Wisconsin Department of Natural Resources
Wastewater Operator Certification

Basic General Wastewater Study Guide

August 2015 Edition (Revised June 2016)

Wisconsin Department of Natural Resources
Operator Certification Program
PO Box 7921, Madison, WI 53707

http://dnr.wi.gov

Printed on 01/12/17

Preface

The General Wastewater 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 you need 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.

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

2. Learn with others! Take classes in this type of wastewater operations to improve your 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 you have 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 General Wastewater 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:

Kurt Birkett, Fort Atkinson WWTP, Fort Atkinson, WI
Gary Hanson, AECom, Sheboygan, WI
Greg Paul, QLF Specialty Products, Dodgeville, WI
Dan Tomaro, Wastewater Training Solutions, Oregon, WI
Mark Corbett, Department of Natural Resources, Oshkosh, WI
Amy Garbe, Department of Natural Resources, Madison, WI
Danielle Luke, Department of Natural Resources, Madison, WI
Jack Saltes, Department of Natural Resources, Madison, WI

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Chapter 1 - Terminology

Section 1.1 - Flows and Pollutants

1.1.1 Define biochemical oxygen demand (BOD).

BOD, expressed in mg/L, is a measurement of the organic strength of a sample by measuring the amount of oxygen consumed over a given period of time.

1.1.2 Define composite sample.

A composite sample is a sample prepared by combining a number of grab samples, typically over a 24-hour period.

1.1.3 Define dissolved oxygen (DO).

DO is the measure of the amount of oxygen dissolved in water and is expressed in mg/L.

1.1.4 Define effluent.

Effluent is the treated wastewater discharged from a treatment plant to the environment.

1.1.5 Define eutrophication.

Eutrophication is the excessive growth of plant and algae in receiving waters due to dissolved nutrients and their decomposition.

1.1.6 Define flume.

A flume is a restriction in an open channel used to measure flow.

1.1.7 Define food to microorganism ratio (F:M or F/M).

F/M is the amount of food (BOD) provided to the microorganisms [mixed liquor volatile suspended solids (MLVSS) or mixed liquor suspended solids (MLSS)].

1.1.8 Define gallons per day (gpd).

The term gpd is a common wastewater flow measurement expressed as the number of gallons flowing each day.

1.1.9 Define gallons per hour (gph).

The term gph is a common wastewater flow measurement expressed as the number of gallons flowing each hour.

1.1.10 Define gallons per minute (gpm).

The term gpm is a common wastewater flow measurement expressed as the number of gallons flowing each minute.

1.1.11 Define grab sample.

A grab sample is a single sample taken at a particular time and place that is representative of the current conditions.

1.1.12 Define hydraulic retention time (HRT).

HRT is a period of time that wastewater remains in a tank. This term is also known as detention time.

1.1.13 Define influent.

Influent is the raw (or untreated) wastewater entering a treatment process.

1.1.14 Define milligrams per liter (mg/L).

The measurement mg/L is a concentration of a substance in a liquid expressed as a weight in milligrams per liter of volume (mg/L). Milligrams per liter is the same as parts per million (ppm). 1 mg/L = 1 ppm
(One liter of water weighs 1,000,000 mg)

1.1.15 Define million gallons per day (MGD).

MGD is a common wastewater flow measurement in a treatment plant, expressed as millions of gallons (MG) of wastewater flowing each day.

1.1.16 Define pH.

pH is a measure of the acidity or alkalinity of a sample on a scale of 0 to 14 (acidic to alkaline). A pH of 7 is neutral.

1.1.17 Define septage.

Septage is the high strength waste pumped out of septic tanks, sometimes disposed at wastewater treatment plants.

1.1.18 Define sludge age.

Sludge age is the theoretical length of time a particle of activated sludge stays in the treatment plant, measured in days. In an activated sludge plant, sludge age is the amount (lbs) of MLSS divided by the suspended solids or excess cell mass withdrawn from the system per day [lbs per day of waste activated sludge (WAS)].

1.1.19 Define total suspended solids (TSS).

TSS is the measure of the total amount of solids suspended in a sample and is expressed in mg/L.

1.1.20 Define weir.

A weir is a level control structure used to provide uniform flow.

Section 1.2 - Sewer Systems

1.2.1 Define combined sewer.

Combined sewers are pipe conveyances that carry both wastewater and storm water in a single pipe. During dry weather conditions, combined sewers discharge to a wastewater treatment plant. In the past, combined sewers discharged directly to a water body during wet weather conditions. Today, the extra wet weather volume is stored until it can be returned to the wastewater treatment plant.

1.2.2 Define inflow and infiltration (I/I)

I/I is any unwanted clearwater that leaks into a collection system. Generally, it consists of groundwater, rainwater, or snowmelt.

1.2.3 Define lift station.

A lift station is an underground chamber with pumps that is used to elevate (lift) wastewater to a higher grade. Lift stations are located within a collection system.

1.2.4 Define manhole.

A manhole is a structure that provides access to a collection system. It is typically a round opening with an iron lid.

