Wisconsin Department of Natural Resources
Wastewater Operator Certification

Introduction to Anaerobic Digestion Study Guide

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Subclass F

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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 4.1.3 was updated January 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 Anaerobic Digestion

1.1.1 List the benefits associated with anaerobic digestion.

1. The production of methane gas
2. Lower operational costs
3. Digested sludge has less odor
4. It reduces pathogens
5. It reduces sludge volume by destruction of volatile solids

1.1.2 Explain the process where waste entering a digester is converted to methane, sludge, and water.

The organic solids in the feed sludge are used as "food" by the bacteria in the digester. The acid forming bacteria break-down organic solids and form organic acids. The methane forming bacteria convert the organic acids to methane gas, carbon dioxide, and water. The non-volatile solids along with a few non-biodegradable organic solids become digested sludge.

1.1.3 Explain why digester is considered "dirty gas".

Digester gas is not pure methane but a mixture of methane, water vapor, carbon dioxide, and hydrogen sulfide.

Section 1.2 - Structure and Function

1.2.1 State the main functions of primary and secondary digesters in a two-stage system.

The primary digester is used mainly for digestion and gas production. The secondary digester is used for settling (liquid-solids separation), drawing-off the supernatant, and gas storage.

1.2.2 List the types of digester covers.

1. Fixed cover
2. Floating cover
3. Gas holding cover

1.2.3 State the function of the water seal on floating cover digesters.

The function of the water seal is to keep the digester gas in and to prevent air from getting into the digester which could cause an explosive condition.

1.2.4 Explain the purpose of corbels in digesters with floating covers.

The corbels limit the downward movement of the digester cover and protect the internal equipment from damage if sludge is withdrawn below the designed operating range.

1.2.5 List the normal types of pumps used to pump and recirculate sludge.

Pump sludge:

1. Piston (most common)
2. Centrifugal

3. Progressive cavity
4. Diaphragm

Recirculate sludge:
1. Centrifugal (most common)
2. Progressive cavity

1.2.6 Explain the purpose of the following component parts:

A. Flame traps
B. Drip traps
C. Pressure/vacuum relief valve
D. Pressure regulator
E. Check valve
F. Gas meters
G. Manometer

A. Flame traps: purpose - to prevent a fire from moving backwards through the piping and reaching the stored digester gas

B. Drip traps: purpose - to remove and collect condensation from the digester gas

C. Pressure/vacuum relief valve: purpose - to prevent structural damage to the digester due to a pressure build-up or vacuum condition

D. Pressure regulator: purpose - to maintain a constant pressure at the point of use

E. Check valve: purpose - to prevent higher pressure gas from getting back to the digester

F. Gas meters: purpose - to measure the output of digester gas in cubic feet per day; this information can be used to indicate digester efficiency

G. Manometer: purpose - to monitor the pressure of gas in the collection and storage system; a manometer is a u-shaped glass column containing a liquid (usually water); pressure is read in inches of water

Chapter 2 - Operation and Maintenance

Section 2.1 - Operation

2.1.1 List what operational factors affect the operation of an anaerobic digester.

1. Organic loading rate (sludge feeding)
2. Temperature (heating control)
3. Control of mixing or recirculation
4. Control of grit and scum blanket
5. Toxic controls
6. Chemicals used for pH control
7. Control of the scum blanket

2.1.2 List two reasons why digester mixing is important.

1. To maintain an even temperature throughout the digester
2. To evenly distribute the entire contents (food, bacteria, alkalinity, and volatile acid) of the digester

2.1.3 List the two main gases that compose digester gas and give the approximate percentage range of each for a well working digester.

1. Methane gas: 65% - 75%
2. Carbon dioxide gas: 25% - 35%

2.1.4 Discuss sludge characteristics that determine potential production of methane.

The higher the organic matter in the sludge the higher the potential for methane production. The starches, fats, and sugars in sludge affect methane production. Toxic or inhibiting substances (metals and ammonia) can also adversely affect production.

