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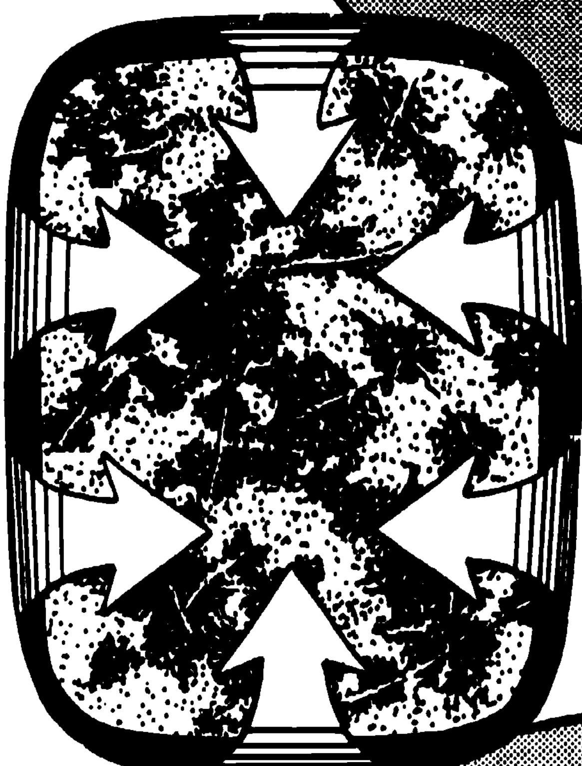
ABSTRACT

This student manual contains the textual material for a single-lesson unit which summarizes and reviews most of the solids handling processes in common use in municipal treatment plants. No attempt is made to detail the theory and operation of the processes. Topics discussed include: (1) sources of sludge; (2) the importance of sludge management; (3) volume reduction; (4) solids reduction; (5) stabilization; (6) conditioning; and (7) ultimate disposal. A list of unit objectives and student worksheet are included. (JN)

Biological Treatment Process Control

Review of Solids Handling



Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL TREATMENT PROCESS CONTROL

REVIEW OF SOLIDS HANDLING

STUDENT MANUAL

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REVIEW OF SOLIDS HANDLING

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REVIEW OF SOLIDS HANDLING

Objectives

Upon completion of this lesson you should be able to do the following:

1. Describe the types and sources of sludge from wastewater treatment plants.

2. Explain the importance of the sludge management program as it relates to the total treatment system.

3. Describe the purpose and goal of each of the following solids handling concepts: volume reduction, solids reduction, stabilization, conditioning, and ultimate disposal.

4. Briefly describe each of the following solids handling processes:

   Gravity Thickening
   Flotation Thickening
   Centrifugation
   Belt Filtration
   Vacuum Filtration
   Filter Presses
   Gravity Concentrators
   Drying Beds
   Aerobic Digestion
   Anaerobic Digestion
   Sludge Lagoons
   Composting
   Heat Conditioning
   Chemical Conditioning
   Lime Stabilization
   Chlorine Stabilization
   Incineration
   Land Application
   Landfill

5. For each of the solids handling processes listed in #4 above be able to indicate whether its main function is volume reduction, solids reduction, stabilization, or conditioning.

REVIEW OF SOLIDS HANDLING

Sources of Sludge

Wastewater contains material which, if allowed to enter a stream or river, would require more oxygen than the stream could provide. Treatment plants were designed to prevent this from occurring. Raw wastewater contains both solid and dissolved material that must be removed. Most biological treatment plants remove solids through primary sedimentation. However, the biological treatment process for removing the dissolved materials, as well as much of the solids, creates more solids by converting the raw wastewater materials (organics) to bacterial cell mass. Plants utilizing physical treatment processes also generate solids.

The removal of solids in the form of settleable sludge is an important part of every wastewater treatment plant's operation. Solids can be removed as raw sludge, biological sludge, or as chemical sludge.

Raw sludge is the material that settles out during primary clarification. Biological sludge is the settled biological cell mass that is produced in the biological treatment process as removed during secondary clarification. Chemical sludge is the result of chemical floc generated during chemical treatment processes and removed during secondary or tertiary clarification.

The Importance of Sludge Management

The sludge that enters and is generated in a treatment plant can amount to a sizable quantity. For an average biological treatment process, about 0.25 lbs of dried sludge must be disposed of for each person per day. For a community of 50,000, that means better than 6 tons per day must be dealt with. In order for the overall treatment process to function properly the accumulation of sludge must not become an operational bottleneck. Too many times the inability to handle and dispose of sludge puts undue pressure on the rest of the plant. Sludge management can easily become "the tail that wags the dog." A sludge management program that allows the operators to treat sludge and properly dispose of it must be considered a critical component of any treatment system.

