors. Research needs and nontechnical aspects of sludge management are discussed.

Composite flow charts are presented to illustrate how the different plants process sewage sludge. Charts are included for primary, secondary, and combined sludges. The quantities of sludge handled by each unit operation and the number of plants using the process are shown. The most commonly used types of equipment in decreasing order of frequency, are anaerobic digestion, gravity thickening, and vacuum filtration. Data on specific types of equipment were correlated with the type of sludge processed, plant size, and other parameters.

Data on sludge handling costs were analyzed. Only limited correlations could be made between types of equipment and costs because most of the data were for the entire sludge handling system and were not itemized by type of equipment. System costs were difficult to compare because of the different cost accounting procedures used by the agencies.

Most personnel believe additional research and demonstration projects will be helpful in improving sludge handling practices. Many indicated a need for more information on ultimate disposal techniques and their effects. Ultimate disposal is now the foremost concern for many administrators because legal constraints have eliminated ocean disposal and, in some cases, incineration.

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I INTRODUCTION

Sludge management has become the center of attention in the wastewater treatment industry. In examining the operation of many treatment plants, sludge management is often found to command a major portion of the budget, whether it be for capital, labor, materials, or energy. The problem of economical sludge management becomes more pressing as the 1977 and 1983 deadlines for more thorough wastewater treatment approach; in many cases bringing with them voluminous quantities of the most difficult of the sludges to dewater---secondary waste activated sludge. The sludge management problem is becoming more complicated as some of the more economical and conventional practices such as ocean disposal and incineration become environmentally unacceptable.

The Environmental Protection Agency (EPA) is preparing technical bulletins and reports to assist design engineers and wastewater authorities in selecting and operating sludge handling systems. These documents will supplement existing federal guidelines for municipal wastewater sludge handling. The present study was undertaken to develop background information on municipal sludge management practices by major cities for use in preparing the technical bulletins. The basic data for this report were collected by the Association of Metropolitan Sewerage Agencies (AMSA) from its members.

AMSA members are responsible for treating a significant portion of the municipal wastewater in the United States. Usable data were obtained from 46 of the 54 member agencies, and included 98 plants serving a total population of over 54 million people, or roughly one-third of the sewered population of the United States. The Appendix lists those AMSA members and plants participating in the study. The treatment plants are located throughout the country as shown in Figure 1, but nearly 50 percent of the flow treated occurs in the heavily populated areas of the East and West coasts.

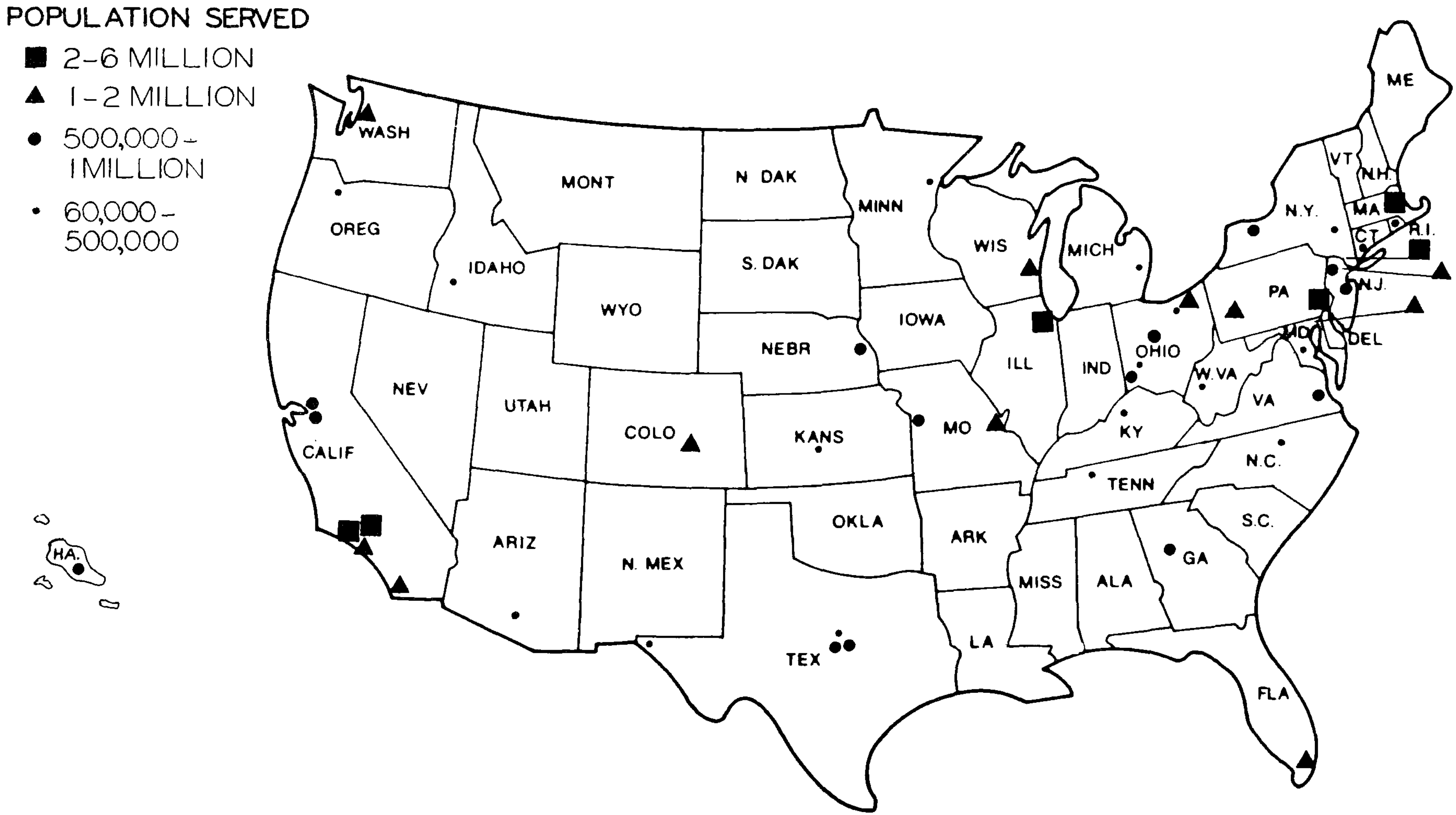


FIGURE 1
LOCATION OF PARTICIPATING AMSA MEMBERS

Current sludge dewatering and disposal practices, costs, and the non-technical aspects of sludge handling are discussed in this report. Substantial information was available on process flow schemes and quantities of sludge dewatered, but only limited data were available on the details of each type of equipment, costs, sludge characteristics, and the nontechnical aspects of sludge disposal. With a few exceptions, efforts to correlate the handling methods with such factors as sludge type, plant size, geographical location, and climate were not successful.

Chapter II discusses the data base in more detail. The sludge dewatering systems used by this segment of the industry are summarized in Chapter III and individual types of equipment are discussed in Chapter IV. Chapter V summarizes what cost information was available and Chapter VI discusses the research and demonstration needs reported by the respondents. Chapter VII is a summary of the non-technical data collected.

II DATA BASE

The data used in this report were collected by AMSA from its members throughout the United States. The data and results were summarized in an AMSA report entitled "Field Report on Current Practices and Problems of Sludge Management" dated June 1976.[1] The report, and in some cases, follow-up telephone calls were the basis for this evaluation report.

AMSA membership is well distributed across the country; however, in terms of population served, the east and west coastal areas predominate. Many of the largest plants in the country are operated by AMSA members. The majority of members control more than one plant.

Fifty of the 54 members provided some data, but only 46 provided enough data to be useable in preparing Chapters III and IV. In some cases a great deal of information was supplied, but others could give only limited information. Many members had a great deal of information for each of the plants under their control. Other authorities had information for selected plants only or the information from several plants was combined in such a way that it was difficult to attribute characteristics or processes to individual plants.

Of the 250 plants operated by AMSA members, no data were available from 67 plants and only very limited data were available from 85 plants. Sufficient information about 98 plants was available for the preparation of the flow charts in Chapter III. The sample group included a wide range of treatment processes, from virtually no treatment to tertiary treatment with chemical precipitation. It was apparent that many agencies are currently upgrading their treatment plants in order to meet the requirements of PL 92-500.

1. More detailed information may be obtained by contacting AMSA, 1015 18th Street, NW, Washington, DC 20036

Table I indicates the relative quantities and types of data available within the original data base. In some cases combined plant data were separated by cross referencing the data with other information. In other cases, the information was used if the multiple source character of the data did not interfere with the nature of the analysis.

A. PLANT SIZE DISTRIBUTION

Plant sizes range from 15 cu m/day (4,000 gpd) to over 3,000,000 cu m/day (800 MGD), and provide a wide sampling of plant types. Table II shows the size distribution of plants covered in the AMSA study.

B. SLUDGE QUANTITATIVE AND QUALITATIVE INFORMATION

Most agencies had information on sludge weight and volume readily available. Forty-eight reported quantitative sludge data on a weight basis, 40 on a volume basis, and 41 specifically indicated the percent solids content of the sludges. The weight basis for sludge quantities appeared to be more consistent than volume and was chosen as the basis for the further analyses in Chapters III and IV of this report.

Qualitative information on the sludges such as nitrogen, phosphorus, potassium, metals, trace organics, and biological indicators was not presented in a readily usable form. However, it is apparent that a number of agencies have substantial quantities of this type of data. One obvious difficulty in obtaining such information is that many plants simply do not routinely analyze for these parameters, if at all. Many take only infrequent grab samples. At other plants, frequent analyses are required for land application programs. Some plants neglected to identify the nature of the reported data as for single grabs, average monthly grabs, or average quarterly grabs, and the units used in reporting some of the data were unclear. Table III shows the data availability.