2.1.5 Describe the physical and chemical characteristics of well-digested sludge versus poorly-digested sludge.

I. Well-digested sludge:

A. Physical characteristics:

1. Musty or relatively low odor
2. Dark to black color, lumpy appearance
3. Easily dewatered

B. Chemical characteristics:

1. Neutral pH
2. Lower in pathogens
3. Volatile acids are low
4. Volatile solids reduction of 40% - 60%

II. Poorly-digested sludge:

A. Physical characteristics:

1. Disagreeable odor
2. Dark or black color with light gray streaks
3. Dewaters poorly

B. Chemical characteristics:

1. Low pH
2. Higher in pathogens
3. Volatile acids are high

4. Volatile solids reduction less than 40%

2.1.6 Outline the general start-up procedure for anaerobic digesters.

1. Add seed sludge (if available and of good quality from a nearby plant); sufficient good quality seed sludge will reduce start-up time
2. Fill the digester with raw wastewater
3. Heat to operating temperature as quickly as possible
4. Start mixing and recirculation
5. Add raw sludge slowly and feed as often as possible
6. Begin monitoring for control parameters
7. Control volatile acids/alkalinity ratio with buffering agents(chemicals) as required

2.1.7 List the items to check before starting a positive displacement (piston, diaphragm, or progressive cavity) pump.

1. Make sure no person is working on the pump
2. Make sure inlet (suction) and outlet (discharge) valves are open
3. Turn-on oilers and lubricate piston packing (if appropriate)

2.1.8 List the consequences of operating a positive displacement piston pump against a closed valve.

1. It could shear a pin
2. It could break the piping
3. It could blow-out packing or gaskets

2.1.9 List what happens if a progressive cavity pump is pumping against a closed valve.

1. It could cause drive motor overheating
2. It could cause a circuit breaker to trip
3. It could damage or destroy the rubber stator

A method of checking pump wear is to temporarily close the discharge valve and measure the discharge pressure.

2.1.10 List what happens when a progressive cavity pump is run dry.

1. It causes overheating
2. It would destroy the rubber stator

A progressive cavity pump can be damaged in a matter of minutes if run dry. Normally there is a flow detector or other devices to prevent operating the pump when dry.

2.1.11 Discuss how an operator can increase or decrease the output from a piston or progressive cavity pump.

A. Piston pump: increases and decreases of output can be accomplished by changing the pin placement in the concentric or adjusting the speed

B. Progressive cavity pump: increases and decreases of output can be accomplished by changing speeds

2.1.12 List the two ways of heating digesters.

1. Use hot water heating coils within the digester
2. Use sludge recirculation with an external heat exchanger

2.1.13 Explain the operation and ranges for mixing, heating, feeding, pH control, and volatile acid to alkalinity ratios for an anaerobic digester.

A. Mixing: mix enough to maintain even temperature through the digester and to prevent solid deposits on the digester floor

B. Heating: the methane forming bacteria can operate in the range of 85 degrees to 100 degrees F. but work best between 90 degrees to 98 degrees F. with 95 degrees F. as a common temperature goal; the acid forming bacteria are not as temperature sensitive

C. Feeding: maintain as constant a feed as possible at or below design feed rates (0.03 to 0.10 pounds of volatile suspended solids/day/ft^3)

D. pH control: 6.8 to 7.2

E. Volatile acid to alkalinity ratio: normally control between 0.1 - 0.35; frequent monitoring of volatile acids, alkalinity, and plotting the ratio is important as they are the first indicators to show that an upset might occur

2.1.14 Explain the affect temperature has on the rate of digestion.

At higher temperatures digestion happens more rapidly and at lower temperatures digestion occurs at a slower rate. The methane forming bacteria's activity for example almost stops at 50 degrees F. and can function well in the 85 degrees to 100 degrees F. range (mesophilic range). They also function well in the 120 degrees to 135 degrees F. range (thermophilic range) but digestion in this range is not the normal practice.

2.1.15 Discuss the maximum temperature of water going into internal digester coils and why this should not be exceeded.

The temperature should not exceed 130 degrees F. High water temperatures will cause sludge to bake onto the heating coils and significantly cut-down on heat transfer.

2.1.16 Discuss the recommended rate of temperature change in degrees per day when changing digester temperature.

A. If starting from ambient temperature bring to operating temperature as rapidly as possible.

B. If changing from one temperature above ambient to a different temperature above ambient bring heat up a maximum of 1 degrees F. a day to allow bacteria to adjust to the new temperature. The methane forming bacteria are more sensitive to temperature changes than the acid forming bacteria. A 2 degrees F. change will affect methane formers, but not acid formers.

