Wisconsin Department of Natural Resources
Wastewater Operator Certification

Biological Solids and Sludges – Handling, Processing, and Reuse Study Guide

Subclass C

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Preface

The Biological Solids and Sludges – Handling, Processing, and Reuse Study Guide is an important resource for preparing for the certification exam and is arranged by chapters and sections. Each section consists of key knowledges of important informational concepts needed to know for the certification exam. This study guide also serves as a wastewater treatment plant operations primer that can be used as a reference on the subject. Any diagrams, pictures, or references included in this study guide are included for informational/educational purposes and do not constitute endorsement of any sources by the Wisconsin Department of Natural Resources.

Preparing for the exams:
1. Study the material! Read every key knowledge until the concept is fully understood and known to memory.

2. Learn with others! Take classes in this type of wastewater operations to improve understanding and knowledge of the subject.

3. Learn even more! For an even greater understanding and knowledge of the subjects, read and review the references listed at the end of the study guide.

Knowledge of the study guide material will be tested using a multiple choice format. Every test question and answer comes directly from one of the key knowledges.

Choosing a test date:
Before choosing a test date, consider the time had to thoroughly study the guides and the training opportunities available. A listing of wastewater training opportunities and exam dates is available at http://dnr.wi.gov by searching for the keywords “Operator Certification”.

Acknowledgements

The Biological Solids and Sludges – Handling, Processing, and Reuse Study Guide was the result of a collaborative effort of yearlong monthly meetings of wastewater operators, trainers, consultants, the Wisconsin Wastewater Operator Association (WWOA), and the Wisconsin Department of Natural Resources (WDNR). This study guide was developed as the result of the knowledge and collective work of following workgroup members:

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Chapter 1 - Theory and Principles

Section 1.1 - Definitions

1.1.1 Define aerobic digestion.

Aerobic digestion is the biochemical decomposition of organic matter in wastewater treatment sludge into carbon dioxide and water by microorganisms in the presence of oxygen.

1.1.2 Define alkalinity.

Alkalinity is the ability of the wastewater to neutralize acid without effect on the pH and is measured as the calcium carbonate equivalent in mg/L.

1.1.3 Define anaerobic digestion.

Anaerobic digestion is the biochemical decomposition of organic matter in wastewater treatment sludge into methane gas and carbon dioxide by microorganisms in the absence of oxygen.

1.1.4 Define biosolids or sludge.

Wastewater sludge, sludge, or biosolids means the solids, semi-solids, or liquid residue generated during the treatment of wastewater in a treatment works.

1.1.5 Define digester buffering capacity.

Digester buffering capacity is the ability of an anaerobic digester to resist pH changes and is indicated by alkalinity.

1.1.6 Define mesophilic bacteria.

Mesophilic bacteria grow and thrive in an anaerobic digester temperature range of 85°F to 100°F (30°C to 38°C).

1.1.7 Define pathogens.

Pathogens are disease-causing organisms. This includes, but is not limited to, certain bacteria, protozoa, viruses, salmonella, and viable helminth ova.

1.1.8 Define pathogen control.

Pathogen control is the use of approved sludge treatment processes or using a combination of sludge treatment processes and land application site restrictions and crop restrictions that reduce exposure to the pathogens in the biosolids and allow time for the environment to reduce the pathogens to safe levels.

1.1.9 Define sludge conditioning.

Sludge conditioning is the treatment of liquid sludge before thickening or dewatering to facilitate the separation of solids and liquids by neutralizing the electrical charges of the fine particles and enhance drainability, usually by the addition of chemicals. These chemicals clump smaller particles together to form larger particles.

1.1.10 Describe what is meant by a sour digester.

A sour digester is a digester that has become upset and is performing poorly. It is characterized by low gas production, high volatile acids to alkalinity (VA/ALK) ratio, and often a low pH. It's often caused by excessive organic loading, but can be affected by low temperatures and toxicity.

1.1.11 Define thermophilic bacteria.

Thermophilic bacteria grow and thrive in an anaerobic digester temperature range of 120°F to 135°F (49°C to 57°C).

1.1.12 Define total solids.

Total solids are the sum of dissolved and suspended solid constituents in water or wastewater. For more information, see Standard Methods (method number 2540 B).

1.1.13 Define treatment facility overflow (TFO).

A TFO is a release of wastewater, other than through permitted outfalls, from a wastewater facility into a water of the state or the land surface. All TFOs must be reported to the Department of Natural Resources within 24 hours of the occurrence.

1.1.14 Define vector attraction.

Vector attraction is the characteristics of sludge that draw rodents, flies, mosquitos, or other organisms capable of transporting infectious agents.

1.1.15 Define vector attraction reduction.

Vector attraction reduction is the use of prescribed processes including treatment and/or barrier methods to reduce the spread of pathogens by birds, insects, rodents, and other disease carriers when land applying sludge.

1.1.16 Define volatile solids.

Volatile solids are primarily organic componds, that can be driven off from a dried sample by heating at 550°C (1,022°F); nonvolatile inorganic solids (ash) remain. For more information, see Standard Methods (method number 2540 G). Compounds that are destroyed in the heating process, but not readily biodegradable include: carbonates, polysaccharides, hemicellulose, and cellulose.

Section 1.2 - Microbiological Principles

1.2.1 Describe the purpose of and list the common biosolids and sludge treatment processes.

The purpose of sludge treatment is to reduce organic content (stabilizing the sludge) and pathogenic organisms, allowing for beneficial reuse while protecting public health and the environment. Treated, or stable, sludge has less odor (reducing vector attraction), good dewatering properties, and is more publicly acceptable.

A. Most common treatment processes
  1. Aerobic digestion

2. Anaerobic digestion

B. Other treatment processes
1. Composting
2. Lime stabilization
3. Pasteurization
4. Heat drying

1.2.2 Describe how anaerobic digesters work.

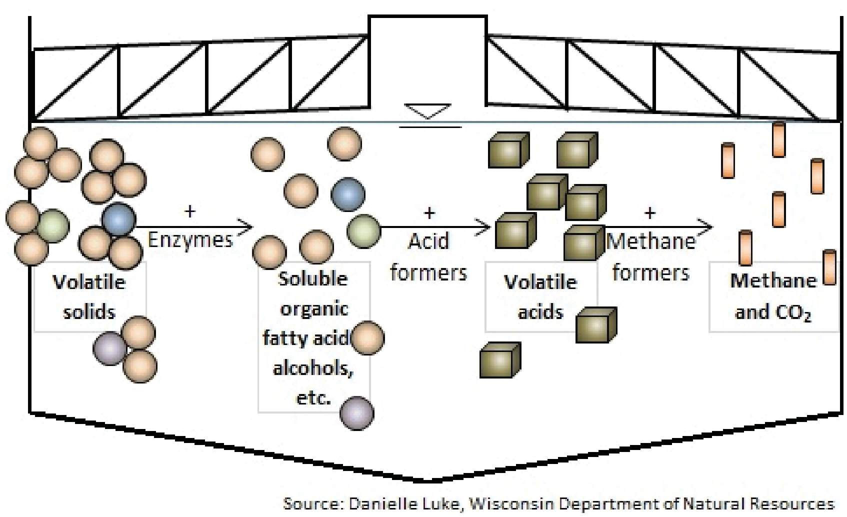
Anaerobic digesters utilize microorganisms without oxygen to digest the remaining organic material in wasted sludge from the liquid primary and secondary treatment processes. The process generates methane gas that can be recovered and used as an energy source in the treatment facility. Most medium to large facilities include both primary and secondary digesters. Primary digesters are mixed, heated and typically provide most of the stabilization, methane gas production and pathogen reduction. Secondary digesters often serve as a component of storage for digested sludge, a standby primary tank, and source of seed sludge and also may be used as a quiescent basin for supernatant withdrawal.

1.2.3 Explain the process where waste entering an anaerobic digester is converted to methane, sludge, and water.

The volatile (organic) solids in the feed sludge are used as food by the bacteria in the digester. Bacteria release extracellular enzymes (enzymes located outside of the bacteria cell) to break down solid complex compounds, cellulose, proteins, etc. into soluble organic fatty acids, alcohols, carbon dioxide, and ammonia.

Acid-forming bacteria convert the products of the first stage into acetic acid, propionic acid, hydrogen, carbon dioxide, and other compounds. Methane-forming bacteria convert the acetate and other volatile acids into methane and carbon dioxide.

Figure 1.2.3.1



1.2.4 Describe aerobic digestion process.

Aerobic digestion is aerobic sludge stabilization, through endogenous respiration.

Aerobic and facultative microorganisms use oxygen and obtain energy from available biodegradable organic matter in the waste sludge, thus stabilizing the sludge and reducing pathogens. When the available food supply in the waste is inadequate, the microorganisms begin to consume their own protoplasm to obtain energy. Eventually, the cells will undergo lysis, which will release degradable organic matter for use by the other microorganisms. The end product of aerobic digestion typically is carbon dioxide, water, and 'nondegradable' materials including polysaccharides, hemicellulose, and cellulose.

Aerobic digesters are operated as a single tank or two tanks in series. The operation of the digesters in series is likely to further reduce the specific oxygen uptake rate (SOUR) in the resulting product.

1.2.5 Describe the environmental factors that influence the health and growth of anaerobic microorganisms.

A. Food
The acid-forming bacteria require volatile solids found in the influent sludge as a food source to produce volatile acids, which the methane-forming bacteria use as a food source. In a stable digester, the volatile acids are used at the same rate they are produced.

B. Temperature
Methane-forming bacteria are more sensitive than acid-forming bacteria and cannot withstand a temperature change greater than 1°F (0.8°C) per day. Maintaining a mesophilic or thermophilic temperature without fluctuation is important to keep the methane-formers stable, especially in colder temperatures.

C. pH
The pH of an anaerobic digester will not fluctuate when running in good condition and will stay in the range of 6.8 to 7.2.

D. Volatile acid
The volatile acids in a well-operating digester will be between 50 and 500 mg/L and will stay in this range as long as the methane-forming bacteria are kept in a stable environment.

E. Alkalinity
The alkalinity is an indication of the digester’s buffering capacity (measured as acetic acid) and in a well-operating digester will be between 2,000 and 3,000 mg/L.

F. Toxicity
Some toxic concerns in an anaerobic digester are heavy metals and sulfides. Although the bacteria can handle small concentrations of these toxic substances, anything substantial will require action. Keeping a digester well mixed will eliminate small concentrated areas of toxins.

1.2.6 Describe the environmental factors that influence the health and growth of aerobic microorganisms.

A. Food

Aerobic bacteria use volatile solids in the influent sludge as a food source. The typical organic loading rate for an aerobic digester is 0.02 to 0.14 lbs of volatile solids/day/ft^3.

B. Dissolved oxygen (DO)
Oxygen is critical to the performance of aerobic bacteria. The typical DO level in an aerobic digester is 0.5 to 2.0 mg/L.

C. Temperature
The temperature in an aerobic digester is normally not controlled, but should be monitored. The temperature should be kept above 50°F (10°C); anything below will lower the bacterial activity, lower pathogen reduction, and render the process ineffective.

D. pH
The normal operating range for an aerobic digester is a pH of 6.0 to 7.6.

E. Toxicity
Heavy metals and sulfides are toxic to the aerobic bacteria, inhibiting performance or, in significant concentrations, causing bacteria to die off.

Section 1.3 - Mechanical Processing

1.3.1 Compare the sources and characteristics of primary and secondary biosolids and sludges.

Primary sludges are the solids that settle out of the raw wastewater in the primary clarifiers. The primary sludges are usually fairly coarse with a specific gravity (density) significantly greater than water, allowing for rapid settling. Primary sludges are typical 60% to 80% volatile solids (organic), varying depending on the raw wastewater characteristics. Primary sludge is odorous and requires additional treatment prior to ultimate disposal.

Secondary sludges are solids generated as a part of the secondary treatment process and settle out in the final clarifiers. These sludges are mainly composed of the microorganisms generated in the secondary process (activated sludge or fixed-film systems). Excess sludge amounts must be removed to keep the secondary system in balance. Secondary sludges are more flocculent, with a specific gravity (density) very close to water making them more difficult to settle than primary sludges. Secondary sludges are 75% to 80% volatile solids (organic) and contain bound water in the cells of the microorganism, making them difficult to dewater or thicken; although chemical additions can be used to enhance dewatering. The higher the volatile solids (organics) content, the more difficult the sludge is to dewater.

Both primary and secondary sludges should be as concentrated as possible with proper operation of clarifiers. At times, additional thickening is used to reduce the amount of water and volume loading on subsequent sludge treatment processes.

1.3.2 Describe the relationship of the sludge blanket depth in a clarifier to pumping rates while under routine operating conditions.

A high blanket would indicate not enough sludge is being pumped. A low blanket would indicate too much sludge is being pumped. Pumping too quickly will create coning in the sludge blanket where the sludge blanket is deeper on the outer edges and thinning as the blanket nears the center.

1.3.3 Discuss the purposes of mechanical sludge processing.

The main purpose of mechanical sludge processing is to reduce the amount of water in the sludge, reducing the volume of material to be handled, stored, or transported. This reduction in volume represents a cost-saving to the facility.

1.3.4 Discuss the pumping of sludge at various solids concentrations.

Thinner sludges can be pumped with a centrifugal pump or double-disk diaphragm pump. Positive displacement pumps (piston, diaphragm, progressive cavity, and rotary lobe) are used to pump sludges up to 10% (100,000 mg/L). For questions regarding the best pumps to use based on sludge solids percentages and characteristics refer to a consultant.

Chapter 2 - Operation and Maintenance

Section 2.1 - Definitions

2.1.1 Define polymers.

Polymers are long molecular chains made of carbon and hydrogen used to aid sludge thickening and dewatering by clumping small sludge particles into larger particles (flocculation). Polymers are available as cationic and anionic, cationic being the most commonly used. The normal floc particle charge is negative. For a polymer to be effective it must have the opposite charge of the floc particle. The operator should work with the facilities polymer vendor to determine the most effective polymer to use, proper dilution, and mixing procedures.

2.1.2 Define siloxane.

Siloxanes are volatile organic chemicals containing silicon that are found in many personal care products, such as shampoos, hair conditioners, deodorants, and cosmetics.

Section 2.2 - Thickening Methods, Equipment, and Maintenance

2.2.1 Discuss the thickening of biosolids and sludges.

The purpose of sludge thickening is to further concentrate and thicken solids settled and wasted from treatment plant processes. In the treatment of wastewater, solids from the primary and secondary treatment processes can range from 0.5% to 5.0% suspended solids. Sludge thickening typically concentrates solids to 3.0% to 6.0%, allowing for further handling and processing (such as digestion).

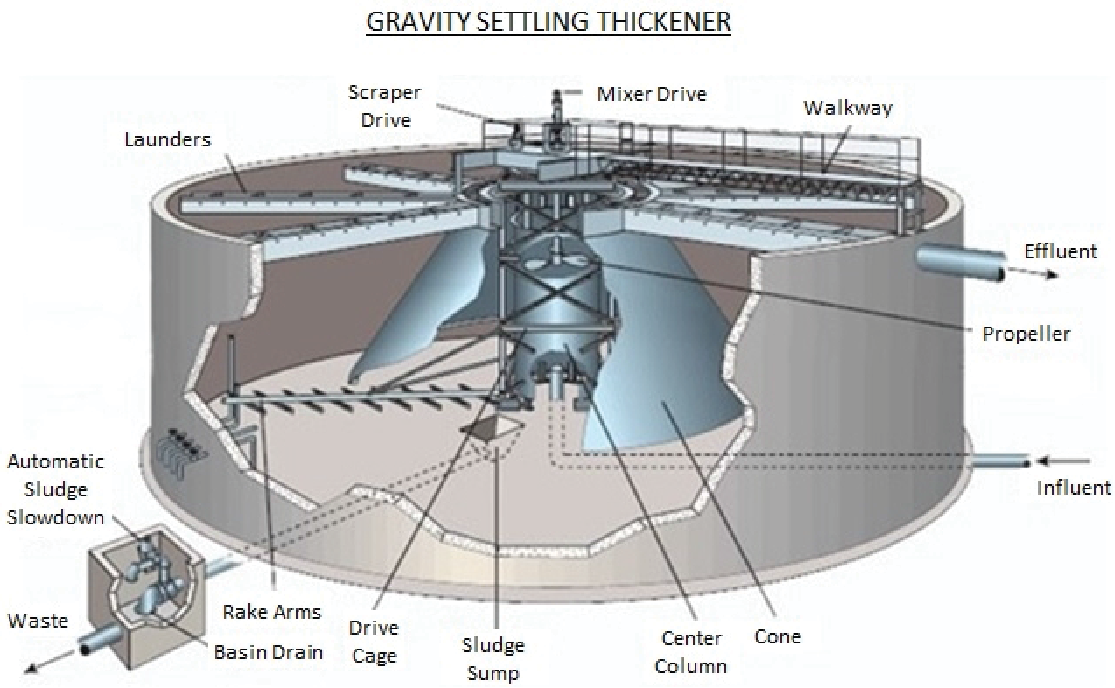
Sludge thickening most commonly consists of gravity thickeners, gravity belt thickeners (GBT), rotary drum thickeners, or dissolved air flotation (DAF). A polymer can be added and used to enhance thickening. Plants with aerobic digesters simply thicken their sludge by turning off the air for a short time, allowing the sludge to settle, and thicken by decanting the clear liquid off the tank.

2.2.2 Describe gravity thickeners.

Gravity thickening takes place in a circular tank with collectors or scrapers at the bottom.

Primary and/or secondary biosolids are fed into the tank through a center well near the surface. Solids settle to the bottom of the tank by gravity and the scrapers slowly move the settled (thickened) solids to a discharge pipe at the bottom of the tank. Relatively clear water overflows the launders and is returned to the head of the plant. Polymer addition can enhance performance.

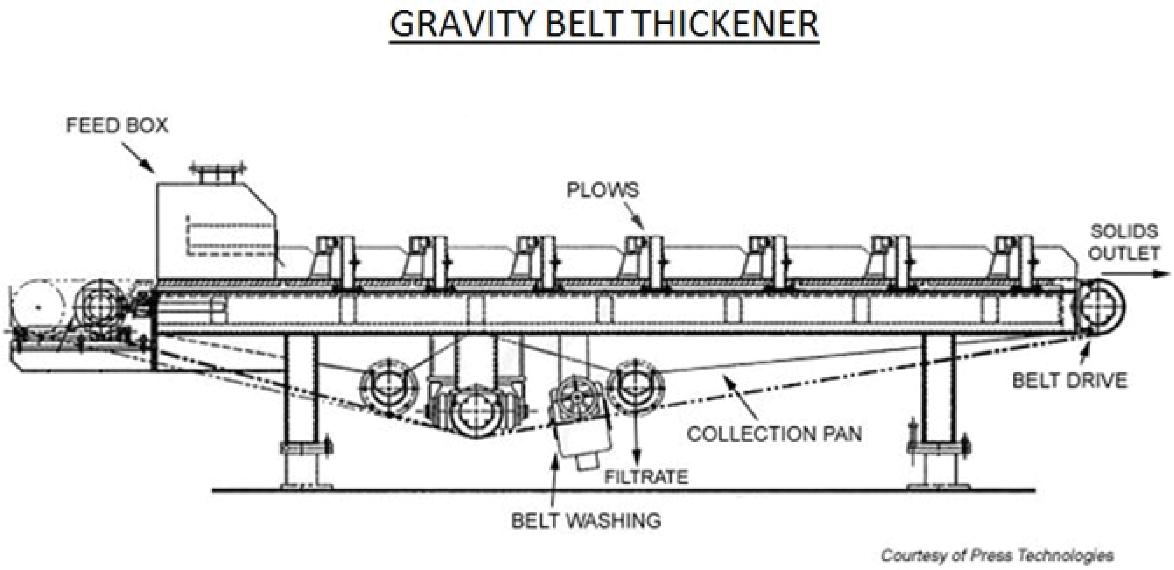
Figure 2.2.2.1



2.2.3 Describe gravity belt thickeners (GBT).

A GBT consists of a wide porous belt rotating between two top rollers. The sludge is mixed with polymer and then fed onto the top of the belt. Water drains through the belt as it travels horizontally between the rollers. Drainage is enhanced by plows that roll the sludge. The thickened sludge falls off the belt as it goes over the end roller.