TABLE I

FREQUENCY OF DATA AVAILABILITY

Data Available	Number of Agencies	Number of Plants Controlled
Few parameters	14	52
Combined data for multi-plant agencies	12	47
Data for selected plants only	5	29
Data for each plant	19	55
TOTAL	50	183

TABL. TI

PLANT SIZE DISTRIBUTION bY AVERAGE DAILY FLOW

Flow Cu m/day	MGD	No. of Plants
Under 5,000	Under 1.3	36
5,000 - 30,000	1.3 - 7.8	42
30,000 - 100,000	7.8 - 26	36
100,000 - 500,000	26 - 132	44
500,000 - 3,200,000	132 - 847	18

TABLE III

SLUDGE QUALITY DATA AVAILABILITY

Parameter	Number of Agencies
Sludge Weight	48
% Volatile	41
Sludge Volume	40
Zinc (Zn)	33
Cadmium (Cd)	33
Copper (Cu)	31
Lead (Pb)	31
Chromium (Cr)	30
Mercury (Hg)	24
Nitrogen (N)	20
Phosphorus (P)	16
Arsenic (As)	14
Potassium (K)	11
Fecal Coliform	11
Total Coliform	10
Selenium (Se)	9
Boron (B)	6
PCB	5
DDT	5
Dieldrin	5
Salmonella	5
Parasite Ova	4
Chlorodane	4
Virus	2

C. SLUDGE PROCESS INFORMATION

Information was provided on the equipment used to process and dispose of sludge, as well as the sludge quantities processed by each type of equipment. The processes were categorized as thickening, stabilization, dewatering, and disposal/utilization. This classification worked reasonably well with a few exceptions. A major difficulty was that some agencies combined their information from different plants, making it unclear as to which processes were used in which plants.

Quantitative information was not always supplied, especially for sludge going to final disposal. In some cases, follow-up telephone calls were made to supplement and clarify the processing and disposal information. This information is presented in Chapters III and IV.

D. OPERATING COSTS AND ENERGY CONSIDERATIONS

Some information was also given on the capital, labor, materials, and energy costs for sludge processing, transportation, and disposal/utilization. Although costs are the most important aspect of any process comparison, the scope of the data did not provide much useful information for cost analysis. One of the major difficulties in analyzing sludge processing costs among a range of plants is that many agencies cannot effectively separate sludge handling costs from the other treatment costs. This is particularly so for labor and energy costs. In addition, there is no standard cost accounting procedure that ensures that any two authorities include the same items within any one cost category. The result is that a wide distribution of costs were reported, when adjusted to a per-ton-of-sludge-processed basis. Without background information to explain the wide variations (most likely because of different accounting procedures), few correlations could be drawn. The evaluation of this data is discussed in Chapter V.

E. RESEARCH AND DEMONSTRATION ACTIVITIES

A listing of possible research and demonstration efforts was made to show both the types of information available to AMSA members and types of information needed.

Some information was provided on research and demonstration projects being conducted by the AMSA members along with a listing of areas requiring additional studies. The greatest area of research and demonstration needs was the subject of health effects of sludge management, and cost effectiveness studies. Other areas of needed information related to energy conservation and market surveys for sludge treatment by-products. Chapters VI and VII discuss this part of the study.

III PROCESS INFORMATION ANALYSIS

One of the principal goals of this project was to analyze the methods used by AMSA members for processing and disposing of wastewater sludges. This chapter describes the processes used, the plant sizes, and the sludge quantity handled by each method.

Present sludge quantities and data from plants now on-line were used in the discussions in this chapter. The anticipated sludge production from plants presently under construction or in start-up was not used. Where the information was not available, it was necessary to estimate some of the sludge quantities in the treatment plant flow scheme. This was restricted to cases in which the sludge quantity was unknown following or preceeding digestion processes. In no case was sludge production estimated on wastewater flow. The estimated percent reduction through digestion processes was based upon other plants in the data group which reported solids quantities before and after digestion. Estimates of solids reductions through incineration processes were not attempted since this figure varies widely.

The 98 plants for which usable data were available were placed into one or two of three classifications, as follows:

1. Plants processing primary sludge (PRIMARY)

   This category includes 40 plants that process only primary sludge and one plant that processes primary sludge independent of secondary sludge (also included in the secondary category)

2. Plants processing secondary sludge (SECONDARY)

   Of the 21 plants in this category 14 preprocess secondary sludge before combining with primary for further dewatering (also included in the combined category) 6 plants process only secondary sludge, and 1 plant processes secondary sludge independent of primary sludge (also included in the primary category)

3. Plants processing a mixture of primary and secondary sludge (COMBINED)

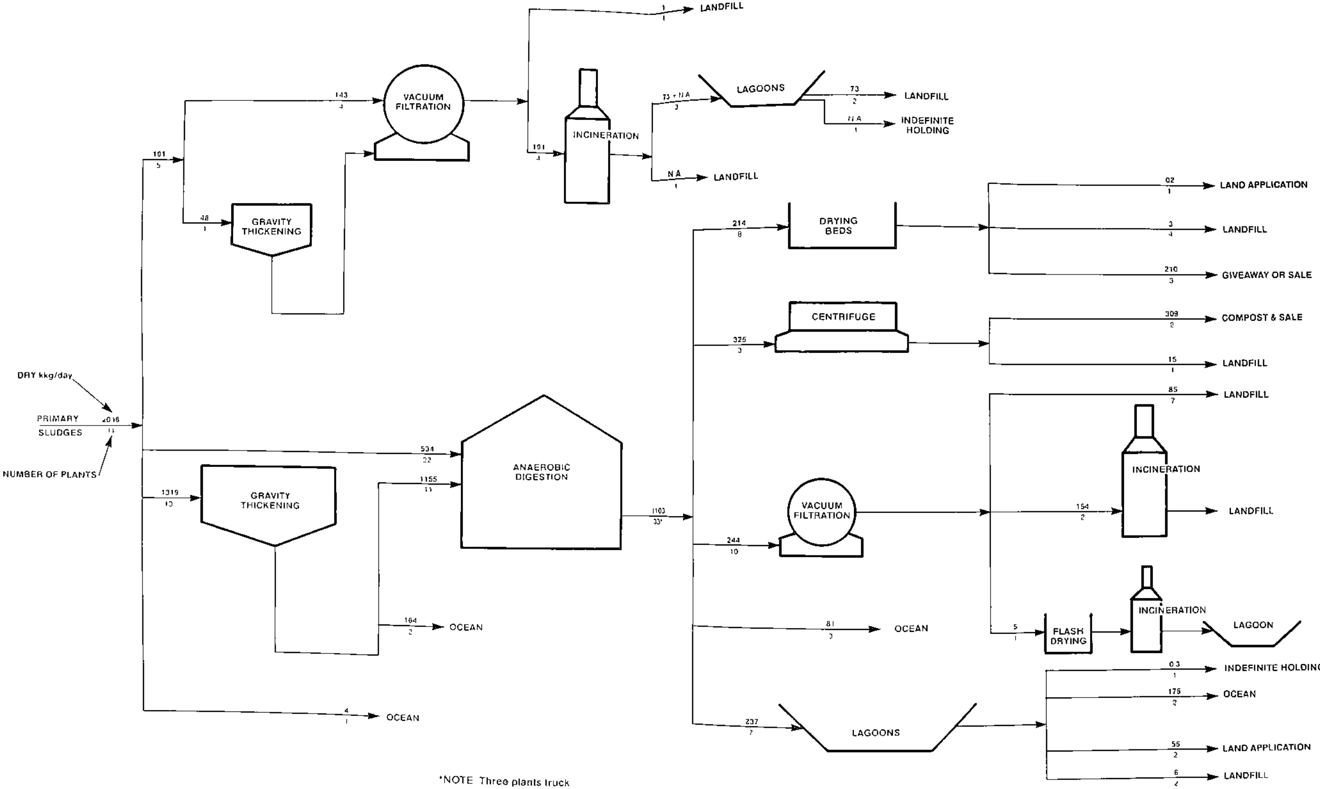
   This category includes 51 plants with 37 mixing primary and secondary sludge before processing and 14 plants preprocessing secondary sludge before combining with primary for final processing (also included in the secondary category). One of the 51 plants also receives a small amount of chemical sludge from a water treatment plant.

The terms Primary, Secondary, and Combined will be used in this Chapter to describe the process flows in the 98 plants. This distinction between plant types allowed the development of Figures 2, 6, and 11, which graphically show the use of the different types of equipment for handling the different types of sludge. None of the plants handles inorganic sludge from chemical physical treatment. The amount of sludge processed by each method is partially indicated by the size of the process representations included on the Figures. The number of plants using each flow line are also included on these diagrams. Since some plants truck partially processed sludge to other plants, or use more than one method to process sludge, the number of plants may change along a process branch line.

A. PRIMARY SLUDGE HANDLING PROCESSES

Forty-one plants process primary sludge only or process it separately from secondary sludge. These are shown in Figure 2. The plants range in size from 295 cu m/day (0.078 mgd) to over 3×10^6 cu m/day (800 mgd). The total average wastewater flow treated by this group is 12.3×10^6 cu m/day (3,260 mgd). The reported quantities of raw primary sludge processed daily ranges from 0.01 to 364 kkg/day (0.01 to 400 dtd), totaling 2048 kkg/day (2,260 dtd). This represents over 160 mg/l of suspended solids removed from the flow of 12.3×10^6 cu m/day (3,260 mgd). Figures 3 and 4 show the distribution by size and the sludge production distribution within this category.