Sludge Management

A sludge management program can be a combination of treatment processes, culminating in ultimate disposal in landfill, as soil conditioner on agriculture land or incineration. The various sludge treatment processes are designed to carry out one or more of the following: sludge volume reduction, sludge solids reduction, stabilization, and conditioning. The sludge treatment processes may be applied in various sequences in order to achieve the most efficient and effective treatment of the type of sludge involved.

The purpose of sludge volume reduction is to concentrate the sludge by separating some of the water from the sludge. After the sludge is concentrated, it can be further treated in less volume. This usually means less capital construction and less energy consumption. Water separated from the sludge is generally returned to the headwork of the treatment plant.

Several treatment processes result in a decrease in the amount of suspended sludge solids. A reduction in the amount of solids present will, of course, mean that a small amount must be disposed of in the end.

The primary purpose of stabilization is to make the sludge less odorous and putrescible and reduce pathogenic organism content.

Conditioning is defined as the pretreatment of sludge to enhance sludge volume reduction. Conditioning by both heat and chemicals can make the volume reduction processes more efficient.

Ultimately sludge must be disposed of in a permanent manner. Ultimate disposal alternatives include landfill, land application, and incineration.

Volume Reduction - "Gravity Thickening"

Gravity thickening is similar to sedimentation or clarification in that the sludge is allowed to settle under the influence of gravity in a tank. Gravity thickeners may be circular or rectangular. Both internally and externally gravity thickeners look very much like clarifiers. There is a sludge collection mechanism and an effluent weir. The amount of volume reduction that occurs depends on how well the solids/liquid separation process works. The relatively clear supernate liquid is piped back to the headworks for further treatment. The settled, thickened sludge is pumped to the next solids handling process, but now in a much smaller volume.

Volume Reduction - "Flotation Thickening"

Flotation thickening separates the sludge from water by bubbling air into sludge to decrease the sludge density. With the air bubbles trapped in the sludge, it floats to the surface where it is scraped off the surface. Relatively clear liquid is removed from one end of the basin over a protected weir. Flotation thickening basins can be rectangular or circular. Structurally they look somewhat like clarifiers except that the scum collector mechanism is more elaborate. The scum collector mechanism skims the floating, thickened sludge off the surface and into a hopper or pit. In addition, gravity thickeners have air piping to supply the diffused air to the sludge. The air is injected into the sludge as it enters the basin decreasing its density and helping it float to the surface. As with the gravity thickeners the clear liquid that is separated from the sludge is piped back to the headworks. The thickened sludge, called float, is greatly reduced in volume and is ready for subsequent solids handling processes.

Volume Reduction - "Centrifugation"

Centrifugation takes advantage of centrifugal force to separate sludge solids from the water. As the sludge is spun in the centrifuge, the solids are forced to the outside and the water removed near the center of the spinning bowl. Three basic designs are in common use. The basket and disc centrifuges spin on a vertical axis much like a washing machine and a cream separator, respectively. The third design, the solid bowl, spins on a horizontal axis. No matter which design is employed, the results are the same. Thickened sludge is recovered in a reduced volume for further treatment and the relatively clear liquid, the centrate, is returned to the headworks for another pass through the treatment plant.

Volume Reduction - "Belt Filtration"

Belt filtration separates sludge solids from the liquid by squeezing the sludge into cakes between porous mats. The liquid is squeezed out of the cakes as the mats pass between rollers. The mats pass through a series of rollers being pressed under more and more pressure. The filter cake falls onto a conveyor and is removed at a considerable volume reduction for further solids handling. The relatively clear liquid is caught in a large pan under the filter and returned to the headworks of the plant. Several different designs are in use. Most designs utilize two continuous porous belts between which the sludge pressed.

Volume Reduction - "Vacuum Filter"

The vacuum filter also uses a filter medium to separate the sludge solids from the liquid. In the vacuum filter, however, the sludge is pushed up against the filter medium by atmospheric pressure. The effective pressure is increased by creating a vacuum on the other side of the filter. Concentrated sludge accumulates on the filter and the liquid passes through. The porous filter media is wrapped around a large drum the inside of which is under vacuum. As the drum dips into the trough sludge is sucked up against the drum. As the drum turns the vacuum pulls more and more liquid from the sludge. Finally the relatively dry sludge is scrapped off the drum onto a conveyor belt and removed at a much reduced volume for further treatment. Again the relatively clear liquid is returned to the headworks of the plant.

Volume Reduction - "Filter Presses"

A filter press also uses a filter media as the name implies. However, the term "press" is a bit misleading. Actually, the process is more like filling a bag with conditioned sludge under pressure. As the pressure in the bag increases the clear liquid passes through the filter media and the thickened sludge accumulates on the inside. With the actual equipment it is difficult to visualize the bag concept. Actually, a series of bags are held side-by-side by the press as the sludge is pumped in. When maximum pressure is reached the press is opened up which allows the sludge cake to fall out the bottom. The cake contains much less water and is greatly reduced in volume. It is removed for further treatment. The relatively clear liquid, called pressate, is returned to the headworks.