1.2.5 Define sanitary sewer or collection system.

A sanitary sewer or collection system is an underground pipe system used to convey wastewater to a treatment facility.

1.2.6 Define sanitary sewer overflow (SSO).

A SSO is a release of wastewater from a sewage collection system or an interceptor sewer directly into a water of the state or to the land surface. All SSOs must be reported to the Department of Natural Resources within 24 hours of the occurrence.

1.2.7 Define storm sewer.

A storm sewer is an underground pipe system that collects rainwater from streets and conveys it to a place other than the wastewater treatment plant.

1.2.8 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.

1.2.9 Define wet well.

A wet well is a tank where wastewater is collected. The wastewater is then pumped from the wet well. Wet wells are commonly found in lift stations and at the headworks of the wastewater treatment plant.

Section 1.3 - Wastewater Processes

1.3.1 Define aeration basin.

An aeration basin is a tank where wastewater is aerated to achieve biological treatment.

1.3.2 Define aerobic (oxic) [O2].

Aerobic is a condition under which free and dissolved oxygen (DO) is available in an aqueous environment.

1.3.3 Define anaerobic (septic) [Ø].

Anaerobic is a condition under which free, dissolved, and combined oxygen is unavailable in an aqueous environment.

1.3.4 Define anoxic.

Anoxic is a condition under which oxygen is only available in a combined form such as nitrate (NO3-), nitrite (NO2-), or sulfate (SO4-2) in an aqueous environment.

1.3.5 Define biosolids.

Biosolids are the nutrient-rich, organic byproduct of a municipal wastewater treatment plant that is utilized as fertilizer.

1.3.6 Define clarifier.

A clarifier is a circular or rectangular tank used to remove floatable and settleable solids in wastewater.

1.3.7 Define disinfection.

Disinfection is a process used to destroy most pathogens to a safe level in the effluent. Disinfection does not destroy all microorganisms.

1.3.8 Define grit.

Grit is the fine, abrasive particles removed from wastewater, such as sand and eggshells.

1.3.9 Define headworks.

Headworks is the beginning, or head, of a treatment plant where influent flow is measured and sampled and where preliminary treatment occurs.

1.3.10 Define microorganism.

A microorganism is a living organism too small to be seen with the naked eye, but is visible under a microscope. They include: bacteria, viruses, fungi, or protozoa.

1.3.11 Define primary treatment.

Primary treatment is a treatment process usually consisting of clarification by solid and liquid separation removing a substantial amount of suspended and floating matter.

1.3.12 Define process control.

Process control is the tools and methods used to optimize treatment plant operations.

1.3.13 Define return activated sludge (RAS).

RAS is the settled activated sludge (biomass) collected in a final clarifier and returned to the secondary treatment process to mix with incoming wastewater. This returns a concentrated population of microorganisms back into the aeration basin.

1.3.14 Define screenings.

Screenings are the materials in wastewater removed with screens at the headworks of treatment plants. They include: sticks, stones, plastics, and personal hygiene products.

1.3.15 Define secondary treatment.

Secondary treatment is a treatment process using biological processes that utilize bacteria to remove pollutants.

1.3.16 Define selector.

A selector is part of the treatment system that selects for a specific type of microorganism by providing an environment (anaerobic, anoxic, or aerobic) that favors its growth.

1.3.17 Define sidestreams.

Sidestreams are flows generated within the plant, usually from solids processing that has been recycled back through the plant.

1.3.18 Define tertiary treatment.

Tertiary treatment is a treatment process using physical, chemical, or biological processes to remove suspended solids and nutrients in wastewater to accomplish a level of treatment greater than what can be achieved by secondary treatment.

1.3.19 Define treatment process.

A treatment process means a physical, biological, or chemical action that is applied to wastewater to remove or reduce pollutants.

1.3.20 Define treatment unit.

A treatment unit is an individual structure or equipment within a collection system or a wastewater treatment facility that is part of a treatment process.

1.3.21 Define waste activated sludge (WAS).

WAS is the activated sludge (excess biomass or cell mass) removed from the secondary treatment process. For most treatment plants, this will be a portion of the RAS flow stream.

Section 1.4 - Safety and Regulations

1.4.1 Define confined space.

A confined space is a space large enough for an operator to enter and perform assigned work. It has limited or restricted means for entry or exit and is not designed for continuous occupancy.

1.4.2 Define pathogens.

Pathogens are infectious microorganisms in wastewater that pose health risks.

1.4.3 Define Wisconsin Pollutant Discharge Elimination System (WPDES) permit.

A WPDES permit is issued to wastewater facility owners and contains facility effluent, biosolids and sludge limitations, conditions, and reporting requirements.

1.4.4 Discuss where a wastewater treatment plant operator would find information on conducting wastewater tests.

The most authoritative source for conducting wastewater testing can be found in 'Standard Methods for the Examination of Water and Wastewater', prepared and published jointly by the American Public Health Association, American Water Works Association, and Water Environment Federation. It is commonly referred to simply as 'Standard Methods'. The first edition was published in 1905 and many editions have since been published as information is updated and instrumentation and methodologies change.

