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Chapter 50 - Wastewater

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58.5 - Conditioning

Conditioning is herein defined as the pretreatment of sludge to facilitate water removal by a thickening or dewatering process. The following table shows the usual conditioning methods, the unit processes they are employed with, and the purposes they serve.

CONDITIONING METHODS AND PURPOSES 6

CONDITIONING METHOD	UNIT PROCESS	FUNCTION
Polymer Addition	Thickening	Improve loading rate, degree of concentration, and solids capture.
Polymer Addition	Dewatering	Improve production rate, cake solids content, and solids capture.
Inorganic Chemical	Dewatering	Improve production rate, cake solids content, and solids capture.
Elutriation	Dewatering	Decrease acidic chemical conditioner demand and increase degree of concentration.
Heat Treatment	Dewatering	Eliminate or decrease chemical use improve production rate, cake solids content, and stabilization. Some conversion may also occur.
Ash Addition	Dewatering	Provide improved cake release from belt type vacuum filters and facilitate filter pressing. It can also result in higher filter yields and reduce chemical requirements.

It should be noted that the first three methods involve addition of chemicals to coagulate and/or flocculate the sludge to accomplish the functions listed. The methods do not otherwise materially change the nature of the sludges. The inorganic chemicals, however, can change the solution pH, increase the inorgainic fraction of sludge, and also affect stabilization. Ferric chloride addition with or without lime has been the principal method for conditioning sludges prior to dewatering. In the past 10 to 15 years, however, polymer conditioning before dewatering has become widespread. The metal salts are generally only used now where ploymers have not yet been demonstrated as economically effective or on sludges where ploymers will not work. Polymers are also widely used for flotation and centrifugal thickening and they are occasionally used in gravity thickening.

Elutriation was originally developed to decrease the alkalinity of anaerobically digested sludges which reduced the demand for acidic metal salts. It is not now as widely practiced as in previous years, although

elutriation basins are still employed in many plants for postanaerobic digestion thickening. Elutriation, depending upon the particular system's design and operation and the type of sludge being treated can result in fractionation of the sludge by particle size and density. This fractionation can result in a serious recirculation side-stream effect.

Heat treatment facilitates dewatering. At the same time it solubilizes a portion of the treated sludge. Depending on the type of sludge treated and the kind of system employed for treatment, this solubilization of sludge may create a cooking liquor recirculation stream which requires a separate treatment system. This is particularly true of process sludges which contain a high percentage of activated sludge. Naturally, treatment of this recirculation stream will generate additional sludge to be handled. Heat treatment also kills pathogenic organisms. Heat treatment is common in Europe and a number of these systems are currently being designed into a number of U.S. plants.

58.51 - Considerations in Selecting a Conditioning Method

In the past few years, the impact of sludge processing systems on total wastewater plant capital and operation costs have been considered more thoroughly. Sludge thickening and dewatering can materially affect the preceding and succeeding unit processes. The conditioning method chosen normally has a significant effect on the efficiency of the thickening and/or dewatering operation. It should also be realized that the method of conditioning can have a pronounced effect on the liquid treatment portion of the plant due to the BOD and suspended solids in the recirculated supernatant stream. It is of utmost importance that the effects of recirculated supernatant, decant and centrate be considered in depth during design of the secondary treatment processes.

Each of the various sludge conditioning methods functions in a different way and causes diverse chemical and physical effects. Conditioning by either organic or inorganic chemical addition, elutriation, and heat treatment are further discussed in EPA's "Process Design Manual For Sludge Treatment and Disposal."

58.52 - Physical Factors in Conditioning Processes

Plant experiences have shown that the conditioning requirements and hence the performance achieved in thickening and dewatering processes are affected by the manner in which sludge is treated.

Any operation which tends to irreversibly disaggregate, hydrate, or subject sludge to high shear conditions is deleterious to solid-liquid separation procedures. One striking example of this tendency is the effect noted when pumping sludges through pipelines from satellite plants to a central dewatering location. It has been demonstrated that sludge is easily and economically dewaterable prior to piping, while the sludge exiting from the pipeline is not easily dewaterable.