2.1.17 Describe gas flame color when a digester is working well and when it is starting to go "sour".

The gas flame color of a well working digester is blue at the base and has a yellow tip. The gas flame color of a "sour" digester is mostly yellow overall.

2.1.18 List three ways to mix digester contents.

1. Sludge recirculation
2. Gas mixing
3. Mechanical mixing

2.1.19 Explain the affect on gas production, volatile acid production, and alkalinity if the feed rate to a digester is suddenly reduced.

A. Gas production: gas production would go down slowly
B. Volatile acid production: volatile acid production goes down
C. Alkalinity: alkalinity would stay the same or go up

2.1.20 Compare the time necessary to digest sludge in a heated mixed digester and in an unmixed digester.

Mixed heated digesters require less detention time than the unmixed digesters as more bacteria are in contact with food increasing the reduction of organic material.

2.1.21 Explain why it works better to feed small amounts of thick sludge more often than to force large amounts of thin sludge less often.

A feed schedule that feeds thick sludge at frequent intervals is the best for anaerobic digester operations. The reasons for this are:

A. Thick sludge fed more often:

1. Reduces heating costs
2. Reduces supernatant volume
3. Prevents upsets
4. Increases treatment (increases detention time)
5. Has even gas production

B. Thin sludge fed less often:

1. Higher heating costs
2. Increases supernatant volume
3. May cause an upset (hydraulic overload)
4. Reduces treatment (reduces detention time)
5. Gas production fluctuates

2.1.22 List the chemicals used to adjust digester pH giving the common name and chemical formula.

Chemical name --- Formula --- Common name

Calcium oxide --- CaO --- Unslaked or quicklime
Calcium hydroxide --- Ca (OH) 2 --- Slaked or hydrated lime
Anhydrous ammonia --- NH3 --- Agricultural fertilizer
Ammonium hydroxide --- NH4OH --- Liquid ammonia
Sodium carbonate --- NaCO3 --- Soda ash
Sodium bicarbonate --- NaHCO3 --- Bicarbonate of soda (baking soda)
Sodium hydroxide --- NaOH --- Lye or caustic soda

2.1.23 Identify where supernatant is returned and describe the impact on plant operation.

Supernatant may be aerated before being directed to the primary clarifier. Impacts of this sidestream can include high levels of suspended solids, BOD, and ammonia. If a very poor quality supernatant is returned it can have a severe impact on plant performance. For the least impact on plant operations sludge should be pumped frequently in small amounts as this will determine the frequency and amount of supernatant return.

2.1.24 State how long mixers should be turned-off in a fixed cover digester to ensure good supernatant when pumping sludge.

Allow the digester to set for 8 to 12 hours. Pump sludge at as slow a rate as possible. When the discharge of supernatant stops resume mixing.

2.1.25 List the reasons why grit accumulation in a digester is undesirable.

1. It causes a loss in effective digestor capacity
2. It may plug lines to and from the digester
3. It may disturb the mixing patterns
4. It can damage pumps handling digested sludge

2.1.26 Explain why some digested sludges will dewater more readily than others.

A well digested sludge dewaters easily while a poorly digested sludge dewaters poorly. The main cause of this difference would be in the operation of the digester or possibly an overloaded system which can not perform as designed. The operating factors would be the type of system, detention time, organic loading rate, temperature, mixing/recirculation, grit/scum control, toxics, and pH control. Low pH sludges normally do not dewater well.

2.1.27 List the reasons why thick scum blankets will have adverse effects on digester operations.

1. It can cause a loss of digester capacity
2. It could plug the supernatant line
3. It could affect the heat exchanger

Note: Large scum blankets must be broken-up by increased mixing, sludge recirculation, or other physical or chemical methods.

2.1.28 Describe the proper method of sludge withdrawal from a fixed cover single-stage digester and state the necessary steps taken to reduce the hazard of fire or explosion.

There are very few single stage fixed cover digesters left in Wisconsin so this objective has limited application. The main concern is to prevent air from being drawn in through the vacuum relief valve. This would cause an explosive mixture in the digester. The second concern, would be that the vacuum relief valve could fail which could cause a vacuum in the digester and the roof could collapse. To prevent either of these from occurring, the digested sludge should be withdrawn slowly and raw sludge, sewage, digester gas (if gas storage is available), or water should be pumped into the digester at the same or higher rate than the digested sludge is being removed.