Chapter 2 - Influent Wastewater

Section 2.1 - Sources

2.1.1 Discuss the early historical methods of dealing with wastewater.

Early on, human waste and wastewater was basically disposed of directly on the land surface. In urban communities, it was common to discharge human waste in gutters and ditches. This situation created sanitary problems (illnesses and diseases), nuisance odors, and unsightliness. Rains were counted on to flush the waste away. Later development of the pit toilet or outhouse facility continued until underground collection systems were developed.

The development of water supply systems increased the volume of wastewater generated. Early health concerns led to the building of pipe collection systems to convey this material away from human habitation, usually to a river, stream, or other body of water. Early systems received both wastewater and storm water. This improved public health concerns, but transferred the problem to receiving water streams.

2.1.2 Discuss the Clean Water Act.

The Clean Water Act is a federal law created in 1972 with the main objective of chemically, physically, and biologically restoring and maintaining the nation's waters. It was created to stop the continuous dumping of pollutants, both point source and non-point source, into surface waters and wetlands.

2.1.3 Discuss the importance of treating wastewater.

Wastewater is treated for two main reasons:

A. Protect public health by destroying pathogens
B. Protect the environment by removing pollutants

Pathogenic organisms are disease-causing microorganisms. They include various bacteria, viruses, and parasites. The discharge of waterborne human wastes will contain these organisms from ailing individuals and would be expected to be present in wastewater entering a wastewater treatment plant.

Although wastewater treatment is taken for granted in the United States, rivers and lakes are more polluted and waterborne diseases are more prevalent in countries that do not properly treat wastewater.

2.1.4 Describe the sources of wastewater in a community.

Wastewater is used water that goes down the drain and flows to the wastewater treatment plant. Flows originate from domestic (household), industrial, and commercial sources. Some wastewater is trucked to the wastewater treatment plant as septage, holding tank waste, leachate, and some high strength industrial wastewater. In addition, clearwater (rain, snow, and groundwater) from inflow and infiltration (I/I) can get into the collection system.

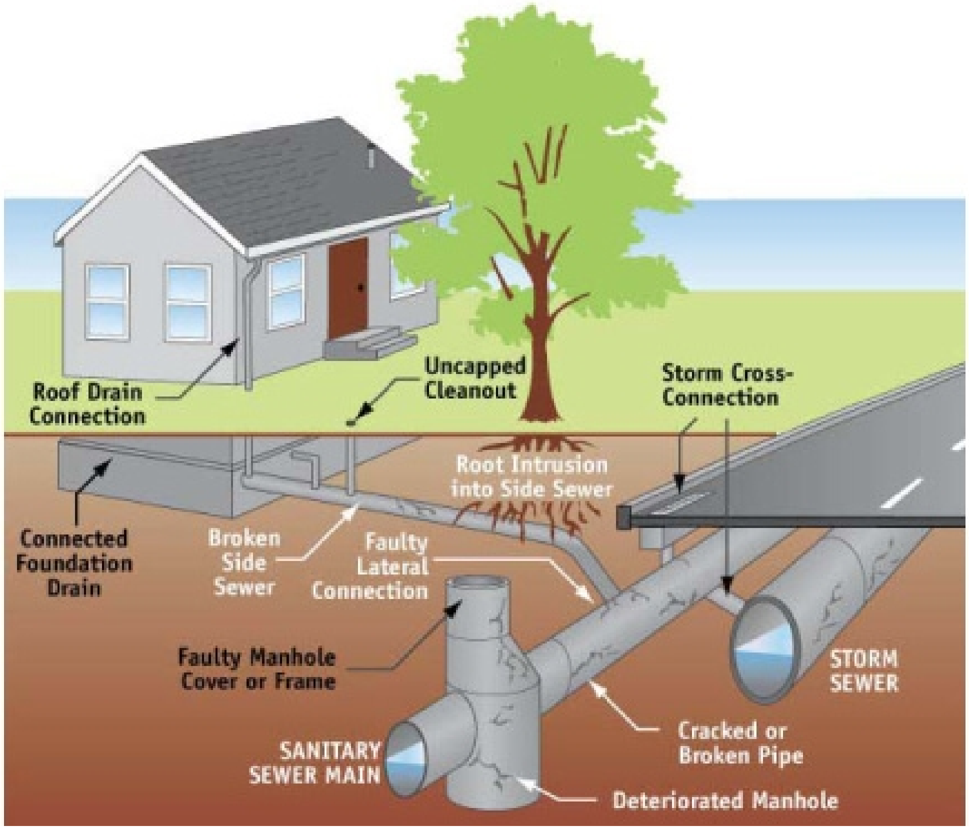
2.1.5 List and define common sources of I/I.

I/I is unwanted clearwater that gets into the collection system. Clearwater is classified by how fast it gets into the collection system and is determined by weather and groundwater conditions. If the flow increases as soon as there is significant rainfall and subsides soon after the rain stops, it is called inflow. If the flow goes up gradually after a rainfall and stays up as long as the groundwater remains high, it is called infiltration.

