PROCESSING AND DISPOSAL OF WASTE ACTIVATED SLUDGE

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TABLE OF CONTENTS

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

A. Purpose

This study examines the processing and disposal of waste activated sludge. In a wastewater treatment facility waste activated sludge is either processed by itself or in combination with the primary sludge. The combining of the two sludges can be done at various points in the process. This study is concerned principally with the processing of the waste activated sludge processed entirely by itself.

The number of possible systems or combination of systems for treating sludge has increased rapidly in the last several years. This study is a review of the literature to determine what systems are now being used, the success of these systems and possible alternatives.

B. Definition

The activated sludge process for treatment of sewage was developed in England in the early 1900's. In April of 1914 the first paper on the process was presented to the Society of Chemical Industry by Edward Arden and William Lockett. The paper entitled "Experiments on the Oxidation of Sewage Without the Aid of Filters" reported the high purification levels which were achieved by the use of an aeration system. In November of 1914 Arden and Lockett presented a second paper entitled "Oxidation of Sewage Without the Aid of Filters". (16)

After the first studies were made little was done to better understand the fundamentals of the process until the early 1950's. At that time, close scientific study of the process began. Several mathematical models have been proposed, tested and revised to a point that the process can now be accurately modeled.

The activated sludge process is a relatively simple system. Biologically degradable waste is aerated for a period of time until a mass of settleable solids form. The settleable solids or activated sludge is an active mass of microorganisms made up of bacteria, fungi, protozoa, rotifiers and nematodes. The microorganisms aerobically stabilize the organic matter in the tank. (25)

When operated properly, the activated sludge process has a high efficiency of BOD removal. This has made it popular for the design of treatment plants required to meet the existing regulations of removal of 85 percent or more influent BOD. This high removal rate has generated increased sludge volumes that previously had been discharged.

Prior to the regulations established by the U.S. Environmental Protection Agency, little work had been done to improve the processing of biological sludges. When government funded secondary plants began to be built, the extent of the problems in sludge management became evident. Haines (18) reported that the cost of sludge treatment and disposal presently accounts for 25%-50% of the total cost of wastewater treatment. In most cases the cost leans toward the higher figure.

These high costs for sludge handling have caught the attention of many people, including the equipment manufacturers. Extensive studies have been done on the processing of waste activated sludge. This has generated not only improvements in existing systems, but also the introduction of many new processes.

Activated sludge presents problems not encountered with primary sludges. (31) It is inherently more variable. This variation can be caused by a number of things, but is generally due to the configuration and operation of the particular treatment process.

The major problem encountered in processing activated sludge is its resistance to settling. The activated sludge particle is finer than that of the primary sludge, contains about 60% to 90% cellular organic material and a great amount of water. As these particles settle they tend to aggregate through bioflocculation. The settlement of the particle is hindered by interparticle interferences, fluid forces and the degree of flocculation.

The degree of flocculation will vary with the operation of a particular plant. In some cases the sludge will not settle at all and even tend to float at times.

Processing of sludge is generally divided into seven categories. Each category is subdivided into several alternate systems. Figure 1 illustrates the unit processes for sludge handling and disposal as defined by the U.S. Environmental Protection Agency (EPA). (31) The seven categories are defined as follows:

1. Sludge Thickening (Blending). Increasing the solids concentration and uniformly blending primary and secondary sludges in plants where combined processing is practiced.
2. Sludge Stabilization (Reduction). Converting sludge to more stable and less offensive form. Reduction is often a benefit of sludge stabilization.
3. Sludge Conditioning. A pretreatment to aid in dewatering.
4. Dewatering. The removal of sufficient water to change the form of the sludge.
5. Heat Drying. The process of using heat to remove moisture from the sludge.
6. Reduction. A process that produces a major reduction in the volatile sludge solids.
7. Final Disposal. The ultimate location of the processed sludge.

In practice many combinations of these seven categories have been used. These vary from stabilization and direct land application to very elaborate systems using all seven categories.

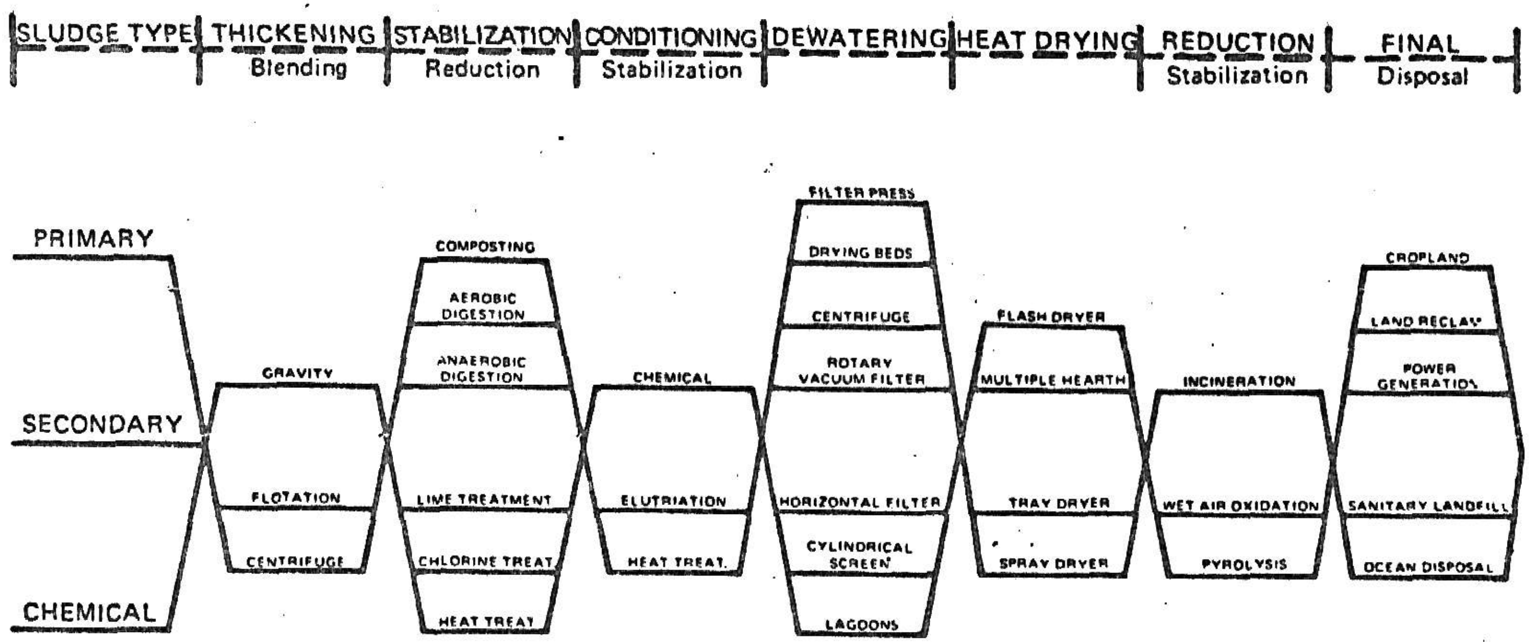

Figure 1. Unit Processes for Sludge Handling and Disposal (31)

II DISCUSSION OF LITERATURE

A. Introduction

The great increase in the number of activated sludge plants in the past several years has stimulated much discussion on possible methods for handling the sludge that is generated. Some of these methods have been used for years and have had extensive performance data accumulated. Other methods are new and have only been used in pilot plants. In evaluating the potential of a sludge handling system for waste activated sludge, it is important to know how it operates under actual treatment conditions. As discussed earlier, activated sludge will vary with plant operation, temperature and the type of waste being treated. The true test of a process is how it will handle these variations.

The evaluation of a sludge handling system involves several parameters. These parameters include initial cost, operating cost, equipment life and performance. To determine the true usefullness of a system each of these must be evaluated.

B. Thickening

Figure 1 contains three unit processes in the sludge thickening category. These are gravity, flotation and centrifuge. In actual practice centrifuges are seldom used for thickening because of their high maintenance and operation costs. The major use of centrifuges is in dewatering. These is discussed in section E.

Gravity Thickening

Gravity Thickening is presently the most common process for sludge concentration. The process is basically the same process that takes place in any sedimentation tank except that thickening is somewhat slower because of the higher solids concentrations. A cross section of a typical thickener is shown in Figure 2. These higher concentrations cause a thickener to operate almost entirely in the hindered zone of settling. A sedimentation basin will operate in both the free and hindered settling zones.

The use of gravity thickening for activated sludge is extremely limited because of two common problems. (26) One problem is rising sludge after a short settling period. The sludge receives its buoyancy from nitrogen gas which is formed by denitrification. The second problem is caused by bulking sludge or a sludge that settles poorly. This bulking is generally caused by filamentous organisms or by bound water in the bacterial cells.

Although problems lead most authors to label gravity thickening of waste activated sludge an impractical process, some design standards are available. Recommended solids loading rates are 4 lbs./sq. ft./day by Culp, (9) 5-6 lbs./sq. ft./day by the EPA (31) and 12-30 lbs./sq. ft./day by Metcalf and Eddy. (26) The large range of values is partially due to the fact that none of the authors give any definite underflow concentrations. The EPA in a later table does give a 2.5 - 3.0% underflow concentration for a gravity thickener but does not indicate the corresponding loading rate.

There are two general practices for wasting sludge to a gravity thickener. One opinion uses return sludge assuming that a thicker influent concentration will give a thicker effluent concentration. Metcalf and Eddy (26) propose that direct wasting of mixed liquor will produce a higher solids concentration than return sludge. They gave no reason for this nor was any data found that would substantiate this idea.

The general design of a gravity thickener as discussed in this section is the same as a sedimentation basin. They are usually a circular basin with a center feed, a scraper for sludge removal and a surface skimmer. If they are in an area where odor might cause a problem, the basin is covered.

