



Wisconsin Department of Natural Resources
Wastewater Operator Certification

Advanced Mechanical Sludge Handling Study Guide

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Subclass G

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Bureau of Science Services
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Preface

This operator's study guide represents the results of an ambitious program. Operators of wastewater facilities, regulators, educators and local officials, jointly prepared the objectives and exam questions for this subclass.

Note: Key knowledge 4.2.5 was updated February 2013.

How to use this study guide with references:

In preparation for the exams you should:

1. Read all of the key knowledges for each objective.
2. Use the resources listed at the end of the study guide for additional information.
3. Review all key knowledges until you fully understand them and know them by memory.

It is advisable that the operator take classroom or online training in this process before attempting the certification exam.

Choosing A Test Date

Before you choose a test date, consider the training opportunities available in your area. A listing of training opportunities and exam dates is available on the internet at <http://dnr.wi.gov>, keyword search "operator certification". It can also be found in the annual DNR "Certified Operator" or by contacting your DNR regional operator certification coordinator.

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Chapter 1 - Principle, Structure and Function

Section 1.1 - Principle of Mechanical Sludge Handling

- 1.1.1 Describe the sources of organic sludge and where it is collected, stored, or treated within a treatment plant.

Primary sludge is generated directly as settled material from the influent flow to the plant. The sludge is collected in the primary clarifier and is pumped to digesters (mainly anaerobic). Digested sludge can be hauled directly to fields, to sludge drying beds, or to dewatering equipment (gravity thickeners, vacuum filters, gravity belt thickeners, pressure belt thickeners, or centrifuges). Other sludge treatment processes could be wet-air oxidation (zimpro) or incineration.

The only place where sludge is actually generated in a treatment plant is in the secondary biological section where dissolved BOD is converted into biological cell mass (aeration basins, trickling filters, or RBC shafts). This secondary sludge is collected in the secondary clarifiers and as with primary sludge can receive additional treatment prior to ultimate disposal.

One additional source of sludge which is really not a source but rather a recirculation is the return flows from other processes. Examples of such sidestreams would include thickening, dewatering, supernating, or final filtration backwash.

- 1.1.2 List some characteristics of dewatered sludge.
1. It may be sticky and hard to spread
 2. It concentrates both nutrients and toxics
 3. It requires less storage space than liquid sludge
 4. Depending on the concentration it cannot be transported by conventional pumping
 5. It will not migrate as readily as liquid sludge
- 1.1.3 List the characteristics of dewatered sludge that cause it to have limited public acceptance.
1. It has the general bad stigma of sludge
 2. It has some offensive odors
 3. It is a source of possible surface and groundwater contamination
 4. It has the possibility of disease organisms
 5. It has the possibility of toxics
 6. Spreading equipment could cause soil compaction
 7. The addition of lime might be required to raise soil pH
- 1.1.4 List some of the ultimate uses of dewatered sludge.
1. It can be spread on agricultural land as fertilizer
 2. It could be mixed with lawn waste/garbage as compost
 3. It can be burned as fuel if the BTU value is high enough
 4. It can be further dewatered, dried, and bagged as fertilizer
- 1.1.5 Define bound and unbound water as related to sludge dewatering.
- Bound water in sludge refers to water held within the cell walls of the various organisms

within the sludge or water strongly held on the surface of colloidal particles. Bound water can be removed by rupturing the cell walls with specific heat treatment processes (wet air oxidation or incineration).

Unbound water is that portion of water within the sludge that has the possibility of being removed by dewatering equipment. Much of the unbound water can be removed.

1.1.6 Explain how various types of treatment affects the fuel value of sludge.

The fuel value of sludge is dependent on the volatile solids in the sludge cake and its moisture content. At equal moisture levels dewatered primary sludge has the highest volatile solids concentration and the highest fuel value. Anaerobically digested dewatered sludge would have lower volatile solids and a lower fuel value. Waste activated sludge dewatered to an equal moisture content would have different fuel values dependent on the type of process. With activated sludge conventional treatment would have a higher volatile solids concentration than an extended aeration process. Chemically precipitated or treated sludge would have a lower fuel value especially if lime is used. Lime is basically inert providing no volatile solids while reducing the percent volatiles in the sludge. The fuel value of sludge at equal moisture content is totally dependent on the volatile solids concentration.