Common sources of clearwater (I/I) are:

A. Roof leaders connected to the sanitary sewer
B. Storm and sanitary crossovers
C. Low lying manholes in roads or ditches subject to flooding
D. Uncapped lateral connections
E. Sump pumps and foundation drains
F. Cracks and offset joints in the sanitary sewer
G. Manhole cracks and defects
H. Buried manholes
I. Cracks and leaks in building sewers

Figure 2.1.5.1



2.1.6 Discuss the effect of I/I on a collection system.

When I/I enters collection system pipes, it can exceed the flow capacity of the pipes and result in surcharging, basement backups, and sanitary sewer overflows (SSO). I/I in the collection system can also lead to very high flows entering the treatment facility and can lead to wastewater pumping and treatment problems. Too much flow going through aeration basins and clarifiers can wash out solids, creating a loss of treatment efficiency and resulting in permit violations.

Section 2.2 - Conveyance

2.2.1 Trace the sequence of events from the time one flushes a toilet until treated wastewater reaches a receiving stream.

Potable water is provided by the water supply system into a building and is used to flush or drain wastes into the building's sanitary sewer pipes and into the wastewater collection system. Wastewater is conveyed through gravity sewers, lift stations, and force mains until it makes its way into the headworks of a wastewater treatment plant. The wastewater is then treated by both physical and biological unit operations and processes and then clean water is discharged into a receiving water body.

2.2.2 Explain the components of a sanitary sewer collection system.

A. Private building lateral sewer

A private building lateral sewer is a 6-inch pipe that conveys sewage from the building to the public sewer main, usually under the street.

B. Mainline sewer
Mainline sewers are pipes that collect sewage from buildings and flow by gravity to the treatment plant.

C. Force mains
Force main sewer pipes are where wastewater is pumped (forced) under pressure to a specific location. Force mains are used when sewage cannot flow by gravity.

D. Lift (pump) stations
A lift station is a location in the collection system where wastewater is collected (wet well) and then pumped to another location. The purpose of a lift station is to lift (pump) wastewater to a higher elevation where it can flow by gravity.

E. Inverted siphon
An inverted siphon is a pipe that must dip below an obstruction and will normally form a U-shaped flow path. The liquid flowing in one end simply forces liquid up and out the other end. Inverted siphons are commonly used when a sewer pipe must be routed under a river or other deep obstructions.

F. Manholes
A manhole is a structure, usually circular, at the surface that allows access to the sewer pipes buried below.

2.2.3 Describe a wet well lift station.

A wet well lift station is a single chamber that collects wastewater. This type of lift station is commonly called a submersible lift station due to the pump and motor being completely submerged in the wet well. The submersible centrifugal pump is watertight and normally controlled by float switches. They are made to be easily removed for cleaning and maintenance using a rail system.

2.2.4 Explain how a wet well and dry well pumping station works.

In wet well and dry well lift stations, the centrifugal pumps and other equipment are located in a separate chamber (dry well), with only the suction pipe being submersed in the wet well. The pump is turned on when the wastewater reaches a certain depth. If the wastewater continues to rise, more pumps will be turned on. The pumps are turned off when the wet well is empty or reach the minimal set point. It is important that the dry well be well ventilated and dehumidified to protect the equipment and ensure the safety of the operator.

2.2.5 Describe sanitary sewer overflows (SSO) and their causes.

SSOs occur for many different reasons. One of the main reasons sewers back-up and overflow is too much clearwater gets into the sewer pipes through infiltration or inflow (I/I) during wet weather events. Sewer pipes are designed for only a certain flow capacity and excessive I/I can exceed that capacity. As sewers age, sewer defects increase, allowing for more clearwater (I/I) to get into them. Other circumstances that can cause an overflow are power outages, plugged sewers due to grease or large objects, broken or collapsed pipes, equipment failure such as a lift station pump, or wide-scale flooding.

2.2.6 Discuss the operation and maintenance (O&M) of a collection system.

The primary activities of operating and maintaining a sanitary sewer collection system are:

A. Cleaning
B. Root removal
C. Televising
D. Flow monitoring
E. Smoke testing
F. Manhole inspections
G. Lift station maintenance
H. Manhole rehabilitation
I. Mainline rehabilitation
J. Private sewer inspections
K. Private sewer I/I removal
L. Fat, oil and grease (FOG) control program

Operating and maintaining a sewer system will ensure the wastewater flows to the treatment plant, without any overflows or basement back-ups anywhere in the sewer system. Regularly televising a certain percentage of the sewer system each year to assess pipe conditions is the most important inspection tool available to operators, as it is the only way to see the pipe.