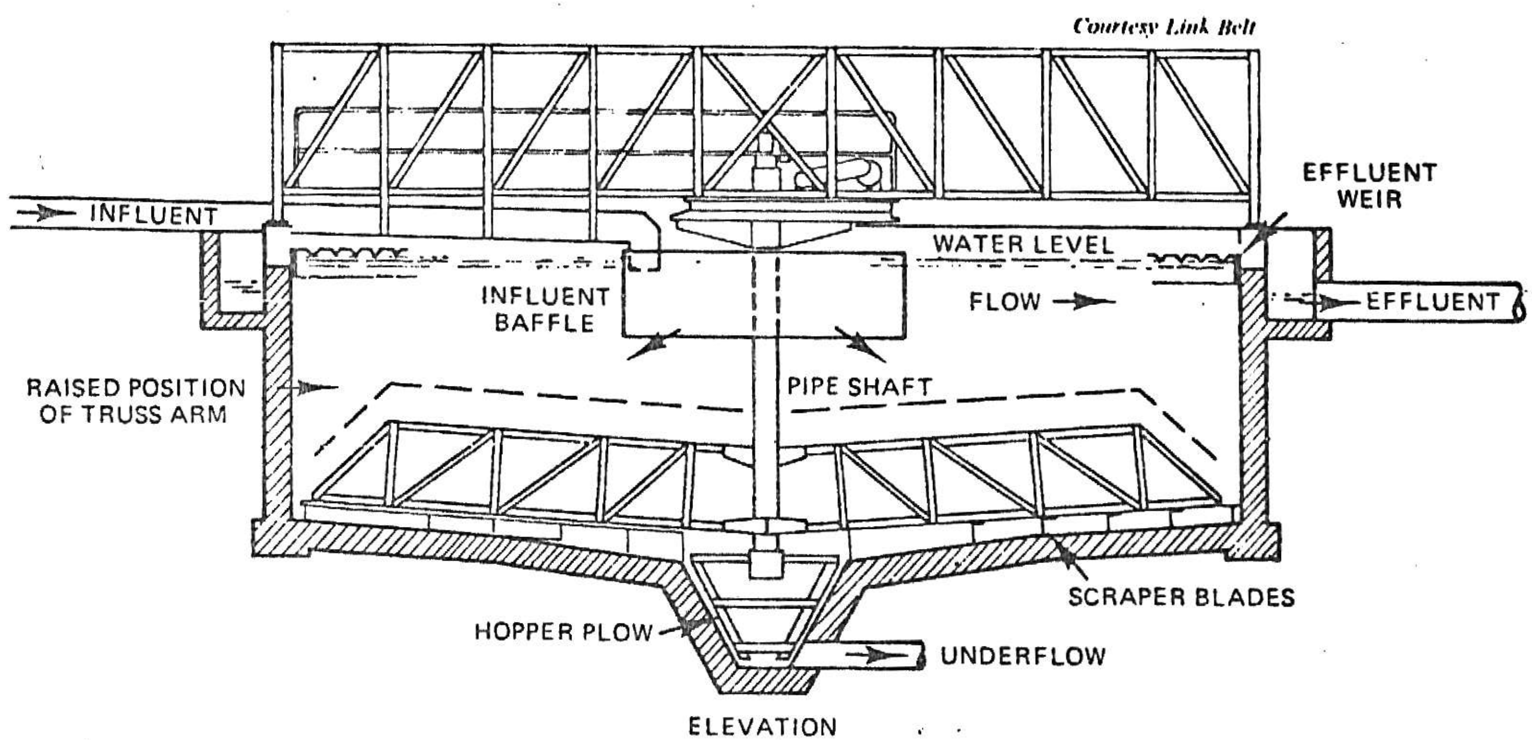

Figure 2. Gravity Thickener (31)

Although gravity thickening of waste activated sludge is possible, it is not considered to be an alternative by most design engineers because of the potential operational problems. One possible solution to this problem could be chemical conditioning or stabilization of the sludge prior to settling. Polymers such as used in sedimentation basins might provide one alternative. Although polymer manufacturers claim that polymers improve the operation of a gravity thickener, there is little data available to prove this. Stabilization of waste activated sludge with lime or other material might also be considered to obtain better settling characteristics and reduce operational problems. Available data on this type of process, however, are scarce.

Air Flotation Thickening

Flotation thickening is the use of gas bubbles to increase the buoyancy of solids which causes them to rise and concentrate at the surface. Culp (9) gives four methods of flotation thickening used in waste treatment. They are:

1. Dispersed Air Flotation. Bubbles are generated by introducing air through a revolving impeller.
2. Dissolved Air-Pressure Flotation. Air is fed to the system under pressure and released to the atmosphere.
3. Dissolved Air-Vacuum Flotation. A vacuum is applied to wastewater aerated at atmospheric pressure.
4. Biological Flotation. Gases which are formed by biological activity are used to lift solids.

Only dissolved air-pressure flotation is discussed in this section. This process has been used in the United States more than the other systems and has become especially popular for the thickening of waste activated sludge. Figure 3 illustrates an air-pressure flotation unit.

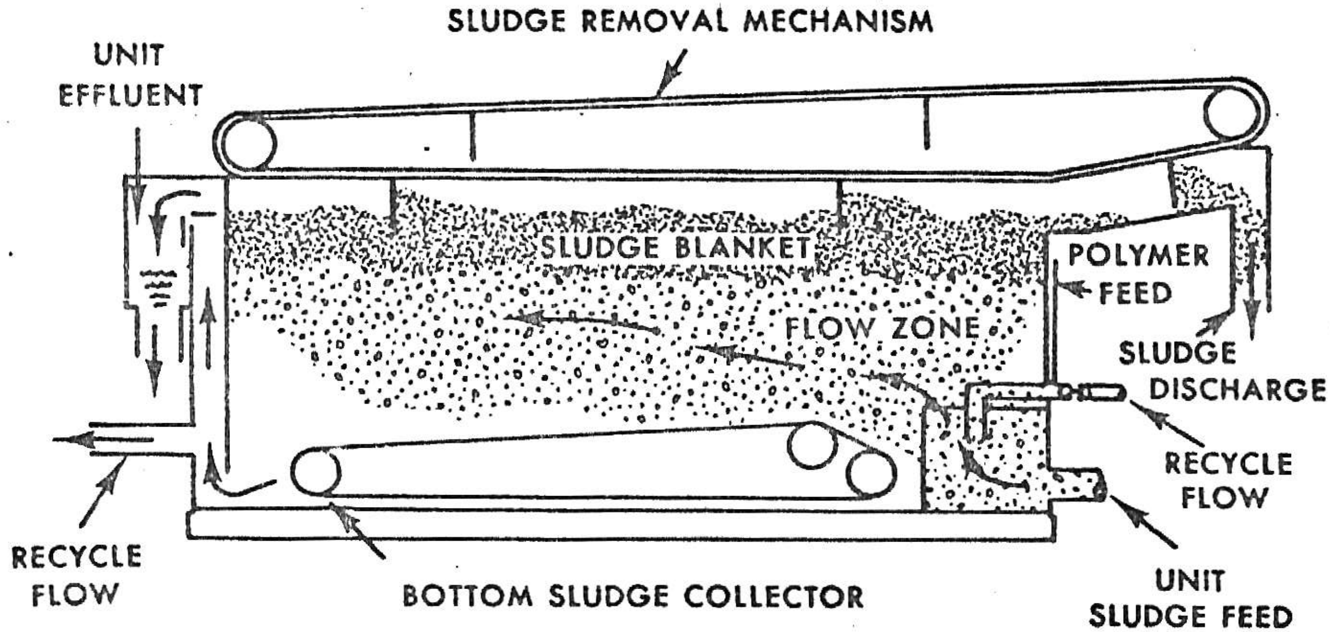

Figure 3. Air Flotation Unit (31)

A dissolved air-pressure flotation system generally operates in one of two design schemes. These are the full flow unit and the recycle unit.

In the full flow unit the waste influent is fed by a pump into a pressurized retention tank at 60 - 70 psig. Air is metered into the pump discharge. This mixture then flows into the flotation tank. In most cases chemical aids are added at this point. In the flotation tank the sludge is removed by surface skimmers from a sludge layer 8 - 24" thick. (9)

The recycle system uses effluent from the flotation tank to inject the air and develop the pressure. This recycled air-effluent mixture is mixed in the front of the flotation tank. The recycle flow will vary with the unit. Adams and Eckenfelder (1) developed a relationship for the recycle flow rate as being a function of influent flow, influent suspended solids, air quantity, gage pressure and the fraction of saturated air in the pressurized system.

The recycle unit has the disadvantage of requiring more area in the flotation tank, but with activated sludge produces better results. This is due to the fact that the floc is not broken down by passing it through the pressurized system.

The loading rates for a unit generally range from 1 - 4 $lb./hr/ft.^2$ but with the use of polymers some plants now operate as high as 8 $lb./hr/ft.^2$. (31) The amount of polymer required varies with the type of sludge, the type of polymer and the results required. In 1974 the EPA (19) gave the cost of polymers at several plants that varied from $2.50 - $4.50/T. Several other chemicals, most being inorganic, have been used in the past but are presently not competing well in terms of overall cost and performance as compared to the polymers.

The amount of air required for an air flotation system is primarily controlled by the type of sludge. Culp (9) states that for waste activated sludge an air to waste volumetric ratio of 0.02 is commonly used.

The selection of dissolved air flotation over gravity thickening has been based on the following criteria: (31)

1. Lower capital cost
2. Higher solids loading rate
3. Thicker sludge underflow
4. Better solids capture
5. Maintenance of sludge in an aerobic condition
6. Reliability

The major disadvantage is the high operating cost.

C. Stabilization

The purpose of stabilization is to reduce the pathogenic organisms and make the sludge less odorous. In general, waste activated sludge is considered to be stabilized if the volatile suspended solids have been reduced to about 50% of the suspended solids or the pH has been raised above 11. If stabilization is accomplished by reduction of the volatile fraction there is also a suspended solids reduction. Stabilization by pH adjustment will increase the solids in most cases. Because the volatile solids reduction method is generally used, many authors speak of this step as the stabilization reduction process.

Composting

Composting of sludge has been so limited in the United States that little data is available on the process. Furthermore, available data does not distinguish between the types of sludge used.

The major disadvantage in composting has been finding a market for the composted sludge. The cost of composting has been reported to be $2 to $20 per ton. (31) To offset this high cost and to make the process feasible the composted sludge must be sold.

Composting is done by one of two general procedures. It can be done in a windrow operation or in a mechanical aeration system. (31) In both cases a moisture content for the composted material between 45 and 65 percent is needed for good digestion. The required moisture content of the sludge can be reduced if the sludge is mixed with solid waste. Normal sludge to refuse ratios of .05 - 1.0 (W/W) have been used.

Pilot plant operations in composting of sewage sludge have been carried out in Beltsville, Maryland by the U.S.D.A. Agricultural Research Service in conjunction with the Maryland Environmental Service and the Blue Plains Wastewater Treatment Plant in Washington, D.C. (11) They used sawdust, shredded paper and wood chips as bulking agents with composting being done by the two common procedures as well as a third procedure. This method consisted of only a compost pile. After preliminary testing they decided to use the windrow system.

In the work at Beltsville, two major operational problems hindered the process, composting in adverse weather conditions and composting raw sludge without producing odors. Epstein and Willson (11) in discussing these problems felt that the major part of these problems could be solved by closer management.

Epstein and Willson (11) in the conclusion of their report on composting at Beltsville stated that cities must remember to think of the process not as a means of making money but as a means of disposing of sludge.

Even when mixed with refuse, the sludge must be dried beyond that required for most ultimate sludge disposal systems. Because of the excessive cost and the limited market, composting cannot be considered a workable alternative for treatment of waste activated sludge at the present time.

Aerobic Digestion

Aerobic Digestion is one of the newest methods of treating waste activated sludge. The principle of the system is the fact that microorganisms will utilize their own cellular material when there is no exogenous food available.

Reynolds (28) gives several advantages of aerobic digestion over anerobic digestion.

1. Volatile solid reduction equal to an anerobic system.
2. Lower BOD concentration in supernatant.
3. Produces odorless end product.
4. Sludge has excellent dewatering characteristics.
5. Recovery of more of the basic fertilizer values in the sludge.
6. Fewer operational problems.
7. Lower capital cost.

Aerobic Digestion is a modification of the activated sludge process. The design and operation of the tank is basically the same as that used for the conventional activated sludge system. The major differences in aerobic digestion are the increased solids in the mixed liquor and the longer sludge age.

Aerobic digestion can be used in several different ways in a sludge handling system. It can be used to follow a thickener. The present trend, however, is to feed the digester with either mixed liquor directly from the aeration basin or with sludge return. The digester is then followed by a gravity thickener. The thickened sludge is returned to the digester to allow operation at a much higher solids level. The level generally ranges from 15,000 to 25,000 mg/l. By increasing the solids concentration, plants can easily operate a week without withdrawing sludge. When sludge is withdrawn it can be taken from the thickener underflow or the air to the digester can be shut off for three to four hours and a portion of the sludge drawn from the bottom. Reynolds (28) reports that Texas A & M University has been drawing sludge directly from the digester and has been able to approximately double the underflow solids content of the digested sludge.