Table IV is a condensation of much of the information in Figure 2 which tabulates the dewatering methods used and indicates the



*NOTE Three plants truck anaerobically digested sludge to a fourth plant for vacuum filtering and one plant uses both vacuum filters and centrifuges before land filling

FIGURE 2
USE OF PROCESSES FOR
PRIMARY SLUDGE MANAGEMENT

FIGURE 3

DISTRIBUTION OF FLOW, cu m/day (mgd), FOR PRIMARY PLANTS

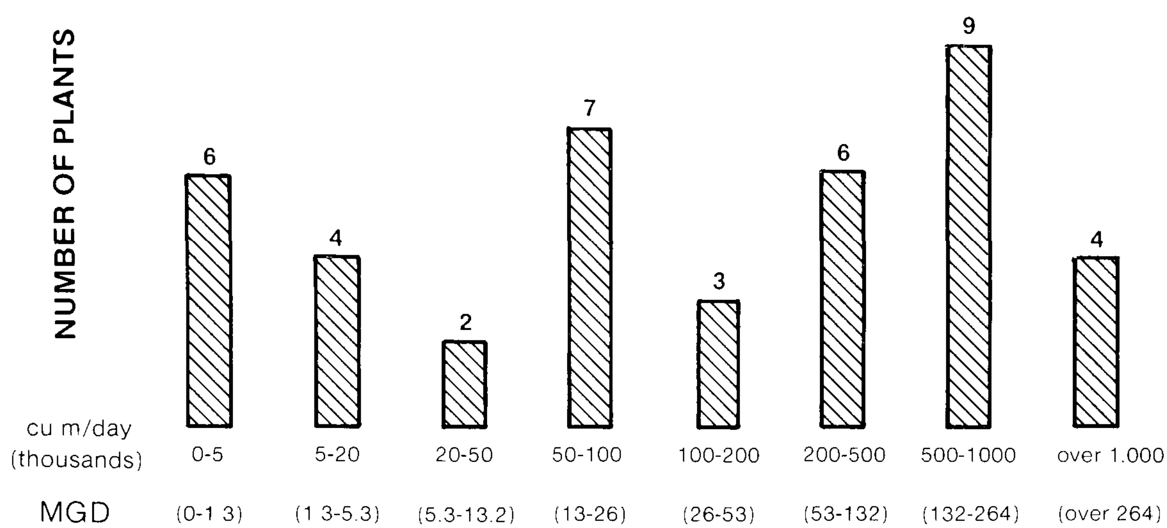


FIGURE 4

DISTRIBUTION OF SLUDGE PROCESSED PER DAY kkg/day (dt/d)
FOR PRIMARY PLANTS

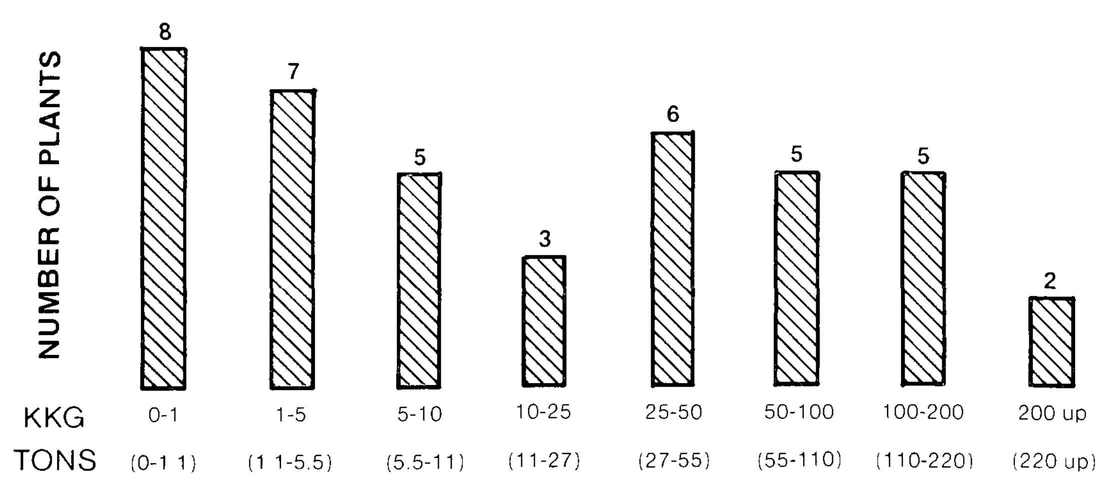


TABLE IV

PRIMARY SLUDGE PROCESSING METHODS

	No. of Plants	%*	kkg/day	dtd	%*
A. Anaerobic Digestion	22**	54	534	589	26
1. Drying Beds	7	17	5	6	1
2. Vacuum Filtration	6	15	66	73	3
a. Disposal	4	10	47	52	2
b. Incineration	2	5	19	21	1
3. Lagoons	4	10	8	9	1
4. Centrifuge	1	2	227	250	11
5. Ocean	1	2	18	20	1
B. Gravity Thickening	14	34	1367	1507	67
1. Anaerobic Digestion	11***	27	1155	1273	56
a. Vacuum Filters	4	10	178	196	9
Disposal	3	7	38	42	2
Incineration	1	2	140	154	7
b. Lagoons	3	7	229	252	11
c. Centrifuge	2	5	98	108	5
d. Ocean	2	5	63	69	3
e. Drying Beds	1	2	209	230	10
2. Ocean	2	5	164	180	8
3. Vacuum Filters - Incineration	1	2	48	53	2
C. Vacuum Filters	4	10	143	157	7
1. Incineration	3	7	142	156	7
2. Disposal	1	2	1	1	1
D. Ocean Discharge	1	1	4	4	1

* As a percentage of primary plants or primary sludge

** Three plants truck anaerobically digested sludge to a fourth plant for vacuum filtering

*** One plant uses both vacuum filters and centrifuges to dewater anaerobically digested sludge popularity of each flow scheme. Figure 2 and Table IV both show the popularity of gravity thickening and anaerobic digestion for primary sludges, but no particular preference was evident for a dewatering method. Vacuum filters, centrifuges, drying beds, and lagoons take similar quantities of primary sludge. Of the four categories, the largest dry weight quantity of sludge is dewatered by centrifuge, but at only three plants. This indicates a greater use of centrifuges among larger plants. Three plants truck anaerobically digested sludge to a fourth plant for vacuum filtering and one plant uses both vacuum filters and centrifuges before landfilling.

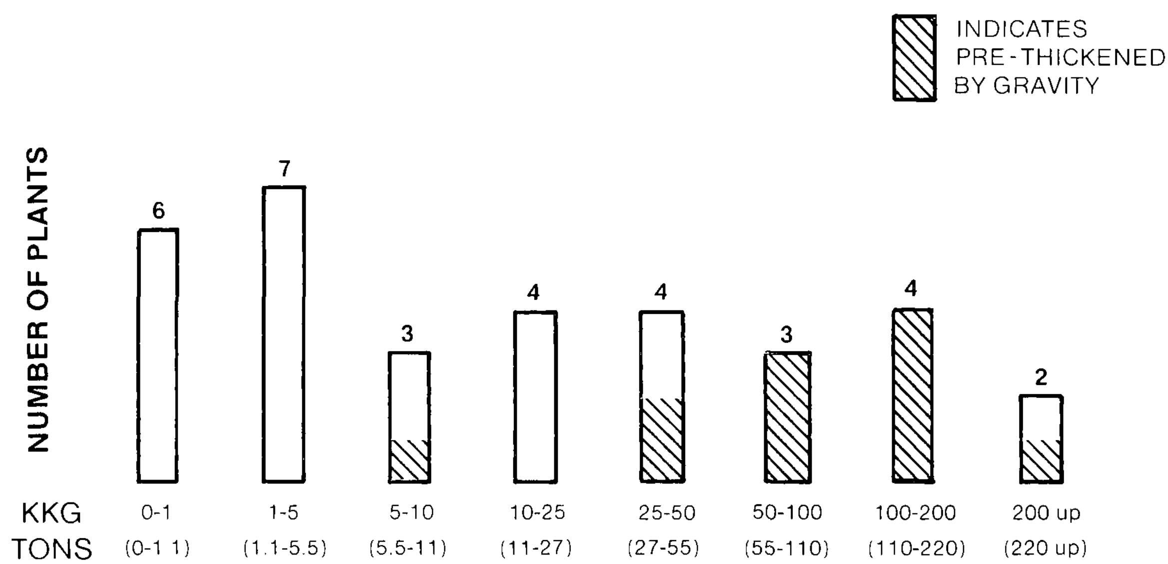
The most direct handling method found in this group is ocean disposal of raw primary sludge. Of three plants discharging raw sludge, two use gravity thickeners to reduce the sludge volume prior to barging and the other plant barges less than 4 kkg/day (4 dtd) without prior thickening. All three plants are located in the New York area.

Within the primary sludge group, sludge that is neither anaerobically digested nor discharged raw to the ocean is dewatered using vacuum filters. Five plants process 191 kkg/day (211 dtd) in this manner. Only one such installation uses a separate gravity thickener before filtration. Four of the five plants use incineration after vacuum filtration to reduce the bulk before landfilling, in some cases preceded by interim ash lagooning. All five of these plants are located in large midwestern cities, four of which have populations of over 300,000.

Anaerobic digestion, the process most frequently used to handle primary sludge, is used at 33 of the plants. Eighty-two percent of the separately processed primary sludge is handled in this manner. Figure 5 illustrates the distribution of these plants by size. The average total solids reduction through this process is 35 percent for those plants reporting solids values both into and out of their digesters. Gravity thickeners are used to reduce the volumetric load to some of the digesters, most notably those at larger installations as seen in Figure 5.