Section 2.3 - Wastewater Characterisitics

2.3.1 Describe the characteristics of influent domestic wastewater.

Raw influent is less than 99% water and is gray in color with an earthy, musty odor. Typical influent wastewater concentrations are:

Figure 2.3.1.1

Pollutant	Concentration (mg/L)
Biochemical oxygen demand (BOD)	250
Total suspended solids (TSS)	300
Total nitrogen	40
Ammonia	25
Total phosphorus	9
Fats, oils, and grease (FOG)	100
pH	6.5 to 8.0

Source: Wisconsin Rural Water Association (WRWA)

2.3.2 Discuss the potential impacts of industrial and commercial discharges.

Industrial discharges may vary in strength and volume. Slug loads are of special concern and can upset or pass through the treatment plant and out with the final effluent. High levels of BOD, TSS, phosphorus, ammonia, and FOG can effect treatment. High or low pH can also be a problem.

2.3.3 Discuss the wastewater characteristics and problems with industrial discharges into a treatment plant.

A. Dairy operations
Many different types of dairy and whey products are produced in Wisconsin. Some dairy operations have their own wastewater treatment plant, but many discharge to the treatment plant in the community in which they are located. Industrial wastes from dairy facilities consist of various dilutions of milk entering the municipal collection system. One of the largest sources of dairy wastewater come from the wash waters and rinse waters of dairy tanks, trucks, equipment, pipelines, and floors. Dairies use clean-in-place systems that alternate acidic and caustic cleaners and rinses in the cleaning of tanks, equipment, and pipes, raising or lowering pH. Milk and milk solids have a very high BOD, sometimes as high as 1,000 to 10,000 mg/L. Milk wastes also contain high amounts of nitrogen, phosphorus, and chlorides. The volume and BOD of dairy wastewater can vary greatly over a 24-hour period. Therefore the collection and equalization of dairy wastewater is very important so that the flow and BOD discharges to the collection system are more uniform. Sometimes dairy wastes have to be pretreated before discharge to a sanitary sewer. A treatment plant can be upset if it receives variable loads, high-strength wastes, high or low pH discharges, or slug loads from a dairy facility.

B. Food industry
Food (meats, canned foods, snacks, etc.) is processed in many different ways, and the wastes from them can vary in composition. Because food industry wastewaters can be variable and are usually high in BOD, suspended solids, nitrogen compounds, phosphorus, chlorides, and vary in pH, it is important for operators to be familiar with the wastewaters from food processors in their community. Sometimes these wastes have to be equalized or even pretreated before they can be discharged to a collection system.

C. Breweries
Wisconsin is known for its many breweries and microbreweries. Brewery wastewater typically has a high concentration of BOD from the carbohydrates and protein used in the brewing process and in the cleaning of brewery vessels, pipes, and equipment. Brewery wastewater can have a BOD of 1,000 to 4,000 mg/L; TSS from 200 to 1,000 mg/L; nitrogen 25 to 80 mg/L; phosphorus 1 to 50 mg/L; and a pH of 4 to 12. The volume and BOD of brewery wastewater can vary greatly over a 24-hour period. Therefore, the collection and equalization of brewery wastewater is very important so that the flow and BOD discharges to the collection system are relatively uniform.

D. Metal finishing
Wastewater from metal finishing has very little BOD associated with it, but has pollutants that can be toxic to fish and aquatic life and treatment plant microorganisms, even in small

concentrations. These pollutants are not always readily removed by conventional secondary biological treatment methods. Cleaning and coating operations can result in wastewater with a pH from 1 to 12 and wastewater can contain phosphates and toxic materials such as chromate, cyanide, and metals. Many metal-finishing industries have federal or state pretreatment requirements before they can discharge their waste to a collection system. Metals can concentrate in treatment plant sludges, and, therefore, metals in sludges must be analyzed and reported to the Department of Natural Resources on sludge characteristic reports. Application of sludge with high metals concentrations is prohibited and/or restricted in rate due to potential toxicity and/or soil accumulation concerns.

2.3.4 Discuss the impact cleaning agents and products can have on a treatment plant.

Cleaning products and sanitizers are used widely in communities and are important in ensuring public health. When used frequently and in large quantities at industries, businesses, schools, nursing homes, medical facilities, or restaurants, they have the potential to affect treatment. Many effective cleaners contain phosphates and thus can contribute a significant amount of phosphorus to wastewater. Wastewater treatment plants with phosphorus limits, especially those with stringent limits, will have to remove nearly all this phosphorus. While ammonia is a very effective cleaning agent, quaternary ammonium compounds (commonly known as quats) can have toxic effects on treatment. Ammonia-based cleaning products also contribute ammonia to the waste stream, which must in turn be removed since ammonia can be toxic to fish and aquatic life. Surfactants can interfere and keep solids from settling in clarifiers as well as create foam in aeration basins.

2.3.5 Discuss the impact FOG can have on a collection system and a treatment facility.

FOGs are waste byproducts of cooking. They are found in meats, dairy products, cooking oils, shortenings, food scraps, and sauces. FOG collects and can form grease plugs in sewer pipes if washed down the drain or through unmaintained grease traps at restaurants or institutions. The most common cause of sanitary sewer overflows (SSO) from sewer pipes are blockages caused by grease. If grease makes its way to the treatment plant, it can plug valves, meters, and pipes. It floats to tank surfaces and can create settling problems. Grease can also favor the growth of filamentous organisms that create surface foam and scum. Grease can involve costly and unpleasant clean-ups.