The use of aerobic digestion has become quite popular in plants that use land application not only for the stabilization aspect, but also because of the potential storage capacity. The required storage for a land application system varies from area to area but for the Midwest it is about 30 days. By increasing the solids content and accounting for solids destroyed, an aerobic digester can be designed that will incorporate the storage and still be competitive with other processes.

The amount of solids destroyed varies between sludges. Reynolds (28) reported 51 percent destroyed in lab tests and 53 percent destroyed in field tests. Lindstedt (22) studied the operation of the treatment facilities of the Metropolitan Denver Sewage Disposal Distict No. 1. During a four month period he found 26.5 percent of the total waste activated sludge solids had been destroyed. Cohen (8) also worked at the Denver plant and found that V.S.S. reduction approached 50 percent under ideal conditions.

The variability of these numbers can be explained by several parameters. Loehr (23) reported that different solids reduction rates are often due to different starting points. He pointed out that authors seldom report the sludge age entering the digester. If a sludge has a high sludge age, it will in turn have a smaller solids reduction. Cohen (8) contradicted Loehr's (23) idea that sludge age was the most important factor in solids reduction. He felt that data from the Denver plant showed that sludge was much more sensitive to temperature. Adams (1) preducted a two-fold rate of change for a 10^{o} C temperature change.

In some cases a lower solids reduction can be traced to lack of oxygen. Reynolds (28) found the oxygen requirements to be 1.9 lb./lb. of solids destroyed. In the majority of digesters the air required for mixing will be greater than that needed for oxygen supply. Both Reynolds (28) and Folk (12) suggest an air supply of about 30 cubic feet per minute for each 1000 cubic feet of digester volume. If the oxygen transfer efficiency is low and the aeration rate does not supply the required oxygen, solid reductions will be hindered. Adams (1) outlined procedures for determining solids reduction and air requirements through laboratory studies. Although these parameters can be predicted mathematically almost all authors agreed that a pilot study was important.

The volume of an aerobic digester is generally determined by the design population. Reynolds (28) suggests 1.5 cubic feet per capita while Folk (12) suggests 2.0 cubic feet per capita. Both authors suggest a depth of 11-15 feet. Folk (12) also suggests that there be a minimum of 2 digesters.

Aerobic digesters have presented problems at certain plants. Jacke (20) reported that the digesters at the Escanaba, Michigan plant failed to operate as expected. Waste activated sludge was fed in at about 1 percent solids. When the air was shut off the solids would not settle. After testing they found that polymers could be used to produce better settling. They tried several polymers and found that Hercules No. 814 produced the best results. For solids concentrations of 0.9 to 1.1 percent, it was found that 25 to 30 mg/l of polymer was required. This produced a concentrated sludge of 1.8 to 2.2 percent sludge.

Anaerobic Digestion

The use of anaerobic digesters for sludge stabilization has been quite popular in the past, but their use for strictly waste activated sludge is extremely limited. The main use of digesters has been with primary sludge or a combination of primary and secondary sludges. Digesters operating with primary sludge produce very good results, but as secondary sludges are added the quality of treatment is depressed.

The major problem with treatment of combined sludges is the poor quality of the digester supernatant. Primary sludge alone will produce a supernatant with a BOD_5

of 500 to 3,000 mg/l and a suspended solids of 200 to 1000 mg/l. When activated sludge is added the BOD_5 increased up to 1,000 to 10,000 mg/l and the suspended solids to 5,000 to 15,000 mg/l. (21)

This poor quality supernanant must then be returned either to the primary settling tank, the aeration basin or treated separately. In each of these alternative locations, an additional burden is added to the plant.

The author could find no information to indicate what the quality of supernatant from an entire digester of waste activated sludge might be. The results from the combination of sludges, however, indicate that it would be of even poorer quality. Anaerobic digestion of waste activated sludge, therefore, would be of little use. The one exception to this might be a digester followed by a land application disposal system in which the supernatant could be applied to the land in the same manner as the digested sludge.

Lime Stabilization

As stated earlier, stabilization is generally considered to be complete when the pH reaches 11. Recent literature tends to show that this is not sufficient. The EPA (31) indicated the pH should be between 12.[illegible] and 12.4 and above 11 for at least 14 days. The EPA (31) also presented data of Paulsrud and Eikum on the lime dosage required to keep the pH of sludge above 11 for 14 days. They predicted 600 to 1,000 pounds of lime would be required for each ton of biological sludge.

Lime stabilization presents two major problems. The first is the chemical cost and the second is the increased solids that must be handled. Lime stabilization does not reduce the volatile solids concentration and may increase the total solids by 25-50%.

The principal advantages of lime addition are not in sludge stabilization, but rather in the subsequent processes. Lime helps to condition the sludge by coagulating the solids. This is helpful in advance of vacuum filtration and centrifugation. (26) The use of these systems is discussed in the section on Dewatering.

Although lime stabilization is being used very sparingly in the Midwest, it may become important in the future. The process is relatively simple to operate, thus making it valuable to smaller plants that do not have a laboratory or technicians available to monitor an aerobic or anerobic system. Although it has a high chemical requirement, it has a low power requirement which is extremely important in plant design.

Chlorine Treatment

Stabilization of sludge with chlorine requires a dosage of about 2000 mg/l. This dosage will leave the pH as low as 2. In many cases this will require additional chemicals be used to raise the pH before final disposal. After stabilization the sludge will dewater quite well on a sand bed.

The high chemical cost makes this process unsuitable for most plants. The EPA (31) estimates a cost of $5/ton of dry sludge. In extreme cases chlorine treatment is feasible, but for general use the high chemical cost eliminates it from consideration.

Heat Treatment

Heat treatment is a combination of two processes since it not only stabilizes the sludge but also serves to condition it. The process itself is relatively new in the United States but has been used for many years in Europe. Both West Germany and Switzerland require heat treatment of sludge before it can be applied to the land.

One of the important results of heat treatment is production of a sludge that has greatly improved dewatering properties. Cheremisinoff and Maglio (7) discussed heat treatment and predicted about a 50 percent reduction in sludge mass with heat treatment and digestion. These two facts lead to several important advantages of heat treatment. Among them are a greatly increased solids content, the elimination of chemicals for conditioning and the elimination of any feed requirements for incineration.

The actual process of heat treatment involves heating the sludge under pressure. This results in a breakdown of the microbial cells, coagulation of the solids and a reduction of the water affinity. (26) The two best known systems for heat treatment are the Porteus and the low-pressure Zimpro system.

In the Porteus system the sludge is heated and then fed into the reactor. Steam is injected to raise the reactor temperature to 290 to 390 degrees F. The pressure is kept in a range of 150 to 200 psi. A 30 minute detention time is used. The resultant sludge can be filtered to produce a solids content ranging from 40 to 59 percent.

The low-pressure Zimpro process adds air with the sludge as it is fed to the reactor. The temperature is raised by steam to 300 to 400 degrees F with pressures ranging from 150 to 300 psi. The dewatered sludge will have solids concentrations of 30 to 50 percent.

The major drawback to both the processes is the poor quality supernatant caused by the breakdown of the cells. Fisher and Swanwick (14) predicted the BOD_5 of this water will be 5,000 to 15,000 mg/l. This supernatant must be fed back to the treatment plant. In design of the treatment plant this load must be taken into account. This additional cost must be considered when calculating the cost of a sludge handling system.

The real importance of heat treatment for sludge in the Midwest is in plants that follow with incineration. Heat treatment with dewatering produces a sludge cake having a solids content that is higher than needed for land application or landfilling and in most cases is not justifiable unless followed by incineration.

D. Conditioning

Sludge conditioning is used to improve the removal of water in a dewatering system. The EPA (31) names three categories in conditioning. These are chemical, elutriation and heat treatment. Elutriation should probably have been added as a subsection under chemical conditioning because it does not directly improve dewatering but does reduce the chemical requirement for conditioning. (26)

Conditioning has traditionally been considered to precede dewatering in a sludge processing system, but is presently being used at almost all points in the treatment plant. This is due mainly to increased use of high molecular weight polymers in chemical conditioning.

Chemical Conditioning

Due to the continued increase in the use of polymers in waste treatment, chemical conditioners can be broken into two main divisions: inorganic and synthetic. The inorganic coagulants have been used for years. These consist of iron salts, lime, alum and others. The synthetic coagulants are newer and consist of the high molecular weight polymers. (29)

Although chemical conditioners are used at various locations within a plant, the goal is the same at each point. That goal is to coagulate the particles for better dewatering. This objective, however, is resisted by three primary factors.

The first is a double layer repulsion. These layers consist of the charged surface on the solid particle and its counter-ion charge in the surrounding liquid. The electrical potential of this area is the zeta potential of the particle. Before coagulation can take place, these charges must be reduced. This will allow the Van der Walls forces to pull the particles together.

Short range hydration repulsion is the second stabilizing factor. This simply refers to absorbed solvent molecules coating the solid particles. Even when electrolytes are present they cannot act through the layer. In this case a flocculent must be used that can penetrate this shell and destabilize the particle system.

The third factor is much the same as the second except surface-active molecules are absorbed on the particles. Again in this case the flocculent must penetrate the surfactant layer, reach the particle surface and cause agglomeration through bridging.

To control these factors one of three polymers families is used.

1. Cationic. These are positively charged ions for neutralization of negatively charged particles. They generally work best at a pH of 5 to 8.
2. Non-ionics. Particles of both positive and negative charges are absorbed by this neutral iron. They work well in a very low pH system.
3. Anionic. These supply negatively charged ions. They are the most commonly used polymer in waste water treatment. They are most effective in a pH range of 7 to 14.

Although several polymers within a family can accomplish a specific goal, the only way to find the best polymer is with jar tests or graduated cylinder tests.

The inorganic chemicals used in chemical conditioning work much the same as the polymers since they serve as coagulants. Their low cost coupled with advantages to a treatment system has greatly increased their use over the last several years. Gross (17) stated that in 1970 the waste treatment processes in the United States used 160 million pounds of alum, 130 million pounds of ferric salts and 1.1 billion pounds of lime. Overall this amounted to 37% of the total coagulants used in water treatment. The other 63% was used in water clarification. By 1980 Gross predicts a total of 42% will be used in the wastewater field.

As with the polymers the use of inorganic chemicals as conditioners has expanded to many different locations in the treatment system. Because their use has become so varied, the specific application and the feed rates are discussed in conjunction with the various processes.

Elutriation

Elutriation is used prior to chemical conditioning. The process itself does not improve the dewatering process, but it does decrease the chemical requirement to condition the sludge. This is done by reducing the alkalinity caused by ammonium and bicarbonate salts. (33)

The process uses fresh water or plant effluent to wash the sludge. The alkalinity is then carried out by the water. The actual washing process is done in tanks similar to sedimentation tanks. These can operate either as single stage, multiple-stage or countercurrent processes.

The major drawback of the process in modern-day plants is the quality of the washing effluent. As the quality of waste water treatment increases, sludges contain more fine particles which are carried out in the wash water. This water is then added to the plant influent to be treated.

E. Dewatering

Sludge dewatering is considered to encompass the methods used to change the form of the sludge from a liquid to a damp solid. This is generally accomplished with one of five mechanical systems or by one of two gravity systems. The mechanical systems include filter press, centrifuge, rotary vacuum filter, horizontal filter and cylindrical screen. The two gravity systems are lagoons and drying beds.