FIGURE 5

DISTRIBUTION OF SLUDGE PROCESSED PER DAY, kkg/day (dt/d) FOR PRIMARY SLUDGES PROCESSED BY ANAEROBIC DIGESTERS

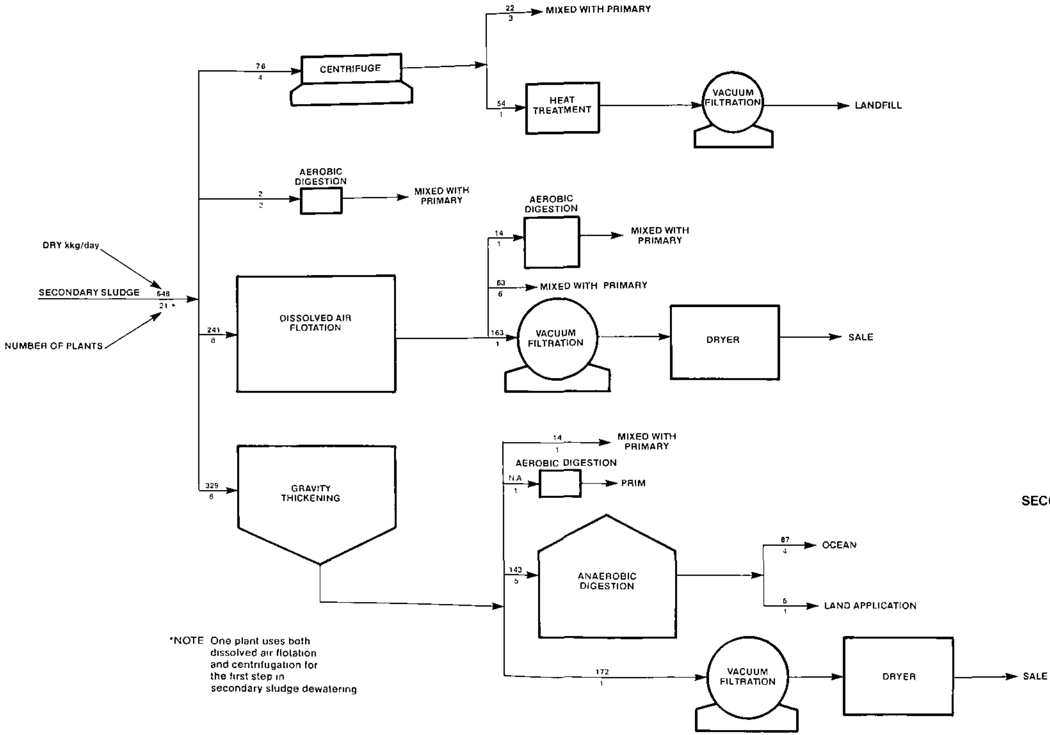


Many different processes were reported for dewatering anaerobicly digested sludge before disposal or use. Within the sampled group, plant size could not be correlated with a preference for dewatering method, except that many of the smaller plants use drying beds. Vacuum filters are used at 10 plants, with three of these incinerating the resultant filter cake. The other plants truck the dewatered cake to landfill. Seven of the plants store the stabilized sludge in lagoons either temporarily or indefinitely. Those plants that must periodically remove this sludge do so to land, landfill, or ocean disposal. Three Atlantic Coast plants barge or use a pipeline to move anaerobically digested sludge directly to ocean disposal.

B. SECONDARY SLUDGE HANDLING PROCESSES

Those plants processing secondary sludge alone or preprocessing it before combining it with primary sludge are in the secondary plant category. Twenty-one of the sample group of 98 plants belong to this category. Figure 6 illustrates the processes, and Figures 7 and 8 relate the distribution of size and sludge production among these plants. One plant processes secondary sludge independently from the primary sludge, and six are contact stabilization plants, with only secondary sludge. The average daily flows within this category ranged from 6400 cu m/day (1.7 mgd) to 3.2×10^6 cu m/day (847 mgd) with a total flow of 7×10^6 cu m/day (1866 mgd) among all 21 plants. The quantity of secondary sludge processed at each plant ranged from 0.39 kkg/day (0.43 dtd) to 164 kkg/day (181 dtd) for a total of 648 kkg/day (714 dtd) for all of the plants. This total figure represents over 90 mg/l of secondary sludge removed from the wastewater treated.

The manner in which secondary sludges are processed varies widely. For this reason, it was difficult to arrange the flow diagram for these plants around a few central processes. Instead, Figure 6 has been arranged around that process by which the secondary sludge is first handled. Table V is a summary of the information contained in Figure 6.



*NOTE One plant uses both dissolved air flotation and centrifugation for the first step in secondary sludge dewatering

FIGURE 6

USE OF PROCESSES FOR SECONDARY SLUDGE MANAGEMENT

FIGURE 7

DISTRIBUTION OF FLOW, cu m/day (mgd), FOR SECONDARY PLANTS

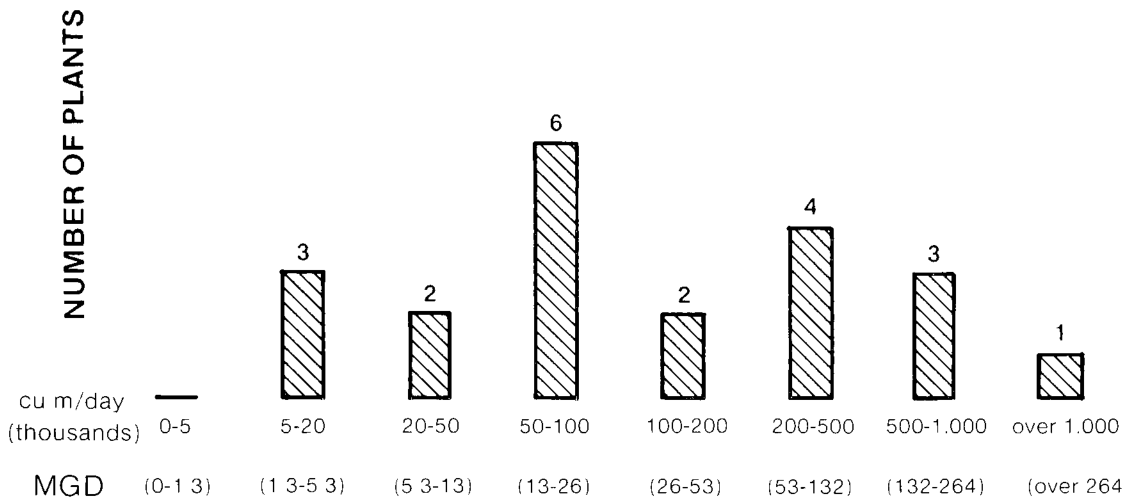


FIGURE 8

DISTRIBUTION OF SECONDARY SLUDGE PROCESSED PER DAY, kkg/day (dt/d), FOR SECONDARY PLANTS

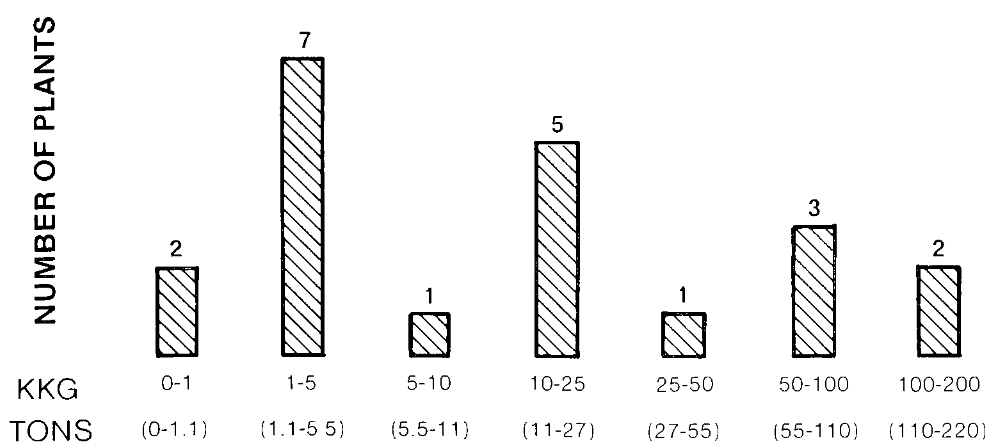


TABLE V

SECONDARY SLUDGE PROCESSING METHODS

	No. of Plants	%*	kkg/day	dtd	%*
A. Gravity Thickening	8	38	329	363	51
1. Anaerobic digestion	5	24	143	158	22
2. Vacuum Filter-Dryer-Sale	1	5	172	190	27
3. Mixed With Primary	1	5	14	15	2
4. Aerobic Dig.-Mixed w/Primary	1	5	n.a.	-	-
B. Dissolved Air Flotation	8**	38	241	266	37
1. Mixed With Primary	6	29	63	69	10
2. Vacuum Filter-Dryer-Sale	1	5	163	180	25
3. Aerobic Dig.-Mixed w/Primary	1	5	14	15	2
C. Centrifuge	4**	19	76	84	12
1. Mixed With Primary	3	14	22	24	3
2. Heat Treatment - Vacuum Filter	1	5	54	60	8
D. Aerobic Digestion	2	10	2	2	1

* As a percentage of secondary plants or secondary sludge

** One plant uses dissolved air flotation and centrifugation for the first step in secondary sludge dewatering

The greater use of thickening processes before dewatering or stabilization in this category reflects the more dilute nature of secondary sludges. Four plants use centrifuges to thicken secondary sludge before combining it with primary sludge or further dewatering the sludge. Dissolved air flotation is also used as a preliminary thickening process. Six of the eight plants using flotation mix the thickened secondary sludge with primary sludge following flotation. One large municipality uses a vacuum filter to dewater flotation thickened sludge, dryers to further dewater the cake, and then sells the dried material. Gravity thickeners are used by eight plants, most frequently before anaerobic digestion for contact stabilization sludges. In a process arrangement similar to the one mentioned above, gravity thickening is used rather than dissolved air flotation, followed by vacuum filtration, drying, and sale as fertilizer/soil conditioner. One plant uses both dissolved air flotation and centrifugation for the first stop in secondary sludge dewatering.