The best practice for controlling grease is to keep it out of the collection system in the first place by having a Grease Control Program in a community. A Grease Control Program usually involves regular inspections of restaurant and institutional (nursing home, hospital, and school kitchens) grease traps or interceptors and an ongoing information and education program with residents and businesses.

2.3.6 Discuss control measures necessary for industrial discharges.

A. Enforce sewer use ordinances
B. Effective communication with industries
C. Grease Control Program
D. Monitoring

2.3.7 Describe the types of materials prohibited from discharge into collection systems and the reasons they should not be discharged.

The materials with the characteristics listed below are generally prohibited from discharge to the sewer system. These prohibitions are included in local sewer use ordinances. Generally, materials that can interfere with wastewater treatment, pass through the treatment system and cause a water quality violation, or accumulate in sludges, making the sludges toxic or hazardous are prohibited. Many of the industrial materials can be handled with proper pretreatment or segregation of waste streams that cannot be pretreated.

A. Volatile organics, including gasoline or solvents, can cause an explosive atmosphere in the collection system or at the treatment plant.

B. Heavy metals, including chromium, zinc, copper, nickel, and cadmium, are very toxic and can cause a treatment plant upset, pass through the plant, or accumulate in the sludge.

C. Acidic and alkaline wastes can damage the collection system or upset the treatment plant. Generally, a pH lower than 5.0 or greater than 10.0 should be neutralized prior to discharge to the collection system.

D. FOG must be controlled at industrial and commercial sources with oil separators and grease traps to prevent maintenance problems in wet wells and at the treatment plant.

E. High-strength loadings of BOD or suspended solids can organically overload the treatment plant. This can especially be a problem with batch dumping that causes large slug loads. Any batch type operation should be handled by flow equalization to prevent plant upsets.

F. High temperature wastewaters can affect biological activity.

G. Solid or viscous materials can cause sewer blockages.

H. Any debris including rags or other materials can cause sewer blockages or pump clogging.

I. Other toxic materials can impair or interfere with the treatment process.

Section 2.4 - Flow Monitoring

2.4.1 Discuss the importance of wastewater flow measurement.

It is very important to know how much influent is flowing and being treated in the plant. Treatment efficiency is dependent on loadings and detention time. It is also required to report how much final effluent flows into a receiving water body. To measure the influent entering a treatment plant from the community, flow measurements should be taken before sidestreams. To know the actual flow and loading to the treatment units, sidestreams need to be included in the flow measurements.

2.4.2 List and describe the common types of flow measurement devices.

A. Open channel flow

Flow through an open channel can be measured by installing a structure in the channel. This structure is typically either a flume or weir. The most common type of flume is a Parshall Flume. The most common type of weir is either a 60° or 90° v-notch (triangular) weir.

As water flows through a flume or weir, the level of water flowing through it is measured. The most common water level measurement device is an ultrasonic meter, but other devices such as pressure measurement, bubbler tubes, and staff gauges are also used.

In order to get an accurate flow measurement, the weir or flume has to be sized correctly for the expected range of flows; the flow leading to it must be smooth and the water level measurement device must be properly located.

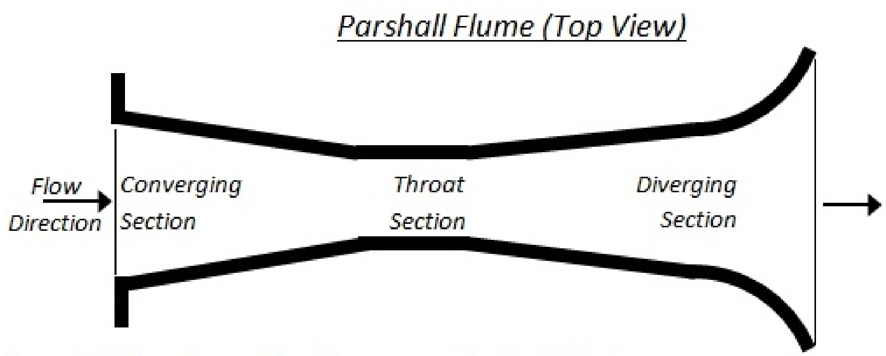
The reader is referred to the 'ISCO Open Channel Handbook' for complete information about open channel flow monitoring equipment and tables.

B. Pipe flow meters

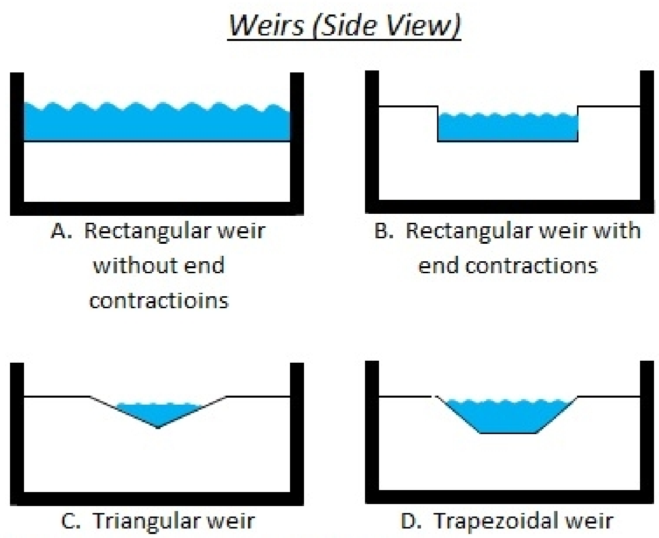
The most common way to measure the flow of wastewater through a pipe is a magnetic flow meter, commonly referred to as a magmeter. A magmeter operates on the principle of electromagnetic induction. Other devices, such as pressure or ultrasonic meters, are also used.