58.53 - Conditioning for Gravity Thickening

Primary sludges and mixtures of primary an trickling filter sludges normally repond to gravity thickening without conditioning. However, mixtures of primary sludge and EAS can present problems for gravity thickening. Flocculants are required to ensure good solids capture and loading rate, and even a high underflow solids concentration is difficult to obtain. It is generally preferable to use dissolved air flotation to thicken excess activated sludge separately. When flocculants are used to condition sludge for gravity thickening, the flocculant solution should be added to either the sludge or the dilution water on its way into the thickener.

58.54 - Conditioning for Flotation Thickening

Chemicals can assist flotation by increasing the solids loading rate, float cake solids concentration, and solids capture. Flotation units normally achieve loading rates of 48 to 96 lb/day/sq ft. with 1 to 5 lb/ton of a chemical and resultant cake solids concentration of 4 to 6 percent solids.

58.55 - Conditioning for Dewatering

An important operating variable in dewatering is the conditioning chemical and dosage. Optimum performance of the dewatering equipment hinges on a determination of the most economical and effective conditioning method. Conditioning for improved dewatering by vacuum filtration, centrifugation, drying beds, and pressure filtration is discussed in the following paragraphs.

58.55a - Drying Beds

Use of conditioning procedures with sludge drying beds is not widespread; however, elutriation and polymers are employed in isolated cases. Additional information is available in the EPA "Process Design Manual For Sludge Treatment and Disposal."

58.55b - Centrifuges

Polymeric flocculants are normally used for sludge conditioning in centrifuges. The metal salts are generally not used because of corrosion problems. Principal performance parameters for gauging effectiveness of conditioners are production rate, cake solids content, and centrate solids content. The point of polymer injection must be selected carefully to avoid exposing flocculated material to high shear. Recently, improved flocculation has permitted centrifuges to perform well at low rotational speeds. This reduces conditioning chemical requirements and maintenance due to wear. Optimum conditioning can best be determined in pilot tests.

58.55c - Rotary Vacuum Filtration

Items of primary concern in conditioning sludge for feed to a rotary vacuum filter include:

Cake pickup on the drum.
Production rate
Cake solids content.
Cake discharge from filter media.
Filtrate quality (solids capture)

The determination of optimum conditioning procedures hinges on trial and error plant testing. However, plant scale testing is often preceded by laboratory and pilot scale testing to narrow down the selection of conditioning systems and levels of operation.

58.55d - Filter Presses

Filter aids, such as ash and inorganic conditioners, are used in dewatering operations with filter presses. Presses depend on the exertion of massive pressure (200 psi) to squeeze water out of sludge. Consequently, conditioning problems are more difficult than with other methods and laboratory and/or pilot plant evaluation is needed. These high pressures tend to destroy the flocculation achieved with normal conditioning. Accordingly, relatively large doses of lime or recycled ash (1.0 to 1.5 parts ash/part dry solids), with or without metal salts, are used.

58.6 - Dewatering

The methods used to remove sufficient water from liquid sludges so as to change the physical form to that of a damp solid are best described in terms of the particular type of dewatering device used. The commonly used devices include:

Drying beds
Lagoons
Centrifuges
Rotary vacuum filters
Filter presses
Horizontal belt filters

The relationship of the various dewatering methods to those processes which immediately precede and follow them are summarized in the following tabulation:

THE RELATIONSHIP OF DEWATERING TO OTHER SLUDGE
TREATMENT PROCESSES FOR TYPICAL MUNICIPAL SLUDGE

SEE PAPER COPY FOR ILLUSTRATION

An ideal dewatering operation would capture practically all the solids in the dewatered cake at minimum cost. The resultant cake would have the physical handling characteristics and moisture content optimal for subsequent

processing. Process reliability, ease of operation, and compatibility with the plant environment would also be optimum.

The technology and design of all available dewatering methods is constantly under development, particularly in the past 5 years. Each type, therefore, should be given careful consideration. The applicability of a given method should be determined on a case-
by-case basis with the specifics of any given situation being carefully evaluated, preferably in pilot tests.

58.61 - Drying Beds

The most widely used dewatering method in the United States is drying of the sludge on open or covered sandbeds. Sandbeds posses the advantage of needing little operator attention and skill. Air drying is normally restricted to well digested sludge, because raw sludge is odorous, attracts insects, and does not dry satisfactorily when applied at reasonable depths. Oil and grease discharged with raw sludge clog sandbed pores and thereby seriously retard drainage. The design and use of drying beds are affected by many parameters. They include weather conditions, sludge characteristics, land values and proximity of residences, and use of sludge conditioning aids. Climatic conditions are most important. Factors such as the amount and rate of precipitation, precentage of sunshine, air temperature, relative humidity, and wind velocity determine the effectiveness of air drying.