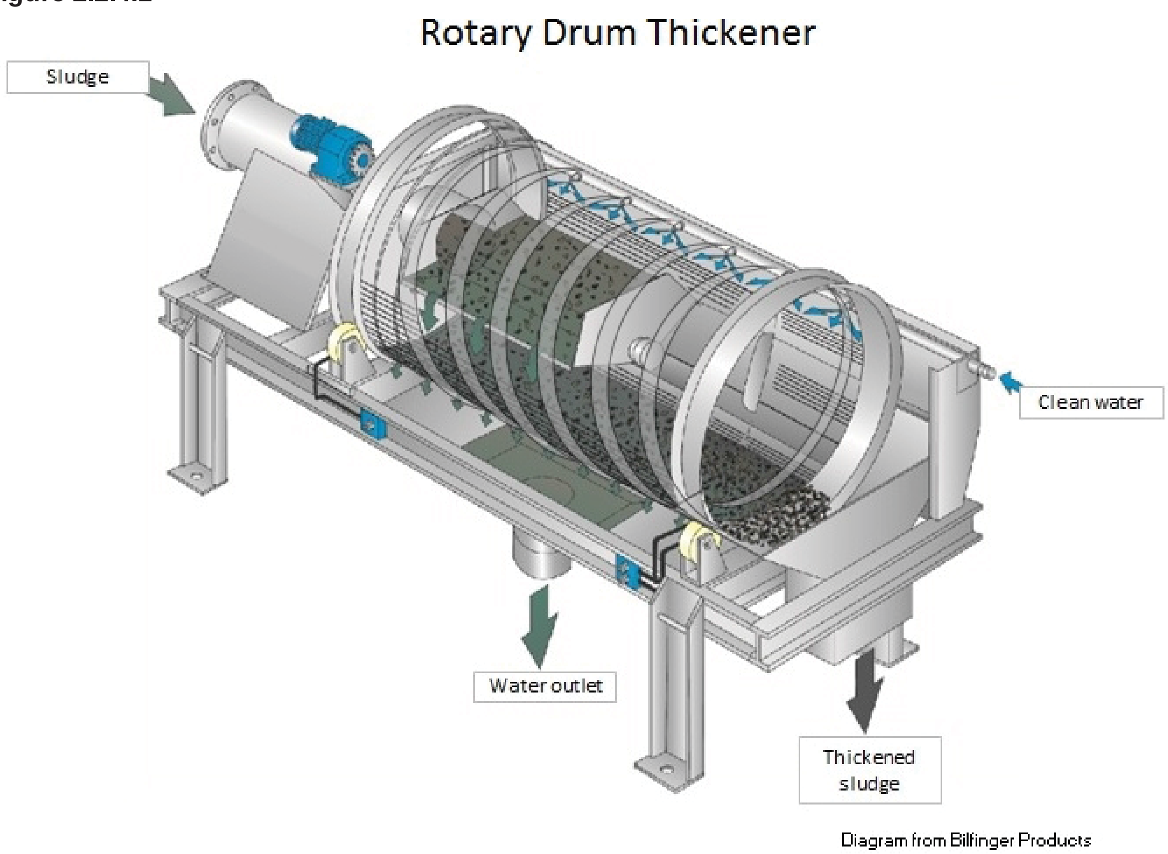
Figure 2.2.3.1



2.2.4 Describe rotary drum thickeners.

Sludge is fed into a horizontal sieve drum, water drains through the drum, and the solids stay on the inside. As the drum rotates, an internal screw pushes the thickened sludge to the discharge chute.

Figure 2.2.4.1

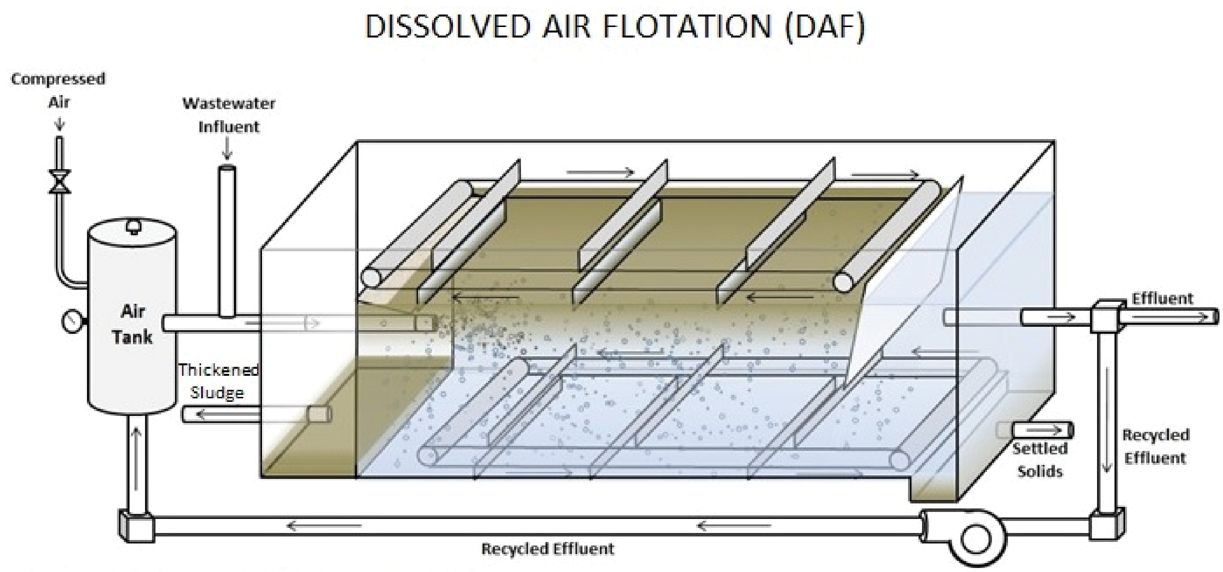


2.2.5 Describe dissolved air flotation (DAF).

The purpose of DAF in the solids treatment train is to thicken secondary sludge, which is often less than 1% solid. The sludge is mixed with air-enriched water as it enters the DAF tank. Small air bubbles attach to solid particles and float them to the surface. The solids form a floating blanket, which is skimmed off the surface. This thickened sludge is generally 3% to 7% solids.

The clear water flows under a baffle and out of the DAF tank. Some of the clear water is recycled and injected with air under pressure. This air-enriched water is mixed with the feed sludge as it enters the DAF tank.

Figure 2.2.5.1



Source: Danielle Luke, Department of Natural Resources

2.2.6 State the importance of sludge blanket depth measurements in gravity thickening.

Routine monitoring of the gravity thickener sludge blanket depth and, in correlation with the solids concentration, is an important operating parameter. If the sludge blanket is too low, the operator can expect the solids concentration will also be lower than desired. An excessively high sludge blanket may cause difficulty in sludge pumping due to high percent solids and generation of odors especially during warmer weather.

2.2.7 Explain the importance of the proper start-up of a positive displacement pump.

Positive displacement pump systems can be damaged if flow through the system is prevented by a closed line valve or lack of liquid in the system. Positive displacement pumps can be damaged if run without liquid or against closed valves. Pipe damage can occur with a closed discharge valve if discharge pressure exceeds pipe rated pressure.

2.2.8 Describe a preventative maintenance system for sludge handling equipment.

A. Inventory and label all equipment
B. Use O&M manuals for preventative maintenance tasks and frequencies
C. Establish a preventative maintenance record keeping system for maintenance

schedules and history of repairs and maintenance for each piece of equipment
D. Establish a follow-up system to ensure maintenance is performed
E. Have a spare parts inventory

Section 2.3 - Anaerobic Treatment Methods, Equipment, and Maintenance

2.3.1 List the benefits associated with anaerobic digestion.

A. Production of methane gas for energy recovery
B. Reduces sludge mass by destruction of volatile solids
C. Digested sludge has less odor
D. Reduces pathogens

2.3.2 List some of the key factors relating to optimal operation of an anaerobic digester.

A. Organic loading rate (OLR)
B. Volatile acid/alkalinity ratio (VA/ALK)
C. Temperature
D. Mixing or recirculation
E. Solids retention time (SRT)
F. pH
G. Grit and scum blanket
H. Toxicity

2.3.3 Discuss the hydraulic retention time (HRT) needed in an anaerobic digester to achieve adequate sludge treatment.

The HRT, or detention time, is defined as the time that a sludge particle remains within the anaerobic digester. Volatile solids percent reduction is directly related to the HRT. As the HRT increases, so does the volatile solids percent reduction. For an anaerobic digester operating at 95°F to 100°F (35°C to 38°C), the design HRT is 15 days. A short HRT (less than 15 days) may result in low volatile solids reduction (less than 38%) and high fecal coliform values (greater than 2,000,000 colony forming units (cfu)/gram), preventing the digested sludge from being classified as a Class B biosolids.

2.3.4 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 and solids separation), drawing off the supernatant, and gas storage.

2.3.5 Describe the temperature ranges commonly maintained in anaerobic digesters and the importance of maintaining stable temperatures.

Most conventional anaerobic digesters in Wisconsin operate at the mesophilic temperature range, normally operating between 90°F and 100°F (32°C and 38°C). The contents should be not changed by more than 1°F (0.6°C) per day to allow the bacteria time to adjust. The temperature sensitivity of the digester's microorganisms are the reason to consider daily logging temperatures and make sure the sludge-heating equipment is maintained to ensure reliable operations and temperature control.

2.3.6 List the areas to check or monitor in an anaerobic digester during winter months.

A. Sludge thickening processes and feed sludge solids concentration, to insure digester feed is properly thickened

B. Heat exchanger water input and output temperatures to identify if there is an issue with the heating boiler or the heat exchanger

C. Heat exchanger sludge input and output temperatures to identify if there is an issue with the heat exchanger heat transfer

2.3.7 Discuss anaerobic digester gas composition and impurity control.

The digester gas production volume is an indicator of the overall condition of the digester system. Gas production volume is a function of the organic loading and the conditions in the digester that can impact gas production such as temperature, mixing, toxicity, etc.

A. Methane
Methane is typically 60% to 64% of the digester gas produced and is the component that impacts the fuel value of biogas. Methane is combustible at 56%, but is not usable as a fuel until it reaches 62%. When digester gas is mixed with air and the methane concentration is in the 5% to 20% range, it is explosive.

B. Carbon dioxide
Carbon dioxide is typically 35% to 40% of the digester gas produced and, when in digester gas, dilutes the energy value (British thermal units or btu). This is the reason why the fuel value of anaerobic digester gas is approximately 600 btu compared to natural gas which is approximately 1,000 btu. The removal of carbon dioxide is typically not done, but can be achieved with membrane permeation, chemical scrubbing, or carbon sieves.

C. Moisture
Water vapor in the digester gas condenses; resulting in water accumulations in piping that must be removed. It will also react with hydrogen sulfide, creating corrosive liquid affecting the equipment. The moisture condensed from digester gas as it cools can be removed through drip traps. The condensation process can be accelerated with a gas-drying (refrigeration) system.

D. Hydrogen sulfide
Hydrogen sulfide is the corrosive component of digester gas, which reacts with water to form acids and is lethal at concentrations above 700 parts per million (ppm). Hydrogen sulfide is often removed with an iron sponge that treats the gas by passing it through a permeable bed of hydrated ferric chloride-dipped chips soaked in water.

E. Siloxane
When burned in equipment utilizing digester gas, siloxanes create an abrasive fine silicon dioxide deposit which damages the equipment. Gas drying (to a dew point of -10°F to -20°F or -23°C to -29°C) can remove a significant amount of siloxanes with moisture when the gas is dried. Siloxane can also be removed by passing the gas through an activated-

carbon vessel.

2.3.8 Explain how to use the quantity of gas produced as an indicator of digester performance.

Gas production is a function of biodegradable organic matter fed to the digester and the digestion of that material to produce methane. The common range of gas production is between 7 to 12 ft^3/lb of volatile matter destroyed.

Incremental increases in volatile matter should increase gas production and decreasing volatile matter should decrease gas production. Toxic chemicals, temperature changes, increases in the volatile acid to alkalinity ratio, or pH changes are likely to decrease gas production.

2.3.9 Discuss the supernatant removal strategies for secondary digesters.

Supernatant removal thickens the sludge in the digester and can provide additional detention time for the solids in secondary digesters. Take supernatant samples at different levels to find the cleanest layer. This layer can then be decanted.

Take care not to create a vacuum. A vacuum can damage the digester cover or allow air to be sucked into the digester creating an explosive atmosphere when mixed with the methane gas. A vacuum could be created with a floating cover by decanting while the cover is resting on the corbels.

2.3.10 Show and explain the parts of an anaerobic digester gas handling equipment (actual parts and configuration at each treatment plant may vary).

A. Foam separator
A foam separator immediately downstream of the digester will prevent foam from entering the biogas stream where it can clog gas-handling equipment. When foam clogs the flame arresters, it may prevent the pressure and vacuum relief valves from properly working causing damage to digesters and the digester roof.

B. Sediment and drip trap assembly
Biogas is saturated when it leaves the digester. To protect downstream equipment and not impede gas flow, moisture and sediment should be removed. A sediment trap with drip trap should be located downstream of the digester.

C. Pressure vacuum relief valves
These devices relieve excess pressure or vacuum to prevent structural damage to the digester due to a pressure buildup or vacuum and are typically installed on the digester cover. The pressure release valve relieves excessive pressures so the water seal will not be blown. Similarly, the vacuum relief valve relieves excessive vacuum pressure so the digester cover won't collapse. Operation of these valves is not desirable because if the pressure relief valve opens, air and gas can mix creating explosive conditions outside the tank and if the vacuum relief valve opens, it may create an explosive condition inside the tank.

D. Gas pressure regulators

Pressure regulators are installed next to the waste gas burner or at various points in the system to regulate the gas pressure to boilers, heaters, and engines. They maintain a constant pressure at the point of use.

E. Flame trap or arrestor

Flame arrestors prevent a fire from moving backwards through the piping and reaching digester gas. Flame arrestors are installed between vacuum and pressure relieve valves and the cover, after sediment traps, at the waste burner, and before boilers, furnace or flame. They typically are a box shape holding many plates or baffles that gas could flow through with little loss in pressure, but if a flame would develop it would be cooled below the ignition point as it passes through the baffles.

F. Gas purifier

A gas purifier typically isn't necessary if the gas is to be burned in a boiler or high-temperature internal combustion engine. However, if the gas is used as a natural gas substitute, fuel to run electrical turbines, or sell for other uses, then a gas purifier may be necessary beyond sedimentation and condensate drip traps. Gas purifiers would normally be installed upstream of the boilers, compressors, or engine generators and often designed to remove highly corrosive hydrogen sulfide and siloxanes; also used to control sulfur emissions and odors.

G. Check valves

Check valves allow flow in one direction only. In anaerobic digesters, these valves are installed to prevent flow of higher pressure gas back to the digester.

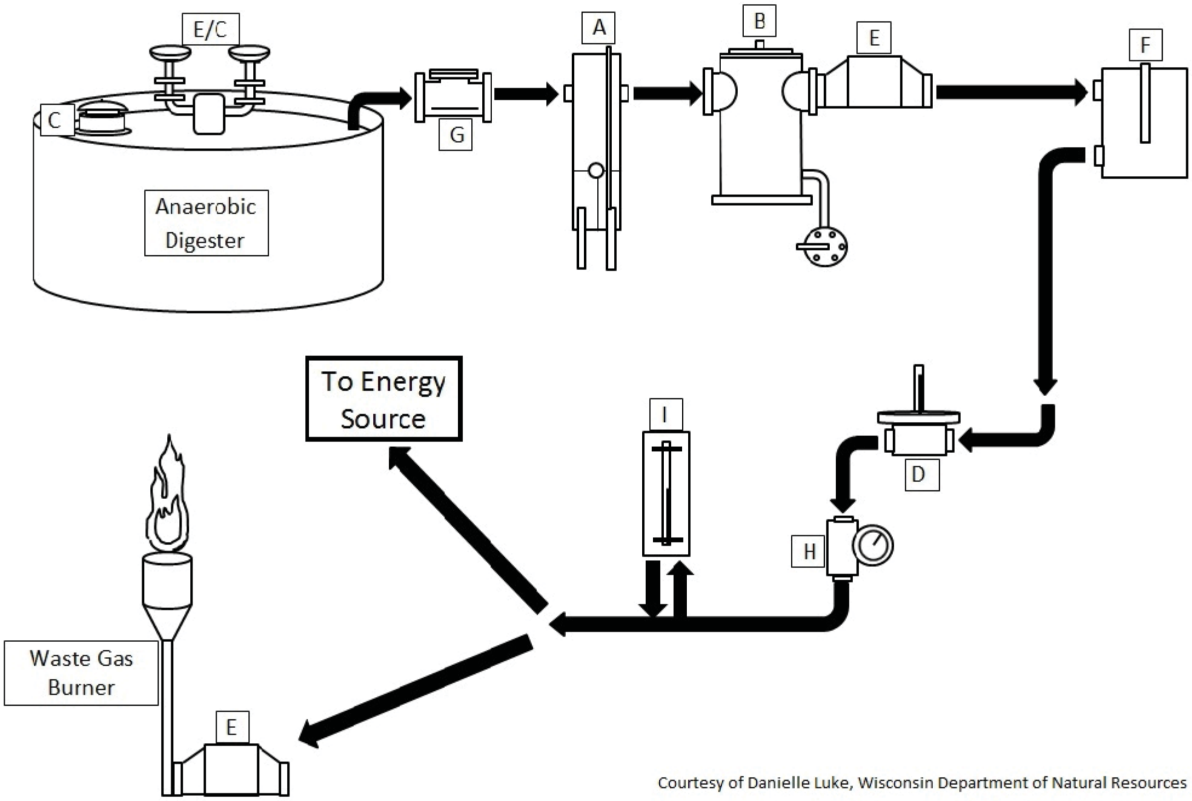
H. Gas meters

Gas meters are used to measure the output of gas production which is often an indicator of digester performance and may alert plant operators to process malfunctions and gas leaks. Types of meters may be positive displacement, thermal-dispersion inserts, pressure-differential orifices, and/or venturis.

I. Manometer

Manometers are low-pressure meters installed at several locations to monitor gas pressure within the system. They are a u-shaped glass columns containing a liquid, usually water. The pressure is read in inches of water column. A typical digester has a gas pressure manometer reading of 6 to 12 inches of water.

Figure 2.3.10.1



2.3.11 List and describe the types of anaerobic digester covers.

Anaerobic digesters are always covered. Four types of covers are used.

A. Fixed cover

In a fixed-cover digester, the cover remains in a fixed position, supported by framework connected to the top of the wall. Fixed-cover digesters require operator attention to liquid levels to maintain the gas seal or avoid overflowing the sludge into the gas removal piping. It's important to monitor digester gas pressure for identifying a vacuum or over-pressurization condition. The gas is kept in a limited space above the liquid surface and held by the cover. The excess gas not kept under the cover is typically kept in a separate gas storage.

B. Floating covers

A floating cover floats directly on the liquid surface and is supported by a system of roller bearings and guide rails that help prevent the cover from tipping. Like the fixed cover, there is limited space for gas under the cover and the excess gas is kept in separate gas storage.