As flows are metered, the flow data is recorded and stored in a computer or charted and totaled. This information is then used for operational and reporting purposes. All flow measurement devices must be calibrated annually according to the Wisconsin Administrative Code and records kept.

Figure 2.4.2.1



Source: ISCO Open Channel Flow Measurement Handbook 3rd ed.



Source: ISCO Open Channel Flow Measurement Handbook 3rd ed.

2.4.3 List flow measuring applications in a wastewater treatment plant.

While flow monitoring is required in Wisconsin Pollution Discharge Elimination System (WPDES) permits for measuring influent and effluent flows, flow measurements are needed in many other places within the plant for proper process control. In an activated sludge plant, measuring return and waste activated sludge is extremely important as they are the key to successful operations. In-plant flow meters are used for measuring:

A. Return activated sludge (RAS)
B. Waste activated sludge (WAS)
C. Recycle or recirculation flows
D. Sidestream flows
E. Sludge flows to digesters
F. Sludge feed rates to sludge dewatering equipment
G. Sludge withdrawal volumes from storage tanks

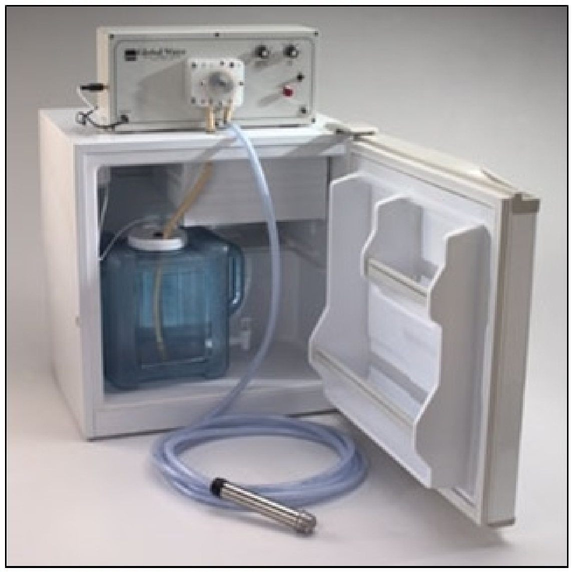
Section 2.5 - Sampling

2.5.1 Discuss grab and composite influent sampling.

A grab sample is a sample collected at a single instant in time. A composite sample is a collection of samples taken over a longer period of time (usually 24 hours) and mixed and stored in a larger container. A composite sample represents the average wastewater quality being received into a wastewater treatment plant. If samples collected over 24 hours are stored in a composite sampling jug or container, the jug or container must be shaken and well mixed before pouring the actual sample to be used for testing. Some samples, such as pH, dissolved oxygen (DO), and chlorine residual, must be grab samples because compositing and holding such samples would change the test results.

Figure 2.5.1.1

Refrigerated Composite Sampler



Source: North Central Labs

2.5.2 Describe how flow-proportional sampling works.

Flow-proportional sampling is the most representative method of collecting wastewater samples for wastewater coming into and being discharged from a wastewater treatment plant on a continuous basis. For most treatment plants in Wisconsin, flow-proportional sampling is a permit requirement. The volume of each sample collected is based on the flow, and this is accomplished by having a flow meter send a signal to an automatic composite sampler. The sampler is programmed to collect a certain sample volume per unit volume of flow (flow pulse interval). For instance, the sampler may take a 50 mL sample every 10,000 gals of flow.

It is more representative to take a small sample more often than it is to take a large sample less often. A sample should be collected at least every 10 to 15 mins (4 to 6 samples every hour) during the peak flow period of the day, such as in the morning of a normal work day. For instance, if a peak hourly flow of 60,000 gals flows into the plant between 8 am and 9 am, the sampler should be programmed to take a sample every 10,000 to 15,000 gals of flow (60,000 gals/hr and 6 samples per hour = 10,000 gals/sample). Conversely, in the middle of the night when flows may drop to only 10,000 to 20,000 gals/hr, the flow-proportional sampler will only collect 1 to 2 samples in an hour. The volume of sample collected each flow pulse interval should be adjusted, as a general rule, to fill at least 1/4 to 1/2 of the compositing container in 24 hours during average flows. This will allow the container to fill, without overfilling, during wet weather periods when daily flows increase 2 to 4 times the average flow. If peak flows are higher than this, then the sample volume will have to be reduced during wet weather so as to not overfill the container and cause the sampler to shut off, thereby not collecting a true 24-hour composite sample. A flow-proportional sample MUST sample during a full 24-hour period, even during wet weather peak flows.