C. COMBINED SLUDGE PROCESSING

The majority of the plants within the sample group have both primary and secondary sludges to dispose of, and combine the two at some point within their processing scheme. Fifty-one plants fit this category, ranging in average daily flow from 3,800 cu m/day (1.0 mgd) to 1.32×10^6 cu m/day (348 mgd), and treat a total average daily flow of 10.7×10^6 cu m/day (2,831 mgd). Raw sludge production ranges from 0.5 to 250 kkg/day (0.5 to 274 dtd), totaling 1972 kkg/day (2,174 dtd) for all 51 of these plants. This represents an average removal of over 180 mg/l of sludge solids for these plants. Distributions by plant size and sludge production are shown in Figures 9 and 10.

FIGURE 9

DISTRIBUTION OF FLOW, cu m/day (mgd), FOR COMBINED PLANTS

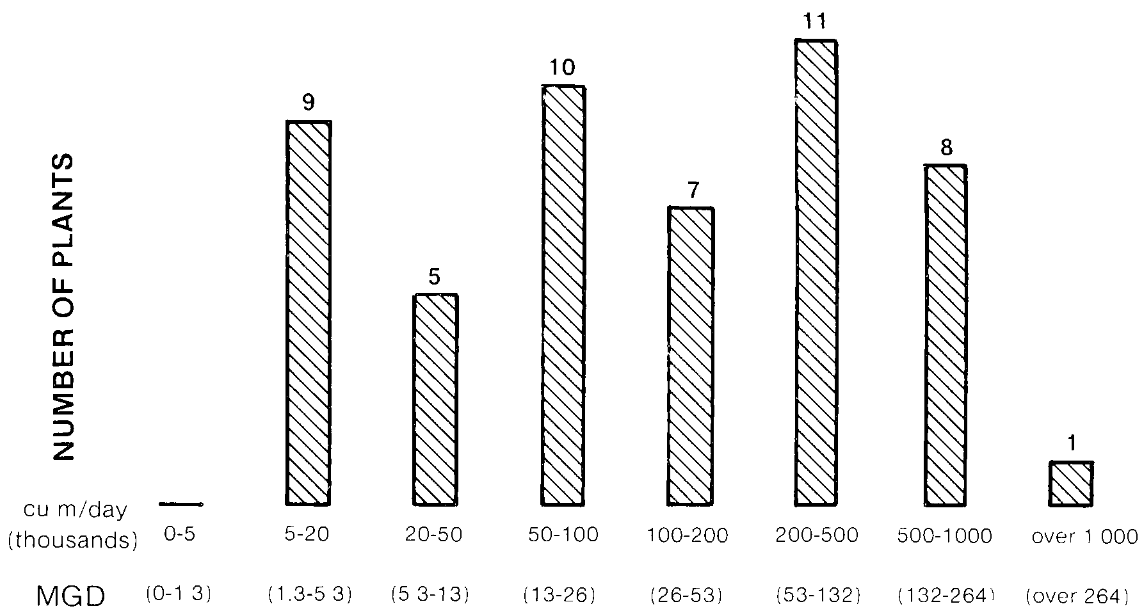
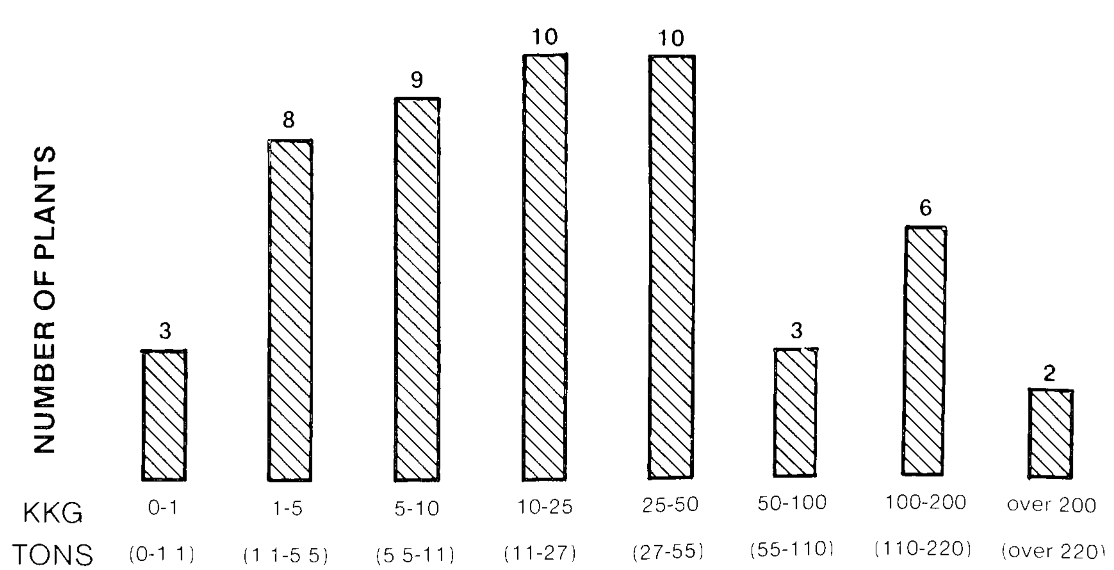


FIGURE 10

DISTRIBUTION OF SLUDGE PROCESSED PER DAY, kkg/day (dt/d)
FOR COMBINED PLANTS.

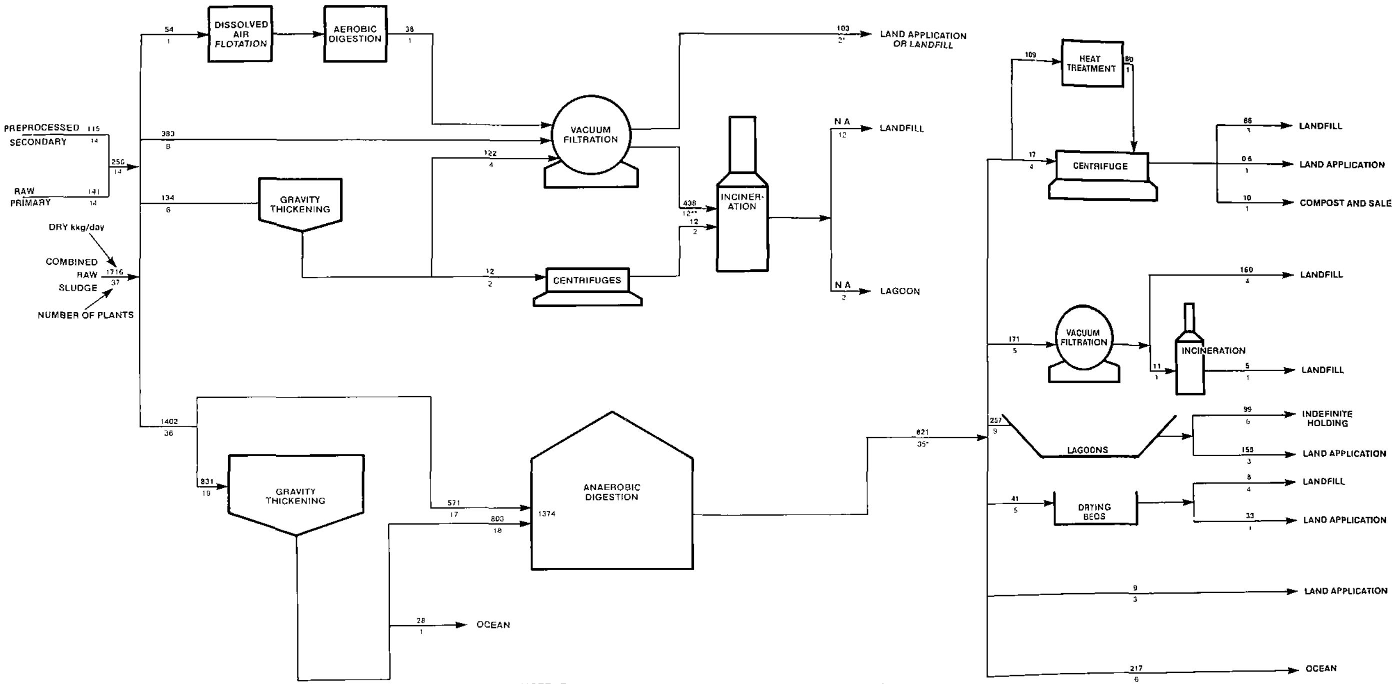


As with uncombined primary sludge, the most common process within the combined category is anaerobic digestion as shown in Figure 11 and Table VI. A total of 35 plants digest 1,374 kkg/day (1,515 dtd) of combined sludges. Figure 12 shows a size distribution of plants processing combined sludges by anaerobic digestion based on the dry tons per day digested. Gravity thickening preceded digestion in more than half of these plants indicating a preference among larger plants for using separate gravity thickeners for combined sludge. The total solids reduction for plants reporting influent and effluent solids from the digesters was 40 percent.

As shown on Figure 11, many methods are used to dewater and dispose of anaerobically digested combined sludges. Five installations reported using centrifuges before land application, landfilling, or composting the dewatered sludge. An equal number of plants use vacuum filters, and one plant incinerates the filtered cake. Fourteen plants use lagoons or drying beds to concentrate a total of almost 300 kkg/day (331 dtd) before landfill or land application. Three of the smaller plants use land application as a means of directly disposing of such digested sludge. Five intermediate and one very large plant use barges or pipelines to discharge these stabilized sludges directly to the ocean. Two plants truck anaerobically digested sludge to other plants for dewatering.