Filter Press

A filter press consists of a series of rectangular plates that are recessed on each side. The plates are supported vertically with a filter cloth on each plate. The plates are held together with hydraulic rams or powered screws. The sludge is pumped into the space between the plates and held at a pressure of 60 to 180 psi for 1 to 3 hours.

The plates are then separated and the sludge removed. A cutaway view of a filter press is shown in Figure 4. The sludge cakes will be about 1 to 1-1/2 inch thick with a moisture content of 55 to 70 percent. The system operates as a batch process with plates being separated and the sludge cake removed between each run. The cycle time for the entire process will run from 3 to 8 hours. (26)

Conditioning of the sludge prior to dewatering is generally done with fly ash, ferric chloride or lime. Forster (15) studied filter press production on various sludge mixtures. The results of his finding on activated sludge are presented in Table I.

Table I (15)

Suspended Solids	Conditioning of Dry Solids (%) (W/W)		Cake Solids (%)	Cycle Time (hr)
	Fly Ash	250	50	2.0
Up to 5%	$FeCl_3$ Lime	7.5 15	45	2.5

The chemical requirements for waste activated sludge were higher than those for other sludges and were much higher than those for raw primary sludge.

Carry, Miele and Stahl (6) studied the use of polymers with a filter press. They found the use of polymers to be completely unsuccessful due to the rapid binding of the filter media. They also attempted to use polymers as a prelude to condition the sludge and reduce the lime and ferric chloride cost. This too failed. Their work was done with digested sludge, but similar results could be expected with waste activated sludge.

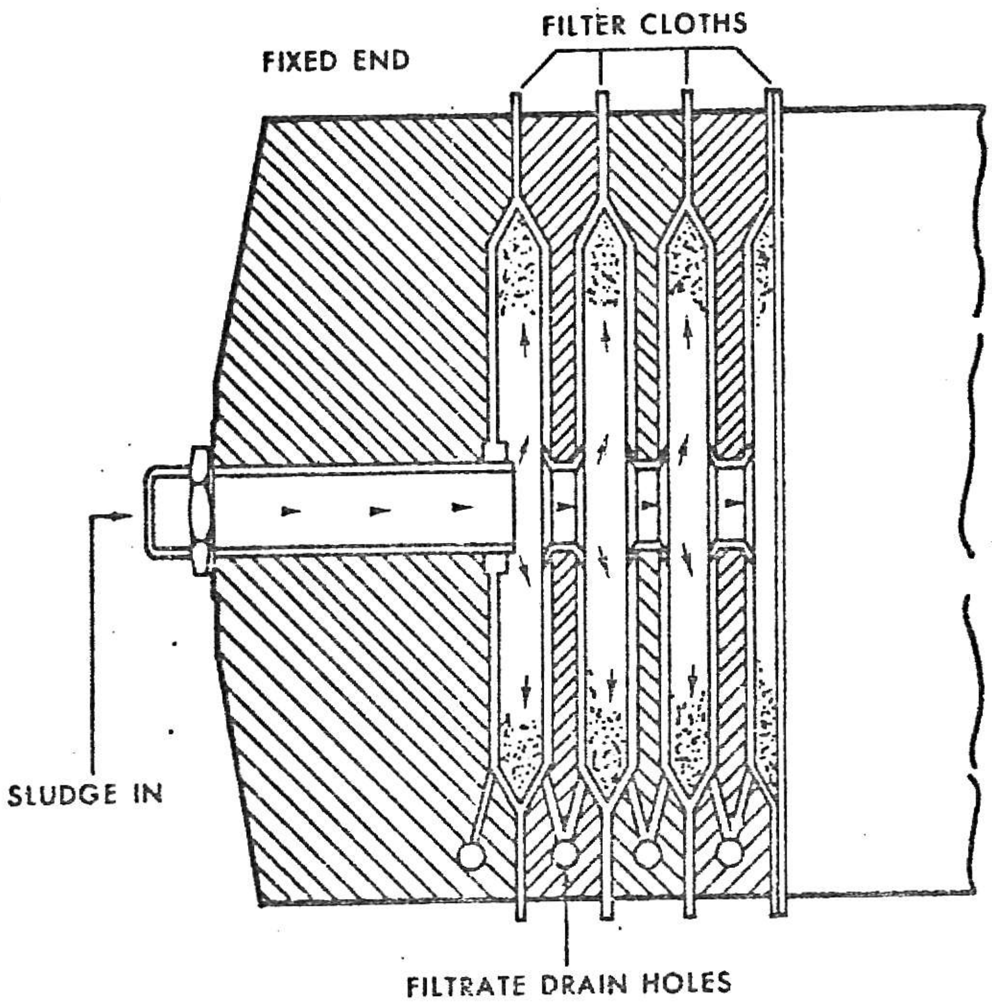

Figure 4. Cutaway View of Filter Press (31)

The use of a filter press for dewatering involves three major costs. These are chemicals for conditioning, maintenance and replacement of filter cloths. (26) In return it produces a very dry cake. This is valuable in a system in which the sludge cake is incinerated. In most Midwestern plants, however, incineration is not used. If the sludge were to be applied to the land, the major advantage it would have would be the reduced sludge volume. It would have a disadvantage in that the cakes would have to be broken down before they were applied to the land. There is presently no equipment for subsurface injection of dry sludge. Any application of sludge to the land would require a following pass to bury it below the surface. Sludge cakes from a filter press would have a slight advantage in a landfill operation because they would require less room. In the Midwest landfill space is seldom this limited and the extra cost to produce these dry cakes is not warranted.

Drying Beds

In the past drying beds have been popular in smaller plants because of their low initial cost and their simplicity of operation. Due to the continuing increases in labor costs, however, the expenses involved in cleaning the beds has decreased their popularity.

The general design for drying beds consists of beds 20 feet wide and 20 to 100 feet long with concrete curbs, a sand bottom and an underdrain system. After drying, the sludge is generally removed by hand for transporting to the point of final disposal. In some instances concrete bottoms have been used in the beds to enable quick clean-up with a front end loader, but this greatly increases the drying time because the water must travel a much longer distance to be drained off. With 10 to 15 days of favorable drying conditions, the moisture content of sludge on a sand drying bed can be lowered to approximately 60 percent.

Design of a sand drying bed is usually done with the use of a population equivalent. The Water Pollution Control Federation (3) presented a list of areas required for drying of various sludges. For a mixture of primary and activated, an area of 1.75 to 2 square feet per capita is required for an open bed. When the bed is covered by a green house the required area is lowered to 1.25 to 1.5 square feet per capita. These numbers were presented for areas in the northern United States.

The use of polymers for sludge conditioning has somewhat rejuvenated the use of drying beds. Beardly (4) estimated that a bed can be loaded with 20 to 50 percent more sludge with the use of polymers. He states that polymers are extremely valuable for drying waste activated sludge treated by itself. In most plants this sludge comes to the bed at a low solids content. This places an extra heavy load on the beds. With the use of polymers the beds can be loaded deeper without increasing the drying time.

Although Beardly (4) did not indicate the chemical requirements for sludge drying beds, he did provide chemical costs for several typical plants. These costs were on the range of 5 - 7 dollars per ton of dry solids.

With the energy shortage becoming more apparent the use of drying beds and chemicals is presently a very workable alternative for sludge dewatering.

CENTRIFUGE

The centrifuge is used to accelerate the sedimentation process by the use of centrifugal forces. In wastewater treatment this may be done by one of three centrifuges: the solid bowl-scroll type, the imperforate basket type and the disc-nozzle type. (1) The use of a certain type of centrifuge is determined by both the sludge characteristics and the performance requirements.

The solid bowl-scroll type centrifuge consists of a horizontal cylindrical bowl with a helical conveyer inside. As the sludge enters the bowl it is forced against the bowl wall by the centrifugal force. The scroll carries the sludge to the end of the bowl where it is removed. When the sludge is conditioned with a polymer prior to the centrifuge, the sludge floc tends to break less as it is carried by the scroll. This floc breakup has been a major problem when dewatering waste activated sludge with the scroll type centrifuge. The solid bowl-scroll is useful for dewatering a wide range of sludges and is used almost exclusively in the wastewater field. A solid-bowl centrifuge is shown in Figure 5.

The imperforate bowl basket centrifuge as shown in Figure 6 is used in sludge dewatering but on a very limited basis. The basket centrifuge consists of a basket rotating on a vertical axis. Sludge is forced to the walls where it builds up until the basket is full. At this point the feed is stopped and the basket is cleaned by a scraper. In most cases polymer is not required because the sludge is not conveyed during the dewatering which is the cause of most floc breakage.

The disc centrifuge is probably the least used of the three types but for thickening of waste activated sludges up to 6 to 8 percent it has the most potential. The influent to a disc centrifuge enters at the top and is fed through a series of stacked conical discs. Between each disc the settling distance is short which makes it valuable for the slower settling flocs. A disc type centrifuge is shown on Figure 7. The solids are flushed out of the bowl with wastewater which places a limit on the extent of dewatering which can be accomplished. The major drawback to the disc has been plugging caused by grit and larger particles of sludge.

The performance of centrifuges has been subjected to extensive studies. Their performance can now be estimated by emperical equations. The process variables can be adjusted in these equations to find the optimum performance point. Although these estimates give general performance guidelines a pilot plant study should be done to verify these estimates.

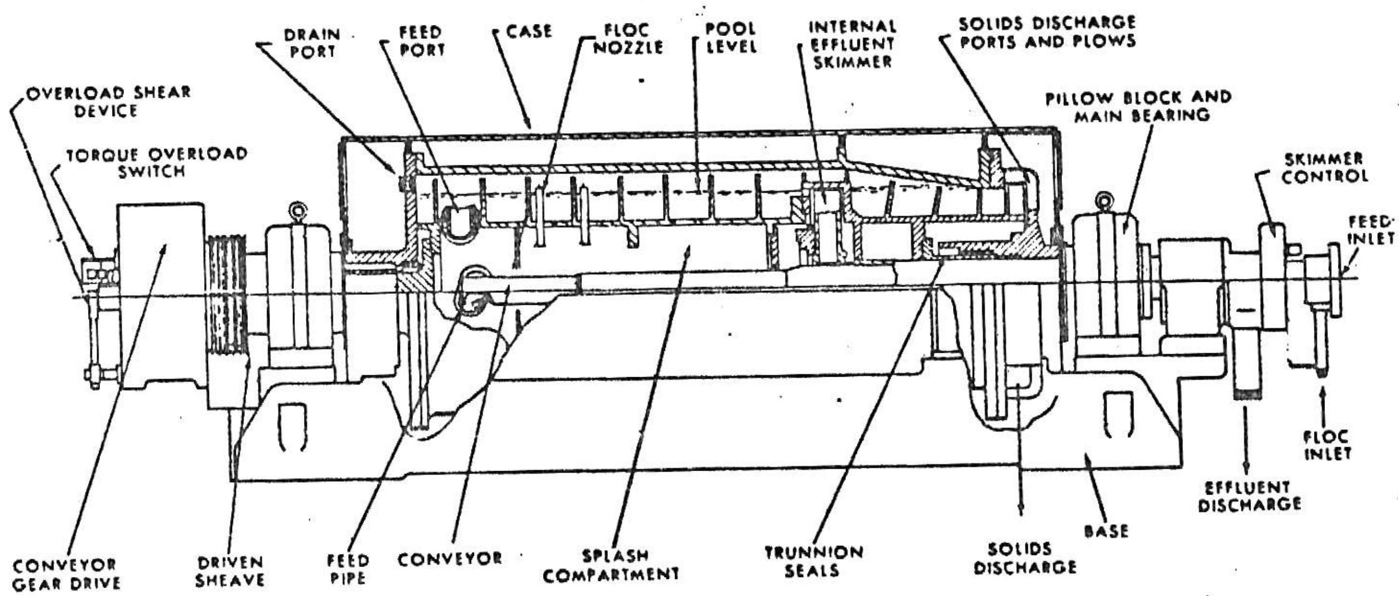

Figure 5. Solid-Bowl Centrifuge (31)