Section 1.2 - Structure and Function

1.2.1 Describe all mechanical processes available for thickening and dewatering sludge.

A. Dissolved air flotation thickeners: the release of fine bubbles from air saturated water with chemical addition will attach to sludge particles causing the sludge to float; this process is especially suited and used predominately to thicken waste activated sludge

B. Wet air oxidation (zimpro): consists of high pressure, high temperature, and air addition in a closed vessel; this process ruptures cell walls to release bound water and produces a sterile sludge

C. Vacuum filters: vacuum is applied to media submerged in the sludge to separate unbound water from the sludge

D. Pressure filtration:

1. Belt press - sludge is dewatered by gravity and pressure caused by squeezing and the shearing action between rotating belts; the process is very similar to a papermaking machine; the majority of the water is removed in the gravity zone

2. Plate and frame filter press - pump induced pressurized feed sludge forces filtrate through media covered plates clamped in a frame

E. Gravity belt thickener: a rotating media (continuous belt) receives sludge and dewateres it using the force of gravity to separate the water

F. Gravity thickening: solids settle and compact by gravity in a clarifier-like settling tank

G. Incineration: involves high temperature to reduce weight and volume by burning the organic portion of dewatered sludge and evaporating the water; the total reduction in sludge volume can be up to 90%

H. Centrifugation - involves high speed separation using centrifugal force in a rotating cylindrical drum or bowl

Note: Mechanical sludge thickening processes usually use chemical additions (ferric chloride, lime, and polymers, etc.) prior to the sludge getting to the equipment (dissolved air flotation, vacuum filters, pressure filters, gravity belt thickeners, and centrifuges). Thickening processes that normally do not use chemicals would be gravity thickening and lagooning.

1.2.2 Discuss the performance goals that are expected of each mechanical thickening and dewatering process.

To achieve the most cost effective operation based on design capability, yield rates, end product, operational problems, and overall unit costs. For belt presses and vacuum filters this means maximizing the percent solids in the filter cake. For DAF units it means the highest percent solids in the float. For gravity thickening it means maintaining the sludge blanket to produce the most concentrated sludge practical.

1.2.3 List all possible sidestreams in a treatment plant.

1. From the sludge thickening process
2. From the degritter
3. Digester supernatant
4. From sludge conditioning processes (wet air oxidation and chemical additions)
5. From tertiary filter backwash
6. From the incinerator scrubber water
7. From on-site floor drains in process areas
8. From the sludge dewatering processes (DAF, vacuum filters, belt presses, centrifuges, plate and frame presses)

Chapter 2 - Operation and Maintenance

Section 2.1 - Operation

2.1.1 Outline the characteristics, dewaterability, and operational adjustments necessary for the following generated sludges:

- A. Primary sludge
- B. Aerobic sludge
- C. Anaerobic sludge
- D. Wet air oxidized sludge

A. Primary sludge:

1. Characteristics: is usually gray and slimy; has an offensive odor
2. Dewaterability: it dewateres easily
3. Adjustments: adjust the rate and frequency of sludge pumping from the primary clarifiers

B. Aerobic sludge :

1. Characteristics: is brown to dark brown; has a flocculent appearance
2. Dewaterability: some thickening is possible
3. Adjustments: by mixing with primary sludge; by adjusting rate and frequency of W.A.S. pumping

C. Anaerobic digester:

1. Characteristics: is dark brown to black; has a large quantity of gas
2. Dewaterability: is difficult to dewater
3. Adjustments: by operating the digester correctly (temperature and pH); by chemical addition (alkalinity)

D. Wet air oxidation (zimpro):

1. Characteristics: is medium to dark brown; the sludge is sterile; the supernatant is amber colored
2. Dewaterability: excellent dewatering due to rupture of cells and release of bound water, providing that feed sludge is a least 40% primary sludge
3. Adjustments: make adjustments to temperature and pressure

Note: Decant or filtrate from this processed sludge is very high in BOD and can affect treatment plant efficiency. This process is maintenance intensive.

2.1.2 List the characteristics of stable sludge.

1. It has a musty/earthy odor
2. It has a brownish/gray color
3. It has good dewatering properties

2.1.3 List the characteristics of unstable sludge.

1. It has an offensive color
2. It is dark in color
3. It has a low pH
4. It releases gases which can impede the thickening process
5. It has poor flocculation and is difficult to treat
6. It resists thickening
7. It has dewatering problems and may also lead to incineration problems

2.1.4 Describe the conditions that would produce unstable sludge and the problems it could cause.

Unstable sludge could be caused by excessive sludge detention time in primary clarifiers (inadequate pumping), poor operation of anaerobic digesters, poor operation of the secondary system, excessive sludge detention time in the secondary clarifiers, and inadequate mixing in storage tanks. This sludge would generally be considered septic and

usually has a low solids concentration. These type of sludges are difficult to dewater and can cause safety problems with the release of hydrogen sulfide (which can also cause corrosion problems). They are more odorous needing additional ventilation and require more chemical preconditioning prior to dewatering.