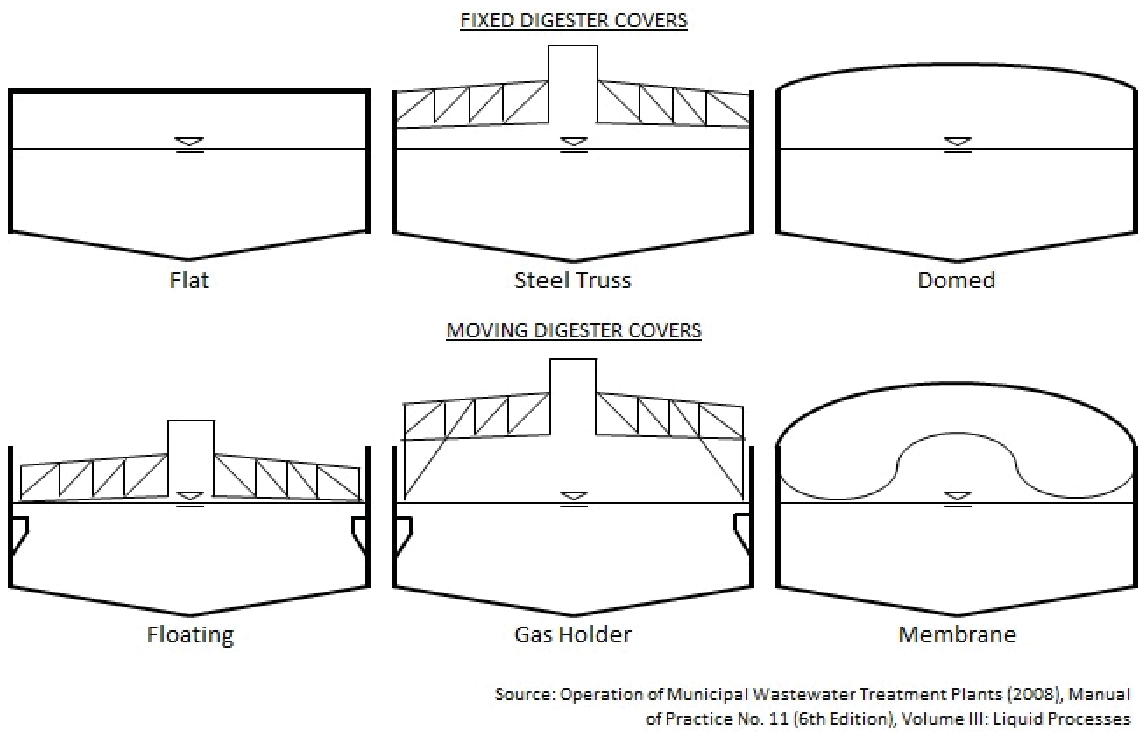
C. Gas-holder covers

The gas-holder covers are similar to floating covers, but they are designed to accommodate gas storage. As gas pressure in the system rises, the cover will rise to provide additional storage capacity.

D. Membrane covers
The membrane cover consists of 2 membranes. A blower system inflates the outer fixed membrane. The membrane is inflated and deflated in response to the volume of gas in the digester or tank head-space.

Fixed, floating, and gas-holder covers all contain a skirt for maintaining a water seal.

Figure 2.3.11.1



2.3.12 Describe a floating cover, gas-holder cover, corbel, and the importance of the position indicator.

A free-floating digester cover provides proper gas pressure. A cover position indicator is a dial, staff gauge, or other device that lets the operator know whether the cover is within its limits of travel. Corbels keep the digester cover from dropping beyond a certain point, protecting the internal equipment from damage if sludge is withdrawn below the designed operating range. If the cover position is too low, the cover will be resting on the corbels and gas pressure will be reduced. If the cover position exceeds the upper range of travel, over pressurization can occur. An alarm system is normally provided to prevent problems with either a high- or low-level cover positions.

2.3.13 List three types of digester mixing systems.

A. Mechanical impellers or mixers
B. Compressed digester gas mixing
C. Sludge recirculation

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

A. Pump sludge
1. Centrifugal
2. Progressive cavity
3. Diaphragm
4. Rotary lobe

B. Recirculate sludge
1. Centrifugal (most common)
2. Progressive cavity
3. Rotary lobe

For further information about these types of pumps refer to the Wisconsin DNR General Wastewater Study Guide.

2.3.15 Describe the two methods of storing digester gas.

A. Gas-holder cover

A gas-holder cover is a digester cover very similar to a floating cover except with a much longer skirt. The gas-holder cover may be able to rise more than 6 ft above the minimum cover height. This type of cover provides much more volume for gas storage but has similar operating problems as a normal floating cover such as free movement up and down without binding and pressure or vacuum relief valves. Most gas stored in Wisconsin is under a cover.

B. Separate gas storage tank

Digester gas can be stored in a separate tank not part of the digester. Normally, digester gas is cleaned and compressed to increase pressure and reduce the volume of storage required. Gas storage tanks are often built as spheres, but other tankage configurations can be used.

2.3.16 Discuss the basic maintenance for equipment used to treat sludge.

Consult the O&M manual for the preventative maintenance tasks and scheduling of all equipment used to treat sludge. Improper maintenance can create more damage than no maintenance.

2.3.17 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, efficiency of grit removal, efficiency of mixing, tank structure and age, and condition of internal equipment. Cleaning should be done at about a 5 to 10 year interval.

2.3.18 Discuss procedures for complete digester cleaning.

Before beginning, the local DNR representative needs to be notified. The first consideration for complete digester cleaning is whether the work is to be done with plant personnel, to use an outside contractor specializing in this service, or a combination of both.

Depending on the type of system (single versus multiple digesters), it is necessary to determine how to handle raw sludge while the unit is down, the equipment necessary to accomplish the job, and how and where to dispose of digested sludge. Other advance planning would include accurate information and a supplier for all internal parts that may have to be replaced during the cleaning process.

The actual sequence of emptying and washing down the inside of the digester is dependent on the type of digester and the types of mixing, recirculation, and heating the unit has. Safety is the key, follow all proper safety procedures. In smaller communities, give consideration to using a contractor for digester cleaning as digester cleaning is not a routine operational activity.

2.3.19 List four reasons why anaerobic digester mixing is important.

A. Distributes the influent solids evenly throughout the digester (food, bacteria, solids, alkalinity, and volatile acid)
B. Maintains a constant temperature throughout the digester
C. Reduces scum buildup on the water surface and settled solids on the digester floor
D. Dilutes digester toxics or inhibitory substances

2.3.20 Describe other variations of the anaerobic digestion process.

A. Temperature-phased anaerobic digestion (TPAD)
TPAD is a treatment process that involves multiple stages of treatment including at least one thermophilic and one mesophilic. The thermophilic stage effectively reduces pathogens and volatile solids and is then followed by a mesophilic-polishing stage, which helps eliminate the odor and dewatering issues associated with thermophilic digestion. The Class A sludge pathogen reduction requirement can be met with the TPAD process if operated in a batch system. The additional heating requirements typically rely on the incoming sludge to be run through sludge heat exchangers.

B. Separate acid-phased and gas-phased
Separate acid-phased and gas-phased digestion is carried out in a two-reactor system to provide separate environments for the acid-forming and methane-forming bacteria. In the first (acid) phase, the feed substrates are hydrolyzed to produce volatile fatty acids (VFA). In the second (gas) phase, the VFAs are converted to methane and carbon dioxide. This process has been used to process difficult to digest solids, such as those with high concentrations of waste activated sludge (WAS) with less foaming.

C. Thermophilic digestion
In thermophilic digestion, the digester is operated to promote the type of bacteria that grow and thrive in the temperature range of 120°F to 135°F (49°C to 57°C). The primary goal of thermophilic digestion is pathogen destruction, increase volatile solids destruction, and reduced digester detention time. Thermophilic digestion does have problems with odor and dewaterability of the final sludge. The additional heating requirements typically rely on sludge heat exchangers to preheat the incoming sludge.

Section 2.4 - Aerobic Treatment Methods, Equipment, and Maintenance

2.4.1 List the advantages of aerobic digestion compared to anaerobic digestion.

A. Lower equipment costs
B. Simpler to operate
C. Fewer noxious odors
D. No hazardous gases
E. Fewer hazardous cleaning and repairing tasks

2.4.2 Describe how aerobic digesters work.

Aerobic digesters utilize microorganisms and oxygen to stabilize the remaining organic material in wasted sludge from the primary and secondary treatment processes. The detention time in an aerobic digester is sufficiently long enough to allow for most of the organic material to be consumed, resulting in a stabilized sludge. Aerobic digesters are similar to the activated sludge process except well-digested, stabilized sludge in the tanks is thicker and darker.

2.4.3 Describe the reasons to consider aerobic-anoxic operation of an aerobic digester.

A. Energy savings
Cycling off aeration equipment for periods of time during the day reduces the cost of aeration. The savings are increased if the equipment is turned off during peak power periods associated with the electric company billing.

B. Nitrogen removal
The aerobic process promotes nitrification (ammonia to nitrates), while the anoxic zone promotes denitrification (nitrate to nitrogen gas). Decant sidestreams returned back to the treatment process from the aerobic digester would then contain less ammonia, and more importantly less nitrites and nitrates. This is important for successful biological phosphorus removal.

C. Alkalinity/ pH control
Nitrification reduces alkalinity, while denitrification returns alkalinity to the process. The result is less issues associated with pH control in the digester. Decant sidestream pH and alkalinity returned back to the treatment process from the aerobic digester would then not be low.

2.4.4 Describe the equipment used for aerobic digestion.

A. Tank
The aerobic digester's tank is either rectangular or circular and below ground or insulated from the cold. The tanks may be covered to provide more protection from the cold.

B. Aeration system
The purpose of the aeration system is to supply oxygen to microbes and provide mixing. This can be either submerged air (usually coarse-bubble diffusers to avoid plugging), surface-mechanical aeration, or submerged-mechanical aeration.

C. Decant system

In the decant system, the aeration is turned off periodically (in many plants daily) to allow solids to settle and to then remove clear water from the surface. The decant process thickens the biosolids. The decanted waters are then run back through the treatment plant.

2.4.5 Describe the auto-thermal thermophilic aerobic digestion (ATAD) process.

ATAD is specialized aerobic process that subjects sludge to temperatures greater than 55°C (131°F) without external heat with a short retention time of 6 to 9 days. The reactors are insulated to conserve the heat produced from the biological degradation of organic solids by thermophilic bacteria. This process is capable of producing Class A biosolids.

Section 2.5 - Dewatering Methods, Equipment, and Maintenance

2.5.1 Discuss the dewatering of biosolids and sludges.

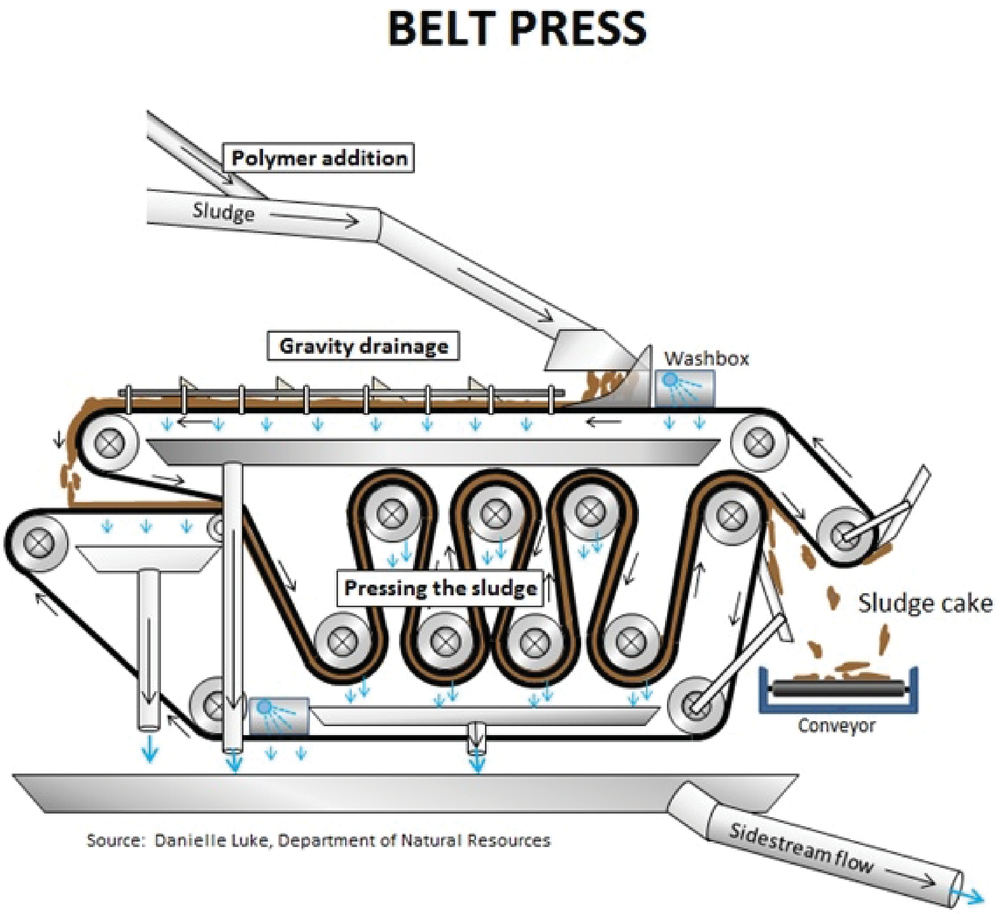
The purpose of dewatering sludge is to reduce the liquid content of the sludge. Dewatering reduces the sludge volume to be stored, transported, and landspread.

Equipment used for sludge dewatering include belt filter press, centrifuge, drying bed, and plate and frame press. Dewatered sludges are typically 15% to 30% solids and are referred to as sludge cake. Dewatered sludge can be shoveled, moved using belt conveyers, or transported in dump trucks.

2.5.2 Describe the belt press dewatering process.

Belt press dewatering involves three steps: polymer addition, gravity drainage, and pressing of the sludge. With a belt press, the dewatered sludge cake can have a solids concentration of 15% to 30%.

Figure 2.5.2.1



2.5.3 Describe the drying-bed dewatering process.

Sludge drying beds provide the simplest method of dewatering, however they may generate odors. The drying bed consists of a shallow layer of sand or gravel in a confined area where wet sludge is applied for draining and air drying. This process allows the sludge to have a solid concentration of 25% to 50%. The collected filtrate is sent back to the headworks for further wastewater treatment. The sludge is then removed with a small front-end loader or skid steer.

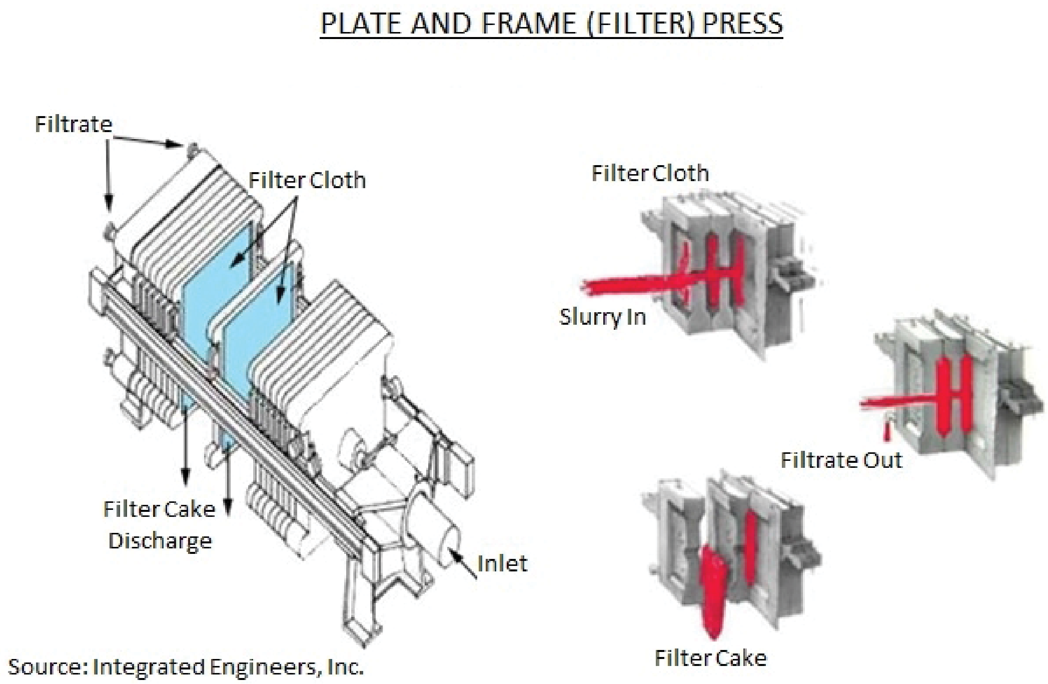
Figure 2.5.3.1

DRYING BED

2.5.4 Describe the plate and frame dewatering process.

The sludge conditioning process for the plate and frame press relies on the addition of inorganic chemical conditioning, such as ferric chloride and lime or quicklime or polymer. The conditioned sludge is pumped into the filter press through a center feed line. The plates have channels to allow the filtrate to be discharged through a filtrate line, while the cloth covering of the plate retains the solids. Municipal plate and frame presses produce up to a 30% sludge cake. Industrial sludges, however, can obtain up to a 50% sludge cake. Plate and frame presses are typically used in industrial applications.

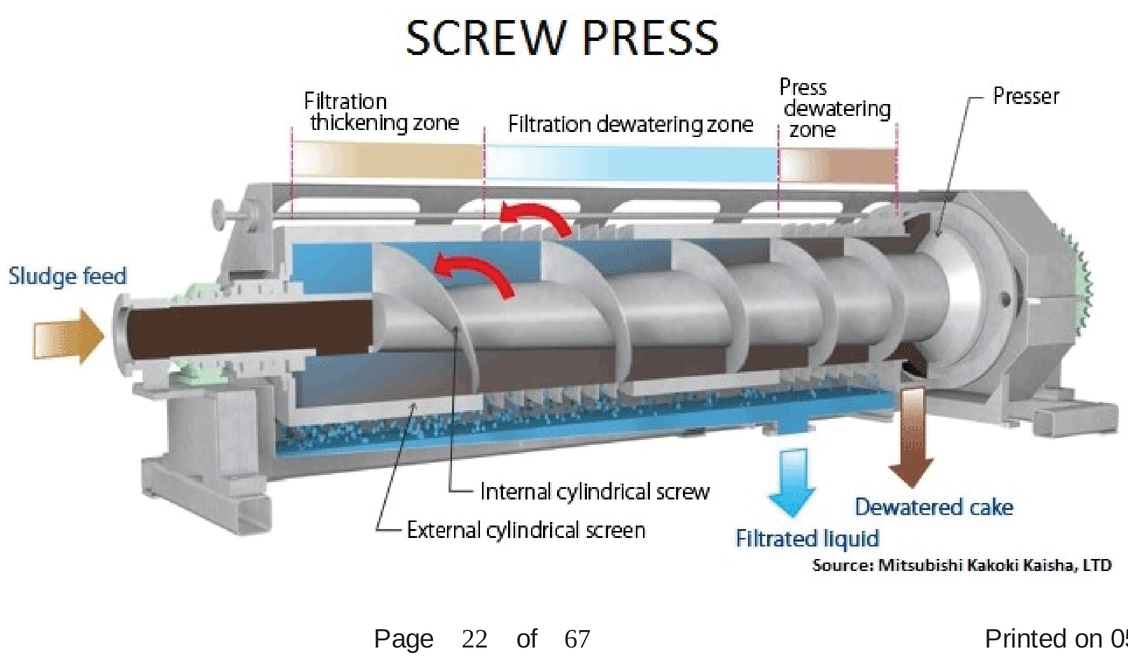
Figure 2.5.4.1



2.5.5 Describe the screw-press dewatering process.

Two types of screw presses are currently in use, horizontal and inclined at a 15° to 20° angle. A screw press consists of a slowly-rotating screw, wedge-wire or perforated-screen drum with very close tolerances to the screw, and a drum-cleaning method. Polymer conditioned sludge is initially dewatered by gravity drainage at the inlet section of the screw and then by squeezing free water out of the solids as they are conveyed to the discharge end of the screw under gradually increasing pressure and friction. The released water passes through the drum surrounding the screw while the solids are retained inside the drum and discharged opposite the inlet end.