The nature and moisture content of the sludge discharged to drying beds influenes the drying process. Sludges containing grit dry rapidly; those containing grease more slowly; aged sludge dries slower than new sludge; primary sludge dries faster than secondary sludge; an digested sludge dries faster than fresh sludge and cracks earlier. It is important that wastewater sludge be well digested for optimum drying. In well digested sludge, entrained gases tend to float the sludge solids and leave a layer of relatively clear liquid, which can readily drain through the sand.

Design standards and performance data are contained in EPA publications and textbooks.

58.62 - Drying Lagoons

Lagoon drying is a low cost, simple system for sludge dewatering that has been commonly used in the United States. Drying lagoons are similar to sandbeds in that the sludge is periodically removed and the lagoon refilled. Lagoons have seldom been used where the sludge is never removed, because such systems are limited in application to areas where large quantities of cheap land are available. Sludge is stabilized to reduce odor problems prior to dewatering in a drying lagoon. Odor problems with lagoons can be greater than with sandbeds, because sludge in a lagoons retains more water for a longer period than does sludge on a conventional sand drying bed.

Other factors affecting design include consideration of groundwater protection and access control. Major design factors include climate, subsoil permeability, lagoon depth, loading rates, and sludge characteristics. The design should provide for uniform distribution of the sludge and for decanting of supernatant to speed the drying process.

58.63 - Centrifugal Dewatering

Centrifuges of various types have been employed for solid-liquid separation processes in agriculture and industry for at least 50 years.

The successful adaption of centrifugal devices to the dewatering of sludges that contain a significant quantity of activated sludge is becoming common. Design improvements are increasingly aimed at obtaining a minimum of 90 percent solids capture with little chemical conditioning. The advent of the concurrent flow and the lower speed machines should materially aid the successful adaption of solid bowl centrifuges. Plant designs should be based upon scale-up of pilot tests whenever possible, and several manufacturers will provide assistance in scaling up the pilot test data. In addition to dewatering functions, solid bowl, basket, or disc centrifuges can also provide classification of organic or chemical sluges. Research has shown that low speed centrifuges (g forces of 500+) produce the same quality sludge an centrates as the high speed centrifuges (1,000 + g forces). However, the low speed units are more economical because of savings in power, conditioner, and wear. Additional information may be obtained from Sludge Treatment and Disposal and from manufacturers.

58.64 - Rotary Vacuum Filtration

Rotary vacuum filtration can be and is, in most cases, an effective and efficient dewatering method. It has been misapplied in some cases in the past. Improper selection of media, failure to thicken the feed sludge conditioning have generally been the cause of failures. In some cases, plant systems have not been designed with the proper sequence of unit processes. This makes efficient dewatering very difficult.

Comprehension of the theoretical aspects of rotary vacuum filtration of wastewater sludges, plus practical application of the theory through the medium of lab, pilot, and full-scale plant test procedures, is essential in evaluating systems. An in-depth review of the theory is presented in various literature.

58.65 - Pressure Filtration

The plate and frame filter press is a batch device, which has been used in industry and in European wastewater plants for many years to process difficult-to-dewater sludges. The press consists of vertical plates which are held rigidly in a frame and which are pressed together between a fixed and moving end as illustrated in exhibit 1. On the face of each individual plate is mounted a filter cloth as shown in exhibit 2. The sludge is fed into the press and passes through feed holes in the trays along the length of the press. The water passes through the cloth, while the solids are retained and form a cake on the surface of the cloth. Sludge feeding is stopped when the cavities or chambers between the trays are completely filled. Drainage ports are provided at the bottom of each press chamber. The filtrate is collected in these, taken to the end of the press, and discharged to a common drain. At the commencement of a processing cycle, the drainage from a large press can be in the order of 2,000 to 3,000 gallons per hour. This rate falls rapidly to about 500 gallons per hour as the cake begins formation and when the cake completely fills the chamber, the rate is virtually nothing. The dewatering step is completed when the filtrate is near zero. At this

point the pump feeding sludge to the press is stopped and any back pressure in the piping is released through a bypass valve. The electrical closing gear is then operated to open the press. The individual plates are next moved in turn over the gap between the plates and the moving end. This allows the filter cakes to fall out. The plate moving step can be either manual or automatic. When all the plates have been moved and the cakes released, the complete pack of plates is then pushed back by the moving end and closed by the electrical closing gear. The valve to the press is then opened, the sludge feed pump started, and the next dewatering cycle commences.