- 2.1.5 Discuss where and when sidestreams should be returned relative to BOD and suspended solids content.

Sidestreams with high BOD and low suspended solids should be returned to the biological treatment systems. Sidestreams with high suspended solids should be returned to the primary clarifiers.

- 2.1.6 List the factors that affect sidestream quality.

1. The type of process
2. Any chemical additions
3. Process controls
4. Feed solids loading
5. Temperature
6. The type of sludge being processed
7. Equipment maintenance
8. Variability in sludge characteristics

- 2.1.7 Describe how sidestream quality is related to total solids concentration of end product sludge.

Generally efficient operations produce sidestreams with low suspended solids and higher total solids in the product sludge. Reduced sidestream loading results in lower solids being recycled and lower return flow plant loadings.

- 2.1.8 List the alternatives that can be implemented to lessen sidestream impact on treatment plant processes.

1. Install a flow equalization system
2. Pretreat the sidestream
3. Dilute or mix with other flows
4. Delay sidestream introduction to plant (feed at low loading times)

- 2.1.9 Explain how sidestream quality affects plant final effluent quality.

High BOD, suspended solids, nutrients, or toxic concentrations can upset or overload other plant processes resulting in poor final effluent quality.

- 2.1.10 Outline ways that the quality of sidestreams can be improved.

- A. Have trained operators
- B. Improve process controls
- C. Change chemical conditioning
- D. Improve equipment maintenance
- E. Maintain detailed records of process conditions

- 2.1.11 Explain the effect of chemical addition on sludge.

Chemicals added for phosphorus removal will generally increase sludge production. Sludge will be more inorganic and less volatile but should compact better. Chemicals added for other purposes such as pH adjustment and filamentous control should not drastically change sludge generation but can affect dewatering.

Chemicals including polymers are added to condition sludges and to improve liquid/solid separation. This results in increased concentration and decreased volume.

The amount of chemicals needed for sludge conditioning varies with the dewaterability of a given sludge. Primary sludges and the processed sludge from the wet air oxidation process dewater easily. Anaerobic sludges need additional chemicals. The most chemical addition is required for biological sludges from aerobic digesters and the processing of waste activated sludge.

- 2.1.12 Identify the mechanical sludge handling processes that might have the higher values of polymer dosage.
Dissolved air flotation (DAF), vacuum filtration, and belt presses.
- 2.1.13 Explain the mechanism by which pH adjustments can be used to condition sludge and make it dewaterable.
Sludge particles must coalesce or flocculate before dewatering of the sludge can occur. Sludges do not readily flocculate because the sludge particles have the same electrical charge and repel each other. The electrical charges can be neutralized by adjusting the pH allowing the particles to contact and flocculate. A contributor to dewatering problems involves layers of water that surround sludge (i.e. hydration) and prevent direct contact between particles.
- 2.1.14 Explain the reasons for pH adjustment and the process to effectively reduce pathogens in sludge.
By elevating the pH of sludge to the range of 11-12, organisms and pathogens are significantly reduced. The process to elevate the pH is normally the addition of lime with adequate mixing. The conditioned sludge can either be hauled directly or dewatered prior to final disposal.
- 2.1.15 Discuss how the pH of sludge influences the type of polymer used and how to select a polymer.
The pH of sludge can influence the floc particle charge. For a polymer to be effective it must be the opposite charge from the floc particle. Jar testing of polymers helps to determine whether to use anionic, cationic, or nonionic polymers. Bench testing will also provide dosage required to help determine cost and effectiveness of various polymers.
- 2.1.16 Describe the variables to consider when predicting the amount of waste activated sludge produced for thickening.
The variables that affect waste activated sludge production include overall organic loading to the secondary system, operational mode used, sludge age, and overall F:M ratio. In general, long sludge ages or low F:M ratios produce less sludge, and short sludge ages

and high F:M ratios produce more sludge.