Figure 2.5.5.1

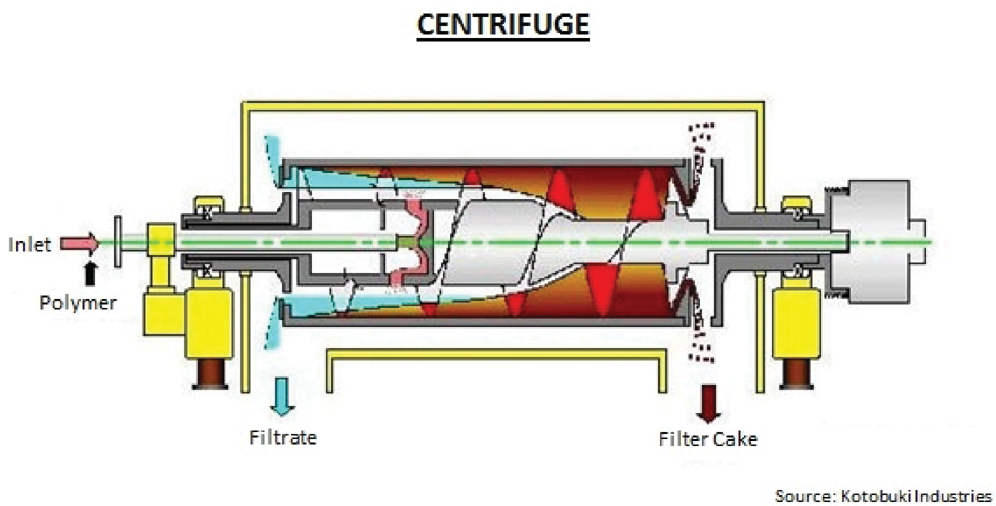


2.5.6 Describe the centrifuge dewatering process.

Feed sludge flows into a high-speed rotating drum (bowl). The liquid rotates with the bowl, held in place by centrifugal force. An internal rotating screw (scroll) scrapes the solids off the bowl and discharges cake sludge at one end. The water (centrate) overflows the weirs and discharges out of the other end of the bowl.

Sludge feed rate, polymer dosage, bowl speed, scroll speed, and weir depth are all adjustable and affect centrifuge performance.

Figure 2.5.6.1



2.5.7 Develop a plan to evaluate a belt press for optimum performance.

The following parameters should be evaluated to achieve optimum performance of a belt press:

A. Sludge feed suspended solids concentration
B. Sludge feed rate to press (gallons per minute or gpm)
C. Polymer feed point
D. Belt speed control
E. Belt tension control
F. Sludge cake concentration and percent solids

Optimum performance should be stressed with the operating staff to achieve the highest possible percent solids.

Chapter 3 - Monitoring, Process Control, and Troubleshooting

Section 3.1 - Definitions

3.1.1 Define struvite.

Struvite is magnesium ammonium phosphate ($MgNH4PO4(H2O)6$). It forms hard, very insoluble, white, yellowish-white, or brownish-white crystals.

3.1.2 Define vivianite.

Vivianite, a hydrated iron phosphate ($Fe3(PO4)2 \bullet 8(H20)$), is a hard crystal that can form in a wastewater treatment plant's piping and valving when iron salts are added in excess for chemical phosphorus removal. Vivianite is associated with anaerobic conditions and when added upstream from head exchanges, it can accumulate causing plugging and interfering with heat transfer. Vivianite is the desired product, however, when iron is added to control struvite.

Section 3.2 - Sampling and Testing

3.2.1 Describe the sampling locations and sampling frequency necessary to ensure good sludge thickening or dewatering operations.

For sludge thickening or dewatering equipment, the sample locations would include the raw feed sludge to the thickening or dewatering equipment and the finished sludge from the thickening or dewatering equipment (sludge cake from dewatering equipment), underflow from gravity thickening, or float from dissolved air flotation (DAF) units. The sampling frequency should be sufficient to ensure good operations (the unit should be operating within the normal range based on historic sampling results). Additional sampling should be done if there are any changes in the feed sludge characteristics, any changes to polymer feed, any apparent change in the finished sludge, or any abnormalities in the return sidestream flow characteristics from the thickening or dewatering unit.

3.2.2 List the considerations associated with obtaining representative samples of liquid sludge for lab tests.

A key goal of any sampling program is to obtain samples which are representative of what is being monitored. Otherwise, any decision based on analysis of the sample could be erroneous.

Factors to consider are:

A. Know what you're sampling and why. Permit compliance sampling may have different concerns from process sampling.
B. Sampling equipment should be clean and maintained to avoid cross contamination.
C. Samples should be well mixed.
D. Areas of stratification should be avoided.
E. Areas of non-representative deposits or accumulation should be avoided.
F. Samples should be appropriately marked and preserved before analysis.

3.2.3 Describe the primary monitoring test used in sludge thickening or dewatering processes.

The total solids test is the primary test and is used to determine the percent solids in a given sludge. This test is normally run on both the feed sludge and the sludge cake.

3.2.4 Discuss how to determine the volume of liquid sludge being pumped.

A. Calibrated flow meter
A calibrated flow meter can be used to determine total flow.

B. Calculate changes in tank level
The tank dimensions can be used with the change in liquid level to calculate the volume of sludge pumped.

C. Pump or motor hour meter
A hour meter can be used to calculate the amount of sludge pumped in a given pump cycle, by multiplying the hours run by the gallons pumped per hour.

3.2.5 Describe tests used to monitor anaerobic digester performance.

Collect representative samples in clean containers (see k.k. 3.2.2).

Figure 3.2.5.1

Parameter:	Sample location:	Why tested:	How often:
Volatile acids/ alkalinity ratio (VA/ALK)	Sampling pipe from the digester, recirculating sludge line, or thief holes	Increased volatile acids concent-rations and decreased alkalinity are the first measurable changes to take place when a digester begins to sour	3 times per week; daily if a result is abnormal until result is back in normal range
pH	Sampling pipe from the digester, recirculating sludge line, or thief holes	pH is strictly measured for record and is not used for plant control; pH changes are the last indicator of troubles with digestion	Daily
Temperature	Thermometer is usually installed in the recirculated sludge line from the digester to the heat exchanger	Measured to ensure the proper temperature is maintained for the microorganisms	Daily
Total solids and volatile solids	Raw sludge entering the digester, recirculated sludge, and supernatant	Determination of sludge (lbs), volatile sludge destroyed (lbs) or reduced, digester loading rates, and amount of solids handled; necessary for the maintenance of efficient digester operation	Weekly

3.2.6 Describe tests used to monitor aerobic digester performance.

Collect representative samples in clean containers (see k.k. 3.2.2).

Figure 3.2.6.1

Parameter:	Sample Location:	Why Tested:	How Often:
Dissolved oxygen (DO)	Well-mixed area	Maintaining adequate DO (0.4 to 0.8 mg/L) allows the biological process to take place and prevent undesirable odors	Daily or continuously
pH	Well-mixed area	Two products, carbon dioxide and nitrate, of aerobic digestion tend to lower the pH, decreasing below 6.0	Daily
Alkalinity	Well-mixed area	pH drop can occur when ammonia is oxidized to nitrate if alkalinity is insufficient (below 500 mg/L)	Weekly
Temperature	Well-mixed area	Temperature significantly affects the rate of volatile solids reduction if below 50°F (10°C)	Daily
Total solids and volatile solids	Wasted sludge entering the digester and supernatant	Determination of sludge (lbs), volatile sludge destroyed (lbs) or reduced, digester loading rates, and amount of solids handled; necessary for the maintenance of efficient digester operation	Weekly
Settleability	Well-mixed area	Good settling characteristics are important to minimize solids returning back to the liquid treatment process	Daily
Specific oxygen uptake rate (SOUR)	Well-mixed area	A SOUR of ≤1.5 mg of DO/h/g of total solids indicates aerobically-digested sludge has been adequately reduced in vector attraction	As required

3.2.7 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.

3.2.8 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 addition doses, process control changes, detention times, and other operational factors. For example, one type of bench test is a jar test wherein a number of jars are set up using different chemicals at different concentrations to determine the best settling characteristics. When the best chemical dosage is determined it can be applied full scale to the sludge-handling process.

3.2.9 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 or test equipment after the bench testing.

3.2.10 Discuss tests and measurements that should be run on sidestreams and the importance of this flow on plant operations.

The return flows from sludge processing should be tested for biochemical oxygen demand (BOD), pH, phosphorus, ammonia, and suspended solids along with a flow volume measurement. The main reasons for testing is to determine the loading that is being returned to the treatment plant. These tests are important to ensure that the treatment process will not be upset by the sidestream flows.

Section 3.3 - Data Understanding and Interpretation

3.3.1 State the expected reduction in volatile solids from a well-operated digester.

The expected reduction of volatile solids of a properly operating digester is 40% to 60% of the total volatile solids present in raw sludge feed. The volatile solids in the feed sludge would be about 70% to 75% while the digested sludge would be 45% to 50% volatile solids.

3.3.2 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 with a yellow tip. The gas flame color of a sour digester is mostly yellow.

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

The gas and volatile acid production would decrease. The alkalinity would stay the same or slightly increase.

3.3.4 Describe specific oxygen uptake rate (SOUR).

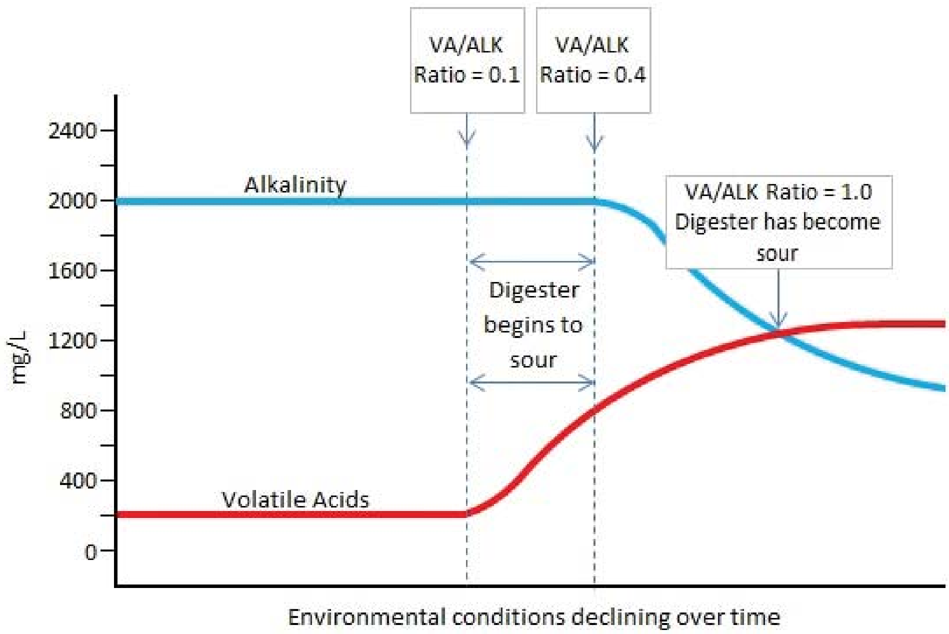
The oxygen uptake rate (OUR) measures the oxygen used per hour by the microorganisms while breaking down the sludge volatile organic matter. The specific uptake rate (SOUR) divides the oxygen uptake rate (mg O2/hr) by the grams (g) of total solids in the sample (mg O2/hr/g TS).
A sour from a well-operated aerobic digester sludge process will range between 0.1 and 1.0 mg 02/hr/g TS. For a Class B sludge to meet the vector attraction reduction requirement, the SOUR must be less than or equal to 1.5 mg/O2/hr/g TS.

3.3.5 Discuss the volatile acid/alkalinity (VA/ALK) ratio.

In a stable digester, the volatile acids are used at about the same rate they are produced. If excess volatile solids are fed into a digester, the acid-forming bacteria population will grow creating an overabundance of acids. The methane-forming bacteria reproduce much slower than the acid-forming bacteria and cannot handle the increase in acids, ultimately causing a digester upset.

A good VA/ALK ratio for most digesters is generally less than 0.2. This ratio is the key to proficient operations. VA/ALK should be monitored consistently because it will be the first warning of problems occurring and action should be taken immediately once it begins to rise.

Figure 3.3.5.1



Section 3.4 - Sidestreams and Recycle Flows

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

A. Delay sidestream introduction to plant (feed at low-loading times)
B. Install a flow equalization system
C. Pretreat the sidestream, especially for phosphorus
D. Dilute or mix with other flows
E. Optimize solids capture
F. Optimize chemical conditioning

3.4.2 Discuss the possible impact of sidestreams or recycle flows back to the activated sludge process.

Sidestreams or recycle flows usually come from biosolids and sludges dewatering and treatment, such as decanting digesters or sludge storage tanks. Sidestreams may be high in biochemical oxygen demand (BOD), suspended solids, ammonia, phosphorus, and sulfides or very low in temperature. It is best to return sidestreams slowly and regularly so microorganisms adjust and acclimate to this loading. If permit limits phosphorus or ammonia, it is critical to know the loading from sidestreams. Sidestreams can upset a treatment plant or result in a pass-through of pollutants to the effluent, resulting in permit violations. If permit limits phosphorus or ammonia, sometimes it is necessary to separately treat the sidestream.

3.4.3 List common sidestreams within a treatment plant.

The most common sidestreams are from:

A. Thickening or dewatering process
1. Gravity belt thickening filtrate
2. Centrifuge centrate
3. Gravity thickening supernatant
4. Dissolved air filtration (DAF) subnatant
5. Rotary drum thickening filtrate
6. Belt filter press filtrate
7. Sludge drying bed underdrain
8. Plate and frame filtrate
9. Reed bed filtrate

B. Stabilization or storage
1. Aerobic digester decant
2. Anaerobic digestion supernatant
3. Biosolids storage decant
4. Effluent filter backwash

3.4.4 Discuss digester decanting.

Digester decanting can increase the performance of the digesters and produce higher total solids in the digester, thereby reducing the volume to haul. The removal of liquid can increase solids retention time, volatile solids destruction, accelerate digestion, and pathogen destruction. An operator needs to be aware supernatant return can cause significant additional BOD, solids, and nutrient loadings to the plant.

Figure 3.4.4.1

Aerobic Digester Supernatant

Parameter	Range	Typical Values
pH (s.u.)	5.9 - 7.7	7
BOD_5 (mg/L)	9 - 1700	500
TSS (mg/L)	46 - 2000	1000
TKN (mg/L)	10 - 400	170
Nitrate-N (mg/L)	-	30
Ammonia-N (mg/L)	-	-
Total Phos. (mg/L)	19 - 241	100
Ortho-Phos. (mg/L)	2.5 - 64.0	25

TSS = Total Suspended Solids
TKN = Total Kjeldahl Nitrogen

Anaerobic Digester Supernatant

Parameter	Range	Typical Values
pH (s.u.)	6.0 - 8.0	6.8 - 7.2
BOD_5 (mg/L)	500 - 10 000	500
TSS (mg/L)	500 - 15 000	<5000
TKN (mg/L)	600 - 1 200	
Nitrate-N (mg/L)	-	-
Ammonia-N (mg/L)	500-1 000	
Total Phos. (mg/L)	Highly variable	
Ortho-Phos. (mg/L)	200 - 400	

BOD_5 = Biochemical Oxygen Demand 5-day test
N = Nitrogen

Section 3.5 - Performance Limiting Factors

3.5.1 Explain why it works better to feed small amounts of thick sludge more often than to feed 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. Reduces heating costs
B. Reduces supernatant volume
C. Prevents upsets
D. Increases treatment (increases detention time)
E. Stabilizes gas production

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

A. Causes a loss in detention time
B. Plugs lines to and from the digester
C. Disturbs the mixing patterns
D. Damages pumps handling digested sludge

3.5.3 Explain how siloxanes affect gas-handling equipment.

Though a portion of siloxanes decompose in the activated sludge process, some end up in sludges. When sludge is treated in the anaerobic digestion process, siloxanes volatize and become part of the biogas. If the gas is combusted, the siloxanes are converted into a glass-like compound called silicon dioxide (SiO2). In engines, it is deposited as an abrasive material that causes damage to internal moving parts and deposited on exhaust components. In boilers, its deposited as a white powder that insulates boiler tubes, decreasing heating efficiency and may cause high exhaust stack temperatures. Special filters can be used to remove siloxanes from the biogas.

3.5.4 Discuss operational problems caused by the formation of struvite.

Struvite deposits can clog pipes and valves, interfere with instrumentation, and reduce the operating life of equipment such as belt filter presses. Struvite commonly forms in anaerobic digesters where ammonia, magnesium, and phosphate are present and pH increases. Enhanced biological phosphorus removal (EBPR) plants with anaerobic digesters have a higher potential for struvite formation than conventional activated sludge plants. Struvite formation is common at pipe elbows, mixer blades, valves, pump impellers, and dewatering equipment. Iron salts added to the digester may help balance nutrients and may reduce struvite formation.

3.5.5 Discuss air permits in regards to anaerobic digester emissions.

Governmental air quality requirements may affect wastewater treatment facilities and in some cases require the facility to apply and obtain an air permit. Facilities should inventory their respective air emission sources to determine whether they may need such air permit or determine whether the facility is eligible for a permit exemption. Air emission sources at a wastewater facility may include boilers which burn biogas, engines, turbines, flares, or any other combustion unit. Once air emission sources are inventoried, an operator may want to contact their environmental consultant, use online resources, and/or DNR staff to determine what requirements may apply to the facility. While specific air regulations and requirements are beyond the scope of this study guide, it is a key role of the facility owner to evaluate, obtain, and comply with all appropriate permit requirements.

Section 3.6 - Corrective Actions

3.6.1 Identify the causes and corrective actions for anaerobic digester problems.

Figure 3.6.1.1

Problem	Cause	Corrective Action
Supernatant is grey or brown	Raw sludge pockets in the tank	Check and repair or replace mixing system
	Short retention time from grit or scum buildup	Clean out the grit or scum from the digester
Supernatant solids are too high	Decanting point is too low	Adjust tank operating level or decanting point
Scum blanket is too thick	Inadequate mixing or the mixing system is off	Adjust mixing or repair/replace system; restart mixing system
Temperature drop inside tank	Low percent solids in feed sludge (high water content); high feed sludge pumping rate	Adjust sludge thickening operations; adjust feed sludge pumping rates
Grey digested sludge	Short-circuiting or insufficient mixing	Adjust mixing or repair/replace mixing system
Digested sludge or supernatant has a sour odor	Digester has gone sour or toxic load	Reduce volatile solids loading; find and address source of the toxic loading

3.6.2 Identify the causes and corrective actions for mechanical mixing equipment problems in a digester.

Figure 3.6.2.1

Problem	Cause	Corrective Action
Shaft seal leaks	Packing old and worn causing gas leakage (confirmed by gas odor or bubbles with a soap solution)	Repack shaft seal as needed or anytime the tank is down for cleaning
Gear reducer wear	Lack of proper lubrication causing noise, vibration, and shaft wear	Use correct type and amount of lubrication as recommended by the manufacturer
	Poor equipment alignment	Properly align equipment and correct for any imbalance of internal parts which cause alignment problems
Internal mixing parts	Imbalance from debris on moving parts causing vibration, motor overheating, and noisy operations	Make sure preliminary treatment (comminution and screening) is operating properly to prevent debris from getting to the digester; if possible reverse direction of the mixer or alternately start and stop the mixer to dislodge the debris; if this does not correct the problem the digester will need to be totally drawn-down and cleaned to remove accumulation of debris
	Wear on internal parts from grit or misalignment	Make sure preliminary treatment (grit removal) is operating properly to minimize grit getting to the digester, excessive wear will require replacement of the worn internal parts

3.6.3 Discuss the important items to consider when an anaerobic digester is taken out of service.

Plant operations that could be affected while the digester is down for service include 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 other treatment process.