58.66 - Horizontal Belt Filter

Belt pressure filters were originally developed in Europe where they are widely used. They have been available in the U.S. since 1971.

The belt filter press has three processing zones along the length of the unit. They are the initial draining zone, which is analogous to the action of a drying bed; the press zone, which involves application of pressure, and a shear zone in which shear is applied to the partially dewatered cake.

A significant feature of the belt filter press is that it employs a coarse, mesh, relatively open weave, metal medium fabric. This is feasible because of the rapid and complete cake formation obtainable when proper flocculation is achieved. Solids concentrations from 20 to 30 percent may be expected.

58.67 - Other Dewatering Systems

Several types of dewatering devices which do not fall into the categories previously discussed are available and in use. These devices include:

Moving screen concentrators
Capillary dewatering systems
Rotating gravity concentrators

Further information on these devices is available from the manufactures and from the EPA "Process Design Manual For Sludge Treatment and Disposal."

58.7 - Reduction

Sludge reduction processes are generally thermal ones an provide a major reduction in the sludge solids. Although composting and heat drying are not truly reduction processes, they occupy the same relative position in the sequence of sludge processing as major reduction processes. They are included in this section for purposes of simplification. Established and experimental sludge reduction processes are listed and categorized in the following tabulation.

REDUCTION PROCESS

Reduction Process	Pretreatment Required	Additional Processing Requirements
ESTABLISHED PROCESSES		
Incineration	Thickening and Dewatering	Landfill ash
Wet air oxidation	Thickening	Treat cooking liquor Landfill ash
*-Heat Drying	Thickening and Dewatering	Use dried sludge as soil conditioner
Composting	Thickening and Dewatering	Use dried sludge as soil conditioner
EXPERIMENTAL PROCESSES		
Pyrolysis	Thickening	Utilize by-products of gas, carbon, steam. Dispose of residue.
Incineration/ Power or steam generation	Thickening and Dewatering	Landfill ash

Where sufficient land was available for proper disposal of liquid, or more frequently dewatered sludge cake, past practice at wastewater treatment plants has been to omit incineration or other reduction processes due to the cost. With decreasing land availability and the possibility of more stringent standards for land disposal, reduction processes have been receiving revived attention. This is also true of municipal solid waste disposal practices. The concurrent increase in the price of energy has sparked wide interest in the combined incineration of solid waste residues and wastewater sludges in reduction systems in incorporating energy recovery as a prime feature.

58.71 - Composting

Composting of wastewater sludge differs significantly from composting solid wastes. There are several advantages of composting sewage sludge compared to solid waste. The past poor publicity and problems associated with solid

waste composting need not discourage the use of composting as an alternative in the treatment and reuse of wastewater sludge.

Composting is defined as the aerobic thermophilic decomposition of organic solid wastes with relatively stable humus like material. The basic composting mechanisms are similar for any organic material and are described in more detail in several publications. Modern composting actually involves both mesophilic and thermophilic temperatures, and, since it is a biological process, is subject to the constraints of any biological system. Decomposition is accomplished by barious micro-organisms including bacteria, actinomycetes and fungi. The principal byproducts of this aerobic decomposition are carbon dioxide, water and heat.

Sludge compost is a natural organic product with high humus content similar to peat. It has a light musty odor, is moist, dark in color, can be bagged; the texture varies depending on the degree of screening. Compost increases the water holding capacity of sandy soils, improves the structure of heavy clay soils, and increases the air content of the soils. The organic matter in compost improves the workability of the soil and makes it easier for plant roots to penetrate. Compost contains small amounts of nitrogen, phosphorus and potash; therefore, its primary usefulness is as a soil amendment and not as a fertilizer.

The composting process may be physically achieved in basically three types of systems: (1) windrow, (2) aerated static pile, and (3) mechanical units of various designs which usually supply continuous mixing and positive aeration. The windrow and static pile methods have been used almost exclusively for composting sewage sludge in the United States.