- 2.1.17 Compare the performance and costs of mechanical dewatering vs. liquid hauling listing advantages and disadvantages of each.
- A. Mechanical dewatering:
1. Advantages - less volume to haul, less storage required for sludge, dry sludge can be hauled with mechanical equipment rather than pumping liquid
 2. Disadvantages - higher capital costs, higher operating costs, difficult to apply, return sidestreams, cost of chemicals for conditioning, increased equipment maintenance and replacement
- B. Liquid hauling:
1. Advantages - cost effective (with short haul distances), reduced capital/operating costs (no dewatering equipment required), easy to apply, no return sidestreams
 2. Disadvantages - large volumes must be hauled, larger sludge storage required, increased vehicle costs, land availability problems, seasonal spreading limitations
- 2.1.18 Develop a written daily plan to evaluate a belt press for optimum performance. The following parameters must be evaluated daily to achieve optimum performance of a belt filter press:
- A. Monitor sludge feed concentration of suspended solids and % solids
- B. Monitor sludge feed rate to press (GPM)
- C. Monitor polymer type effectiveness
- D. Monitor polymer feed point
- E. Monitor belt speed control
- F. Monitor belt tension control
- G. Monitor sampling frequency and accuracy
- H. Determine efficiencies and compute:
1. Sludge cake % solids yield rate in pounds per hour
 2. Filtrate - suspended solids (mg/L)
 3. Percent capture
 4. Total pounds/day recycled
 5. Total dry tons removed
 6. Polymer used pounds/ton dry solids
 7. Polymer cost/ton dry solids

The operating parameters should be reevaluated at a minimum annually. Charts and graphs should be constructed to better understand each parameter in relation to performance. Optimum performance should be stressed with the operating staff. Operational experience and needs should be included in the overall procedure.

- 2.1.19 Describe the criteria used by an operator to evaluate the performance of mechanical thickening and dewatering processes.
Visual and physical observations of feed sludge and sludge cake, sidestream flows, lab analysis, chemical additions, and cost comparisons all are criteria used for performance evaluation.
- 2.1.20 List the conditions which determine whether a sludge should be dewatered or hauled as a liquid.
1. The condition of the sludge (ability to dewater)
 2. The travel distance to approved farm sites
 3. The amount of sludge to be hauled
 4. The manpower available
 5. The handling costs
 6. The equipment available (for hauling or dewatering)
- 2.1.21 List the advantages of hauling dewatered or thickened sludge rather than liquid sludge.
1. Due to reduced volume dewatered sludge requires less travel time and total mileage
 2. Thickened sludge allows for more volume of sludge solids to be hauled per trip
- 2.1.22 Describe any possible advantages in hauling liquid sludge rather than dewatered sludge.
In hauling liquid sludge there would not be any sidestream loading to the headworks caused by dewatering equipment. There would be no preconditioning chemical or operational expenditures for dewatering equipment. This might represent a cost savings.
- 2.1.23 Explain what information is needed to determine the cost effectiveness of a sludge handling process.
Operating within budgetary limitations. Use energy, manpower, chemical, equipment, and maintenance costs to determine effectiveness. Replacement costs are vital to cost effectiveness as most systems will need replacement in the future.
- 2.1.24 List the alternatives to consider if landfill costs were to increase significantly.
1. Check the feasibility of land application
 2. Increase the solids content:
 - a. Evaluate the entire existing dewatering process
 - b. Evaluate the conditioning before dewatering
 3. Consider incineration or other dewatering equipment
- 2.1.25 List some operational strategies that can be used to eliminate the problems that limit public acceptance of dewatered sludge.
1. Develop a good public education and communication network
 2. Control odor problems
 3. Develop a good management program
- 2.1.26 Discuss the kinds of information that should be exchanged between different crews and work shifts concerning sludge handling equipment.

Exchange of information between crews and shifts is a basic necessity of a sludge handling operation. Information concerning existing problems with equipment or material handling is of the most immediate concern. Information such as equipment on or off line changes in sludge or chemical conditioning, and status of final product disposal should be discussed.

Information to exchange:

- A. Existing problem
- B. Chemical quantities being used
- C. Process modifications made during the previous shift
- D. Changes in raw sludge feed
- E. Clean-up needed
- F. Sample collection/testing

- 2.1.27 Discuss the need and ways in which information can be communicated between diverse groups of operators at a treatment plant.

Open communication is necessary because of the effects of solids handling on other plant processes, for continued optimum operation of the solids process, and for alerting other operators to potential equipment malfunctions and personal hazards.

Operational information can be communicated by person to person verbal communication, log book entries, written memos, and work orders. Information can also be communicated in the form of complete/concise O&M manuals and clearly written and understood performance objectives.

Methods of information transfer:

- A. Log books
- B. Verbally
- C. Memos from supervisor/foreman
- D. Work orders

Section 2.2 - Maintenance

- 2.2.1 Outline the elements that should be included in a preventive maintenance program.