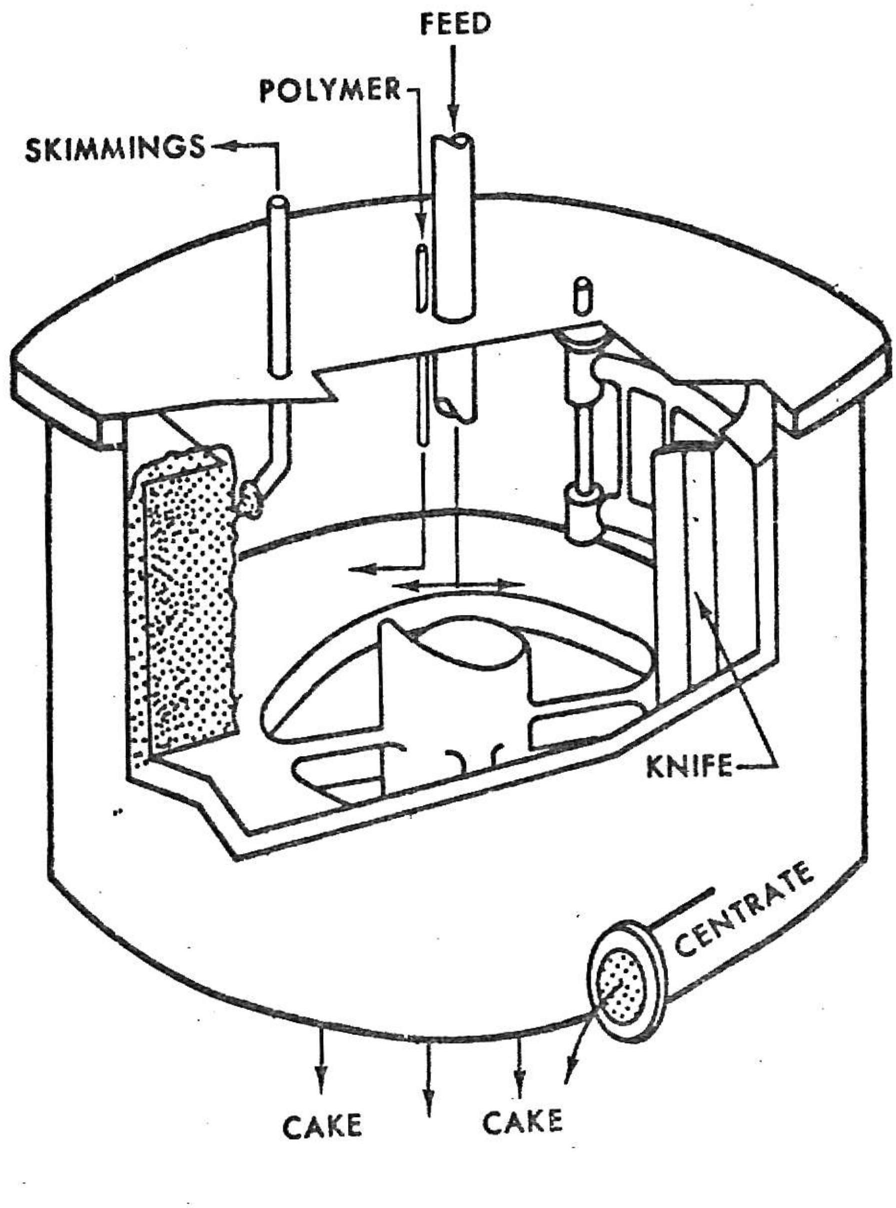

Figure 6. Basket Centrifuge (31)

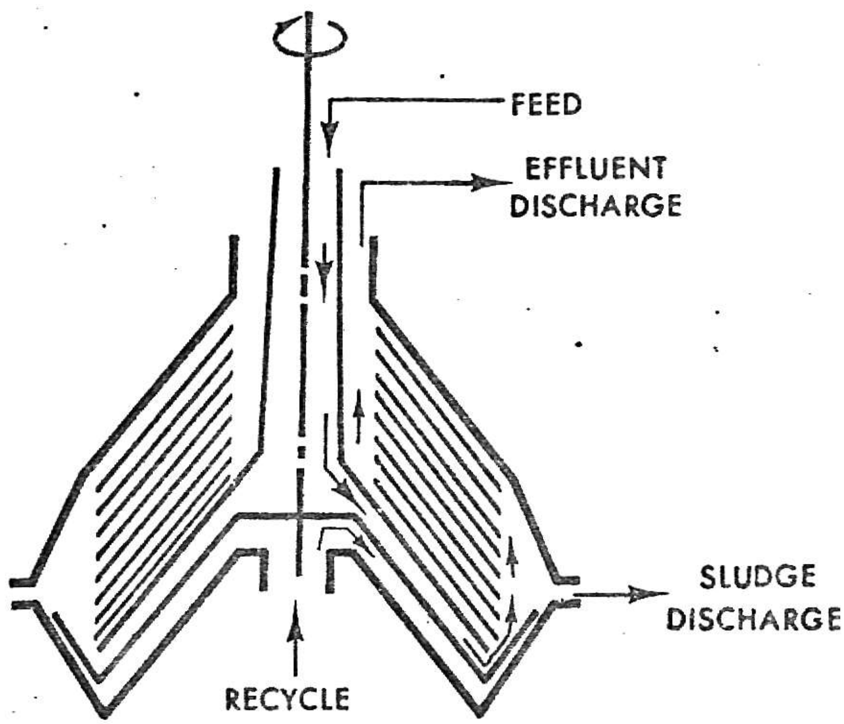

Figure 7. Disc Type Centrifuge (31)

Because of the variability of results with different combinations of sludges, chemicals and centrifuges no data was found to indicate what might be expected with waste activated sludge. In the past engineers have tended to limit the use of centrifuges because of operational problems, but with new technology most of these problems have been solved. Their new popularity suggests that they will in the future replace the vacuum filter as the most popular method of sludge dewatering.

VACUUM FILTER

Vacuum filtration removes solids from a liquid by passing the liquid through a porous media. The solids are retained on the media. A vacuum filter uses atmospheric pressure to force the liquid through the media. This is helped by applying a vacuum to the underside of the filter. A variety of filter media have been used. Among these are woven stainless steel mesh, stainless steel coil springs, natural and synthetic fiber cloth and cloth precoated with diatomaceous earth.

Several types of vacuum filters are manufactured. These include disc, pan, horizontal belt and rotating drum filters. (1) The rotary drum filter is generally used in waste treatment and is shown in Figure 8. The following discussion is limited to only the drum filter.

The rotating drum filter consists of a filter media supported by a drum rotating about a horizontal axis. About 10 to 40 percent of the drum is submerged. The drum is generally divided into 12 segments around its circumference. Each segment is sealed at the end and between the adjacent segments. The segments each have separate drains controlled by a rotating valve. The segments can also have a vacuum applied to each segment individually.

As the drum rotates it passes through several zones. These zones are illustrated in Figure 9. In the cake forming zone, vacuum is applied and the sludge is picked up

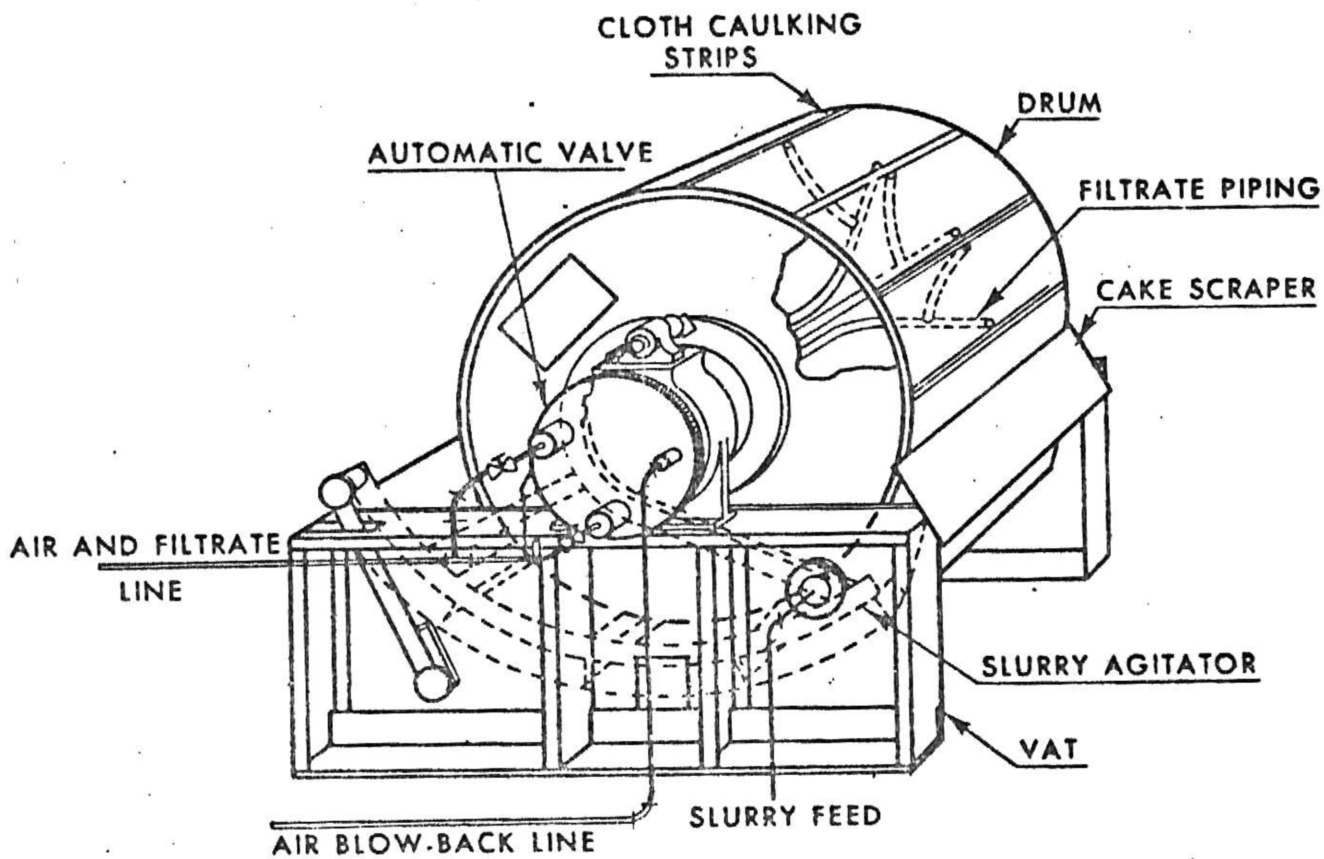

Figure 8. Rotary Drum Vacuum Filter (31)