Vacuum filtration is the second most commonly used process to handle raw combined sludges. Four of the thirteen plants that handle sludge in this manner use gravity thickeners to increase feed solids to the vacuum filters. One plant uses flotation thickening followed by aerobic digestion to increase dewaterability and decrease the loading on the filters. Of the thirteen plants using vacuum filters, twelve incinerate the filter cake, and either lagoon or landfill the resultant ash.

Two plants use centrifuges to dewater raw combined sludges. Both of these plants use gravity thickening before centrifuging, then incinerate the centrifuged cake.



*NOTE Two plants truck anaerobically digested sludge to other plants for further dewatering. One to vacuum filtration followed by incineration and the other to a plant not shown.

**NOTE One plant disposes of sludge by landfilling and incineration

FIGURE 11

USE OF PROCESSES FOR COMBINED SLUDGE MANAGEMENT

TABLE VI

COMBINED SLUDGE PROCESSING METHODS

		No. of Plants	%*	kkg/day	dtd	%*
A.	Gravity Thickening	25	49	965	1064	49
	1. Anaerobic Digestion	18	35	803	885	41
	a. Lagoons	6	12	208	229	11
	b. Disposal	5	10	59	66	3
	c. Vacuum Filter	3	6	78	86	4
	Disposal	2	4	67	74	3
	Incineration	1	2	11	12	1
	d. Drying Beds	3	6	37	41	2
	e. Heat Treat.-Centrifuge	1	2	109	120	6
	2. Vacuum Filters	4***	8	122	135	6
	a. Incineration	4	8	112	123	6
	b. Disposal	1	2	9	10	1
	3. Centrifuges-Incineration	2	4	13	14	1
	4. Ocean	1	2	28	31	1
B.	Anaerobic Digestion	17**	33	571	630	29
	1. Disposal	4	8	166	183	8
	2. Centrifuge	4	8	17	19	1
	3. Lagoons	3	6	49	54	2
	4. Vacuum Filters	2	4	93	103	5
	5. Drying Beds	2	4	3	3	1
C.	Vacuum Filters	8	16	383	422	19
	1. Incineration	7	14	288	318	15
	2. Disposal	1	2	94	104	5
D.	Flotation - Aerobic Digestion- Vacuum Filters - Incinceration	1	2	54	60	3

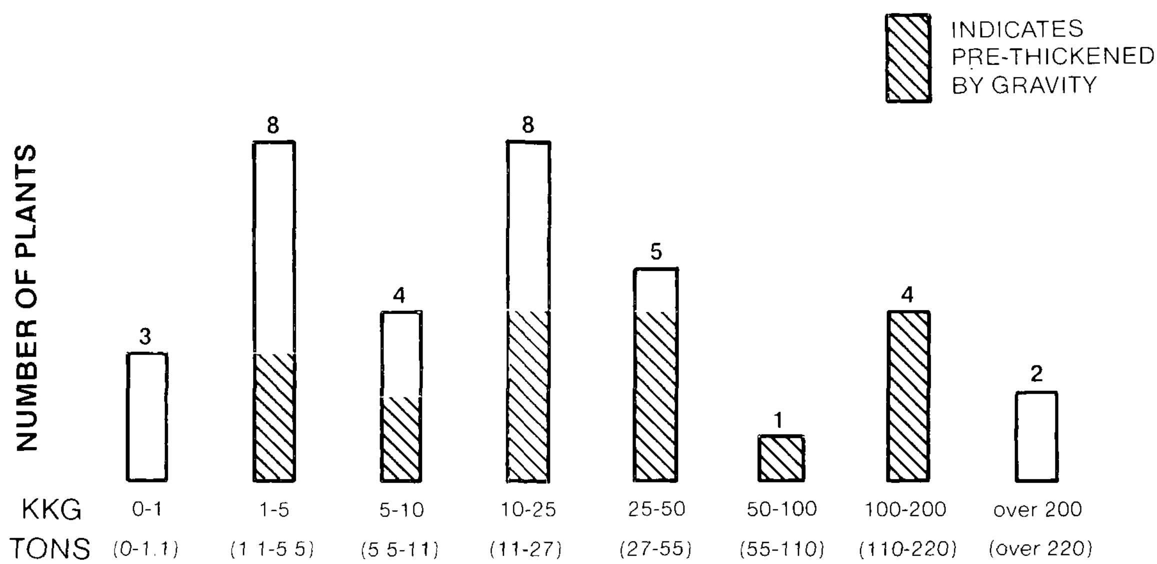
* As a percentage of combined plants or combined sludges

** Two plants truck anaerobically digested sludge to other plants for further dewatering: one to vacuum filtration followed by incineration and the other to a plant not shown.

*** One plant disposes of sludge by landfilling and incineration

FIGURE 12

DISTRIBUTION OF SLUDGE PROCESSED PER DAY, kkg/day (dt/d) FOR COMBINED SLUDGES PROCESSED BY ANAEROBIC DIGESTERS



IV ANALYSIS OF TYPES OF EQUIPMENT AND DISPOSAL INFORMATION

The preceding Chapter summarized the information about the different systems used by AMSA members to process various types of sludges. This Chapter summarizes the information available on the types of equipment and disposal methods used within these dewatering systems. The numbers of plants using each of these unit operations are tabulated in Table VII. Particular cost items are included if cost data can be attributed to any particular equipment such as chemical addition costs for vacuum filtration. A series of telephone contacts made to complete information for Chapter II was a major source of this information.

TABLE VII EQUIPMENT SUMMARY

Type of Equipment	No. of Plants	% of 98 Plants	kkg/day	(dtd)
Anaerobic digestion	73	74	3,206	(3,535)
Gravity thickening	47	48	2,661	(2,934)
Vacuum filtration	36	37	1,538	(1,695)
Incineration	22	22	812	(895)
Lagoons	22	22	567	(625)
Centrifuge	14	14	540	(595)
Dryers	3	3	340	(375)
Dissolved air flotation	9	9	295	(325)
Drying beds	13	13	255	(281)
Heat treatment	2	2	163	(180)
Aerobic digestion	5	5	70	(77)

A. ANAEROBIC DIGESTION

Within the sample group, 73 plants use anaerobic digestion for stabilization and volume reduction of sewage sludge. The breakdown of sludge types so processed is as follows:

1. Combined - 35 plants
2. Primary - 33 plants
3. Contact stabilization - 5 plants

The total feed of solids was 3206 kkg/day (3535 dtd). The average solids content of the feed sludge was 5.5 percent, which indicates that over 58,000 cu m/day (15 mgd) of sludge is anaerobically digested within this sample group alone.

The personnel of twelve plants using anaerobic digestion provided detailed information about the operation of their digesters. The group was evenly divided between single- and multiple-stage digesters. All use internal gas mixers, and seven use external heat exchangers. The remainder use steam injection or internal hot water circulation pipes for heating. The average volatile suspended solids reduction through the digesters was reported as 50 percent. The detention times reported ranged from 15 to 65 days, and averaged 30 days. The cleaning schedules for digesters ranged from none (eight-year old digesters) to every two to three years. The addition of pretreatment by major industrial users was cited by some members as a great aid in extending the time between cleanings.

Of the 73 plants using anaerobic digestion, data on gas production, utilization, and wastage were available from 52. The quantity of gas produced per pound of volatile matter destroyed could not be determined from the data; 152 cu m/kkg (4,880 cu ft/dt) were produced, however. The total quantity of digester gas produced was indicated as 178×10^6 cu m/yr (6.3×10^9 cu ft/yr). Within the group, the number of plants practicing digester gas energy recovery is as follows:

Plants reporting	52
Plants recovering energy as:	
Usable heat	30
Electricity	12
Mechanical energy	4

One facility with extensive digester operations indicated that over half of the daily digester gas production is sold. Other agencies indicated plans to sell digester gas in the future. Two agencies specifically indicated that digester gas is not wasted.

B. VACUUM FILTRATION

Thirty-six plants use vacuum filters to dewater raw and digested sludges. Of these plants, 19 process raw sludge, 16 process digested sludge, and one processes heat treated sludge with vacuum filters. Twenty incinerate the cake and 17 landfill it or dispose of it in some other manner. A total of 1538 kkg/day (1,695 dtd) are dewatered on vacuum filters within this group.

Information on the common operational characteristics of vacuum filters was provided by 16 plants. Within this group, eight plants are equipped with belt type filters, and an equal number have coil spring media filters. A preference for either type for either raw or digested sludge was not apparent. The average solids content for raw sludge cake was 29 percent. Digested sludges yielded a wetter cake with 21 percent solids. Very few of the plants had cost figures attributable directly to the vacuum filters; however, chemical conditioners were quoted as costing $4 to $19 per kkg processed ($4 to $17 per dt). Six plants rely solely on polymer conditioners, three on lime and ferric chloride, and three reported using a combination of all three chemicals. Personnel at one plant stated that polymer works well in winter months, but becomes very difficult to control in the warmer months.

C. CENTRIFUGES

Fourteen plants use centrifuges for dewatering or thickening, eight for digested and six for raw sludges. Most of the centrifuges are the solid bowl type, except for two plants that use disc-nozzle type machines. Both authorities using the disc-nozzle centrifuges reported concentration to 4 to 4.5 percent solids with waste activated sludge. Nozzle wear and plugging were cited as difficulties with the machines, and one plant noted that fines buildup was a potential problem.