- A. Scheduled maintenance records
- B. Equipment identification records
- C. Equipment lubrication records and schedules
- D. Equipment adjustment records and schedules
- E. Filing system/work orders (computerized)
- F. Log system for non-scheduled maintenance

- 2.2.2 List some reasons for a preventive maintenance program for mechanical sludge handling equipment.

1. To reduce operating down-time
2. To preserve the longevity of equipment
3. To control the corrosive chemical effect on equipment

4. To protect the safety of the operators

2.2.3 Outline the steps necessary for setting up a preventive maintenance program and where to locate necessary information.

- A. List equipment and lubrication specifications (O&M or manufacturers manual)
- B. Set-up a schedule (by time or by run-time)
- C. Create a log for reference of completed P/M
- D. Designate P/M operators/mechanics

Information may be found:

1. In O&M manuals
2. From manufacturers
3. From suppliers
4. From engineers
5. From equipment name plate data

2.2.4 List the important elements of a lubrication program.

1. List all equipment specifications
2. Establish proper recordkeeping
3. Use proper lubricants
4. Provide proper operator/mechanic training

2.2.5 List the components of a "three card systems" of preventive maintenance.

1. Develop a data card showing specifications
2. Develop a frequency card showing time/hrs. for required maintenance
3. Maintain a history showing maintenance that was performed

Chapter 3 - Monitoring and Troubleshooting

Section 3.1 - Monitoring

3.1.1 Describe the alternatives to field testing of equipment that could be taken to evaluate the selection of sludge handling equipment.

The alternatives to field testing would be bench scale testing, pilot evaluation of various equipment, and visiting other facilities that are using the type of equipment being considered.

3.1.2 List the expected sidestream value ranges for BOD and suspended solids for the following processes:

1. Gravity sludge thickeners
2. Wet air oxidations (zimpro)
3. Vacuum filters
4. Dissolved air flotation (DAF) units
5. Gravity belt thickeners
6. Belt press thickeners

1. Gravity sludge thickeners: BOD = 50-100 mg/L; TSS = 100-600 mg/L
2. Wet air oxidation: BOD = 7,000-8,000 mg/L; TSS = 50-1,000 mg/L
3. Vacuum filters: BOD = 500-5,000 mg/L; TSS = 100-8,000 mg/L
4. DAF units: BOD = 30-500 mg/L; TSS = 80-2,000 mg/L
5. Gravity belt thickeners: BOD = 20-260 mg/L; TSS = 30-450 mg/L
6. Belt press thickeners: BOD = 50-250 mg/L; TSS = 80-2,500 mg/L

Note: The above numbers have a large range and are dependent on the type of sludge being thickened (or mixtures of sludges), the type of chemical pre-conditioning, loading to the unit (including overloading), and proper equipment operation. Operators need to recognize the importance of these sidestreams on overall plant operations and need to determine their actual sidestream quality from their equipment through an adequate sampling and volume measurements of these flows.

3.1.3 Explain the purpose of a bench test.

A bench test is an attempt to simulate on a small scale what may be expected under full-scale operation. It is helpful in determining chemical additions, process control changes, detention times, and other operational factors.

3.1.4 Explain why a good bench test might not translate into successful operation.

Bench testing is only an approximation of actual full-scale operations. Bench test results do not always translate to full-scale operation because the actual operating condition cannot be absolutely duplicated. Many factors may affect full-scale operations, such as: temperature, mixing, hydraulic and mechanical loading, and the actual equipment being used. To fully verify operational factors it would be necessary to pilot/test equipment after the bench testing.

3.1.5 Briefly describe the following bench tests:

- A. Specific resistance test (Buchner funnel method)
- B. Filter leaf test
- C. Capillary suction time
- D. Jar test

A. Specific resistance test (Buchner funnel method): a filter paper sample or wire sample is placed in the funnel; a vacuum is applied to the flask holding the funnel; filtrate is collected in the flask; cake is collected in the funnel

B. Filter leaf test: similar to the Buchner funnel test except that a sample of filter cloth on a frame is immersed in the feed sludge; vacuum is applied and a sludge cake builds-up on the cloth; precoat may be used; this test is often used to simulate vacuum filter operations by testing various filter material

C. Capillary suction time: the time required for the liquid fraction of a sludge to travel a given distance in a porous or absorbent paper

D. Jar test: consists of setting-up an identical sample in a series of jars; differing dosages

of chemicals are added to each jar; after equal mixing the liquid/solids separations are observed over specific time periods; this can be used to select chemicals and optimize the chemical dosage for full-scale operations