Volume Reduction - "Gravity Concentration"

The gravity concentration process separates sludge solids from the liquid by tumbling the sludge in two rotating drums which are covered with a porous filter medium. The liquid passes through the medium, is collected under the concentrator and returned to the headworks. The thickened sludge solids fall out one end of the drum and are sent to subsequent solids handling processes at a much reduced volume.

Volume Reduction - "Drying Beds"

Dry beds separate sludge solids from the liquid by allowing the liquid to evaporate and drain away from the solids. Both covered and uncovered beds are in use. Sludge is applied in a relatively thin layer in the beds. Liquid drains out through the supporting sand under the bed as well as evaporates. The resulting sludge is fairly dry and can be removed mechanically for further processing. Dried sludge is often applied to land, landfilled or incinerated.

Solids Reduction - "Aerobic Digestion"

Along with anaerobic digestion aerobic digestion is one of the most common solids reduction processes. The goal of solids reduction is to reduce the quantity of solids in terms of dry weight, not simply separate the solids from the liquids. Solids reduction is accomplished in aerobic digestion by the aerobic biological stabilization of organic material. The aerobic digestion process is very similar to the activated sludge treatment process. Aerobic digestion basins can be rectangular as well as circular and can be aerated mechanically as well as with diffused air. The design and operation of aerobic digestion is presented in detail in another part of this material.

Solids Reduction - "Anaerobic Digestion"

Anaerobic digestion reduces sludge solids by anaerobically stabilizing the organic material in the sludge. Anaerobic digestion takes place in an enclosed tank so that anaerobic conditions can be maintained. Sludge is heated and mixed with the digester and the gas that is produced accumulates above the supernatant and scum layers. Piping is provided to allow continuous feed and withdrawal. Fixed roof and floating roof digesters are designed to continuously draw off gas. The gas holding roof design provides gas storage capacity. The gas that is produced can be used as fuel to heat the digester and plant buildings. In both aerobic and anaerobic digestion the stabilized sludge contains less solids by dry weight, and because the digesters can be decanted there is also a volume reduction. Concentrated sludge is withdrawn for further solids handling processes and the supernatants piped back to the headworks. The theory and operation of anaerobic digestion is discussed in detail in another section of this material.

Solids Reduction - "Sludge Lagoons"

Where adequate land area is available sludge lagoons are used to store and treat sludge. Although storage prior to other treatment processes is many times the primary objective, significant stabilization of organic material also occurs. Lagoons can be aerated or operated facultatively similar to stabilization ponds. Sludge can be fed to the lagoon continuously and the supernatant decanted back to the headworks of the plant. Sludge is withdrawn periodically (usually annually) and disposed of by land application, landfill, or incineration.

Solids Reduction - "Composting"

Composting is rapidly gaining popularity as a method of reducing solids content, reducing volume, stabilizing the organics and, at the same time, creating a soil supplementing material. In the composting process, some sort of relatively inert material is mixed with the sludge to allow air to reach all parts of the compost piles. The mixture is then formed into windrows which are turned periodically or into static piles where air is blown into them to keep the decomposition going. Within the piles the aerobic, thermophilic decomposition of the organic material proceeds for a period of time. Eventually, decomposition stops as the materials reaches stabilization. The inert material is separated from the stabilized material which can then be applied to land as a soil supplement.

Stabilization - "Lime and Chlorine"

The goal of stabilization is to render sludge less odorous and putrescible and to reduce pathogenic organism content. Stabilization is often carried out prior to another solids handling process. Stabilization can be achieved by the addition of lime or chlorine. The addition of lime to sludge in quantities sufficient to raise the pH to about 11.0, will stabilize the sludge and destroy pathogenic bacteria. Lime can be fed into the system either in batches or with automatic equipment.

Chlorine in doses of about 2,000 mg/l will stabilize sludge. Chlorine addition lowers the pH to about 2.0 and stabilizes by the process of oxidation, which effectively controls odor causing and disease causing bacteria. Chlorine can be fed as a gas or as hypochlorites. Both the addition of lime and chlorine require specialized pumping and mixing equipment to bring the stabilizing agents and the sludge into contact for the appropriate period of time.

Conditioning - "Heat and Chemical"

Conditioning has been defined as the pretreatment of sludge to enhance volume reduction. Almost any of the volume reduction processes described above will perform more effectively if the sludge has been conditioned. The thickeners, any of the filter variations, centrifuges, and drying beds can all benefit.