Section 2.2 - Maintenance

2.2.1 State the approximate time intervals that digesters should be drained, cleaned, inspected, and repaired.

Complete digester cleaning is dependent on the type of waste treated (especially grease), efficiency of grit removal, efficiency of mixing, tank structure and age, condition of internal equipment, and alternatives of sludge handling when the tank is out-of-service. Cleaning should be done at about a 3-5 year interval.

2.2.2 List the proper maintenance steps for sludge draw-off lines after sludge is removed from the digester.

1. Flush with water to remove all sludge, grit, and debris
2. Inspect all valves and if necessary lubricate
3. Leave the valve open at the end of the line so it totally drains

2.2.3 Describe the basic maintenance procedures for a piston, progressive cavity, and a centrifugal recirculation pump.

A. Piston pump:

1. Check the lubrication (oil in reservoir and grease as needed)
2. Check packing for leakage (slight leakage sometimes occurs)
3. Listen for unusual noises
4. Check the pressure gauge for normal deflection during pumping sludge; if not deflecting normally the ball checks may be obstructed

B. Progressive cavity pump:

1. Listen for unusual noises
2. Check the seal for leakage
3. Check the discharge pressure gauge
4. Check the pump temperature; if hot it may be running dry and this could damage the stator
5. Periodically stator wear can be checked by temporarily closing the discharge valve and noting the discharge pressure

C. Centrifugal recirculation pump:

1. Listen for unusual noises (especially cavitation)
2. Check packing for leakage (slight leak is acceptable)

3. Check mechanical seal for leakage (should not leak)
4. Check the discharge pressure gauge; if lower and normal it may indicate a plugged impeller that will have to be cleaned
5. Record ammeter readings and watch for trends; if lower than normal it may indicate wear on the impeller

2.2.4 Outline the procedure used to remove check balls for inspection of replacement.

1. Turn-off, lock-out, and tag circuit breaker
2. Close the gate valves
3. Relieve any pressure by slowly loosening the cover
4. Remove ball cover
5. Remove ball
6. Check seats and balls for roundness or nicks

2.2.5 Discuss the basic maintenance for gas mixers and mechanical mixers.

Inspect, lubricate, change oil, and adjust mechanical equipment according to the manufacturers specifications.

On gas mixers monitor gas feed rates by observing pressure at the compressor and verify that gas is flowing. This is done by checking valve positions, observing manometer readings, and/or feeling gas lines (flowing gas lines will be warmer than those with no flow).

2.2.6 Describe the basic maintenance for pressure/vacuum relief valves.

Routinely inspect the pressure/vacuum relief valve every six months. Monitor gas pressure and service pressure/vacuum relief valve as needed. This may include manually operating the valves and checking for corrosion or other malfunctions (especially condensation and freezing in very cold weather).

2.2.7 State how often operators should drain drip traps and discuss the consequences if this is not done.

Drip traps should be drained once per day or more frequently when condensation rates are high. If not done the lines may become constricted or plugged with water causing gas pressure to rise above normal.

2.2.8 Describe the consequences of continued use of uncleaned flame trap baffles.

Unclean baffles can cause restriction or plugging of the gas flow through the trap. Failure to clean can cause corrosion and may require replacement.

2.2.9 Describe the basic maintenance for flame traps and state the frequency of cleaning.

The pressure drop across flame trap arrestors should be checked monthly and should be disassembled and washed-out with a safe solvent at least annually. Excessive pressure drop may require more frequent disassembly and cleaning.

Chapter 3 - Monitoring and Troubleshooting

Section 3.1 - Monitoring

3.1.1 Explain how to get representative samples for feed sludge, digested sludge, supernatant, volatile acids/alkalinity, and digester gas.

A. Feed sludge: sample the sludge pump discharge or a well mixed sludge pit or vault

B. Digested sludge: sample the contents being transferred to another digester (or storage tank) or as pumped to a drying bed, dewatering unit, or sludge truck

C. Supernatant: grab sample somewhere near the middle of the supernatant process; perhaps a composite of three grabs (not at beginning or end)

D. Volatile acids/alkalinity: at the discharge of the recirculation pump

E. Digester gas: sample on gas collection dome or gas line from the digester

3.1.2 Select the laboratory control test that indicates food available for digester bacteria.

The laboratory test that indicates the "food" available for digester bacteria would be the volatile solids test. The volatile solids test represents the organics present in the feed sludge.