A possible odor problem can occur 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.

3.6.4 Discuss problems associated with the control of scum blankets in an anaerobic digester.

A thick mat of scum, grease, and hair can develop in an anaerobic digester with insufficient mixing. The mat reduces the available space in the digester, reducing the detention time. It can also lead to blocked supernatant lines. The material can be broken-up and removed during digester cleaning. Long-term solutions include installing a more effective digester mixing system, regulating the discharge of grease to the sewer system, or stop pumping grease into the digester.

3.6.5 Discuss the toxicity concerns of heavy metals and sulfides.

A. Heavy metals

Heavy metals in solution can act as biocides (killing the bacteria in the digester). Heavy metal sources are often from industries, especially metal-finishing and metal-plating operations. Common toxic heavy metals would include copper, chromium, mercury, arsenic, nickel, zinc, cadmium, selenium, molybdenum, and lead.

B. Sulfides

Sulfides can come from septage, holding tanks, and industrial sources as sulfate salts that are reduced to sulfides in the digester. The bacteria can tolerate between 50 and 100 mg/L of soluble sulfide but concentrations above 200 mg/L are toxic and would require treatment with iron salts to precipitate the sulfides. The sources of this waste stream should be reduced or eliminated.

3.6.6 Outline an action plan to use if an anaerobic digester is starting to become upset or go sour.

A. Monitor volatile acid/alkalinity (VA/ALK) ratio and pH
B. Reduce loading to the digester by reducing sludge pumping
C. If needed, increase alkalinity through the addition of lime or sodium bicarbonate
D. Once the VA/ALK ratio has decreased and pH returns to normal, begin to gradually increase the sludge pumping rate to normal.
E. Continue monitoring VA/ALK ratio and pH

3.6.7 Identify the causes and corrective actions for gas system problems in an anaerobic digester.

Figure 3.6.7.1

Problem	Cause	Corrective Action
Gas pressure lower than normal	Gas leaking out through pressure/vacuum relief valve	Service valve to ensure proper seating adding more weights if necessary; install new parts if worn
	High gas usage in the plant	Check gas usage in the plant against gas production and adjust usage
	Gas leaking out of the cover or gas piping	Check for leaks around the cover and repair; check all piping for leaks and repair
	Poor digester operations	Monitor alkalinity, volatile acids, pH, and gas quality (carbon dioxide concentration); adjust raw sludge feed rate (to prevent organic or hydraulic overloading) and add chemicals to restore good digester operations
	Excessive sludge or supernatant removal	Stop sludge or supernatant removal until the digester gas pressure returns to normal
	Excessive use of lime	Stop addition of lime and increase mixing to restore normal gas pressure

Figure 3.6.7.2

Problem	Cause	Corrective Action
Gas pressure higher than normal	Stuck pressure/vacuum relief valve	Service the valve to ensure proper operations and install new parts as necessary; in winter condensation and freezing conditions can cause the valve to freeze; the valve should be inspected regularly in very cold weather and vented barrel could be placed over the valve with an explosion proof light bulb inside to reduce freezing temperatures
	Low gas usage in the plant	Check the waste gas burner and all piping for proper operation so excessive gas will be burned
	Gas piping blocked or pressure regulating valve not functioning	Check all drip (condensate) traps, check all low spots in the piping for water or other blockage, and clean/repair as necessary; isolate pressure regulating valve and service/repair as necessary
	Supernatant lines are frozen or blocked	Check lines frequently in very cold weather and protect with insulation to reduce freezing problems

Figure 3.6.7.3

Problem	Cause	Corrective Action
Yellow gas flame at the waste gas burner	Poor quality digester gas with high carbon dioxide content from poor digester operations	Correct digester operations; check raw feed sludge operations to prevent hydraulic or organic overloading; check volatile acids, alkalinity, and pH; adjust with chemicals to improve gas composition
Gas flame lower than usual	High gas usage in the plant	Check gas production against usage
	Gas leakage in the collection and distribution system	Check for gas leaks, repair piping, and other appurtenances as needed
	Low gas production due to process problems	Correct digester operations (see above)
Waste gas burner not lit	Pilot flame not burning	Check for adequate pressure, service and relight
	Obstruction or water in the pilot gas line	Clean with air and check low spots for in-line water
	Obstruction or water in main gas line	Drain all drip (condensate) traps; check for low spots in piping for water or other blockages; clean and repair as necessary

Figure 3.6.7.4

Problem	Cause	Corrective Action
Pressure control valve failure	malfunction of the valve	Clean, service and repair valve as necessary
Gas meter failure	Debris in gas line	Clean by flushing with water
	Mechanical failure or diaphragm problems	Isolate the meter, disassemble, service, and replace worn or damaged parts

3.6.8 Explain the possible causes and corrective actions for a sudden loss of gas production combined with a low volatile acid concentration in an anaerobic digester.

Figure 3.6.8.1

Problem	Cause	Corrective Action
Sudden loss of gas production combined with low volatile acid concentration	A toxic material is being introduced into the digester which is causing the bacteria to be inhibited or killed	Dilute and recycle from the secondary digester; attempt to identify the toxicity, its source, and eliminate it from the wastewater flow

3.6.9 Explain the possible causes and corrective actions for a gradual loss of gas production combined with a high volatile acid concentration in an anaerobic digester.

Figure 3.6.9.1

Problem	Cause	Corrective Action
Gradual loss of gas production combined with a high volatile acid concentration	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; reduce the loading if possible and/or pumping sludge more frequently for shorter durations

3.6.10 List the methods for testing for digester gas leaks.

A. Online
1. Gas detector
2. Soapy water

B. Offline
1. Pressure test with water or inert gas
2. Vacuum test

[NOTE: Always use spark-proof tools and keep any open flames away from all digester equipment and structures to prevent fire or explosion.]

3.6.11 Explain the possible causes and corrective actions for water getting into a gas meter in an anaerobic digester.

Figure 3.6.11.1

Problem	Cause	Corrective Action
Water getting into a gas meter	Condensate (drip) traps are not being drained	Drain the condensate (drip) traps

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

Figure 3.6.12.1

Problem	Cause	Corrective Action
Intense anaerobic digester foaming	Intermittent digester feeding	Feed digesters continuously
	Separate feeding or inadequate blending of primary sludge and WAS	Blend different feed sludges before feeding
	Insufficient or intermittent gas mixing	Confirm that digester mixing system is operating; repair or replace
	Excessive amounts of grease or scum in digester feed	Limit quantities of grease or scum in the digester feed; implement a Grease Control Program
	Filamentous bacteria, such as Nocardia, trapping gas in their structure, plus releasing surface-active agents that collect on bubble surface, causing foaming	Modify activated sludge process to control growth of Nocardia or other problematic organisms
	Digester fed with 100% WAS or high proportion of WAS causing foaming problems	Pretreat WAS before feeding into digester, e.g. ultra-sound treatment or acid-phased pretreatment; or consider enhanced primary clarifier pretreatment to reduce secondary treatment loading, to reduce the amount of WAS produced

3.6.13 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 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.

3.6.14 Discuss problems, causes, and corrective actions associated with aerobic digestion.

Figure 3.6.14.1

Problem	Cause	Corrective Action
Excessive foaming	Organic overload	Reduce feed rate; increase solids in digester by decanting and recycling solids
	Excessive aeration	Reduce aeration rate
Low dissolved oxygen (DO)	Clogging	Clean diffuser or replace with coarse-bubble diffusers or sock-type devices
	Improper liquid level	Establish proper liquid level
	Blower malfunction	Repair pipe leak; set valves in proper position; repair blower
	Organic overload	Reduce feed rate
Sludge has objectionable odor	Inadequate solids retention time	Reduce feed rate
	Inadequate aeration	Increase aeration or reduce feed rate
Ice formation on mechanical aerators	Extended freezing weather	Break and remove ice before it causes damage
pH in digester has dropped to undesirable level (less than 6.0 to 6.5)	Nitrification is occurring and wastewater alkalinity is low	Add sodium bicarbonate to feed sludge or lime or sodium hydroxide to digester
	In covered digester, carbon dioxide is accumulating in air and is dissolved into sludge	Vent and scrub carbon dioxide

(U.S. EPA, 1978)

3.6.15 Describe how odor problems can generally be eliminated.

Many odors can not be eliminated, only controlled to an acceptable level. Control measures can include good housekeeping, ventilation, air scrubbing, and/or chemical treatment (oxidizing agents).

3.6.16 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 low concentrations produces a very noticeable odor. The characteristic odor is often described as smelling similar to rotten eggs. At relatively low concentrations, the gas is very toxic and causes a special problem in confined spaces.

3.6.17 Explain how the generation of hydrogen sulfide gas can be controlled.

Hydrogen sulfide gas is typically associated with low-oxygen conditions and can be controlled by the addition of oxidizing agents such as potassium permanganate and hydrogen peroxide. Other control measures would include aerating the sludge or processing the sludge before septic conditions can occur. Hydrogen sulfide can be removed from digester gas with an absorbing agent such as an iron sponge.

3.6.18 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. The precipitate causes buildup in pipe lines, pumps, and other areas which will require cleaning with dilute hydrochloric acid.

3.6.19 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.

Chapter 4 - Residuals Management

Section 4.1 - Definitions

4.1.1 Define agronomic rate.

Agronomic rate is the sludge application rate that provides the amount of nitrogen and phosphorus (nutrients) needed by the crop or vegetation grown on that land while minimizing the amount that passes below the root zone.

4.1.2 Define incorporation.

Incorporation is the mixing of sludge with topsoil to a minimum depth of 4 inches by such means as discing, moldboard plowing, chisel plowing, rototilling, or other tillage methods.

4.1.3 Define injection.

Injection is the subsurface placement of liquid sludge to a depth of 4 to 12 inches.

4.1.4 Define land application.

Land application is the uniform distribution of sludge to the soil by spreading sludge onto the soil, incorporating sludge into the soil, or injecting sludge below the land surface. Adding sludge to the soil improves soil quality by conditioning and/or fertilizing the soil for improved vegetative cover and crop production purposes.

4.1.5 Define total Kjeldahl nitrogen (TKN).

TKN is the sum of organic nitrogen and ammonia.

4.1.6 Define total nitrogen.

Total nitrogen is the sum of organic nitrogen, ammonia, nitrite, and nitrate.

4.1.7 Define total phosphorus.

Total phosphorus is the total concentration of all forms of phosphorus found in a sample.

Section 4.2 - Sludge Quality

4.2.1 List the typical physical appearance of sludge at certain solids concentrations.

A. 5% solids
   1. Appearance of thick slurry
   2. Flows and pumps readily

B. 15% solids
   1. Appearance of damp soil
   2. Holds its shape (stands-up) but is not suitable for conventional pumping
   3. Normally handled with conveyor equipment

C. 40% solids
   1. Appearance of dry soil
   2. Handled with mechanical equipment, such as front-end loaders or shovels

[NOTE: There are pumps available for industrial applications that can pump sludge at 25% solids.]

4.2.2 List four characteristics of dewatered sludge.

A. Concentrates both nutrients and toxics
B. Requires less storage space than liquid sludge
C. Depending on the concentration, it cannot be transported by conventional pumping
D. Will not migrate as readily as liquid sludge

4.2.3 List the three sludge quality criteria which must be satisfied before the sludge may be land applied.

A. Metal concentrations
B. Pathogen control and treatment processes
C. Vector attraction reduction

4.2.4 Discuss biosolids or sludge treatment processes to meet the pathogen control criteria for Class A and Class B sludges.

There are two broad categories of sludge pathogen quality criteria identified as Class A and Class B sludges. Class A pathogen requirements are more stringent to meet, but, if met, result in a very low pathogen risk to public health and the environment. Sludges meeting Class A pathogen requirements provide more opportunities for sludge use including the potential of public distribution. Class B pathogen requirements require a higher degree of use managing because of higher pathogen risk to public health and the environment. Specific pathogen requirements are defined in Wisconsin Administrative Code NR 204.

4.2.5 Explain the effect of chemical addition on sludge.

Chemicals, including polymers, are added to condition sludges and to improve liquid and solid separation. This results in increased concentration and decreased volume. Chemicals added for phosphorus removal will increase sludge production. The amount of chemicals needed for sludge conditioning varies with the dewaterability of a given sludge.

4.2.6 Discuss wet weight and dry weight of sludge.

The wet weight is the total mass of the solids and water in sludge, while the dry weight (measured in tons) is the mass of only the solids of the sludge. The amount of land applied sludge is calculated using the dry weight (dry tons/acre). To calculate the dry weight of sludge applied:

Dry weight (tons/acre) = amount applied (gals/acre) × % solids content × 0.0000417

[NOTE: the conversion constant 0.0000417 is calculated by:
0.0000417 = 8.34 × 10,000 mg/L (1% solids) ÷ [1,000,000 MGD × 2,000 lbs/ton]

Section 4.3 - Management Options

4.3.1 List the common methods of sludge reuse or disposal.

Federal and State regulations establish two levels of quality for municipal biosolids for final use or disposal. Class A biosolids receive a very high degree of treatment and can be used by the public in parks, gardens, and golf courses. Some biosolids are used in composting programs. Class B biosolids do not meet all the criteria of a Class A sludge and are land applied on agricultural lands or disposed of in a landfill. Land application is the most common method of sludge reuse in Wisconsin.

4.3.2 Describe the factors that improve the public acceptance of sludge land application.

The most important factor in the acceptance of sludge land application is to have a good education program explaining the benefits of sludge in terms of nutrient value (fertilizer), the soil conditioning it provides, and the regulatory standards the sludge has met. All spreading equipment should be clean and well maintained to provide a good overall appearance.

A strong public relations program is essential. Some aspects of a good program could include:

A. Direct contact with neighbors
B. Use of flyers, news releases, and brochures
C. Provide a point of contact for any questions or concerns
D. Avoid blocking traffic
E. Clean any debris left on the roadways
F. Limit dust during application

4.3.3 Discuss municipal sludge storage requirements in Wisconsin.

All municipal treatment plants that land apply shall have the ability to store sludge for 180 days. No land spreading is applicable during winter or on frozen ground. Having adequate sludge storage allows the operator the ability to waste the proper amount of sludge at all times during the year.

Section 4.4 - Land Application

4.4.1 Discuss the importance of recycling biosolids and sludge through land application.

The Environmental Protection Agency (EPA) defines biosolids as a “primarily organic solid product yielded by municipal wastewater treatment processes that can be beneficially recycled” as soil amendments (fertilizer and conditioners). Industrial sludges offer the similar benefits as biosolids. Recycling biosolids through land application is a sustainable management method to reuse nutrients and soil conditioners in place of commercial fertilizers and avoid disposal in landfills.

4.4.2 Discuss the criteria for the land application of sludge.

For land application of sludge to occur in Wisconsin, it should be demonstrated or determined to have a beneficial use and non-detrimental impact to the environment. The Wisconsin Administrative Codes regulating the land application of sludge in Wisconsin are NR 204 and NR 214 for municipal and industrial sludge application respectively. The codes establish pollutant characteristic criteria such as metals which may not be exceeded, site restrictions which must be met, vector attraction criteria, and pathogen reduction criteria. Operators should be familiar with the administrative codes applicable to their situation.

4.4.3 Discuss the importance of nitrogen and phosphorus in nutrition.

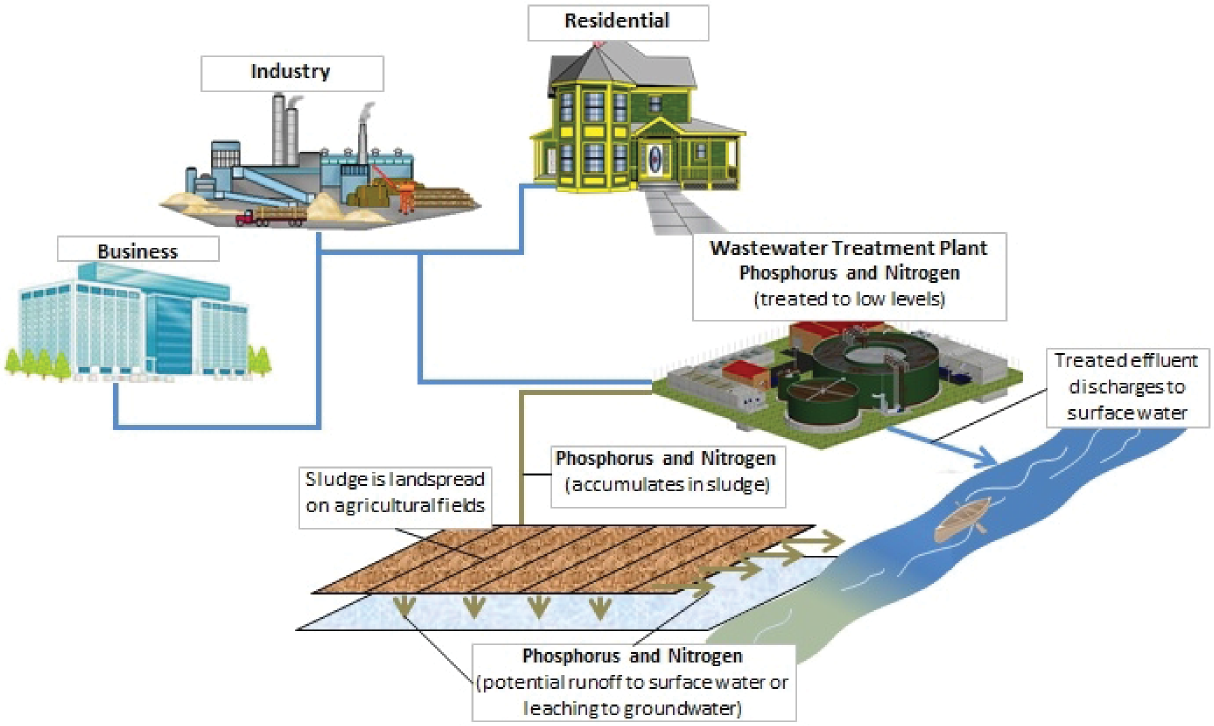
Living organisms need nutrition in order to sustain life and carry out their daily functions. Nitrogen and phosphorus are both essential for all living organisms. Nitrogen is fundamental for building proteins and is a major component of chlorophyll. Phosphorus helps turn nutrients into energy. Organisms ingest these elements from the food they eat, whether it is from plants or animals. Nitrogen and phosphorus are then discharged into wastewater treatment plants from human excretions, household, commercial, and industrial activities.

4.4.4 Discuss and show the fate of nitrogen and phosphorus from a community through a wastewater treatment plant back to the environment.

Nitrogen naturally occurs in the atmosphere and phosphorus naturally occurs in rocks and sediment. They are both essential for all living organisms. People ingest these elements from the food they eat, whether it is from plants or animals. Nitrogen and phosphorus are then discharged into wastewater treatment plants from human excretions and household activities. Nitrate is a concern for groundwater, which can be toxic if it enters a drinking well and is consumed, especially to infants and pregnant women. Excess phosphorus is a concern for surface water. It can lead to algal blooms and excessive growth of aquatic plants, depleting oxygen causing fish and other aquatic organism fatalities. The algal blooms can also cause health concerns.