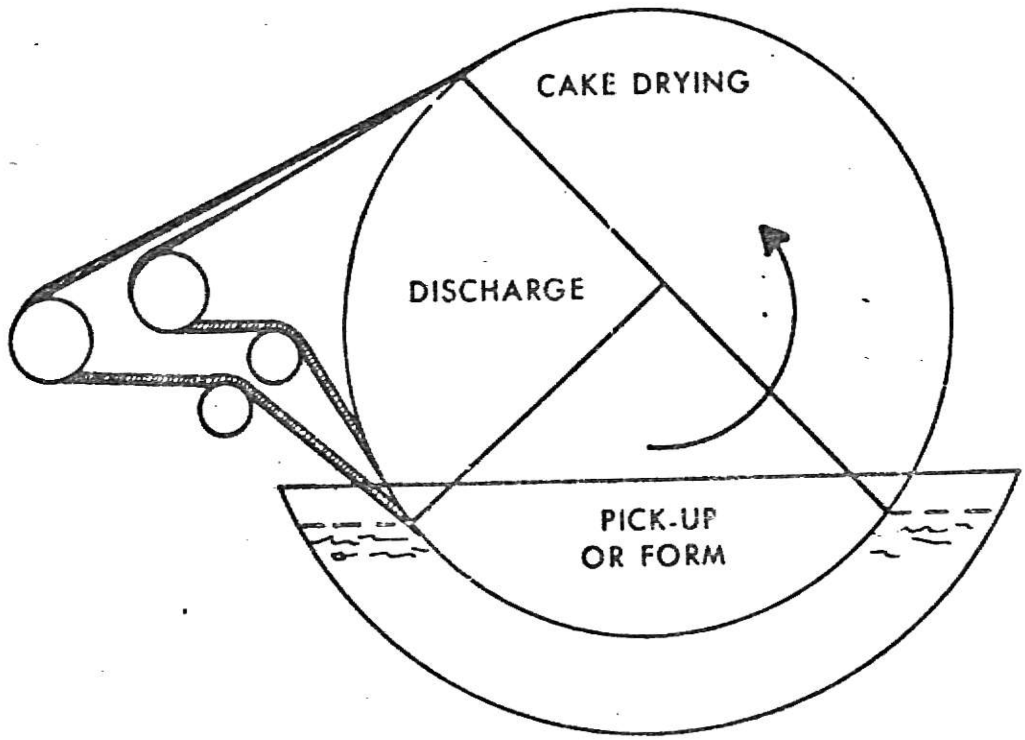

Figure 9. Operating Zones of Vacuum Filter (31)

onto the media. The filtrate is pulled into the drum for discharge. The second zone is the next area after the cake is raised from the sludge vat. In this area the vacuum is left on to remove more moisture from the cake. The final zone is the cake discharge zone. In this area the vacuum is shut off and the cake is removed by scraping.

The results obtained from the use of a vacuum filter are affected by a large number of variables. These were discussed by Bennett, Rein and Linstedt. (5) They categorized the variables as: sludge characteristics and operational variables.

Sludge characteristics which have a direct effect on filter cake solids concentrations include:

1. Size and shape of solid particles
2. Suspended solids concentration in feed
3. Compressibility of sludge particles
4. Chemical composition and particle charge on sludge solids
5. Sludge age and temperature
6. Sludge and filtrate viscosity
7. Origin of sludge

Conditioning of the sludge by chemical addition or heat treatment will alter or change these sludge characteristics. This is especially true with waste activated because it can be quite variable.

Chemical conditioning prior to a vacuum filter is generally done with iron salts and lime, or with synthetic organic polyelectrolytes. These chemicals help the particles to agglomerate into larger particles. The chemical dosage required is quite variable which in turn results in a limited amount of data on the subject. The EPA (31) gave estimated chemical dosages required for various types of sludges but gave no estimate for waste activated alone. They estimate a dosage for "digested (primary and EAS)" of 372 lb/ton of CaO and 110 lb/ton $FeCl_3$ or 36 lb/ton of polymer. They also estimated the cost of the CaO plus $FeCl_3$ to be almost equal to that of the polymer alone.

The use of heat treatment for conditioning prior to vacuum filtration is relatively new in the United States. Its main advantage is that it removes some of the fines in the sludge and reduces the ability of the sludge to hold water.

Adams and Eckenfelder (1) discussed a third means of sludge conditioning prior to vacuum filtration. This is by use of physical conditioners. These include diatomaceous earth, fly ash and blast furnace slag. These conditioners are less affected by variable sludge characteristics and can generally be obtained at a low cost. Their major drawback is the great amount of bulk they add to the sludge.

The operational variables mentioned by Bennett et al.: (5)

1. Vacuum levels during the form and dry cycles
2. Form and drying times
3. Drum submergence
4. Drum speed
5. Characteristics of the filter media
6. Degree of agitation during and after chemical addition

The effect of these variables on the sludge cake can be predicted to a certain extent by the use of emperical equations. These relationships generally begin with the basic filtration equation derived from Poseilles and D'Arcys law. (1)

Bennett, Rein and Linstedt (5) evaluated the vacuum filter in both laboratory and field tests. Their work was done with sludge from the Denver Metropolitan Plant. They studied sludge conditioning as well as many of the operational variables. Their conclusions include several that are important in dewatering of waste activated sludge.

They concluded that the optimum point of filter operation is dictated by the sludge, the method of conditioning used and the required results. This would seem to be a foregone conclusion, but it can be easily overlooked in a treatment plant design. The optimum operation point for handling waste activated sludge will vary with the sludge and be different than that for primary sludge or even for another waste activated sludge. To operate most efficiently, the optimum point for each sludge must be found.

They concluded that the best means of handling waste activated sludge was to process it in a mixture with primary sludge. They felt every effort should be made to keep the activated sludge content as low as possible.

They did study activated sludge handling by itself. They used sludges both before and after aerobic digestion. The results from the two tests were similar with some indication that digestion caused a reduction in filter yield.

The expected performance of a vacuum filter will vary. For waste activated sludge, solids in the dewatered cake can be expencted to range from 15 to 20 percent. Metcalf and Eddy (26) estimated the filter should handle 2.5 to 3.5 lb./sq. ft./day.

HORIZONTAL FILTER

Several versions of horizontal filters are available for dewatering sludge, but all work under the same basic principle. The thickened sludge is passed between two endless belts that continue to apply increasing pressure to force the water through the filter belt. In most cases the sludge is conditioned prior to the filter system.

One of the major problems with the belt presses for use with waste activated sludge has been the cost of chemical conditioning. The EPA (31) in discussing the use of the Smith and Loveless Company model of the horizontal filter estimated a chemical cost of $6.60 per ton to provide a cake of 8.8 percent solids. This was based on 1970 prices. In 1973 sludge from the Oakland Sewage Treatment Plant in Topeka, Kansas was tested on the same type of machine. (32) The cost at that time was estimated to be $9 to $20 to produce cakes of 7 percent solids.

The second major problem is the low cake solids. The sludge is too wet to haul in a dump truck to a landfill and too wet to be of much value in an incineration system.

On the other hand it is almost too thick to be of any value in a land application system. The cake solids can be increased, but this requires either a dryer influent or additional filter units. Both methods increase the cost of processing.

The use of a horizontal filter for waste activated sludge is a possible alternative for dewatering, but at the present time there is a lack of system technology. There are several ongoing studies on the filter press which should increase its productivity and make them most cost effective.

CYLINDRICAL SCREEN

The major use of a cylindrical screen is the "Dual Cell Gravity (DCG)" dewatering unit manufactured by Permutit Company and shown in Figure 10. The DCG unit consists of two circular cells with a continuous filter cloth that travels over both cells. The sludge is fed into the first cell where gravity dewatering takes place. The traveling screen carries the dewatered sludge over a high point between the cells into the second cell where the sludge cake is formed. The weight of the cake helps to force out additonal water as the sludge is fed. Sludge cakes are pushed out the end of the second cell. In most cases the DCG is followed by a "Multi-Roll Press (MRG)" also manufactured by Permutit and shown in Figure 10.

The number of wastewater plants using the DGG units has been extremely limited in the wastewater field. Much of the available information on performance of the units is published by Permutit in their advertisements. (10) They predict a filtrate of 40 to 60 mg/l suspended solids. With a waste activated sludge of 1.9 to 3.0 percent they estimate a dry solids of 9.4 to 13 percent. They do not predict a chemical cost for conditioning but the EPA (31) did mention a cost of $8 to $10 per ton on a sludge mixture of anaerobically digested primary and trickling filter sludge. Permutit representitives

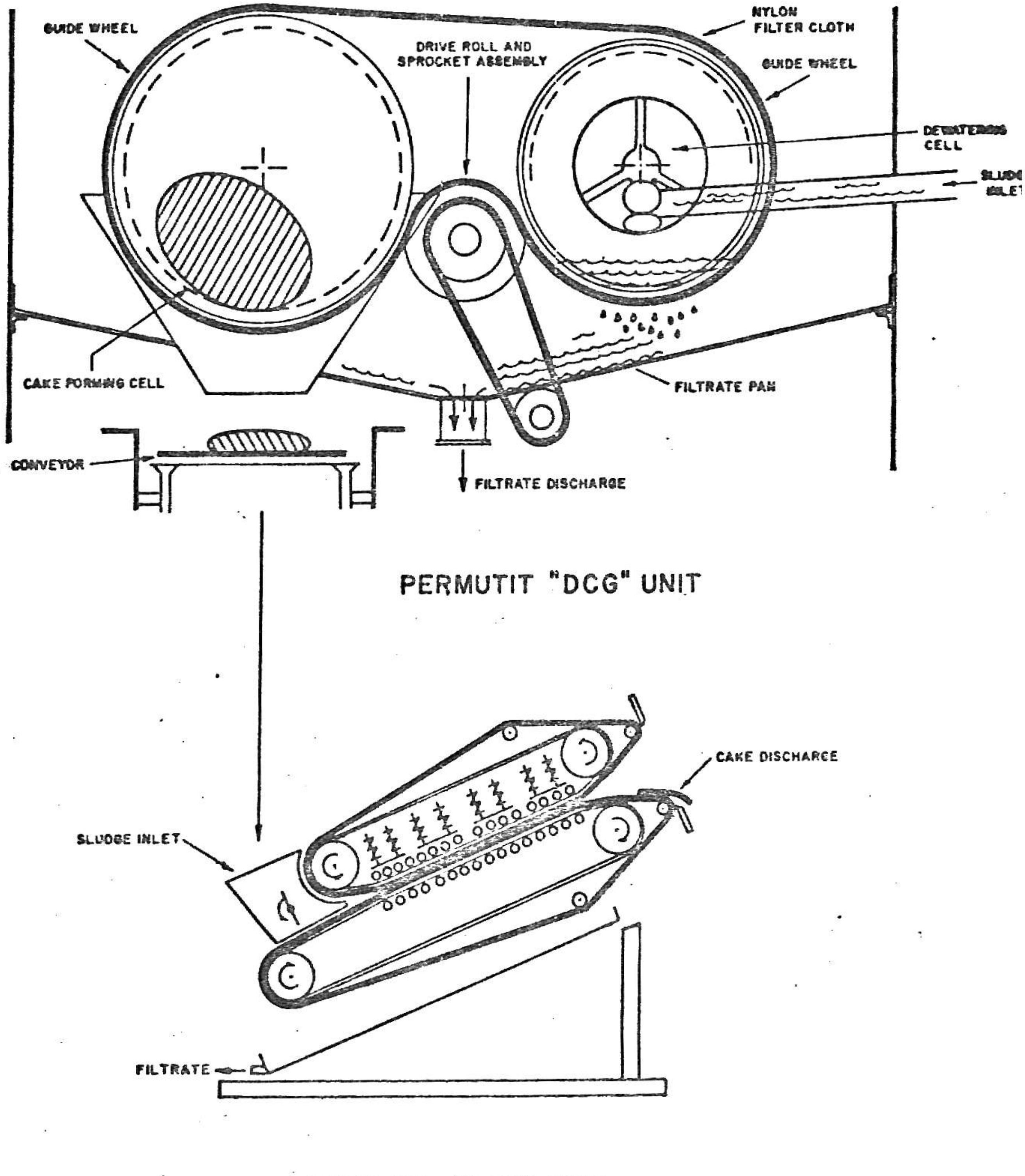

Figure 10. Permutit "DCG" and "MRP" Unit (32)

after testing the waste activated sludge at the Oakland Plant in Topeka estimated they could dewater a sludge of 1.2 percent solids to 15 percent cake solids with the DCG unit. The chemical cost for this was estimated to be $5.35. (32)

If the DCG units can perform as advertised, they could become the answer to a large number of dewatering problems. They have an extremely low power cost while the chemical costs are at least comparable to other systems. In addition they produce a relatively dry cake that can be dried even more by the use of the Permutit MRP unit with no additional chemical cost.