Conditioning is normally accomplished by the addition of chemicals or by subjecting the sludge to heat under pressure. Although less common, the process of elutriation or washing of sludge also improves some of the volume reduction processes.

Conditioning with chemicals is essentially the same as the physical/chemical process of coagulation/flocculation. By adding primary coagulants such as alum or ferric chloride the fine, dispersed sludge particles are encouraged to stick together in larger floc particles. These larger, tougher particles will settle better, be removed on filters better and separate from the liquid better in centrifuges and drying beds. Typical chemical feed and mixing equipment is needed. Liquid coagulants or dry chemicals can be added to sludge for the purpose of conditioning.

Conditioning by heat treatment is very close to a pressure cooker. Sludge is subjected to a rapid rise in temperature and pressure which causes the bacterial cells in the sludge to burst open releasing the bound water in the cells. The reactor is the heart of the heat treatment system. Sludge flow continuously through the reactor where the steam and pressure are applied. A heat exchanger usually accompanies the reactor to pre-heat and cool the sludge.

Ultimate Disposal

Ultimate disposal refers to the "final resting place" for the sludge in the environment. The solids handling processes discussed so far reduce volume or solids contents or stabilize sludge but there is still material to dispose of. Incineration, land application, and landfill are considered ultimate disposal processes.

Ultimate Disposal - "Incineration"

When sludge is incinerated the organic material in the dewatered sludge cake is completely converted to gas leaving behind a relatively small amount of inert ash. The multiple hearth furnace is the most common furnace design although other incineration processes are in use. Dewatered sludge cake is fed in near the top of the furnace. The sludge falls from hearth to hearth as it is stirred by rotating scrapper arms inside the furance. Multiple burners around the periphery of the unit provide the incinerating temperature. Gas is vented off the top and ash collected at the bottom. Furnaces require significant fuel to incinerate the moist sludge. The ash that is left is usually buried in landfill.

Ultimate Disposal - "Land Application"

Sludge do have some value as fertilizer although the levels as nutrients are not as high as most commercial fertilizers. Typically sludge is applied to agriculture or forest land either by surface or subsurface injection. Sludge can be hauled to the application site by truck, railroad cars, or applied through irrigation pipes. The biggest value of the sludge is as a soil conditioner. Aerobic and anaerobic digested sludges are typically disposed of by land application.

Ultimate Disposal - "Landfill"

Digested sludge and sludge from centrifuges, filters and drying beds are frequently placed in sanitary landfills. Sludge is typically mixed with soil and used to cover municipal solid waste. Landfill is used in populated urban areas where agriculture land is not available. When sludge is applied over municipal waste or mixed and compacted with it and covered in a timely manner, minimal odor problem result. A major drawback of landfill is that there is no value gained from the sludge as there is with land application.

The Systems Approach

Sludge management is a critical part of any treatment system. Solids handling processes and ultimate disposal methods must be considered an integral part of a treatment plant in order to realize the most effective treatment of wastewater. Sludge management is a part of the system. It is the final piece of the puzzle without which the total treatment program is not complete.

REFERENCES

1. "Process Design Manual for Sludge Treatment and Disposal." U.S. EPA, EPA 625/1-79-011, Cincinnati, 1979.

2. "Sludge Treatment and Disposal." Linn-Benton Community College, Albany, Oregon, and U.S. EPA. EPA Grant #900953010, 1980.

REVIEW OF SOLIDS HANDLING

Worksheet

1. Which of the following is NOT one of the three major types of solids found in wastewater treatment plants?

   _____ a. Suspended
   _____ b. Chemical
   _____ c. Raw
   _____ d. Biological

2. Match the following sludge handling processes with their most important function:

   _____ a. Anaerobic Digestion
   _____ b. Elutriation
   _____ c. Landfill
   _____ d. Vacuum Filtration
   _____ e. Heat Treatment
   _____ f. Sludge Lagoon
   _____ g. Composting
   _____ h. Gravity Thickener
   _____ i. Land Application
   _____ j. Belt Filter
   _____ k. Chemical Treatment
   _____ l. Lime Addition
   _____ m. Filter Press
   _____ n. Flotation Thickener
   _____ o. Incineration
   _____ p. Centrifugation
   _____ q. Aerobic Digestion
   _____ r. Drying Beds
   _____ s. Chlorine Addition
   _____ t. Gravity Concentration

   1. Conditioning
   2. Stabilization
   3. Volume Reduction
   4. Solids Reduction
   5. Ultimate Disposal

3. The "systems approach" to the design of a solids handling system means:

_____ a. That a "systems analyst" using computer based design will always give the best results.

_____ b. That the solids handling portion must be part of the overall waste treatment system.

_____ c. That with any wastewater plant design, the approaching collection systems are the key issue.