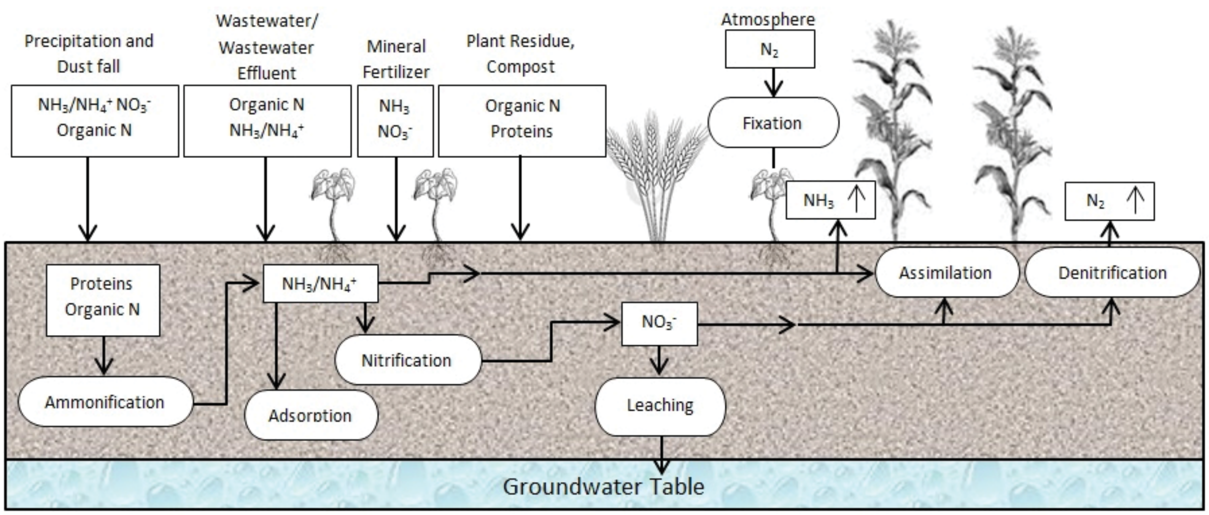
Phosphorus can be removed in wastewater treatment by chemical precipitations with metal salts (iron or aluminum) or biologically. Biological phosphorus removal utilizes specialized bacteria (phosphorus-accumulating organisms) that uptake phosphorus. The sludge that is settled out and removed from the chemical or biological phosphorus removal system contains a fairly high amount of phosphorus. Sludge is then landspread returning nitrogen and phosphorous back to agricultural fields for crop use. Most nitrogen and phosphorous is removed from the liquid wastewater and accumulates in the sludge. Sludge is then applied to the land to recycle nutrients.

Figure 4.4.4.1



4.4.5 Show the nitrogen cycle in soil and groundwater.

Figure 4.4.5.1



Courtesy of Danielle Luke, Wisconsin Department of Natural Resources

4.4.6 Discuss how nutrients end up in sludge.

A. Nitrogen

Nitrogen goes through a biological treatment process where it is both oxidized and removed as a gas or accumulates in biosolids.

B. Phosphorus
Phosphorus can be removed by solids separation and chemical processes where it then accumulates in the biosolids.

C. Potassium
Potassium is a soluble salt and passes through the treatment plant with the liquid stream. It does not accumulate in biosolids.

4.4.7 Discuss nutrient management plans.

Nutrient management plans address the application and budgeting of nutrients for plant production. Nutrient sources such as soil reserves, fertilizers, manure, and crop residue are accounted for in the plan. Nutrient management documentation and planning are required for operators who will be land-applying sludge, for the prevention of over-applying fertilizers to cropland, and assisting with meeting water quality standards. Planning reduces nutrient entry into surface water, groundwater, and atmospheric resources while maintaining and improving the soil condition.

Biosolids managers need to communicate with farmers and land owners when providing biosolids for nutrient reuse. Communication is essential for farmers and land owners to account for the additional nutrients from biosolids as farmers and landowners may be required to complete more extensive nutrient management plans often referred to as 590 plans pursuant to Natural Resource Conservation Service (NRCS) 590 standards required for specific farmers and producers. Communication is also necessary to communicate pathogen control crop harvesting limitations and collect planting and harvesting details such as dates of planting and harvesting, yields, and any changes from proposed crop rotations.

4.4.8 Discuss the value of the land application of biosolids.

Biosolids primarily provide nitrogen and phosphorus. Biosolids also provide potassium, calcium, magnesium, sulfur, and micronutrients for plant growth. Applying biosolids to soil has shown to increase water holding capacity, lessen wind and water erosion, and improve aeration due to the addition of organic matter.

4.4.9 Discuss nutrients in biosolids.

A. Nitrogen
Nitrogen is crop available in biosolids in three forms: ammonium, organic, and inorganic. Ammonium nitrogen is readily available to crops, but due to its volatility, it must be injected to recover the full amount of nitrogen. When biosolids are surface applied, one half of the available ammonium nitrogen is lost due to volatilization. Organic nitrogen has a slow release form that is available as crops mature. The dry weight concentration of nitrogen in municipal biosolids is typically 2% to 12% as total Kjeldahl nitrogen (TKN).

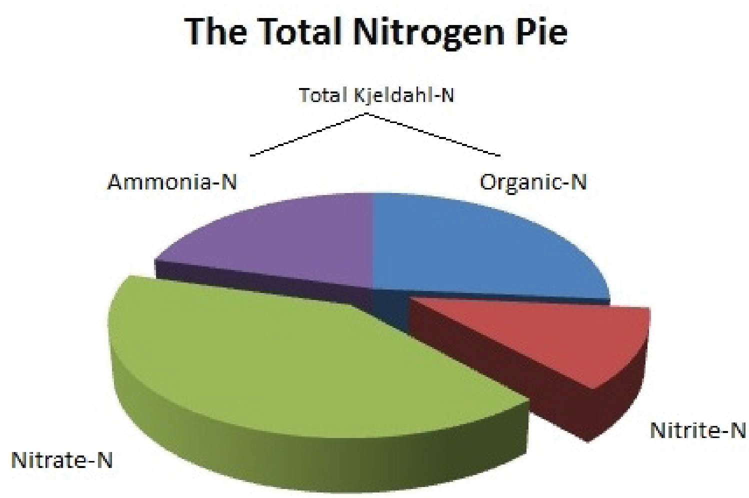
B. Phosphorus
Phosphorus in biosolids is reported in percent P. The dry weight concentration of phosphorus in biosolids is typically between 2% to 8% as total phosphorus.

C. Potassium
Potassium in biosolids is reported in percent K. There is very little potassium in municipal biosolids; the dry weight concentration is typically less than 1% as total potassium.

4.4.10 Discuss the forms of nitrogen in sludge.

Sludge contains nitrogen in the forms of organic nitrogen. TKN is the added forms of organic nitrogen and ammonia nitrogen. Nitrogen is a very important nutrient for plants. The amount of nitrogen in biosolids is relatively high making it a favorable fertilizer. Anaerobically-digested sludge contains ammonia and organic nitrogen. Aerobically-digested sludge contains nitrate and organic nitrogen.

Figure 4.4.10.1



4.4.11 Discuss soil testing for nitrogen, phosphorus, and potassium.

Soil testing for nitrogen, phosphorus, and potassium (also referred to as NPK) is done in order to match biosolids land application to the cover crop nutrient needs. All soil testing must be performed by laboratories approved by the State of Wisconsin. Recommendations for nutrient applications are given based on the crop planted, the expected crop yield, soil type, and soil organic matter. Some laboratories do not routinely provide nutrient recommendations. It may be necessary to ask for lime and nutrient recommendations or refer to the publication Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin (A2809). When sending soil samples for testing, an operator must fill out a submittal form with acreage, tillage depth, irrigation, previous crop, 4-year crop rotation, and expected crop yield.

4.4.12 Discuss crop recommendations.

Using crop recommendations helps minimize excessive nitrogen and phosphorus applications. Wisconsin's nitrogen guidelines are based on crop yield, quality, and economic return. The phosphorous or potassium guidelines are based on the crop in the planned rotation with the highest demand level. Application rate guidelines vary according to the crop grown, soil characteristics and yield potential, and soil organic matter content. The amount of available nitrogen from sludge and other nitrogen sources applied per growing season may not exceed the nitrogen requirement of the crop as determined by the recommendations based on the University of Wisconsin Extension Bulletin A-2809.

4.4.13 Discuss the potential environmental impacts of excessive nutrients applied from biosolids and sludge.

A. Nitrogen
Nitrogen in surface waters can stimulate aquatic plant growth, be toxic to aquatic life in high concentrations, and can deplete dissolved oxygen (DO). Nitrate nitrogen is very soluble in water and can leach into groundwater where it can contaminate drinking water.

B. Phosphorus
Phosphorus can stimulate aquatic plant growth where it can lead to toxic blue-green algal blooms and deplete DO causing aquatic organism fatalities.

C. Potassium
Potassium, while necessary for plant growth, is not an element limiting algal growth in surface water. It would be rare that biosolids would contain enough potassium to be the limiting crop nutrient, however industrial wastes could be high in potassium.

4.4.14 Discuss important field and site requirements.

The pH of the soil must be 5.5 or greater at the time biosolids are applied. If biosolids contains radium, soil pH must be at least 6.0. Biosolids land application vehicles or equipment shall be moving at all times while sludge is being applied to ensure uniform application. Biosolids are to be applied in a manner to minimize soil compaction, which helps prevent surface runoff and controls objectionable odors. If the soil at a field and site is classified as highly erodible by the USDA's Soil Conservation Service Soil Survey, the Department of Natural Resources may impose additional management practices.

4.4.15 Discuss important field and site constraints.

Biosolids may not be land applied if it is likely to adversely affect a threatened or endangered species or its designated critical habitat or a designated historical site. It also may not be applied to soils with a high groundwater level or bedrock at a depth of less than 3 ft. Sites with soils that have a rapid permeability of greater than 6 in/hr may not have sludge applied. Land applied Class B sludge will also have restricted public access for a period of 30 days for low exposure sites, such as a farm field, and up to one year for high exposure sites, such as a city park, following sludge application. Application of biosolids on frozen or snow covered ground is not allowed unless approved by the Department of Natural Resources on a case-by-case basis.

4.4.16 Discuss the importance of the land application field and site separation distances.

Land application separation and slope requirements protect the environment and public health by avoiding run-off and groundwater contamination and avoiding nuisances and complaints. Biosolids may not be land applied within specified distances from an occupied residence, a public or private water supply well, a river, lake or stream, and on floodway sites or floodplains or on slopes greater than 12%. The specific separation distances and slopes requirements can be found in Table B of Wisconsin Administrative Code NR 204 for municipal and NR 214 for industrial.

4.4.17 Compare the performance and costs of dewatering versus liquid hauling, listing advantages and disadvantages of each.

A. Mechanical dewatering

1. Advantages
   a. Less volume to haul, less storage required for sludge
   b. Dry sludge can be hauled with mechanical equipment rather than pumping liquid
1. Disadvantages
   a. Higher capital costs
   b. Higher operating costs
   c. Difficult to apply
   d. Return sidestreams
   e. Cost of chemicals for conditioning
   f. Increased equipment maintenance and replacement

B. Liquid hauling

1. Advantages
   a. Cost effective (with short-haul distances)
   b. Reduced capital and operating costs (no dewatering equipment required)
   c. Easy to apply
   d. No return sidestreams
1. Disadvantages
   a. Large volumes must be hauled
   b. Larger sludge storage required
   c. Increased vehicle costs
   d. Land availability problems
   e. Seasonal spreading limitations

4.4.18 Discuss chloride limitations when applying industrial sludge and other wastes.

For industrial sludges to be land spread, they have to be shown they have beneficial properties as a soil conditioner or fertilizer and may not have a detrimental effect on soils, vegetation, or groundwater. Well water contaminated with excessive chloride contributes to hypertension and other heart related conditions in humans. Maximum safe level in drinking water is 250 mg/L. Further chloride ions may injure plant tissue, reduce water uptake, and cause nutrient imbalances. Land treatment of industrial liquid wastes and by-product solids and sludges are regulated under NR 214 of the Wisconsin Administrative Code. This code provides limits to application of chlorides to 170 lbs/acre/1-year period or 340 lbs/acre/2-year period.

4.4.19 Compare direct land spreading of sludge to the injection of sludge into the soil.

Direct land spreading of sludge may result in some immediate minor odor problems, the possibility of run-off, and the visual appearance of drying sludge on the field. Injection into the soil virtually eliminates all of the problems but requires more power and specialized equipment to accomplish.

4.4.20 Describe the vector attraction reduction methods.

Sludge may not be land applied unless one of the following vector attraction reduction options is satisfied:

A. Volatile solids reduction
The mass of volatile solids in the sludge shall be reduced by a minimum of 38% between the time the sludge enters the digestion process and the time it either exits the digester or a storage facility. This is the most common method of vector attraction reduction for anaerobically-digested sludge. In a conventional aerobic digester, reduction is not normally met.

B. Specific oxygen uptake rate (SOUR)
The SOUR for aerobic sludge should be equal to or less than 1.5 mg of oxygen per hour per gram of total solids on a dry weight basis.

C. Benchscale test
Demonstrate in a benchscale test that additional volatile solids reduction for anaerobically-digested sludge is less than 17%, or less than 15% for aerobically-digested sludge.

D. Aerobic process
Sludge shall be treated in an aerobic process for 14 days or longer. During that time, the temperature of the sludge shall be higher than 104°F (40°C) and the average temperature of the sludge shall be higher than 113°F (45°C). This process is not common in Wisconsin because of the cold winters.

E. pH adjustment
The pH of the sludge shall be raised to 12 or higher by alkali addition, remain at 12 or higher for 2 hours without the addition of more alkali, and then at 11.5 or higher for an additional 22 hours.

F. Drying without primary solids
Dry the sludge to 75% total solids when the sludge contains no unstabilized solids from primary treatment.

G. Drying with primary solids
Dry the sludge to 90% total solids when the sludge contains unstablized solids from primary treatment

H. Injection
No significant amount of sludge will be present on the land surface within 1 hour after the sludge is injected. Class A sludge must be injected within 8 hrs after being discharged from the pathogen treatment process.

I. Incorporation
Class A sludge should be surface applied within 8 hrs after being discharged from a pathogen treatment process and then incorporated within 6 hrs of surface application, unless otherwise specified by the Department of Natural Resources. Class B sludge should be incorporated within 6 hrs after being discharged, unless otherwise specified by the

Department of Natural Resources. Injection and incorporation are the most common methods of vector attraction reduction for aerobically-digested sludge.

Section 4.5 - Regulations and Reporting

4.5.1 Discuss the records an operator must keep when biosolids or sludge is landspread.

A treatment plant operator has to maintain a daily application log for biosolids land applied on every day when land application occurs. The following minimum records must be kept in addition to all analytical results for the biosolids land applied. The daily log must include the following information:

A. Approved site used
B. Number of acres of sludge applied on that day
C. Amount of sludge applied that day and amount per acre
D. Amount of nitrogen applied per acre
E. Sludge application method (injection, incorporation, or surface application)

4.5.2 Discuss the most common monitoring report forms needed for land application.

A. Sludge/Waste Characteristics Report form (3400-49)
This form is used for reporting the sludge parameters for metals and nutrients as required by the Wisconsin Pollutant Discharge Elimination System (WPDES) permit issued to the wastewater facility (see figure 4.5.2.1).

B. Agriculture Site Worksheet (form 3400-054)
The Agriculture Site Worksheet is used to calculate the recommended sludge application rate based on the crops need for nitrogen. To determine how much nitrogen may be applied to the site, the residual nitrogen is subtracted from the total recommended nitrogen for the crop. Based upon the application technique (incorporated, injected, or surface applied) and sludge nitrogen level, the maximum application rate (in gals/acre/year) is determined.

C. Annual Land Application Report (3400-55)
The Land Application Records Worksheet is completed each year for each site that received sludge. This form is due to the Department of Natural Resources by January 31st of the following year. The Land Application Records Worksheet incorporates information from the Agriculture Site Worksheet (mentioned above) along with other sample results of the sludge. This form is used to convert the total gallons per acre applied into dry tons per acre, calculate the amount of nitrogen made available to each crop, and calculate the metals added with the sludge (see figure 4.5.2.2).

D. Other Methods of Disposal or Distribution Report (3400-52)
This form is used for reporting the annual totals for other methods used to discharge sludge (see figure 4.5.2.3).

Figure 4.5.2.1

CHARACTERISTIC REPORT: s.283.55(1), Wis. Stats. Form 3400-49 Rev. 1-98 Permit No: Page 1 of 2
(Municipal Sludge, Industrial Sludge, Liquid Industrial Waste and By-Product Solids) Facility:

Reporting Period: 07/01/2012 - 08/31/2012
Form Due Date: 01/31/2013

FIN: Region: DOC:

Did you land apply this period? No
FID: Date Received:
If yes and Municipal Sludge:
A) Were Class A Pathogen Requirements Satisfied? Yes
B) Were Vector Control Requirements Satisfied? Yes

Forms require electronic submittal.
Submit form electronically and keep a version of the form for your records.

Submit a copy of your lab reports, to your facility's DNR sludge representative or basin engineer unless instructed otherwise. Email submittal is preferred.