Section 3.2 - Troubleshooting

- 3.2.1 Describe how odor problems can generally be eliminated.
The source of the odor needs to be eliminated or controlled. Many odors can not be eliminated only controlled to an acceptable level. Control measures can include good housekeeping, masking agents, ventilation, air scrubbing, and/or chemical treatment (oxidizing agents).
- 3.2.2 Explain the conditions which contribute to the production of hydrogen sulfide gas.
Conditions which contribute to the production of hydrogen sulfide include length of sludge storage, oxygen content, and low pH sulfur source.
- 3.2.3 Explain how the generation of hydrogen sulfide gas can be controlled.
The gas can be controlled by the addition of oxidizing agents such as potassium permanganate and hydrogen peroxide. The gas is typically associated with low oxygen conditions. Control would include aeration of the sludge or processing the sludge before septic conditions can occur.
- 3.2.4 Discuss the problems associated with hydrogen sulfide gas.
Hydrogen sulfide in the presence of moisture forms weak sulfuric acid which is highly corrosive to a wide variety of materials (most metals, electrical equipment, and concrete). The gas in very low concentrations produces a very noticeable odor. The characteristic odor is often termed "rotten eggs". At relatively low concentrations the gas is very toxic and causes a special problem in confined spaces.
- 3.2.5 Describe the problems associated with low pH sludge.
A low pH sludge can generate hydrogen sulfide, be corrosive to equipment, and may have strong particle charges which prevent floc from coming together.
- 3.2.6 Describe the problems associated with high pH sludge.
A high pH sludge can be corrosive to equipment and may have strong particle charges which can prevent flocculation. Many times high pH sludges result from the addition of lime. This can cause operational problems from the precipitation of calcium carbonate. This precipitate causes build-up in pipe lines, pumps, and other areas which will require cleaning with dilute hydrochloric acid.

Chapter 4 - Safety and Calculations

Section 4.1 - Safety

- 4.1.1 List the hazards associated with operating and maintaining mechanical sludge dewatering equipment.

1. Hydrogen sulfide and other gases
2. Confined space entry problems
3. Loose clothing around mechanical equipment
4. Wet conditions may cause slips and falls
5. Corrosiveness of preconditioning chemicals
6. Air under pressure or vacuum
7. Infections
8. High temperatures and pressures (wet air oxidation/zimpro)

4.1.2 Describe how hazards associated with operating mechanical sludge handling equipment can be reduced through the following:

- A. Education
- B. Good housekeeping
- C. Proper maintenance
- D. Use of protective equipment
- E. Changes in employee attitudes about safety

A. Education and training of operator personnel in the understanding of the possible hazards of the equipment

B. Good housekeeping to prevent problems with slips and falls; keep floors and equipment clean and use non-slip surfaces where possible

C. Proper maintenance of equipment including lubrication, maintaining all equipment guards, servicing tag, and lock-out equipment; ensuring that ventilation equipment is operating properly

D. Use of protective equipment as necessary for the type of work being done (eye protection, hearing protection, and appropriate clothing)

E. Develop a positive accident prevention program making sure that all personnel are involved with its implementation

4.1.3 List the emergency measures that should be taken in the event of the following:

- A. Fire
- B. Explosion
- C. Serious personal injury

A. Fires:

1. Evacuate the area
2. Notification - 911 system activation/or local fire department phone numbers
3. Shut-down/isolate equipment and area
4. Extinguish the fire if possible

B. Explosions:

1. Evacuate the area

2. Notification - 911 system activation/or local fire departments phone numbers
3. Shut-down/contain equipment and area

C. Serious personal injury:

1. Notification - 911 system activation/or local police phone numbers
2. First aid and transportation if appropriate
3. Use medical personnel to transport to a health care facility

4.1.4 Describe the safe storage requirements and personal hazards in handling the following chemicals:

- A. Powdered chemicals (in general)
- B. Lime
- C. Alum

All chemicals must be stored according to the manufacturers label instructions.

A. Powdered chemicals (in general):

Storage: store in a dry area; make sure containers are tightly closed (to keep out moisture); keep in original containers and make sure they are protected from physical damage

Hazards: depending on the powdered chemical, hazards could include the possibility of fumes, toxic gases, and the general problem of inhaling dust

B. Lime:

Storage: lime is generally supplied in two forms-

1. Quick lime (unslaked) - store in its original container in a dry location as the powder is very hygroscopic (readily absorbing moisture)
2. Hydrated lime (slaked) - is supplied as a slurry and should be stored in its original container; slaked lime is a very corrosive chemical and containers used for mixing should be rubber, PVC, or iron/steel

Hazards: dust from lime in powdered form can cause irritation of eyes, nose, and respiratory system; a special concern when adding water to unslaked lime is that heat is generated and splattering can occur; these chemicals are very corrosive and can cause severe burns; protective clothing with full face protection is required when using lime

C. Alum:

Storage: alum is hydrated aluminum sulfate and is usually supplied in a liquid form; it is moderately corrosive and can be stored in fiberglass reinforced plastic, 316 stainless steel, steel lined with rubber or saran, PVC, or other plastic tanks; alum tanks must be kept above 25 degrees F.