LAGOONS

In the past sludge lagoons have been used for both stabilization and dewatering. Generally the lagoons used for stabilization have met with problems. They not only give rise to unpleasant odors but also serve as breeding grounds for insects. Discussion here is limited to lagoons used for dewatering.

The operation of a lagoon is similar to a drying bed in that sludge is added, allowed to dewater and then removed for final disposal. Sludge depths in the lagoons range from 15 to 24 inches with some up to 4 feet. The drying time varies with depth and climate but will range anywhere from 3 months to several years.

The EPA (31) recommends designing lagoons with a capacity of 1 sq. ft./capita for primary digested sludge in an arid climate. For activated sludge plants with 36 inches of annual rainfall they suggest 3 to 4 sq. ft./capita.

Lagoons provide the simplest means for dewatering sludge and in most cases the cheapest. They provide a workable alternative for smaller plants and especially those in warmer climates if a few difficulties can be overcome. Among these are the large land requirements, the subsoil permeability and odor problems. These problems have caused many engineers to bypass lagoons in favor of drying beds or some mechanical system.

F. Heat Drying

This step in the process of sludge handling and disposal is considered an extra step by some. Metcalf and Eddy (26) in their diagram of sludge handling alternatives use only six major steps and leave heat drying out.

In a wastewater treatment plant heat drying can generally be thought of as a primary system for incineration. A good dewatering system should leave sludge dry enough to transport it to a landfill or to a field for land application. Incineration would however value greatly from a dryer influent sludge. With this dryer sludge an incinerator could operate close to a self sustaining point.

Heat drying has also been used in drying sludge for the production of fertilizer but this practice is quite limited.

The use of a heat drying system would have an advantage in drying activated sludge in that its performance is dependent on incoming moisture content and not on the quality of the sludge.

G. Reduction

The three main processes in reduction are incineration, wet air oxidation and pyrolysis. The goal of each of these systems is to reduce the sludge volume. Although each of these systems is important their value to treatment of waste activated sludge is hard to evaluate. Like the heat drying systems their performance is controlled more by the moisture content of the incoming sludge than by the type of sludge. In addition almost all plants have combined their primary and secondary sludges by this point in the sludge handling scheme. Although data is lacking for reduction of waste activated sludge, a short discussion on each of the processes is included because of their importance to sludge disposal.

PYROLYSIS

Pyrolysis or destructive distillation is used to decompose sludge by heating temperatures of 1000 to 2000^{o} F in the absence of air. The process yields three major products: gas, oil and char. The use of this system for sewage sludge is relatively new, but the process dates back to Biblical times. The Egyptians used the process to pyrolyze wood to make charcoal and acids used in embalming.

Folks et al (13) list the following advantages of using pyrolysis as a method of sludge disposal;

1. 90 percent reduction of waste volume
2. Elimination of odors
3. Inert, sterile residue
4. Production of char and oil as a fuel source
5. Potentially self-sustaining

At the present time no full size systems are in operation that use sewage sludge so it is impossible to evaluate the value of pyrolysis. It would have a major advantage over incineration if the expensive air pollution equipment could be removed. At present there seems to be some question about whether this could be done. At this time pyrolysis can not be considered for sludge disposal in the majority of sewage treatment plants. It may in the future play an important part in the sludge handling system.

WET AIR OXIDATION

The wet air oxidation process oxidizes sludge in the presence of liquid water at temperatures between 250 and 700^{o} F. (31) The actual oxidation achieved is a function of the temperature, pressure, reaction time and air supply. Although the process does not approach the oxidation achieved in an incineration system, it does produce a sludge with optimum dewaterability characteristics.

In the actual process the wet sludge is mixed with compressed air and fed into a heat exchanger and then into the reactor. With some sludges and a high level of oxidation, the process can be self-sustaining. Pressure in the reactor ranges between 1000 and 3000 psi. The gases from the system are released by means of a pressure relief valve. They then go to a catalytic gas purifier for odor control. A complete wet air oxidation system is shown in Figure 11.

Maintenance is one of the major problems with the system. About every 30 to 60 days the system must be shut down and the heat exchangers cleaned with acid or caustic. In addition the pumps and compressors must be maintained and once a year the reactor must be cleaned.

Two other less mentioned problems with the system are the odor problems and the return liquors. Odors can be contolled, but this adds to the cost. The return liquors are handled by returning them to the front of the plant. In some cases this cost is omitted in a cost analysis of sludge handling systems, but it is a very real cost in the total plant design.

Although wet air oxidation is a possible alternative for waste activated sludge, its use in most plants is not practical. It has both a high first cost and a high operation and maintenance cost. The cost per ton for treatment will decrease as the plant size increases, but in most cases it is still difficult to prove the system cost effective.

Incineration

The incineration process operates in two steps. The sludge is first dried and then combustion takes place. If sludge can be fed at 50 percent solids or higher, the system will be self-sustaining except for supplemental fuel required for warm-up and heat control. (26) The principal system used for sludge incineration is the multiple hearth, but the flash drying system and the fludized bed are also used on a limited basis.

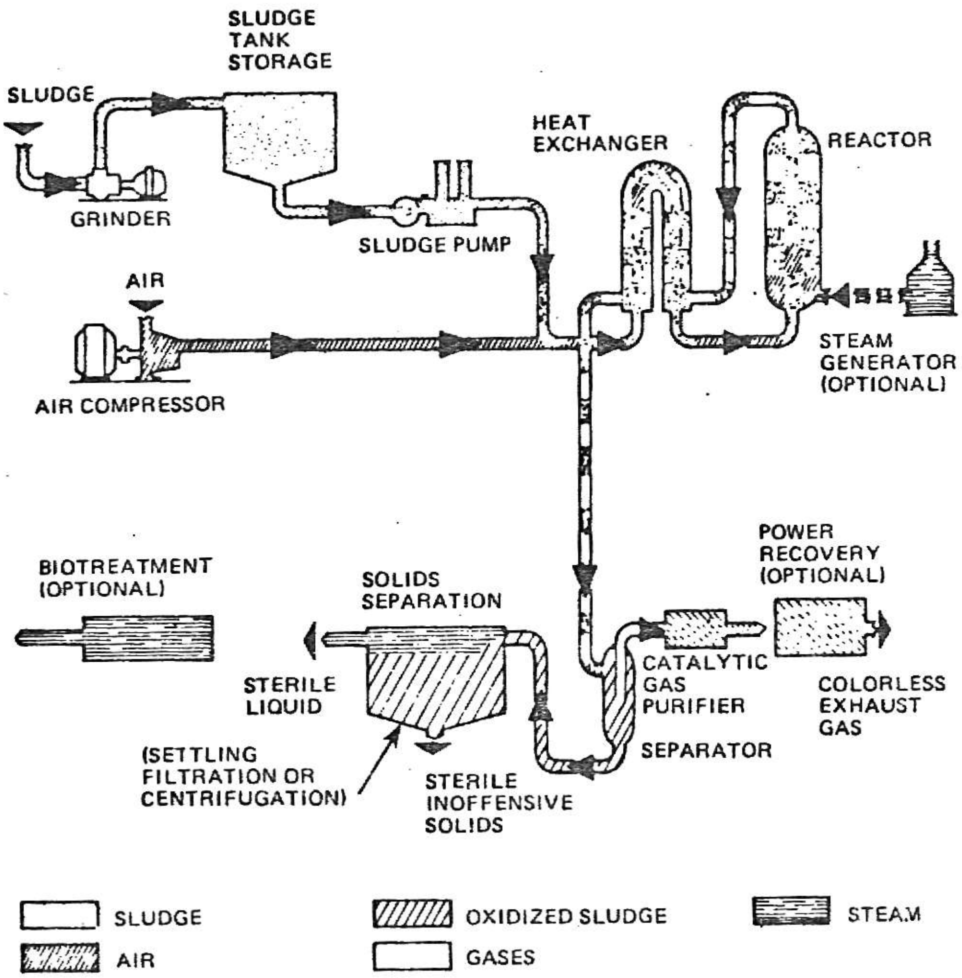

Figure 11. Wet Air Oxidation System (31)

The multiple hearth incinerator is simply a series of hearths in the vertical direction. The sludge is fed in the top and is carried down through each hearth where it is first dried and then combusted. Its extensive use in sludge is because of its flexibility both in the type of solids it will handle and the required feed rate. A multiple hearth incinerator is shown in Figure 12.

In a fluidized bed incinerator dewatered sludge is fed in above a sand bed. Upward air flows of 3.5 to 5.0 psig then fluidizes the bed. The sludge is dried by both evaporation and combustion.

Flash drying of sludges is basically an instantaneous drying of sludge by a hot gas stream. The influent sludge is first mixed with previously dried sludge and mechanically agitated with hot gas. This dries the sludge to a moisture content of 8 to 10 percent. The combustion then takes place in a combustion chamber. The dried sludge is fed in along with a high velocity air which helps cause complete combustion.

Each one of the systems is much more involved than the simple description given here. They must have trained personnel both to maintain and operate them. This along with the fact that they must have a large supply of sludge to make them cost effective limits the possible applications in the Midwest.

H. Final Disposal

In the longrange scope final disposal of sludge is the most important step in the entire system. If water quality in the country is to be maintained or improved, sludge must be kept out of the water. Ocean disposal, even if it were found to be safe, is not a feasible alternative in the Midwest. This leaves only the land as a final disposal point with the alternative of either burial in a landfill or mixing with topsoil on either cropland or in a land reclamation system.