A) **Parameters to be Sampled** **DNR Contact:**

Sample Point Number	Parameter Number	Parameter	Date Sample Taken	Sample Type	Analytical Results	Units	Limit	Municipal Sludge Only		Lab Certification Number
								High Quality Limit	Date Analyzed for Organics	
001	461	Solids, Total	07/17/2012	COMP	43.6	Percent			07/18/2012	617013980
001	33	Arsenic Dry Wt	07/17/2012	COMP	0.995	mg/kg	75	41	07/25/2012	617013980
001	86	Cadmium Dry Wt	07/17/2012	COMP	0.911	mg/kg	85	39	07/25/2012	617013980
001	145	Copper Dry Wt	07/17/2012	COMP	225	mg/kg	4300	1500	07/25/2013	617013980
001	282	Lead Dry Wt	07/17/2012	COMP	4.47	mg/kg	840	300	07/25/2012	617013980
001	278	Mercury Dry Wt	07/17/2012	COMP	0.766	mg/kg	57	17	08/10/2012	617013980
001	298	Molybdenum Dry Wt	07/17/2012	COMP	5.48	mg/kg	75		07/25/2012	617013980
001	313	Nickel Dry Wt	07/17/2012	COMP	7.68	mg/kg	420	420	07/25/2012	617013980
001	421	Selenium Dry Wt	07/17/2012	COMP	<0.261	mg/kg	100	100	07/25/2012	617013980
001	551	Zinc Dry Wt	07/17/2012	COMP	261	mg/kg	7500	2800	07/25/2012	617013980
001	335	Nitrogen, Total Kjeldahl	07/17/2012	COMP	2.87	Percent			07/20/2012	617013980
001	324	Nitrogen, Ammonium (NH4-N) Total	07/17/2012	COMP	0.204	Percent			07/27/2012	617013980
001	388	Phosphorus, Total	07/17/2012	COMP	1.26	Percent			07/25/2012	617013980
001	686	Phosphorus, Water Extractable	07/17/2012	COMP	1.5	%ofTotP			08/07/2012	617013980
001	396	Potassium, Total Recoverable	07/17/2012	COMP	0.115	Percent			07/26/2012	617013980

OUTFALLS
001 - SLUDGE MONITORING

CHARACTERISTIC REPORT: s.283.55(1), Wis. Stats. Form 3400-49 Rev. 1-98 Permit No: Page 2 of 2
(Municipal Sludge, Industrial Sludge, Liquid Industrial Waste and By-Product Solids) Facility:

Reporting Period: 07/01/2012 - 08/31/2012
Form Due Date: 01/31/2013

FIN: Region: DOC:

Municipal Sludge Only

Pathogens

Sample Point Number	Requirement Met	Class	Process Code	Bacteria	Amount	Unit	Start Date	End Date
			Process Description					
001	Yes	A	Alkaline Stabilization	Fecal Coliform	0	MPN/g TS	07/09/2012	07/17/2012
			Schwing Bioset Alternative 1					

Vectors

Sample Point Number	Requirement Met	Vector Reduction	Amount	Date
001	Yes	pH Adjustment of Sludge (pH > 12 s.u. for 2 hrs)	Yes	

Description of Facility Sample Point:

Comments:

Figure 4.5.2.2

ANNUAL LAND APPLICATION REPORT
Section 283.55(1) or 281.48(3)(b), Wis. Stats.
Form 3400-55 Rev. 11-97

Form requires electronic submittal by January 31
Please keep a completed version of the form for your records.
Year Submitted for : **2012**
☒ Did you land apply this period

WPDES Permit No:
Permittee/Licensee Name
FID Number:
County:

Total Municipal Sludge Generated **292** Metric tons
Total Municipal Sludge Land Applied **1,123** Metric tons

DNR #	Fac Site #/ Field #	Landowner	Acres Land Applied	Outfall No*	Amount of Waste	Units	N supplied from waste (lbs/acre)	Other Sources of N (lbs/acre)	Crop Code	Crop Year	Nitrogen Rec. (lbs/acre)	Method	Chlorides Applied (lbs/acre)	Site no longer used
29337	12/1	Sue Smith	27.5	002	190	MT	61	0	17	2012	140	INC		
82875	12/20	Sue Smith	8.0	002	139	MT	154	10	18	2012	180	S		
82877	12/22	Sue Smith	11.0	002	65	MT	111	0	18	2012	140	INC		
99314	16/25A	GREAT WISCONSIN FARMS	4.5	002	38	MT	76	0	17	2012	140	INC		
99316	16/25B	GREAT WISCONSIN FARMS	6.0	002	66	MT	99	0	17	2012	140	INC		
99318	16/26	GREAT WISCONSIN FARMS	2.0	002	20	MT	89	0	17	2012	170	INC		
99311	16/30	Joe and Lillie Gordon	4.5	002	26	MT	65	4	40	2012	140	INC		
85788	24/1	John Deer	11.0	002	78	MT	63	0	17	2012	140	S		
85790	24/3	John Deer	5.0	002	36	MT	64	0	17	2012	140	S		
100370	26/5	Estelle Melnick	4.5	002	33	MT	75	0	34	2012	170	S		
101062	21/21	GREAT LAKES FARMS	33.0	002	289	MT	91	0	58	2013	140	INC		
101064	21/23	GREAT LAKES FARMS	11.0	002	131	MT	92	0	58	2013	140	INC		
82889	23/2	Daniel Champlin	2.0	002	13	MT	61	0	1	2013	170	S		

ANNUAL LAND APPLICATION REPORT
Section 283.55(1) or 281.48(3)(b), Wis. Stats.
Form 3400-55 Rev. 11-97

Form requires electronic submittal by January 31
Please keep a completed version of the form for your records.
Year Submitted for : **2012**
☒ Did you land apply this period

WPDES Permit No:
Permittee/Licensee Name:
FID Number:
County:

Total Municipal Sludge Generated **292** Metric tons
Total Municipal Sludge Land Applied **1,123** Metric tons

Comments:

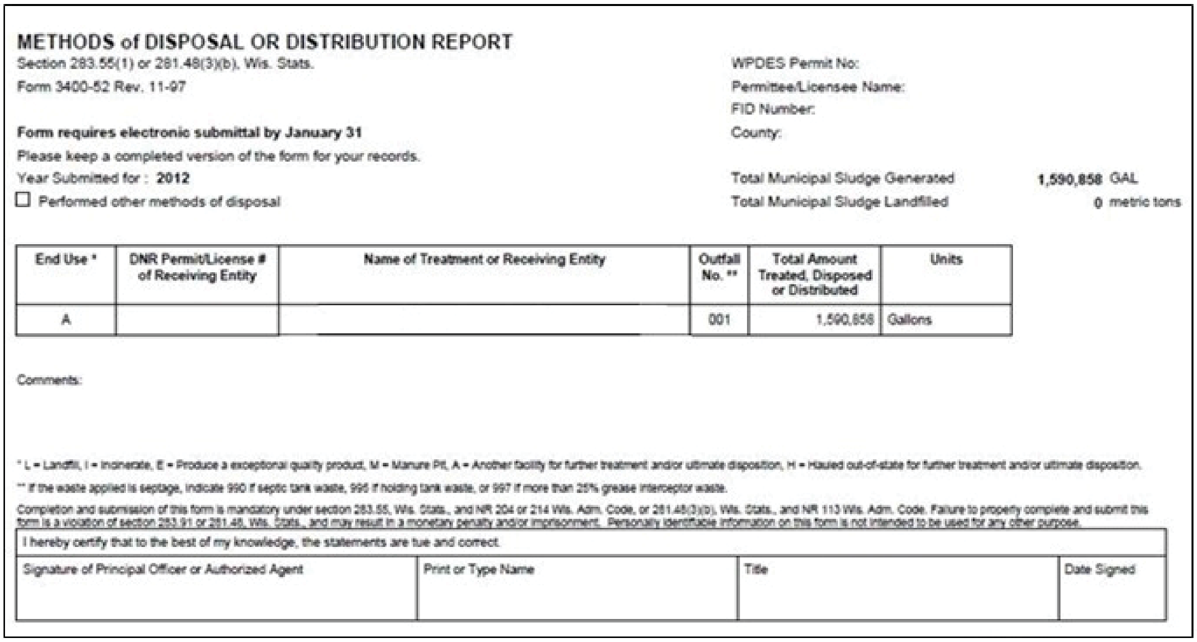
* If the waste applied is septage, indicate 990 if septic tank waste, 995 if holding tank waste, or 997 if more than 25% grease interceptor waste.

Completion and submission of this form is mandatory under section 283.55, Wis. Stats., and NR 204 or 214 Wis. Adm. Code, or 281.48(3)(b), Wis. Stats., and NR 113 Wis. Adm. Code. Failure to properly complete and submit this form is a violation of section 283.91 or 281.48, Wis. Stats., and may result in a monetary penalty and/or imprisonment. Personally identifiable information on this form is not intended to be used for any other purpose.

I certify, under penalty law, that information gathered to determine compliance with applicable pollutant concentrations, pathogen, vector control requirements, and management practices, as specified in chs. NR 204, 113 or 214, Wis. Adm. Code, has been prepared under my direction and supervision in accordance with a system designed to ensure that qualified personnel properly gathered and evaluated this information. I am aware that there are significant penalties for false certification, including the possibility of fine and imprisonment.

Signee's Name	Title	Date Signed

Figure 4.5.2.3



METHODS of DISPOSAL OR DISTRIBUTION REPORT
Section 283.55(1) or 281.48(3)(b), Wis. Stats.
Form 3400-52 Rev. 11-97

Form requires electronic submittal by January 31
Please keep a completed version of the form for your records.
Year Submitted for : **2012**
☐ Performed other methods of disposal

WPDES Permit No:
Permittee/Licensee Name:
FID Number:
County:

Total Municipal Sludge Generated **1,590,858** GAL
Total Municipal Sludge Landfilled **0** metric tons

End Use *	DNR Permit/License # of Receiving Entity	Name of Treatment or Receiving Entity	Outfall No. **	Total Amount Treated, Disposed or Distributed	Units
A			001	1,590,858	Gallons

Comments:

* L = Landfill, I = Incinerate, E = Produce a exceptional quality product, M = Manure Pit, A = Another facility for further treatment and/or ultimate disposition, H = Hauled out-of-state for further treatment and/or ultimate disposition.

** If the waste applied is septage, indicate 990 if septic tank waste, 995 if holding tank waste, or 997 if more than 25% grease interceptor waste.

Completion and submission of this form is mandatory under section 283.55, Wis. Stats., and NR 204 or 214 Wis. Adm. Code, or 281.48(3)(b), Wis. Stats., and NR 113 Wis. Adm. Code. Failure to properly complete and submit this form is a violation of section 283.91 or 281.48, Wis. Stats., and may result in a monetary penalty and/or imprisonment. Personally identifiable information on this form is not intended to be used for any other purpose.

I hereby certify that to the best of my knowledge, the statements are tue and correct.			
Signature of Principal Officer or Authorized Agent	Print or Type Name	Title	Date Signed

4.5.3 Discuss sludge sampling and reporting prior to their reuse or disposal.

Municipal sludge regulations require that sludge meet certain criteria before they can be re-used as a Class A or Class B sludge. Industrial sludges must also meet certain criteria. This is to ensure the environment and public health are protected. The main parameters analyzed prior to the land application of a Class B sludge are:

A. Nutrients (nitrogen and phosphorus)
Nitrogen and phosphorus should be added to the cropland at the proper amount for the crop being grown (the agronomic rate). If more nutrients are added than the crop will use, the excess may leach into the groundwater or run-off into rivers and streams.

B. Metals
Metals can be toxic and thus limits are set for their safe application on agricultural lands. Consult the facility's WPDES permit for metal restrictions.

C. Pathogen reduction
Fecal coliform bacteria must be below certain limits before the sludge can be landspread.

D. Vector attraction reduction
Sludge must be treated and stabilized to below an acceptable level so that when land applied it does not attract flies, mosquitoes, vermin, and birds that can carry and transmit diseases.

4.5.4 List the requirements for approving an agricultural field/site for the application of biosolids.

A. DNR Land Application Site Request Form 3400-053
B. Soil map (websoilsurvey.nrcs.usda.gov)

C. Plat map
D. U.S. Geological Survey (USGS) topo map or aerial photograph
E. Soil test results
F. Signed permission from landowner and farmer

Operators should keep all this information in a site file for each approved land application site, including the DNR Approval Letter.

4.5.5 Show and discuss a soil test report.

Soil testing is one of the most important crop production tools as it balances and optimizes nutrients for improving crop yield and profits. A standard soil test report provides a variety of data including: soil pH, percent organic matter, and phosphorus and potassium concentrations. Soil tests are required every 4 years on land spreading sites. Following the nutrient recommendations helps prevent nutrient over-application enhancing profitability and reducing surface and groundwater contamination (see figure 4.5.6.1 showing a standard University of Wisconsin (UW) Soil Test Report).

A. Field information
The majority of this data is supplied to the laboratory and represents information collected from and representing the field tested including: field ID number, field name, acreage, soil type, slope, plow depth, and previous crop.

B. Nutrient Recommendations
The nutrient recommendations provided in the report are based on several factors including: the anticipated cropping sequence for the field as provided to the laboratory, the soil type provided to the laboratory (see A above), the nutrient needs of the crop corresponding to that particular soil type, any fertilizer credits that may be associated with the cropping sequence (i.e. alfalfa credits) or previously applied nutrient sources (i.e. carryovers or mineralized organic nitrogen from manure or biosolids). DNR form 3400-54 assists facilities calculate the available nitrogen as a result of mineralization of organic nitrogen applied to fields.

C. Suggested Nitrogen Application for Corn
Because corn yield is directly related to nitrogen application rates, and because nitrogen costs are directly related to corn profit, many Midwestern states developed a regional approach to find profitable nitrogen rates to growing corn rather than simply relying on corn yield. This approach is known as the Maximum Return to Nitrogen (MRTN) calculating the maximum return to N at selected prices of N and corn. The UW provides the MRTN on the soil test report. Other approved soil test laboratories may refer to a website to retrieve the information.

D. Additional Information
This section includes additional fertilizer and soil amendment information associated with the testing to the farmer. Other approved soil test laboratories may not have this section.

E. Test Interpretation

The table displays a graphic interpretation of the soil test results for the field.

F. Laboratory Analysis

Because several areas of a field are soil tested, the lab results for each area soil test sampled is listed in this table with averages for the field. Included in the table are the percent organic matter and the phosphorus, potassium, pH and lime recommended for each soil test sampled in the field. Any additional or secondary micronutrients laboratory results, if requested, will be included in the report as well.

Figure 4.5.5.1

Samples Analyzed By:
UW Soil & Plant Analysis Lab
8452 Mineral Point Road
Verona, WI 53593
(608) 262-4364

SOIL TEST REPORT

COOPERATIVE EXTENSION
University of Wisconsin-Extension
University of Wisconsin-Madison
Department of Soil Science

Results also available on-line at http://uwlab.soils.wisc.edu/reports
lab number: 54321 access code: mtwbx

This Report is for:
Bucky Badger

LAB #: 54321

County: Dane
Account No.: 556996
Date Received: 8/1/2007
Date Processed: 8/10/2007
Slope: 0%
Acres: 1.3
Plow Depth: 7"
Soil Name: Antigo
Field Name: Randall
Previous Crop: Alfalfa, established

NUTRIENT RECOMMENDATIONS

Cropping Sequence	Yield Goal	Crop Nutrient Need N	Crop Nutrient Need P_2O_5	Crop Nutrient Need K_2O	Legume N	Fertilizer Credit Manure N	Fertilizer Credit P_2O_5	Fertilizer Credit K_2O	Nutrients to Apply N	Nutrients to Apply P_2O_5	Nutrients to Apply K_2O
	per acre	lb/a	lb/a	lb/a	lb/a	lb/a	lb/a	lb/a	lb/a	lb/a	lb/a
Corn, grain	131-150 bu	see below	30	85	120	45	45	108	see below	0	0
Soybean, grain	46-55 bu	0	0	130	0	15	8	14	0	0	120
Alfalfa, seeding	1-2.5 ton	0	25	155	0	8	4	7	0	25	150
Alfalfa, established	4.6-5.5 ton	0	65	350	0	0	0	0	0	65	350

The lime required for this rotation to reach pH 6.8 is 12 T/a of 60-69 lime or 9 T/a of 80-89 lime.

SUGGESTED N APPLICATION RATES FOR CORN (GRAIN) AT DIFFERENT N:CORN PRICE RATIOS

Previous Crop — Medium/Low Yield Potential Soils	N:Corn Price Ratio ($/lb N:$/bu) 0.05 Rate[1]	0.05 Range	0.10 Rate[1]	0.10 Range	0.15 Rate[1]	0.15 Range	0.20 Rate[1]	0.20 Range
	lb N/a (Total to Apply)[2]							
Corn, Forage legumes, Leguminous vegetables, Green manures[3]	120	100-140	105	90-120	95	85-110	90	80-100
Soybean, Small grains[4]	90	75-110	60	45-70	50	40-60	45	35-55

[1] Rate is the N rate that provides the maximum return to N (MRTN). Range is the range of profitable N rates that provide an economic return to N within $1/a of the MRTN.
[2] These rates are for total N applied including N in starter fertilizer and N used in herbicide applications.
[3] Subtract N credits for forage legumes, leguminous vegetables, green manures and animal manures. This includes 1st, 2nd and 3rd year credits where applicable. Do not subtract N credits for leguminous vegetables on sand and loamy sand soils.
[4] Subtract N credits for animal manures and 2nd year forage legumes.

Guidelines for choosing an appropriate N application rate for corn (grain)

1) If there is more than 50% residue cover at planting, use the upper end of the range.
2) For small grains grown on medium and fine textured soils, the mid to low end of the profitable range is the most appropriate.
3) If 100% of the N will come from organic sources, use the top end of the range. In addition, up to 20 lb N/a in starter fertilizer may be applied in this situation.
4) For medium and fine textured soils with 10% or more organic matter, use the low end of the range; for medium and fine textured soils with less than 2% organic matter, use the high end of the range.
5) If there is a likelihood of residual N, then use the low end of the range or use the high end of the range and subtract preplant nitrate test (PPNT) credits.
6) For corn following small grains on medium and fine textured soils, the middle to low end of the range is most appropriate.

For more information on the new N application rate guidelines for corn see http://uwlab.soils.wisc.edu/pubs/MRTN.pdf.

ADDITIONAL INFORMATION

First year legume N credit is based on a previous fair stand of alfalfa, established with less than 8" of regrowth, as specified on sample submission form.

Fertilizer credit based on 1 year(s) of 15 tons/acre of surface dairy manure.

Lime recommendation may not achieve desired pH in 3 years. Retest then and apply as recommended.

If lime has been applied in the last two years, more lime may not be needed due to incomplete reaction.

Recommended rates are the total amount of nutrients to apply (N-P-K), including starter fertilizer.

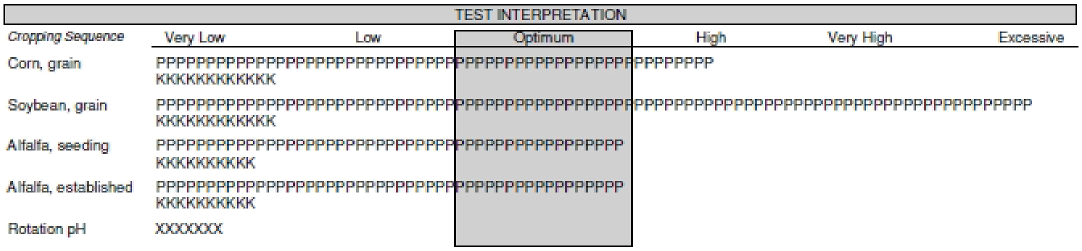
This soil should be monitored more closely because of it has a relatively low potassium buffering capacity.

Starter fertilizer (e.g. 10+20+20 lbs $N+P_2O_5+K_2O$/a) is advisable for row crops on soils slow to warm in the spring.

Year 1: If corn is harvested for silage instead of grain add extra 30 lbs P_2O_5 per acre and 90 lbs K_2O per acre to next crop.

If alfalfa will be maintained for more than three years, increase recommended K_2O by 20% each year.

TEST INTERPRETATION



LABORATORY ANALYSIS

Sample Identification	Soil pH	O.M %	Phosphorus ppm	Potassium ppm	60-69 Lime Req (T/a)	Calcium ppm	Magnesium ppm	Estimated CEC	Boron ppm	Manganese ppm	Zinc ppm	Sulfate-Sulfur ppm	Sulfur Avail. Index	Texture Code	Sample Density	Buffer pH
1	5.8	2.1	23	65	19.8									2	1.01	6.2
Adjusted Averages	5.8	2.1	23	65												

Recommendations based on UW Extension publication 'Nutrient Application Rate Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin' (A2809).

Farmer's Copy

Chapter 5 - Safety

Section 5.1 - Personal

5.1.1 Describe the applicable safety program and requirements municipal wastewater treatment plants must follow.

Wisconsin Department of Safety and Professional Services - Code Chapter SPS 332- Public Employee Safety and Health must be followed. Some of the important safety requirements are confined space, excavation, hearing conservation, bloodborne pathogens, CPR/First Aid, Safety Data Sheets (SDS), electrical, fall protection, hazardous materials, as well as others. Non-public entities follow the Occupational Safety and Health Administration (OSHA) Code CFR 29 part 1910.

5.1.2 Discuss the importance of flotation devices at a wastewater treatment plant.

Sampling from basins, channels, and other treatment processes puts an operator at risk of falling into the wastewater. Basins that are aerated can be the most dangerous because the aeration process makes it extremely difficult, if not impossible, to stay afloat in waters saturated with high concentrations of air. For this reason, an operator should never extend beyond the protection of the guardrails. The Occupational Safety and Health Administration (OSHA) highly recommends ring buoys with at least 90 ft of line be provided and readily available for emergencies and strategically placed around all process basins. OSHA also recommends any operator working over or near water where a risk of drowning is present be provided with a life jacket or buoyant work vest.