1. Sequential Steps - Windrow and Static Piles. The basic steps in both the windrow and static pile composting systems are similar and are illustrated in the process flow diagram in exhibit 1. The sequential steps in the windrow and static pile methods are as follows:

a. Dewatered sludge is delivered to the site and usually mixed with a bulking agent. The purpose of the bulking agent is to decrease the moisture content of the mixture, increase porosity of the sludge and assure aerobic conditions during composting. Various bulking agents can be used, including wood chips, bark chips, leaves, papers, etc. Unscreened finished compost has also been used. Generally, one part sludge is mixed with two to three parts bulking agent.

b. Piles are constructed by placing the sludge-bulking agent mixture in windrows or static piles.

c. Piles are aerated for 21 to 30 days by mechanically turing (windrow method) or by forced aeration (static pile method). Oxygen levels are maintained in the range of 5 to 15 percent of gas volume to assure aerobic conditions. Temperatures in all parts of the pile should be maintained at 60 C or above for at least 48 consecutive hours.

d. Piles are dismantled and the sludge-bulking agent mixture moved to a curing area for an additional 30 days. Curing provides time for additional stabilization and drying. The curing piles are not mechanically aerated.

e. The sludge-bulking agent mixture (compost) is screened to recover and reuse the bulking agent. It may be possible to screen the mixture before curing if it has dried sufficiently to permit screening and to prevent the development of anaerobic conditions. About 70 to 75 percent of the wood and bark bulking agents have been recovered in composting operations. Finished compost is then used or stored.

Exhibit 1

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                              SLUDGE
                    ____________|________________
                   |                             |
                   |            MIXING           |
                   |                             |
     MAKEUP        |                             |
     BULKING       |                             |
                   |                             |
_________________\|  2-3 parts bulking agent    |/____________
     AGENT        /|      to 1 part sludge       |\            |
                   |_____________________________|             |
                                |                              |
                    ____________V________________              |
                   |        COMPOSTING           |             |
                   |                             |             |
                   |                             |             |
                   |        aeroted pile         |             |
                   |          21 days            |             |
                   |_____________________________|             |
                                |                              |
                          ______V______                        |
                         |   DRYING    |                       |
                         |_____________|                       |
                                |                              |
                         ______ V_______                       |
                        |  SCREENING   |____________________   |
                        |______________|                RECYCLE
                                |                   BULKING AGENT
                                |
                       _________V_________
                      | CURING/STORAGE   |
                      |    30 days       |
                      |__________________|
                                |
                                |
                                V
                         PRODUCT COMPOST

                            60% solids
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Aerobic composting

2. Fundamentals of Composting. The fundamentals of composting are summarized as:

a. Obtaining thermophilic temperatures requires no input of external energy when the composting mass is sufficiently insulated and favorable environmental conditions are maintained for the biological organisms.

b. No inoculation with external microbial culture is necessary either before, during, or after the composting process.

c. The relationship between environmental factors and the course of the process are characteristic of any biological process.

The minimum moisture content at which bacterial activity takes place is from 12 to 15 percent. The moisture content of composting material should be maintained in the range of 45 to 50 percent. Most sludge composting experience has been with sludge solids concentrations of 10 to 35 percent. The single most important variable in determining the successful composting of sludge is the solids content produced during dewatering.

Modern composting processes are designed to operate within the mesophilic and thermophilic ranges. The range of optimum temperatures for the composting process as a whole is quite broad, probably from about 36 C to 65 C. The temperature of a reasonably large composting mass will gradually rise to within the thermophilic range due to an excess energy from microbial activity. This increase will inevitably take place unless positive measures are taken to dissipate the heat or improper composting procedures are used.

Sludge composting should reach thermophilic temperatures for a significant period of time for several reasons (1) the optimum temperature for some of the organisms involved in the composting process is within the thermophilic range, (2) most pathogenic organisms and weed seeds cannot survive long exposure to thermophilic temperature, and (3) a composting mass will reach thermophilic temperature unless definite countermeasures are taken to dissipate heat.

In practical operations little can be or needs to be done to alter the pH in a composting mass.

One of the most important nutrient requirements in composting is the carbon-nitrogen balance or ratio (C/N ratio). Part of the carbon is lost as CO_2 and carbon is present in the cellular material in greater concentration than is nitrogen; therefore, the amount of carbon required is considerably greater than nitrogen. The optimum C/N ratio for most wastes falls within the 20 to 25 parts carbon to 1 part nitrogen range.