3.1.3 List the tests that should be run to monitor digester operation.

1. pH
2. Temperature
3. Volatile acids/alkalinity
4. Total volatile solids of raw sludge
5. Gas production

3.1.4 Given the approximate values for BOD and suspended solids for a "typical" digester supernatant.

Values for BOD and suspended solids for a typical supernatant will have a wide range of values. Suspended solids can range between 500 and 15,000 mg/L. BOD can range between 500 and 10,000 mg/L. This sidestream is significantly higher in BOD and suspended solids than normal raw domestic wastewater. Very poor quality supernatant can adversely affect the wastewater treatment process.

Section 3.2 - Troubleshooting

3.2.1 Define what is meant by a digester upset.

An upset digester is one that is not functioning to properly decompose the organic matter. This is characterized by low gas production, high volatile acids, low alkalinity, high volatile acids to alkalinity ratio, and a low pH. A digester that is upset is sometimes called a "sour" or "stuck" digester.

3.2.2 Describe what should be done to a gas handling system after a sludge foaming incident.

After a foaming incident it will be necessary to clean all gas lines, sediment, drip traps, flame arrestors, gas meters, regulators, manometer lines, check valves, pressure/vacuum relief valves, and any other gas handling equipment that was affected by the foaming event. This would include the use of water, solvents, and air as specified in the O&M manual or as recommended by the manufacturer.

3.2.3 Outline an action plan to use if the digester is starting to become upset or go "sour."

1. Monitor volatile acid/alkalinity and pH
2. Reduce loading to the digester by reducing sludge pumping
3. Recirculate sludge from the secondary digester; if needed begin adding a base to increase the alkalinity.
4. Once the volatile acid/alkalinity ratio has decreased and pH returns to normal, begin to gradually increase the sludge pumping rate to normal.
5. Continue monitoring volatile acid/alkalinity and pH

3.2.4 Discuss the important items to consider when correcting digester mechanical or structural problems.

The first item to consider in correcting a digester problem would be all the safety concerns i.e.: asphyxiation or suffocation in working in a confined space, the possibility of a fire or explosion from the digester gas, the safety concerns in handling and using chemicals, and all the other routine safety items (electrical, mechanical, and equipment).

A second concern would be other plant operations that could be affected while the digester is out-of-service such as how to handle waste sludges, heating alternatives if the digester gas is not available, and possible changes to the digester sidestreams that may negatively affect the secondary treatment process.

A third concern would be a possible odor problem if the digester gas system had to be vented to the atmosphere to make the repair. Neighboring residences and other buildings in close proximity to the plant would be affected.

3.2.5 Explain the possible causes and corrective actions for a gas burner that keeps going out.

1. Cause: low % methane (poor quality with high carbon dioxide content)
Correction: increase quality of gas through "better" operation

2. Cause: condensate blocking the gas feed line
Correction: drain lines, purge with air, and check operation of condensate traps

3. Cause: low gas pressure
Correction: check in-plant gas usage and check for leaks in the gas piping system including meters and all other devices

4. Cause: pilot blown-out by wind
Correction: relight and adjust the pilot light

3.2.6 Explain the possible causes and corrective actions for a digester cover floating unevenly.

1. Cause: the cover is obstructed by debris, ice, or scum
Correction: remove the obstructions

2. Cause: water or sludge in the floating cover
Correction: drain fluid the from the cover and fix the leak

3. Cause: cover rollers are misaligned or damaged
Correction: repair the rollers

3.2.7 Explain the possible causes and corrective actions for water getting into a gas meter.

Cause: condensate (drip) traps are not being drained
Correction: drain the condensate (drip) traps

3.2.8 Explain the possible causes and corrective actions for a sudden loss of gas production combined with a low volatile acid concentration.

Cause: a toxic material is being introduced into the digester which is causing the bacteria to be inhibited or killed
Correction: dilute and recycle from the secondary digester; attempt to identify the toxicity, its source, and eliminate it from the wastewater flow

3.2.9 Explain the possible causes and corrective actions for a gradual loss of gas production combined with a high volatile acid concentration.

The gradual loss of gas (methane) production with high volatile acids (decrease in pH) indicates that a digester is imbalanced and is tending towards going "sour". Assuming that temperature is not a problem the obvious problem is excessive volatile solids loading in too short of a time to the digester. A correction to this problem would be to reduce the loading if possible and/or pumping sludge more frequently for shorter durations.