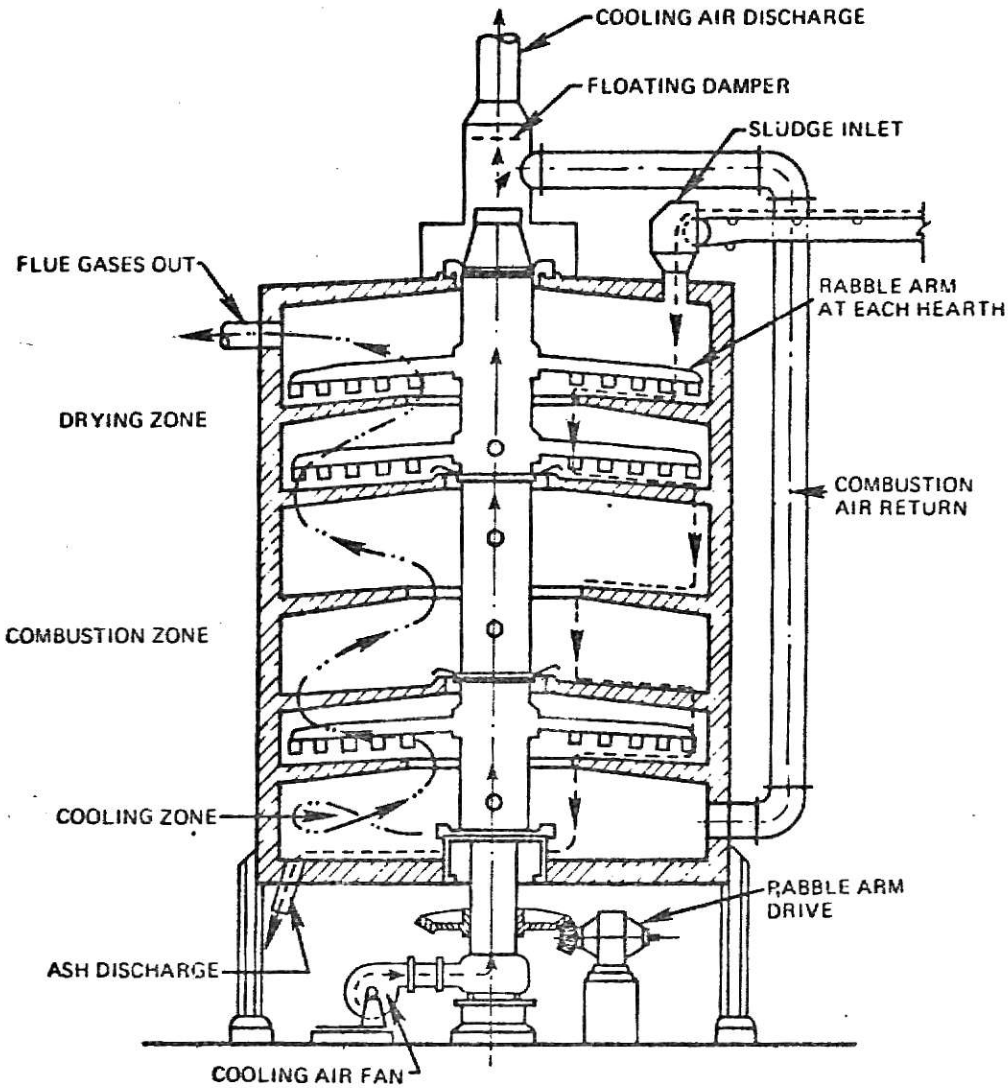

Figure 12. Multiple Hearth Incinerator (31)

The EPA includes power generation as a final disposal. This would better fit in the reduction system with incineration. Although the sludge would be mixed with another fuel such as solid waste, there will always be some ash left for disposal. Power generation is not discussed in this report because it entails the use of many wastes besides that of sludge and especially waste activated sludge.

Sanitary Landfill

A sanitary landfill can be used for final disposal of sludge in the same way solid waste is landfilled. This is handled in several different ways. Dewatered sludge can be landfilled by itself or mixed with municipal refuse. Incinerator ash can be handled in the same manner.

Landfilling has been popular for disposal of secondary sludge in the past because it was felt no prior stabilization was required. (26) This made landfilling very cost effective in most plants. It is now generally accepted that sludge must be stabilized prior to final disposal.

In the design of a land fill the most important consideration must be surface water infiltration and leachate from the fill. Odors have been problems only in fills that lack sufficient soil cover.

If landfilling is chosen for final disposal, the distance from the plant to the fill and the space available in the fill can often play a very important role in the dewatering process. When the capacity of the fill is limited or there is a long haul distance involved, it is often cost effective to use a more expensive method to produce a dryer sludge.

Cropland and Land Reclamation

The final disposal of sludge on cropland or for land reclamation has been combined in this section because both systems are operated basically the same. The State of

Kansas as well as other governmental agencies now requires that sludge be covered when applied to the land. In the past the cover method was generally practiced on cropland, but land reclamation systems tended to use spray gun nozzles to apply sludge on the land without cover.

The Metropolitan Sanitary District of Greater Chicago is now operating the world's largest project to dispose of sludge on the land. The project is advertised as a strip mine reclamation project, but it is basically a farming operation. A portion of the land being farmed has been regraded to near level ground after having been left rough from a mining operation. Sludge is applied to land by means of a spray gun nozzle. (2)

The Chicago system uses waste activated sludge combined with a small percentage of primary sludge in their application system. The sludge is digested in high rate anerobic digesters and loaded onto barges for the 200 mile trip down the Illinois River to Fulton County where the farming operation is carried out. At Fulton County the sludge is pumped into holding basins and finally applied to the land. Drainage is controlled in each field by a berm that diverts the runoff into holding basins. (34) The runoff can then be tested and released to the stream or held and pumped onto the land.

Land application such as that in Fulton County has aroused several questions. Among them are the handling of odors, eliminating water pollution in both surface and groundwater and the build-up of heavy metals. The first two problems have not been solved to an acceptable point. Subsurface injection instead of spray application has eliminated a major portion of the odor problem. Extensive studies have been done at several sludge application sites to determine the extent of the water pollution. One of these was the Fulton County sites. Zenz et al. (34) monitored both surface water and ground water in the area. They concluded that there was no evidence of contamination in either the groundwater or the major stream. The annual sludge loading rates during their three year study are listed below:

1972	2.3 to 5.8	dry tons/acre/yr
1973	0.5 to 1.9	dry tons/acre/yr
1974	17.7	dry tons/acre/yr

Studies on groundwater pollution from a sludge application system are also under way at Boulder, Colorado. They are now experimenting with much higher application rates. Preliminary data from the study is not published yet but indications are that there is no problem.

The problem of heavy metal buildups has not been solved. If a sludge is low in metals, nitrogen is generally considered to be the controlling factor in determining the application rate. As the metal content increases it reaches a concentration that should be considered a limit: (27)

Zn	5000 ppm
Cu	1000 ppm
Ni	500 ppm
Cd	50 ppm

The maximum amount of total metals that can be applied to agricultural land varies with the author. Table II gives the total allowable load as suggested by Sommers and Nelson. (30)

TABLE II - Total Amount of Sludge Metals Allowed on Agricultural Land. (30)

Metal	Soil Cation Exchange Capacity (meg/100 g)*		
	0 - 5	5 - 15	15
	Maximum Amount of Metal (Lb./Acre)		
Pb	500	1000	2000
Zn	250	500	1000
Cu	125	250	500
Ni	50	100	200
Cd	5	10	20

*Determined by the pH 7 ammonium acetate procedure.

In addition a soil pH 6.5 must be maintained to limit the plant uptake of the metals.

The total amount of sludge that can be applied to the land even though it has a very low metal content is also in a state of flux. Some authors believe that no more nitrogen should be applied each year than can be assimilated by the plant growth on the land. Sommers and Nelson (30) state that because of the losses from such things as denitrification and ammonia volatilization, as much as 50% more nitrogen than the plant requirement can be added with little environmental risk. With this criteria the sludge load will generally be under 10 tons/acre. The State of Kansas in their preliminary standard for sludge disposal set a maximum of 20 tons/acre for well drained soil. Manson and Merritt (24) concluded after a survey of land application systems that although much of the literature indicated a conservative limit of 20 tons/acre, experience indicated that for long term systems, 10 tons/acre should be the limit.

Although land application of sludge does present some problems, it offers a very workable solution for final sludge disposal. It is especially valuable in the Midwest where treatment plants are relatively small and land is generally available. The literature points to three items that must be controlled to make the system workable. These are controlling drainage, controlling odor and limiting the sludge loading. When these factors are successfully controlled, land application is not only a cost effective system, it is also valuable to the land.

CONCLUSION

A. Trends

Although the present trend of treatment of waste activated sludge is difficult to assess without extensive data, some trends can definitely be seen. In small to medium sized plants, treatment is leaning towards air flotation, aerobic digestion, vacuum filtration and landfilling. The EPA is now requiring land application to be evaluated in each cost effective study. This is causing many engineers to study the process more closely and in turn is increasing the number of applications. In the Midwest where land is readily available, land application systems are increasing rapidly and could possibly become the chief method of dewatering and disposal.

Larger treatment plants on the other hand are moving more towards incineration. The lack of usable land and the long haul distances are greatly increasing the value of incineration. Chicago is one exception to this. Although this land application system appears to be working satisfactorily, some of the literature is pessimistic about the system over an extended period of time. They feel that the increased loading, the increased value of land and an eventual overloading of the soil will catch up with the system in the future.

B. Future

In studying the different sludge handling processes and flow schemes it becomes evident that no one method is universally applicable. A number of systems are being used in various sequences. This leaves the design engineer somewhat baffled as to which direction to turn.

In the past several years engineers have moved towards the most positive methods of sludge handling. This in almost all cases meant a system with a greater power requirement. The power acts as the driving force in the system and serves to stabilize the system and control the performance. The future of these high energy systems is questionable. It seems that the practice of using great amounts of energy for sludge disposal when low energy alternatives are available will be abandoned.

The most promising low energy disposal alternatives are those which have been avoided in the past. One alternative is gravity thickening. This has been avoided in the past because of occasionally settling and odor problems. One solution to this might be chemical addition during the problem times. Another possible solution is anaerobic digestion. As stated in the literature review, problems have arisen with the supernatant being of poor quality. This problem could be solved by land application of the supernatant.

Most design engineers have labeled sand drying beds as a thing of the past, but they could also solve problems for small to medium sized plants. If they are to be of any great value they must be designed to be cleaned with a loader. At least two solutions are available for reducing the large area required for the beds. One is the use of polymers to improve dewatering. The other is the use of covered drying beds heated by solar energy to reduce the problems of winter drying.

Another alternative that has been utilized is incineration of a sludge-refuse mixture either for disposal only or to generate power for plant operations.

The direction of future sludge handling operations is hard to predict, but there will be two major needs: continued improvement in performance and reduction in power requirements.

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PROCESSING AND DISPOSAL OF WASTE ACTIVATED SLUDGE

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An Abstract of

A MASTER'S REPORT

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This report is a literature review of the systems used for the processing and disposal of waste activated sludge. It follows through the seven steps as outlined by the United States Environmental Protection Agency. These seven steps are thickening, stabilization, conditioning, dewatering, heat drying, reduction and final disposal. The available systems for sludge handling in each step are reviewed. In each process the problems of treating waste activated sludge with that particular system are discussed. In addition loading rates, chemical requirements and chemical costs are discussed where applicable.

The advantages and limitations of each system are reviewed to determine what methods are producing acceptable results. These results such as solids content, return concentrations and degree of stabilization will then control to a certain degree the steps that must be followed in a sludge handling and disposal system. The steps or combination of steps that can be used are also discussed.

The paper points to the fact that the present trend is to systems that require more and more power. These systems will produce a better sludge in most cases without a large variation in performance. The paper points to the fact that power requirements must be studied more closely and more work should be done in alternate systems that use less power but can produce acceptable results.