The more the carbon-nitrogen balance deviates from the optimum, especially in the upper range, the slower the process proceeds. However, the actual upper limit for an individual application depends upon the degree of availability of the carbon. The principal deleterious effect of too low a C/N ratio is the loss of nitrogen through the production of ammonia and its subsequent volitilization. Apparently, any excess nitrogen ends up as ammonia. As far as the composting process itself is concerned, excess nitrogen is not

detrimental. Nutrient concentrations and balances in most sludges are adequate and not limiting to the composting process.

Optimum oxygen levels in a composting mass are believed to be between about 5 and 15 percent. Some method must be employed to achieve these levels in any aerobic composting method. Since the composting process is aerobic, low oxygen levels will slow down the process and may precipitate anaerobic conditions in some parts of the composting mass. Excessively high oxygen concentrations increase aeration expense and may reduce temperature.

The windrow process is conducted in uncovered areas and relies on natural ventilation plus periodic turning to maintain aerobic conditions. The sludge bulking agent mixture is spread in windrows with a triangular cross section normally 6 to 15 feet (1.8 to 4.6 m) wide and 3 to 5 feet (0.9 to 1.5 m) high. An alternative method to mixing the bulking agent and sludge before forming the windrow is placing the bulking agent as a base for the windrow. The sludge is then dumped on top of the bulking agent and spread. A composting machine (similar to a large rototiller) then mixes the sludge and bulking agent and forms the mixture into a windrow. Several turnings (about 8 to 10 times) are necessary to adequately blend the two materials.

The windrow is normally turned at least once per day, with a composting machine, for a 3-week period, or longer depending on the weather and efficiency of composting. During rainy periods, turning is suspended until the windrow surface layers dry.

Studies by the USDA at Beltsville, MD, determined that the windrow process can be used successfully for digested sludge, but is unsatisfactory for composting undigested primary and waste activate sludges because offensive odors were produced. Also, survival of coliforms and salmonella was extensive, with indications of regrowth as material in the center of the compost windrows was shifted to the exterior when the windrows were turned. The unsatisfactory performance of the windrow process for composting undigested sludges led to the development of the forced aeration, static pile method.

In the forced aeration static pile process, the pile remains fixed, as opposed to the constant turning of the windrow, and a forced ventilation system maintains aerobic conditions. The static pile system is illustrated in exhibit 2.

SEE PAPER COPY FOR EXHIBIT 2

Although sludge composting is shown to be viable method of stabilizing and reducing sludge, the basic processes are still in the development and demonstration phase.

58.72 - Incineration

An incinerator is usually part of a sludge treatment system which includes sludge thickening, a macerating or disintegrating system, a dewatering device, an incinerator feed system air pollution control devices, ash handling facilities, and the related automatic controls. Important considerations in evaluating incineration methods include the composition of

the sludge feed and the amount of auxiliary fuel required. Air pollution constraints and resultant equipment and treatment requirements as well ash disposal are also important.

Wastewater sludges have been incorrectly classified as low grade fuels. While the heating value of the dried sludge solids may be substantial, sludges cannot be considered as fuel because of the high moisture content for the raw sludge. Heat is emitted by the burning of sludge in a furnance. Some of this heat is absorbed by the furnance and lost by radiation. A large portion of the emitted heat is lost with the stack gases, while a small portion is lost with the ash. The difference between the heat generated and the heat lost is available for heating the incoming sludge and air. Self-sustained combustion is often possible with dewatered raw sludge once the burning of auxiliary fuel raises incinerator temperatures to the ignition point.

The multiple hearth furnace is the most widely used wastewater sludge incinerator in the United States today because it is simple, durable, and has the flexibility of burning a wide variety of materials even with fluctuations in the feed rate. Other systems which have been used include fluidized bed incineration, the cyclonic furnace and the electric furnace. Additional information on wastewater sludge incineration is available in the "Process Design Manual For Sludge Treatment and Disposal" and in "Sludge Treatment and Disposal."