Hazards: alum is moderately corrosive and protective clothing, gloves, and goggles should be worn; in addition chemical storage tanks are a level 2 confined space requiring meeting the requirements of state and national safety standards

4.1.5 Describe the safe storage requirements and personal hazards in handling the following chemicals: [Continued]

- D. Ferric chloride
- E. Polymers
- F. Acids (in general)

All chemicals must be stored according to the manufacturers label instructions.

D. Ferric chloride:

Storage: ferric chloride is very corrosive and fume producing; it is usually supplied as a 35-43% liquid product; it needs to be stored in tanks made of fiberglass, reinforced plastic, rubber, or saran lined steel; certain other plastics and rubber are also adequately resistant; the tank should be surrounded with a containment area equal in volume to the tank in order to control possible leaks

Hazards: ferric chloride is very corrosive; rubber protective clothing with a full face guard should be used when handling this product; as with alum chemical storage tanks are a Class 2 confined space

E. Polymers:

Storage: polymers are supplied in either liquid or powder form and should be stored in their original containers; some of the liquid polymers can be fed directly using a "drum-head" feeder; for dilution or mixing of polymers of most types storage containers can be used (e.g. fiberglass, polyethylene, PVC, rubber, and various steels, etc.); since there are so many different kinds of polymers it is best to check with the chemical supplier for any special storage requirements for the polymer being used

Hazards: polymers are relatively benign chemicals as some are used in potable water supplies for treatment purposes; the powdered forms do pose problems with the dust being an irritant to the mucus membranes; the main problem with polymers is to thoroughly clean-up spills as they cause extremely slippery surfaces that can cause falling accidents

F. Acids (in general):

Storage: all acids should be stored in recommended acid proof containers; in most cases this will be glass or various types of plastic materials and almost never any metal containers; one exception to using glass containers would be for forms of hydrofluoric acid which etches glass; acids should be stored in a safe location to prevent physical damage as they are extremely corrosive if spilled

Hazards: all acids are extremely corrosive especially to metals; they can cause severe burns and fumes can cause respiratory problems; acids should be handled with extreme care using rubber protective clothing, full face shields, and adequate ventilation; when diluting acids it is very important to add acid to water; if water is added to a concentrated acid splattering could occur and heat release

Section 4.2 - Calculations

4.2.1 Given data, find the cost of operating a belt press in cost per dry ton of processed sludge.

Given:

2 million gallons/year of feed sludge

2% solids feed sludge (20,000 mg/L)

6 lbs. polymer per dry ton of feed

\$3.00 per pound polymer cost

12% solids filter discharge

10 miles to landfill @ \$0.14 per mile per ton

\$2.40 per ton landfill fee

Formula:

dry pounds = feed sludge (MG) x concentration (mg/L) x 8.34

dry pounds = 2 MG x 20,000 (mg/L) x 8.34 = 333,600 dry lbs.

dry tons = dry pounds ÷ 2,000

dry tons = 333,600 ÷ 2,000 = 166.8

wet tons = dry tons x 100% ÷ % solids

wet tons = 166.8 x 100 ÷ 12 = 1,390

OR

12% of total ÷ 166.8 dry tons = 100% ÷ wet tons = 1,390 wet tons

pounds polymer = dry tons x dry ton feed

polymer = 166.8 x 6 = 1,000.8 lbs.

landfill cost 1,390 x \$2.40 = \$3,336.00

hauling cost 1,390 x \$0.14 x 10 miles = \$1,946.00

polymer cost 1,000 x \$3.00 = \$3,000.00

total cost per year = \$8,282.00

total cost per dry ton = total cost per year ÷ dry tons

total cost = \$8,282.00 ÷ 166.8 = \$49.65 per dry ton

4.2.2 Given data, calculate the cost comparison of hauling sludge at different concentrations.

Given:

Original volume = 72,000 gallons

Original concentration = 2%

Volume per load = 6,000 gallons

Cost per load = \$100.00

New concentration = 8%

Formula:

$$C_1V_1 = C_2V_2$$

new volume = original volume x original concentration ÷ new concentration

of loads = total volume ÷ volume/load

1. Cost of hauling 72,000 gallons at 2%:

of original loads = 72,000 ÷ 6,000 = 12

cost = loads x cost per load

cost = 12 x 100 = \$1,200

2. Cost of hauling 8% concentration:

new volume = 72,000 x 2 ÷ 8 = 18,000 gallons

of new loads = 18,000 ÷ 6,000 = 3

new cost = 3 x 100 = \$300

savings = \$1,200 - \$300 = \$900

4.2.3 Given data, calculate the increased loading of suspended solids (or BOD) to a treatment plant due to the return of sidestreams from dewatering equipment.

Given:

Plant loading suspended solids = 150 mg/L

Daily plant flow = 10 MGD

Sidestream suspended solids = 1,000 mg/L

Sidestream flow = 200,000 GPD

Formula:

$$\text{pounds} = \text{flow (MGD)} \times \text{concentration (mg/L)} \times 8.34$$

$$\text{loading from influent} = 10 \times 150 \times 8.34 = 12,510 \text{ pounds}$$

$$\text{loading from sidestream} = 0.2 \times 1,000 \times 8.34 = 1,668 \text{ pounds}$$

$$\text{percent increase} = 1,668 \div 12,510 \times 100 = 13.3\%$$

- 4.2.4 Given data, calculate polymer dosage in lbs/tons at effective bench test dosage and gallons fed at a given dilution.

Given:

Sludge feed = 500,000 gallons

Sludge concentration = 5%

Unmixed polymer dilution for feeding = 2%

Bench test dosage (mg/L) (undiluted) --- Settled volume after 5 minutes

- A. 5 mg/L --- 950 ml
- B. 10 mg/L --- 900 ml
- C. 15 mg/L --- 850 ml
- D. 20 mg/L --- 900 ml
- E. 25 mg/L --- 950 ml

Formula:

$$\text{tons of sludge} = \text{flow (mg)} \times \text{concentration (mg/L)} \times 8.34 \div 2,000$$

$$\text{sludge} = 0.5 \times 50,000 \times 8.34 \div 2,000 = 104.25 \text{ tons dry solids}$$

1. The best polymer dosage is 15 mg/L:

$$\text{pounds of polymer} = 0.5 \times 15 \text{ (mg/L)} \times 8.34 = 62.55 \text{ pounds}$$

$$\text{polymer pounds/ton} = 62.55 \div 104.25 = 0.6 \text{ pounds/ton}$$

2. If polymer is diluted for feeding purposes to a 2% solution how many gallons of diluted polymer will be fed?

Formula:

$$\text{gallons} = \text{weight} \div \text{density}$$

$$\text{gallons} = 62.55 \div 12 = 5.21 \text{ (undiluted)}$$

$$C1V1 = C2V2$$

$$100 \times 5.21 = 2 \times V2$$

$$V2 = 261 \text{ gallons (diluted)}$$

- 4.2.5 Given data on jar testing of a diluted polymer, calculate the number of gallons needed to precondition a volume of sludge from the jar testing.

Given:

Polymer concentration = 1%

Amount of polymer (diluted) added = 10 mL

Volume of test sludge = 1,000 mL

Volume of sludge to be treated = 10,000 gallons

Formula: Volume of polymer directly proportional to jar test.

Volume of dilute polymer (gal) = (volume of sludge to be treated) x (amount of polymer added) ÷ (volume of test sludge)

$$\text{Volume of dilute polymer (gal)} = 10,000 \times 10 \div 1,000$$

$$= 100 \text{ gallons}$$

- 4.2.6 Given data on chemical dilutions used for jar testing, calculate the effective concentration in mg/L and the pounds of chemical needed to treat a volume of sludge.

Given:

Alum added to 1,000 mL = 10 grams

Amount of this dilution added to 1,000 mL sludge = 2 mL

Sludge to process = 100,000 gallons

Find pounds of alum needed to condition this sludge:

10 grams per 1,000 mL = 10,000 mg/L

Adding 2 mL of 10,000 mg/L to 1,000 mL (10 mg/mL) of sludge would be $2 \times 10 = 20$ mg/L effective concentration

Formula:

$$\text{pounds} = \text{volume (mg)} \times \text{concentration (mg/L)} \times 8.34$$

$$\text{pounds} = 0.1 \times 20 \times 8.34$$

$$= 16.7 \text{ pounds of alum}$$

References and Resources

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