5.1.3 Describe how hazards associated with operating sludge handling equipment can be reduced.

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

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, all equipment guards, servicing tag, and lock-out equipment; ensuring that ventilation equipment is operating properly

D. Personal protection equipment (PPE) 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

5.1.4 Discuss the safety cautions to be taken before entering an anaerobic digester.

All confined space procedures should be followed. PPE should be used. All tools and equipment used should be non-sparking and explosion proof. This type of work is often contracted to a specialty company.

Follow the plant's Safety Management Plan!

5.1.5 List the hazards associated with operating and maintaining sludge equipment.

A. Hydrogen sulfide and other gases
B. Confined space entry problems
C. Loose clothing around moving parts on mechanical equipment
D. Wet conditions and/or polymer may cause slips and falls
E. Corrosiveness of preconditioning chemicals
F. Air under pressure or vacuum
G. Pathogens
H. High temperatures and pressures

5.1.6 Discuss the negative consequences of leaving sludge sit in a pipe between two closed valves.

If sludge is trapped in a pipe between two closed valves, bacteria in the sludge could generate gas. If the bacteria generate enough gas, the pressure inside the pipe could build and rupture the pipe. Not only a safety concern, there is a possibility of clogging the piping system if sludge is left in the pipe over a period of time.

Section 5.2 - Chemicals and Gases

5.2.1 Describe safety monitoring equipment to identify hazardous conditions created by digester gas.

A quad-gas or tri-gas meter, stationary or portable, can be used to measure the following gases:

A. Hydrogen sulfide
B. Combustible
C. Carbon monoxide
D. Oxygen

5.2.2 Discuss the chemicals used to adjust anaerobic digester pH and safety considerations.

Chemicals may be used to raise the pH of a sour digester. Two common chemicals used are lime and sodium bicarbonate. The total amount of chemical needed is calculated and then added in small increments, checking pH after each addition. Specific procedures and addition should be checked in the O&M manual or with a consultant.

The use of calcium oxide (quicklime) or calcium hydroxide (slaked or hydrated lime) can be dangerous when these chemicals are mixed with water. Lime must always be added to water and not water added to lime. When water is added to lime, a violent reaction and splashing can occur, splattering this strong caustic. Strong caustic chemicals can burn the skin or eyes (similar to an acid burn).

5.2.3 Discuss the chemicals used for sludge thickening and dewatering and their safety considerations.

When handling polymers, it is important to use the correct personal protective equipment (PPE) and to be aware of the extremely slippery properties. Caution should be used when walking in areas where polymers are used. The addition of rock salt or bleach may be used in clean up. Consult with the Safety Data Sheets (SDS) for additional ways to clean polymer spills.

Oxidizing agents, such as chlorine, are added to elutriate (rinse fine solids out of) the sludge as a way to control biological activity and septicity. Oxidizing agents can be very harmful when exposed to unprotected skin, using the proper PPE is vital. Use equipment that is dedicated solely for the use with these chemicals to avoid cross contamination and possible explosive reactions.

5.2.4 State the function of the water seal on digester covers.

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.

5.2.5 Identify the locations in a mechanical sludge handling plant that should have ventilation equipment.

Ventilation equipment should be provided in all areas where sludge is handled. This would include liquid storage or mixing tanks, conveyor systems, and sludge cake storage areas.

5.2.6 List three purposes for ventilation regarding safety, odor control, and corrosion prevention.

A. Safety
Ventilation removes toxic gases and particulates from work areas.

B. Odor control
Ventilation pulls outside air into work areas and reduces odor.

C. Corrosion prevention
Ventilation keeps the humidity and hydrogen sulfide down which reduces corrosion.

5.2.7 Describe the potential safety hazards with anaerobic digesters and methane gas.

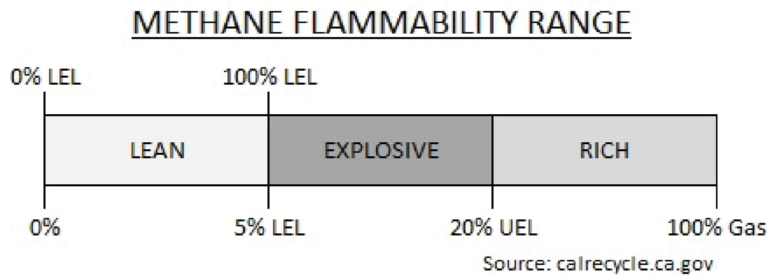
Two digester gases, methane and hydrogen sulfide, can be explosive if the concentration (percentage) is above the lower explosive limit (LEL) and less than the upper explosive limit (UEL). LEL is the lowest concentration of a gas or vapor in air capable of producing a flash of fire in the presence of an ignition source. UEL is highest concentration of a gas or vapor in air capable of producing a flash of fire in the presence of an ignition source. The LEL and UEL for methane gas is 5% and 20%, respectively. For hydrogen sulfide, the LEL is 4% and the UEL is 44%.

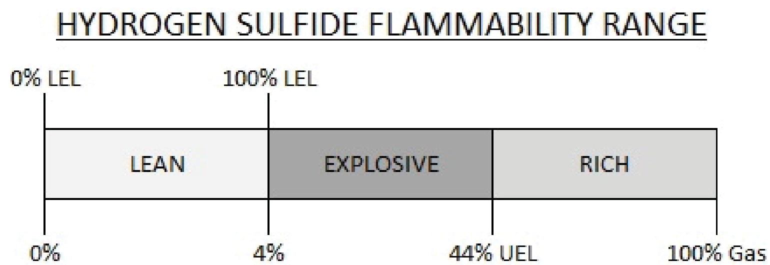
Fixed-cover digesters require diligent operator attention during sludge addition and withdrawal, because the additional flow must be equal to the withdrawal flow. A sludge addition without an accompanying withdrawal over-pressurizes the digester cover and will cause gas venting from the digester to the atmosphere. Air can enter a digester through the vacuum/pressure relief valve forming a potentially explosive atmosphere in the digester when a sludge withdrawal occurs without a corresponding sludge addition.

A floating cover used in anaerobic digesters eliminates many of the sludge addition and withdrawal issues associated with fixed covers. The potential for air entering a floating-cover digester and forming an explosive mixture exists when the cover is resting on the corbels and the water seal is lost or if the floating cover were to become tilted.

Digester gas consists of methane, carbon dioxide (CO2), and hydrogen sulfide (H2S). All of these gases are asphyxiants as they replace oxygen for breathing. Methane and H2S can also form an explosive mixture.

Figure 5.2.7.1





Chapter 6 - Calculations

Section 6.1 - Thickening

6.1.1 Given data, calculate the change in volume (gals) when the sludge concentration (%) changes.

GIVEN:

Initial sludge volume = 1,200 gals
Initial sludge concentration = 4%
Thickened sludge concentration = 6%

FORMULAS AND SOLUTION:

C1V1 = C2V2
4% × 1,200 gal = 6% × V2
= (4% × 1,200 gals) ÷ 6%
= 800 gals

Volume change (gals) = initial sludge vol. (gals) - thickened sludge volume (gals)
= 1,200 gals - 800 gals
= 400 gals

6.1.2 Given data, calculate the process loading (lbs/day) from a sidestream.

GIVEN:
[gpd = gallons per day]
[BOD = biochemical oxygen demand]
[TSS = total suspended solids]

Sidestream flow = 56,000 gpd
Sidestream BOD = 560 mg/L
Sidestream TSS = 910 mg/L
Sidestream phosphorus = 23 mg/L
Sidestream ammonia = 26 mg/L

FORMULAS AND SOLUTION:
[MGD = million gallons per day]

BOD loading (lbs/day) = flow (MGD) × BOD conc. (mg/L) × 8.34
= 0.056 MGD × 560 mg/L × 8.34
= 261.5 lbs/day

TSS loading (lbs/day) = flow (MGD) × TSS conc. (mg/L) × 8.34
= 0.056 MGD × 910 mg/L × 8.34
= 425 lbs/day

Phos. loading (lbs/day) = flow (MGD) × phos. conc. (mg/L) × 8.34
= 0.056 MGD × 23 mg/L × 8.34
= 10.7 lbs/day

Ammonia loading (lbs/day) = flow (MGD) × ammonia conc. (mg/L) × 8.34
= 0.056 MGD × 26 mg/L × 8.34
= 12.1 lbs/day

6.1.3 Given data, calculate the solids capture rate (%).

GIVEN:

Feed sludge flow = 48,000 gals
Feed sludge percent solids = 1.6% (16,000 mg/L)
Return flow = 28,000 gals
Return flow percent solids = 0.1% (1,000 mg/L)

FORMULAS AND SOLUTION:

Feed sludge solids (lbs) = feed sludge flow (MG) × feed solids conc. (mg/L) × 8.34
= 0.048 MG × 16,000 mg/L × 8.34
= 6,405.1 lbs

Return flow solids (lbs) = return flow (MG) × return solids conc. (mg/L) × 8.34
= 0.028 MG × 1,000 mg/L × 8.34

= 233.5 lbs

Solids capture rate (%) = [feed sludge solids (lbs) - return solids (lbs)] ÷ feed sludge solids (lbs)
= [(6,405.1 lbs – 233.5 lbs) ÷ 6,405 lbs] × 100
= 96.4%

Section 6.2 - Treatment

6.2.1 Given data, calculate the volume (gals) of sludge pumped from a piston pump.

GIVEN:

Gallons pumped per stroke = 3 gals
Number of strokes per minute = 15 strokes/min
Number of minutes pumping = 20 min

FORMULA AND SOLUTION:

Volume pumped (gals) = sludge pumped (gals/stroke) × strokes per min × time (mins)
= 3 gals × 15 strokes/min × 20 min
= 900 gals

6.2.2 Given data, calculate the amount of sludge (gals) that had been pumped into an anaerobic digester based on the change in height (ft) of the floating cover.

GIVEN:

Diameter = 40 ft
Initial cover height = 20.5 ft
After pumping height = 21.0 ft
1 ft^3 = 7.5 gals

FORMULAS AND SOLUTION:

Volume (ft^3) = area (ft^2) × height (ft)
Change in height (ft) = height at pump stop (ft) - height at pump start (ft)
= 21.0 ft - 20.5 ft
= 0.5 ft

Volume of sludge pumped (ft^3) = 3.14 × (radius (ft))^2 × change in height (ft)
= 3.14 × (20 ft)^2 × 0.05 ft
= 3.14 × 400 ft^2 × 0.50 ft
= 628 ft^3

Volume of sludge pumped (gals) = volume of sludge (ft^3) × 7.48 gals/ ft^3
= 628 ft^3 × 7.48 gals/ ft^3
= 4,697 gals

6.2.3 Given data, calculate the hydraulic retention time (HRT) (days) in an anaerobic digester.

GIVEN:
[gpd = gallons per day]

Anaerobic digester diameter = 60 ft
Anaerobic digester height = 20 ft
Sludge pumped to anaerobic digester = 20,185 gpd
1 ft^3 = 7.48 gals/ft^3

FORMULAS AND SOLUTION:

Digester volume (ft^3) = 3.14 × [radius (ft)]^2 × height (ft)
= 3.14 × (30 ft)^2 × 20 ft
= 56,520 ft^3

Digester volume (gals) = volume (ft^3) × 7.48 gals/ft^3
= 56,520 ft^3 × 7.48 gals/ft^3
= 423,900 gals

HRT (days) = digester volume (gals) ÷ sludge pumped (gpd)
= 423,900 gals ÷ 20,185 gpd
= 21 days

6.2.4 Given data, calculate the volatile acids/alkalinity (VA/ALK) ratio.

GIVEN:

Volatile acids = 300 mg/L
Alkalinity = 2,000 mg/L

FORMULA AND SOLUTION:

VA/ALK ratio = volatile acids (mg/L) ÷ alkalinity (mg/L)
= 300 mg/L ÷ 2,000 mg/L
= 0.15

6.2.5 Given data, determine the volatile solids (VS) (lbs of VS/day/ft^3) loading to an anaerobic digester.

GIVEN:

Digester volume = 60,000 ft^3
Primary sludge feed rate = 4,500 lbs of VS/day

FORMULA AND SOLUTION:

VS loading (lbs of VS/day/ft^3) = feed rate (lbs of VS/day) ÷ digester volume (ft^3)

= 4,500 lbs of VS/day ÷ 60,000 ft^3
= 0.075 lbs of VS/day/ft^3

6.2.6 Given the volumes of feed sludge, sludge concentrations, volatile solids (VS), and volume of a digester, calculate the organic loading rate (OLR) (lbs/day/ft^3).

GIVEN:

Digester volume = 40,000 ft^3
Raw sludge volume = 5,000 gpd
Sludge concentration = 5%
VS = 80%

FORMULAS AND SOLUTION:
[NOTE: Percent expressed as decimal]

VS (lbs/day) = raw sludge vol. (gpd) × sludge conc. (%) × 8.34 × VS (%)
= 5,000 gpd × 0.05 × 8.34 × 0.8
= 1,668 lbs of VS/day

VS (lbs/day/ft^3) = VS (lbs/day) ÷ digester volume (ft^3)
= 1,668 lbs of VS/day/ft^3 ÷ 40,000 ft^3
= 0.042 lbs of VS/day/ft^3

6.2.7 Given data, calculate the digester efficiency (% volatile suspended solids (VSS) reduction) using the van Kleeck formula.

GIVEN:

Feed solids (in) VSS % = 70%
Digested sludge (out) VSS % = 50%

FORMULA AND SOLUTION:
[NOTE: Percent volatile solids expressed as decimal]

Efficiency (%) = [[(VSS in - VSS out) ÷ [VSS in - (VSS in × VSS out)] × 100
= [(0.70 in - 0.50 out) ÷ [0.70 in - (0.70 in × 0.50 out)]] × 100
= [0.20 ÷ (0.70 - 0.35)] × 100
= (0.20 ÷ 0.35) × 100
= 0.57 × 100
= 57%

6.2.8 Given data, determine the oxygen uptake rate (OUR) (mg/L of DO/min) and specific oxygen uptake rate (SOUR) (mg/L of DO/hr/mg).

GIVEN:

Initial DO = 2.5 mg/L
Final DO = 1.7 mg/L

Time = 15 mins
Aerobic digester total solids = 2.5 g/L

FORMULAS AND SOLUTION:

OUR = [initial DO (mg/L) - final DO (mg/L)] ÷ time (mins)
= (2.5 mg/L - 1.7 mg/L) ÷ 15 mins
= 0.8 mg/L ÷ 15 minutes
= 0.053 mg/L of DO/min

SOUR = [OUR (mg/L of DO/min) × 60 mins/hr] ÷ solids (g/L)
= (0.053 mg/L of DO/min × 60 min/hr) ÷ 2.5 g/L
= 3.18 mg/L of DO/hr/mg/L ÷ 2.5 g/L
= 1.27 mg/L of DO/hr/mg

Section 6.3 - Dewatering

6.3.1 Given data, calculate the proper setting for a chemical feed pump (gallons per minute or gpm).

GIVEN:
[gpd = gallons per day]

Undiluted polymer used = 10 gpd
Polymer feed concentration = 1%

FORMULAS AND SOLUTION:
[NOTE: percent is expressed as a decimal]

Polymer flow (gpd) = undiluted polymer (gpd) ÷ polymer conc. (%)
= 10 gpd ÷ .01
= 1,000 gpd of diluted polymer

Polymer flow (gpm) = polymer flow (gpd) ÷ 1,440 mins/day
= 1,000 gpd ÷ 1,440 mins/day
= 0.7 gpm

Section 6.4 - Land Application

6.4.1 Given data, calculate the amount of sludge cake (dry tons/acre) applied to the land spreading site.

GIVEN:
[MGD = million gallons per day]

Volume of sludge applied = 10,000 gals/acre
Total solids content = 25.2%
Conversion constant = 0.0000417
[NOTE: 0.0000417 = 8.34 × 10,000 mg/L (1% solids) ÷ 1,000,000 MGD × 2,000 lbs/ton]

FORMULA AND SOLUTION:

Sludge applied (dry tons/acre) = sludge applied (gals/acre) × % solids content (%) × 0.0000417
= 10,000 gals/acre × 25.2% × 0.0000417
= 10.51 dry tons/acre

6.4.2 Given data, calculate the amount of liquid sludge (dry tons/acre) applied to the land spreading site.

GIVEN:

Volume of sludge applied = 10,000 gals/acre
Total solids content = 2.53%
Conversion constant = 0.0000417
[NOTE: 0.0000417 = 8.34 × 10,000 mg/L (1% solids) ÷ 1,000,000 MGD × 2,000 lbs/ton]

FORMULA AND SOLUTION:

Sludge applied (dry tons/acre) = sludge applied (gals/acre) × solids content (%) × 0.0000417
= 10,000 gals/acre × 2.53% × 0.0000417
= 1.06 dry tons/acre

References and Resources

1. **UW WATER LIBRARY**

   Most of the resources listed on this page can be borrowed through the UW Water Library as part of a partnership between the UW Water Library, the Wisconsin Wastewater Operator Association (WWOA), Central States Water Environmental Association (CSWEA), and the Wisconsin Department of Natural Resources. Instructions for borrowing materials from the UW Water Library can be found by visiting the website provided below, clicking on 'WISCONSIN RESIDENTS', and then clicking on 'HOW TO BORROW MATERIALS'.

   www.aqua.wisc.edu/waterlibrary

2. **OPERATION OF MUNICIPAL WASTEWATER TREATMENT PLANTS: MANUAL OF PRACTICE NO. 11**

   Water Environmental Federation (WEF). (2008). Operation of Municipal Wastewater Treatment Plants: Manual of Practice No. 11 (6th ed., Vols. I, II, III). New York, New York: McGraw-Hill.

   www.wef.org

3. **OPERATION OF WASTEWATER TREATMENT PLANTS**

   Office of Water Programs, California State University, Sacramento. (2008). Operation of Wastewater Treatment Plants (7th ed.). Sacramento, CA: University Enterprises, Inc., California State University.

   www.owp.csus.edu

4. **NUTRIENT APPLICATION GUIDELINES FOR FIELD, VEGATABLE, AND FRUIT CROPS IN WISCONSIN (A2809)**

   Laboski, C. A., & Peters, J. B. (2012). Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin (A2809). Madison, WI: Cooperative Extension Publishing.

   www.soils.wisc.edu

5. **WISCONSIN ADMINISTRATIVE CODE CHAPTER NR 204: DOMESTIC SEWAGE SLUDGE MANAGEMENT**

   Wisconsin Administrative Code Chapter NR 204: Domestic Sewage Sludge Management. (2011).

   docs.legis.wisconsin.gov

6. **WISCONSIN ADMINISTRATIVE CODE CHAPTER NR 214: LAND TREATMENT OF INDUSTRIAL LIQUID WASTE, BY-PRODUCT SOLIDS AND SLUDGES**

   Wisconsin Administrative Code Chapter NR 214: Land Treatment of Industrial Liquid Wastes, By-Product Solids and Sludges. (2015).

   docs.legis.wisconsin.gov

7. **NATURAL RESOURCES CONSERVATION SERVICE (NRCS) CONSERVATION PRACTICE STANDARD: NUTRIENT MANAGEMENT CODE 590**

Natural Resources Conservation Service Conservation Practice Standard: Nutrient Management Code 590. (2011).

www.nrcs.usda.gov

8. **OSHA CFR 29 PART 1910**

Occupational Safety & Health Administration (OSHA). (2012). Regulations (Standards-29 CFR 1910.1200)

www.osha.gov

9. **WISCONSIN ADMINISTRATIVE CODE SPS 332 PUBLIC EMPOLYEE SAFETY AND HEALTH**

Wisconsin Administrative Code SPS 332 Public Employee Safety and Health (2014)

docs.legis.wisconsin.gov