58.73 - Pyrolysis

Like incineration, pyrolysis is a controlled combustion process. Unlike the term incineration, however, pyrolysis does not imply that a waste is being burned. The pyrolysis process has been used for years by industry - for example, production of charcoal and methanol from wood, and coal gasification. The process requires raising the fuel to a temperature at which the volatile matter will distill, leaving carbon and inert material behind. The carbon and volatile matter will burn in the process because the heating occurs in an atmosphere deficient in oxygen. Volatile matter may be burned off as waste in a secondary chamber to which air is added, or the off-gas may be cooled and condensed to recover oils and tars or cleaned and used as fuel. Like incineration, pyrolysis reduces the sludge volumes and sterilizes the end product. Unlie incineration, it offers the potential advantages of eliminating air pollution and producing useful by-products. Air pollution can be controlled because heating takes place in a closed system that allows the collection of gases for beneficial use as a fuel or controlled burning. Those systems ready for marketing are offered on a proprietary basis in which design, construction, and usually operation are offered on a turnkey basis. Cost data from full-scale operating systems are not yet available, and there is no basis on which to assess the reliability of these new plants. Available information, however, indicates that the developers of the new systems are willing to proceed at costs which are initially competitive with conventional incineration. Additional information on sludge pyrolysis is available in Sludge Treatment and Disposal.

58.74 - Starved Air Combustion

This process is frequently referred to as partial pyrolysis, an incorrect term. Starved air combustion can be defined as gasification of the combustible elements by heat in the present of controlled amounts of oxygen.

The process uses less than the stoichiometric combustion air requirements. The ash product contains combustible material and some fixed carbon which was not volatilized during combustion. The gas, also called fuel gas, from the reactor consists of various combustible gases, such as carbon monoxide, methane, ethylene, and some higher hydrocarbons, and appreciable quantities of carbon dioxide and water vapor. Small quantities of hydrogen, oxygen and nitrogen are sometimes present. The yield and composition of the combustion products are dependent upon several variables; the interrelationships of these are so complex that predicting the final product characteristic is a difficult task and is determined empirically. Starved air combustion is addressed futher in Sludge Treatment and Disposal.

58.75 - Heat Drying

This process is similar to incineration except the sludge is heated only long enough to drive off the water.

The flush drying method involves pulverizing the sludge in a cage mill or by an atomized suspension technique in the presence of hot gases. The equipment should be designed so that the particles remain in contact with the turbulent hot gases long enough to accomplish the mass transfer of moisture from sludge to the gases.

Rotary kiln dryers have also been used in several plants for the drying of sludge. Many different designs have been developed including direct-heating types in which the material being dried is in direct contact with the hot gases, indirect-heating types in which the hot gases are separated from the drying material by steel shells, and indirect-direct types in which the hottest gases surround a central shell containing the material but return through it at reduced temperatures. Coal, oil, gas, municipal refuse, or the dried sludge may be used as fuel. Plows or louvers may be installed for lifting and agitating the material as the drum revolves.

58.76 - Wet Air Oxidation

The wet air oxidation process is based on the principle that any substance capable of burning can be oxidized in the presence of liquid water at temperatures between 250 F and 700 F. The process can operate on difficult to dewater waste liquors and sludges where the solids are but a few percent of the water streams.

In general, given the proper temperature, pressure, reaction time, and sufficient compressed air or oxygen, and degree of oxidation desired can be accomplished. By operating at lower temperatures and pressures, the same approach may be used for sludge conditioning.

The wet air oxidation process has been commercialized and patented as the Zimpro process. This process has also been known as wet incineration, wet combustion, and wet oxidation processes. Wet air oxidation does not require preliminary dewatering or drying as required by conventional combustion processes. Water can be present up to 99 percent in this process, whereas in conventional combustion it must be reduced to much lower levels to make incineration practical.

Another significant difference is the flameless oxidation of the organics at low temperatures of 300 F and 400 F when compared to 1,500 F to 2,700 F in

the conventional combustion processes. Air pollution is minimized because the oxidation takes place in water at low temperatures and no flash, dust, sulfur dioxide, or nitrogen oxides are formed.

58.8 - Conveyance Systems

Transportation may be accomplished by tank truck, barge, rail or pipeline. Sludge characteristics, elevation differences, distance, sludge volume and land availability are important factors in selecting a method of transporting sludge from the treatment plant to the disposal site. Tank trucks afford flexibility in the selection of disposal sites, and they are widely used to haul and apply sludge. The ton to mile cost is relatively high, so small communities with available land near the treatment plant are most apt to find the use of tank trucks feasible. Pipelines usually entail relatively high capital and low operating costs, so assurance of the availability of land for a long period of time is an important consideration. Cost analysis should be used in selecting the mode of transportation.