3.2.10 Explain the possible causes and corrective actions for intense digester foaming.

1. Cause: during digester start-up excessive chemical additions to control volatile acids could cause foaming
Correction: feed chemical incrementally with adequate mixing while monitoring volatile acids, alkalinity, pH, and gas production

2. Cause: excessive digester foaming could occur if large amounts of chemicals are added too quickly to a "sour" digester; this could release carbon dioxide and cause foaming
Correction: when correcting a "sour" digester chemicals should be fed slowly with adequate mixing while monitoring volatile acids, alkalinity, pH, and gas production; do not try to correct for all the organic acids with one massive chemical addition

3.2.11 Discuss what happens when check balls are not seating properly.

The pump will not pump because fluid is forced back and forth past the balls.

3.2.12 Discuss what happens when items such as sharp bone chips or other cutting abrasives are pumped through a progressive cavity pump.

It will cause excessive wear to the stator. To reduce wear caused by abrasive materials the progressive cavity pumps' speed should be reduced from the normal 300 RPM to 200

RPM.

Chapter 4 - Safety and Calculations

Section 4.1 - Safety

4.1.1 Explain why there should be a way of shutting off sludge pumps from an area other than where the pumps are located.

The main reason is to prevent electrical hazard in case of flooding or severe leakage.

4.1.2 List the personal safety equipment that should be on-hand before entering a digester for cleaning or repair.

1. A tri-gas meter for confined entry
2. A sparkless ventilator
3. At least two other individuals outside the digester
4. Some form of communications to summon help
5. Self-contained breathing apparatus
6. Proper clothing
7. Eye protection
8. Rubber gloves
9. Hard hat
10. A harness and tri-pod
11. Non-sparking tools
12. Explosion-proof lights

4.1.3 Describe the chemicals used in controlling digester pH including the storage and handling concerns for:

A. Calcium oxide
B. Calcium hydroxide
C. Anhydrous ammonia
D. Ammonia (liquid)
E. Ammonium hydroxide
F. Sodium carbonate
G. Sodium bicarbonate
H. Sodium hydroxide

These chemicals are all used to control pH in digesters. When handling at a minimum an operator should prevent the chemical from touching the skin (wear rubber gloves and full face mask or goggles). In addition to the items listed below the operator should be sure to read all label instructions provided by the manufacturer and store as directed in the original containers.

Chemical --- Storage and handling

A. Calcium oxide --- this chemical comes in 50 pound bags in powder form; normally water must be used (slaked) to form a slurry before using; always add quicklime to water to prevent a violent reaction which can cause splattering; it is very caustic and can cause severe burns; it is difficult to wash off as it is a very slimy material when slaked; the powder is dusty and can cause nasal irritations; this powder is hygroscopic (absorbing moisture from the air) so it needs to be stored in a dry area

B. Calcium hydroxide --- this chemical comes as a powder and keeps better in storage than calcium oxide.

C. Anhydrous ammonia --- this chemical is commonly used as an agricultural fertilizer and comes in cylinders or tanks as a gas; it should be stored at temperatures below 70 degrees F. in a well ventilated room; the gas should not come in contact with chloride solutions as free chlorine gas can be liberated

D. Ammonia (liquid) --- is an irritating alkali that can cause severe skin burns and is corrosive to copper; when using it to raise digester pH, care must be exercised to prevent ammonia toxicity which occurs at concentrations of 1,500-1,600 mg/L as nitrogen

E. Ammonium hydroxide --- this chemical is available in liquid form from farm supply dealers; as with the other caustics it can cause skin burns and is an eye irritant

F. Sodium carbonate --- this chemical is usually supplied in 50 pound bags in powder form; it is highly soluble in water, is caustic, can cause skin burns, and is an eye irritant

G. Sodium bicarbonate --- this chemical is supplied as a powder in 50 pound bags and should be treated the same as sodium carbonate

H. Sodium hydroxide --- this chemical is supplied in steel drums or in bags; it is available as a flake, crystals, or a liquid; normally, it is purchased as a flake or a crystal form; the common name is "lye" and has all the problems of the other caustics previously mentioned

4.1.4 Explain why air should never be allowed to mix with methane.

If air and methane gas are allowed to mix they create an explosive mixture. When methane is between 5% to 20% in a methane/air mixture it is the most explosive.