Seven plants centrifuging primary sludge provided information on solid bowl centrifuge operations. The average cake dryness was 22 percent, with feed solids averaging 5.7 percent. Four of these plants use polymers, with costs averaging $13 per kkg ($12 per dt) for the three which had costs available. Most of the authorities were pleased with their centrifuges, but stated that maintenance was a high cost item for the process.

D. INCINERATION

Twenty-two plants incinerate 812 kkg/day (853 dtd) of primary and combined sludge solids. The resultant ash quantities were not reported in many cases. Twenty of the plants use vacuum filters before incineration, with two using centrifuges. Only four plants incinerate anaerobically digested sludge.

E. OTHER TYPES OF EQUIPMENT

Few process or operating details were available for the other sludge handling methods and equipment, such as heat treatment and dryers. As would be expected, there is little operational information available for simpler operations such as lagooning and sand bed drying.

F. TRANSPORATION INFORMATION

A broad base of information on transporting processed sludge was not available for analysis. Of those agencies reporting, trucking to disposal was the most commonly reported transportation method. Pipelines are also used by several agencies, but little additional information was available on costs or operational characteristics.

G. DISPOSAL METHODS

The disposal methods used by the plants discussed in Chapter III are summarized in Table VIII. The chart reflects the limited applicabilit of certain disposal/utilization methods and the versatility of others with respect to the sludge solids content. Whereas landfill is used to dispose of liquid sludge, dewatered sludge and ash, sale or giveaway programs must produce a dry cake. There is, on the other hand, apparently no advantage for land applying ash, or for ocean dumping dewatered sludge.

TABLE VIII DISPOSAL METHOD DISTRIBUTION

	LIQUID			DEWATERED		
	Plants	kkg/day	(dtd)	Plants	kkg/day	(dtd)
Sale & giveaway	-	-	-	8	864	(953)
Ocean	19	756	(833)	-	-	-
Landfill*	2	6	(7)	25	412	(454)
Land Application*	9	228	(251)	5	137	(151)
Lagoons*	7	n.a	n.a.		-	-
Incineration**	-	-	-	22	812	(895)

* Incinerator ash not included

** Of those plants incinerating sludge, 18 landfill and 4 lagoon the ash for final disposal.

The range of disposal methods was carefully examined to correlate geography and plant size with the method chosen. Definite preferences could not be discerned, aside from the expected preference of large coastal cities for ocean disposal.

One significant factor common to all the plants, large and small, is that many are located in relatively large urban areas, especially within the dense population centers of the East and West coasts.

Air emission requirements compatible with the constraints of densely populated areas, and effective land use planning restrict the available acceptable methods of disposal in these locations. Many of the agencies in these areas expressed great concern about the disposal problem, in many cases because of impending ocean dumping restrictions.

V COST DATA ANALYSIS

Limited data were available on the cost of sludge dewatering. The costs were given for the entire sludge dewatering process and it was not possible to itemize costs for particular types of equipment. Because of the many combinations of equipment, only very general correlations can be drawn between cost items and processing methods. Cost information development was further complicated by the difficulty most plants have in determining what part of their budget is attributable to sludge handling as contrasted with the main flow wastewater treatment costs. The data were analyzed to reflect the dollar-per-kkg or manhours-per-kkg costs on a plant by plant basis. In all cases, the costs were related to raw sludge processed, not to the reduced sludge quantity following digestion. Although the scatter in the data does not warrant including it here, general cost trends are discussed below.

Labor costs were examined on a manhours per kkg basis for the 59 plants reporting this data. Information from the participating plants was carefully examined to determine the more prevalent methods at the low and high ends of the distribution. Although the data were very scattered, it was apparent that plants expending less than one mh/kkg frequently use anaerobic digesters followed by indefinite lagooning or ocean disposal. The highest mh/kkg plants included a few using anaerobic digesters and lagooning or ocean disposal, plus a significant number of the more labor intensive operations such as flotation, incineration, and vacuum filters. It was apparent that much of the variation in costs could be attributed to data reporting differences and that the range of manhour requirements for a given type of equipment would generally have been less had all of the data been reported on the same basis.

Materials costs were compared on a dollar per kkg of raw sludge basis. This category includes such items as conditioning chemicals and spare parts. As with other cost items, it was difficult to draw conclusions about the relative costs of different individual types of equipment. Forty-five plants reported materials costs. Equipment requiring high dosages of chemical conditioning agents were prevalent in the plants with high materials costs. This group includes plants using centrifuges, flotation units, and vacuum filters.

Electrical costs were reported by 53 plants, and were extremely variable. Although the data were scattered, the highest figures were reported for plants that employ one or more of the following: air flotation, vacuum filtration, centrifugation, and incineration.

VI RESEARCH AND DEMONSTRATION NEEDS

In addition to covering process flows and equipment, 30 authorities indicated the areas they felt were lacking in sludge management information. Five general topics were covered: management activities, socio-political or institutional constraints, public health, monitoring and surveillance, and disposal alternatives. A strong interest was shown in cost effective sludge handling and disposal processes that will not adversely affect public health. Public health is the most important factor in many cases.

Only 15 percent of the authorities felt sufficient information was available on the public health aspects of sludge management. Topics of particular interest were epidemiological studies, disinfection alternatives, and landfill leachates.

Eighty-five percent of the study group also want more information related to management activities such as energy conservation efforts, market surveys for commercial projects, and cost-effectiveness studies on sludge management.

The majority of the 19 authorities indicating a need in the socio-political or institutional constraints category felt more information was needed in the areas dealing with legal constraints, environmental groups, competition or cooperation from other government groups, and public acceptance and public meeting response.

A similar indication was seen regarding the issues of monitoring and surveillance. Although 42 percent indicated that sufficient information was available on ocean and estuary monitoring, fewer authorities felt there was sufficient material available associated with land disposal, such as surface and groundwater, soil, and crops monitoring.

Over 20 authorities indicated that more information was needed on disposal alternatives. The greatest need was for information on soil reclamation, soil enrichment, and composting. Fewer indicated a desire for more information on ocean disposal, incineration, pyrolysis, and sludge and solid waste landfill. Only minor interest was expressed in by-product recovery, co-incineration, the Carver-Greenfield process, and sale as commercial fertilizer.

In addition to the specific listings discussed above, authorities listed other information needs. Too numerous for listing here, over 60 needs for research and demonstration projects were listed. Generally, interest was in the areas of processing and disposal with emphasis on the health aspects and the effects of land disposal on agriculture and livestock. Only minor interest was indicated in the areas of utilization and regulatory requirements.

VII NON-TECHNICAL INFORMATION

Non-technical information was also provided by twenty selected AMSA members on such issues as energy recovery, disposal problems, land acquisition for disposal, institutional constraints, funding, public involvement, health issues, and metals concentrations. The agencies providing information represented a cross section of the membership based on size, location, and agency type (city, county, special district, or state). The most common difficulty reported was establishing a disposal method that is compatible with existing local, state, and federal regulations at an acceptable cost.

Many authorities are reluctant or find it impossible to use land application. This, in most cases, is because of the unavailability of suitable land within economical transportation distances. Other related problems are the inability to transport sludge across jurisdictional lines or other legal problems associated with overland transportation and land disposal. One agency cited the lack of a heavy metals ordinance as preventing the implementation of land application programs. Other agencies felt that land application was totally unacceptable because heavy metal concentrations could not be acceptably reduced. The unknown effects of trace materials on groundwater were also viewed as reason for a cautious approach to land application. Those authorities in favor of land application (5 of the 20) had been doing so for some time, either to park areas, golf courses, etc., or to farms. In all of these cases, the chance of human ingestion was felt to be unlikely for the particular practices used. Of the group interviewed, only three had actually purchased land for ultimate disposal.

Several of the agencies oppose incinerating as a means of sludge disposal. The most frequently cited point of opposition is the strict air pollution codes that require costly control measures. One agency felt that incineration was a waste of both fuel and residual materials that can be used as a valuable resource for soil enrichment.

The twenty selected agencies also commented on public involvement with sludge management issues. The most common form of public involvement is complaints about odors around disposal sites or treatment plants. Although usually limited to specific areas, the resolution of such problems takes considerable effort. The other form of public involvement is selecting disposal sites and processes. Such input is usually negative, in the form of opposition by particular groups which feel they will be unfairly jeopardized by particular locations. Reduced property values are a major concern. On the positive side, some environmental groups encourage the use of processes that they feel are the most environmentally acceptable, e.g., regulated land application.

In review of the non-technical comments, the most pressing problem is evidently the ultimate disposal of sludge. As sludge quantities increase and environmental restrictions become more stringent, the agencies feel they are often faced with unrealistic deadlines set by regulatory agencies.

APPENDIX A

LIST OF AMSA MEMBERS

PARTICIPATING IN THE STUDY

SUMMARY CHARACTERISTICS OF AMSA MEMBERS

Agency	ADF		Raw Sludge (dry).		Service Population	Plants
	Thousand cum/day	mgd	kkg/day	dt/d		
Chicago, IL	5,378	1421	568	626	5,500,000	7
New York, NY	3,846	1061	260	287	7,867,760	12
Philadelphia, PA	1,805	477	269	297	3,000,000	3
Los Angeles County, CA	1,665	440	372	410	3,800,000	12
Boston, MA	1,654	437	122	135	2,176,000	2
Los Angeles City, CA	1,359	359	249	274	3,100,000	3
St. Louis, MO	1,048	277	145	160	1,520,000	4
Cleveland, OH	929	245	211	233	1,276,000	3
Passaic Valley, NJ	924	244	111	122	1,157,215	1
Baltimore, MD	765	202	123	136	1,550,000	2
Milwaukee CO, WI	719	190	263	290	1,272,000	2
Allegheny Co, PA	681	180	116	128	1,250,000	1
Orange Co, CA	659	174	159	175	1,400,000	2
Cincinnati, OH	621	164	162	179	920,000	4
Miami-Dade Co, FL	568	150	171	188	1,800,000	3
Seattle, WA	537	142	41	45	1,200,000	5
Denver, CO	530	140	94	104	1,100,000	1
Atlanta, GA	519	137	23	25	850,000	6
Dallas, TX	462	122	73	80	993,400	3
Columbus, OH	454	120	n/a	n/a	790,000	2
San Diego, CA	424	112	81	89	1,200,000	5

Agency	ADF		Raw Sludge (dry)		Service Population	Plants
	Thousand cum/day	mgd	kkg/day	dt/d		
San Francisco City & Co, CA	409	108	n/a	n/a	700,000	3
Monroe Co, NY	379	100	46	51	714,000	3
Hampton Roads, VA	367	97	35	39	859,238	9
Akron, OH	341	90	29	32	377,700	1
Kansas City, MO	337	89	48	53	500,000	15
Louisville, KY	333	88	38	42	495,000	1
Middlesex Co, NJ	318	84	54	59	600,000	1
Portland, OR	314	83	82	90	307,000	2
Bergen County, NJ	299	79	60	66	600,000	1
Oakland (East Bay M.U. Dist.), CA	291	77	18	20	625,000	1
Wayne County, MI	280	74	82	90	450,000	4
Nashville, TN	250	66	54	59	290,000	5
Fort Worth, TX	242	64	71	78	606,000	2
Dayton, OH	208	55	38	42	371,000	1
Omaha, NE	197	52	33	36	530,000	3
Hartford Co, CT	170	45	33	36	283,517	4
Providence, RI	170	45	54	60	210,000	1
Ventura Regional Co, CA	155	41	n/a	n/a	370,000	9
El Paso, TX	148	39	15	17	376,000	4
Trinity River, TX	144	38	28	31	363,000	2
Wichita, KS	132	35	33	36	280,000	1

Agency	ADF		Raw Sludge (dry)		Service Population	Plants
	Thousand cum/day	mgd	kkg/day	dt/d		
Albany, NY	132	35	22	24	250,000	2
Tuscon, AZ	121	32	n/a	n/a	349.000	2
Washington, Suburban MD	106	28	33	36	203,000	3
Duluth (Western Lake Superior Sanitation Dist.) MN	79	21	9	10	116,480	9
Greensboro, NC	76	20	23	25	167,000	2
Honolulu, HI	68	18	11	12	531,627	19
Boise, ID	38	10	10	11	64,155	3
Charleston, WV	26	7	n/a	n/a	75,000	1

APPENDIX B

SLUDGE PROCESSING METHODS
AT
PARTICIPATING AMSA PLANTS

SLUDGE PROCESSING METHODS
AT
PARTICIPATING AMSA PLANTS

City	Plant	Sludge Type	Gravity Thickening	Dissolved Air Flotation	Anaerobic Digestion	Aerobic Digestion	Centrifugation	Vacuum Filtration	Mix with Primary	Truck to Another Plant	Heat Treatment	Flash Drying	Drying Beds	Incineration	Ocean Disposal	Sale	Lagoon	Landfill	Land Application
AKRON		S	1						2										
		C						1						2				3	
ALBANY	North	S		1					2										
		C						1						2				3	
	South	S		1					2										
		C						1						2				3	
ALLEGHENY CO.		C						1						2				3	
ATLANTA	South River	S		1					2										
		C			1			2										3	
	Intrenchment	C			1		2											3	
	Flint River	S				1			2										
		C			1		2												3
	Camp Creek	C			1		2											3	
	Utoy Creek	S				1			2										
		C						1						2				3	
BALTIMORE	Patapsco	P			1			2										3	
	Back River	C	1		2			3										4	
BERGEN CO.		P	1		2										3				
BOISE	Lander Street	S		1			1		2										
		C			1														2
BOSTON	Deer Island	P	1		2										3				
	Nut Island	P			1										2				
CHICAGO	Calumet	C	1		2												3		4
	West-SW	P	1		2								3			4			
		S		1				2				3				4			
CINCINNATI	Mill Creek	P	1		2			3						4				5	
CLEVELAND	Southerly	C			1			2										3	
	Westerly	P			1			2										3	
DALLAS	Central	C	1		2												3		
DAYTON		C	1		2												3		
DENVER		S		1					2										
		C						1											2

Numbers Indicate Process Order

SLUDGE PROCESSING METHODS AT PARTICIPATING AMSA PLANTS

City	Plant	Sludge Type	Gravity Thickening	Dissolved Air Flotation	Anaerobic Digestion	Aerobic Digestion	Centrifugation	Vacuum Filtration	Mix with Primary	Truck to Another Plant	Heat Treatment	Flash Drying	Drying Beds	Incineration	Ocean Disposal	Sale	Lagoon	Landfill	Land Application
DULUTH	Main	P			1			2				3		4			5		
	Fairmont	P			1					2									
	Cloquet	P						1										2	
	Smithville	P			1					2									
	Carlton	P			1								2						3
	Gary New Duluth	P			1					2									
	Scanlon	P			1								2					3	
EL PASO	Haskell Street	S	1			2			3										
		C			1		2									3			
FORT WORTH	Village Creek	S					1		2										
		C	1		2								3						4
	Riverside	C			1												2		3
GREENSBORO	North Buffalo	C	1					2						3				3,4	
HARTFORD CO.		S		1		2			3										
		C						1						2			3		
HONOLULU	Mililani	C			1								2					3	
	Wahiawa	C	1		2			3										4	
	Kaneohe	C			1								2					3	
	Kailua	C	1		2								3					4	
	Pearl City	P			1								2					3	
KANSAS CITY	Blue River	P	1					2						3			4		
LOS ANGELES CITY	Hyperion	C			1										2				
LOS ANGELES CO.	Joint	P			1		2									3			
	District 14	P			1									2		3			
	District 20	P			1									2		3			
	District 26	S					1		2										
		C			1														2
	District 32	S		1					2										
		C			1														2
LOUISVILLE		P			1			2										3	
MIAMI-DADE CO.	Central	C	1		2		4				3							5	

Numbers Indicate Process Order

SLUDGE PROCESSING METHODS AT PARTICIPATING AMSA PLANTS

		SLUDGE TYPE	GRAVITY THICKENING	DISSOLVED AIR FLOTATION	ANAEROBIC DIGESTION	AEROBIC DIGESTION	CENTRIFUGATION	VACUUM FILTRATION	MIX WITH PRIMARY	TRUCK TO ANOTHER PLANT	HEAT TREATMENT	FLASH DRYING	DRYING BEDS	INCINERATION	OCEAN DISPOSAL	SALE	LAGOON	LANDFILL	LAND APPLICATION
MIDDLESEX CO.		P	1												2				
MILWAUKEE CO.	Jones Island	S	1					2					3			4			
	South Shore	C	1		2												3		4
MONROE CO.	Frank E. Vanlare	C	1					2						3			4		
	Northwest Quadrant	C	1					2						3				4	
	Gates-Chili-Ogden	P			1								2					3	
NASHVILLE	Central	C		1		2		3						4				5	
NEW YORK CITY	26th Ward	C	1		2										3				
	Wards Island	C	1												2				
	Newtown Creek	S	1		2										3				
	Rockaway	S	1		2										3				
	Jamaica	C	1		2										3				
	Coney Island	S	1		2										3				
	Port Richmond	P													1				
	Oakwood Beach	C	1		2								3					4	
	Tallman Island	C	1		2										3				
	Bowery Bay	C	1		2										3				
	Owls Head	S	1		2										3				
	Hunts Point	C	1		2										3				
NORFOLK	Chesapeake	S	1		2														3
	Army Base	P			1								2					3	
	Lamberts Point	P			1												2	3	
	Boat Harbor	P			1												2	3	
	James River	C	1		2												3		
	Williamsburg	C	1				2							3				4	
	Western Branch	P			1												2		3
	Washington	P			1												2		
OAKLAND	East Bay Munic.	P			1			2										3	

Numbers Indicate Process Order

SLUDGE PROCESSING METHODS AT PARTICIPATING AMSA PLANTS

Plant	Facility	SLUDGE TYPE	GRAVITY THICKENING	DISSOLVED AIR FLOTATION	ANAEROBIC DIGESTION	AEROBIC DIGESTION	CENTRIFUGATION	VACUUM FILTRATION	MIX WITH PRIMARY	TRUCK TO ANOTHER PLANT	HEAT TREATMENT	FLASH DRYING	DRYING BEDS	INCINERATION	OCEAN DISPOSAL	SALE	LAGOON	LANDFILL	LAND APPLICATION
OMAHA	Missouri River	P			1			2						3				4	
	Papillion	P						1						2				3	
ORANGE CO.		P	1		2		3									4			
PASSAIC VALLEY		P	1												2				
PHILADELPHIA	Northeast	P	1		2										4		3		
	Southwest	P	1		2										4		3		
PORTLAND	Columbia	P / S	1		2		1	3 / 3			2							4 / 4	
	Tryon Creek	C			1					2									
PROVIDENCE		C	1					2						3				4	
SAN DIEGO	Point Loma	P	1		2												3		4
SEATTLE	West Point	P	1		2		3	3										4	
ST. LOUIS	Bissell Point	P						1						2			3	4	
	Lemay	P						1						2			3	4	
	Coldwater	C			1												2		
	Sugar Creek	C			1					2									
TRINITY RIVER	Central Region	C	1		2												3		
WASHINGTON SSC	Piscataway	P	1		2			3										4	
	Western Branch	C	1		2			3						4				5	
	Parkway	C	1				2							3				4	
WAYNE CO.	Wyandotte	C						1						2				3	
WICHITA		C			1												2		

Numbers Indicate Process Order

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