4.1.5 Discuss how air and methane could be mixed in a fixed cover digester and define the precaution to minimize the condition.

If digested sludge is withdrawn without the addition of raw sludge a vacuum could be created drawing-in air through the vacuum relief valve.

Precaution: withdraw digested sludge and add raw sludge at the same rate

4.1.6 Discuss how air and methane could be mixed in a floating cover digester and define the precaution to minimize the condition.

Air could be drawn in through the vacuum relief valve if a floating cover is unbalanced, jams, rests on the corbels, or the water seal is broken.

Precaution: maintain a balanced cover and keep sludge above the level of the corbels

Section 4.2 - Calculations

4.2.1 Given data calculate how many British Thermal Unit (BTU's) are required to heat sludge to operating temperature.

A British Thermal Unit (BTU) is the quantity of heat required to raise 1 pound of water 1 degree fahrenheit (consider sludge to be the same weight as water).

Given:
Initial temperature = 55 degrees F
Final temperature = 95 degrees F
Gallons pumped = 500 gallons
One gallon = 8.34 pounds

Formula:

BTU's required = temperature rise x volume x 8.34

BTU's required = (95 - 55) x 500 x 8.34 = 166,800 BTU's

4.2.2 Given data calculate the amount of sludge that has been pumped based on the change in height of the floating cover.

The height that a floating cover rises after pumping sludge is directly proportional to the amount of sludge pumped. It is the volume of a cylinder formed by the difference in cover height change and the digester diameter.

Given:
Diameter = 40 feet
Initial cover height = 20.5 feet
After pumping height = 21.0 feet
1 cubic foot = 7.5 gallons

Formula:

volume = 3.14 x r^2 x height

volume = 3.14 x 20^2 x 0.5

volume = 628 cubic feet

volume = 628 cubic feet x 7.5 gallons per cubic foot

= 4,710 gallons

4.2.3 Given data, calculate the volume (gallons) of a digester.

To determine the approximate volume of a cylindrical digester it is necessary to know its diameter and height and to convert cubic feet to gallons.

Given:
Diameter = 40 feet
Height = 20 feet

Formula:

volume = 3.14 x r^2 x height

volume = 3.14 x 20^2 x 20

volume = 25,120 cubic feet

(one cubic foot = 7.5 gallons)

volume = 25,120 x 7.5 = 188,400 gallons

4.2.4 Given data, calculate a sludge recirculation rate in GPM.

Given:
Digester volume = 300,000 gallons
Recirculation = digester volume once per day

Formula:

flow rate = volume ÷ time

flow rate = 300,000 gallons ÷ (24 hours/day x 60 min/hours)

flow rate = 300,000 ÷ 1,440

flow rate = 208 GPM

4.2.5 Given data calculate the volume (gallons) of sludge pumped from a piston pump.

Given:
Gallons pumped per stroke = 3 gallons
Number of strokes per minute = 40
Number of minutes pumping = 20 minutes

Formula:

volume pumped = gallons/stroke x number of strokes/min. x time

volume pumped = 3 x 40 x 20

volume pumped = 2,400 gallons

4.2.6 Given data calculate the change in volume (gallons) when the sludge concentration changes.

Given:
Initial sludge volume = 1,200 gallons
Initial sludge concentration = 4%
Thickened sludge concentration = 6%

Formula:

$C1V1 = C2V2$

$1{,}200 \times 4 = 6 \times V2$

$V2 = (1{,}200 \times 4) \div 6$

V2 = 800 gallons

References and Resources

1. **ADVANCED WASTE TREATMENT.**

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2. **ANAEROBIC SLUDGE DIGESTION.**

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3. **CONTROLLING WASTEWATER TREATMENT PROCESSES.**

   (1984). Cortinovis, Dan. Ridgeline Press, 1136 Orchard Road, Lafayette, CA 94549.

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5. **OPERATION OF WASTEWATER TREATMENT PLANTS.**

   3rd Edition (1990), Volumes 1 and 2, Kenneth D. Kerri, California State University, 6000 J Street, Sacramento, CA 95819-6025. Phone (916) 278-6142.

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   Manual of Practice No. 11 (MOP 11) (1976). Water Pollutions Control Federation, 601 Wythe Street, Alexandria, VA 22314-1994. Phone (800) 666-0206. (Probably Out-of-Print, See Reference Number 4)

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