2.5.3 Discuss the difference between a time-proportional and flow-proportional composite sample.

Time-proportional composite samples are a collection of samples over time, usually after so many minutes. Flow-proportional composite samples are samples collected per unit of flow, after so many gallons. The frequency at which flow-proportional samples are collected is directly proportional to the flow, with more samples taken when flows are higher and less samples when flows are lower. Automatic flow-proportional composite samplers are required for almost all wastewater treatment plants, as they are the most representative means of collecting samples from continuous flowing treatment systems, especially for biochemical oxygen demand (BOD) and total suspended solids (TSS).

2.5.4 Describe a good sampling location and procedure for collecting representative influent wastewater samples.

It is important that raw influent wastewater be sampled in a location where it is well mixed and represents the actual wastewater coming into the treatment plant. It is best to collect the sample after the headworks (after screenings and grit removal), as this is most representative of the BOD and TSS going into downstream treatment units.

2.5.5 Discuss the information that must be recorded for influent wastewater samples.

Automatic composite samplers must be refrigerated and maintained at a temperature not to exceed 6°C (Celsius) and must never be frozen. A thermometer immersed in a small capped bottle of liquid is usually kept in the sampler to check and record temperatures on a daily basis. A 24-hour composite sample is the common requirement. For Discharge Monitoring Reporting (DMR), the date on which the majority of the composite sample was taken is the date of the sample. A sampling log must be maintained at the automatic composite sampler and the following information recorded:

A. Sample identification
B. Date started
C. Time started
D. Date collected
E. Time collected
F. Sampler temperature
G. Operator initials
H. Comments

Chapter 3 - Wastewater Treatment

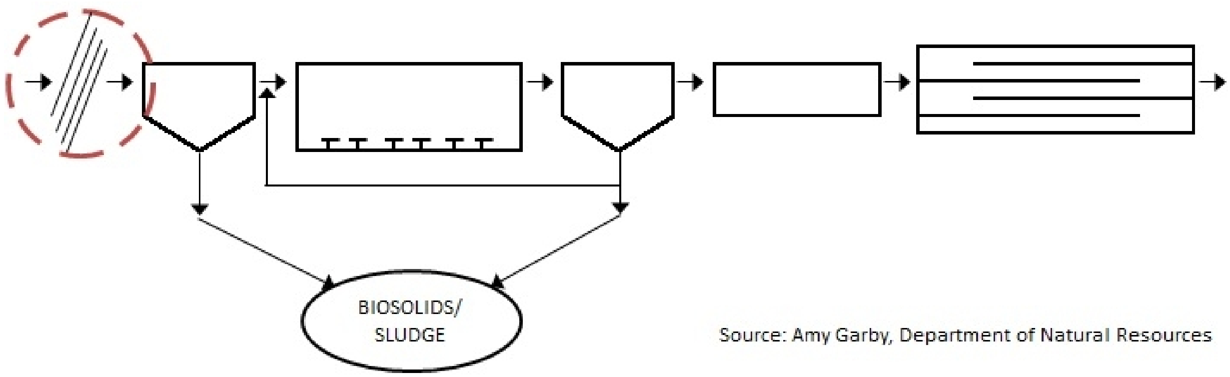
Section 3.1 - Preliminary Treatment

3.1.1 Discuss the preliminary treatment process.

The purpose of preliminary treatment is to remove larger materials (rags, sticks, stones, plastics, personal hygiene products, etc.) and grit from the waste stream before it flows to downstream treatment units. This is done to significantly reduce the plugging and clogging of pumps and pipes, the abrasive action of grit on equipment, and the settling of these materials in down streams tanks and basins.

Preliminary treatment usually consists of screening and grit-removal equipment. Sewage grinders and comminutors that shred larger materials into smaller pieces are not commonly used anymore. Newer preliminary treatment units now automatically clean, dewater, and bag or containerize these materials thus greatly reducing exposure to operators.

Figure 3.1.1.1



3.1.2 Describe common equipment used in preliminary treatment.

The purpose of preliminary treatment is to remove larger, inorganic materials (rags, sticks, stones, plastics, personal hygiene products, etc.) and grit from the waste stream before it flows to downstream treatment units.

Preliminary treatment equipment primarily consists of screening and grit removal systems. Septage handling, grinders, odor control, and flow equalization are also considered preliminary treatment.

A. Screening
Common screening systems are manually cleaned bar screens, mechanically cleaned bar screens, and rotary fine screens. These processes simply remove debris which is then land filled.

B. Grit removal
Common grit removal systems are aerated grit chambers and vortex-type (Pista®) unit. An aerated grit chamber uses air that separates light from heavier solids (grit). A vortex-type (Pista®) unit consists of a cylindrical tank creating a vortex flow in which the heavier grit settles to the bottom.

Figure 3.1.2.1

Manually Cleaned Bar Screen

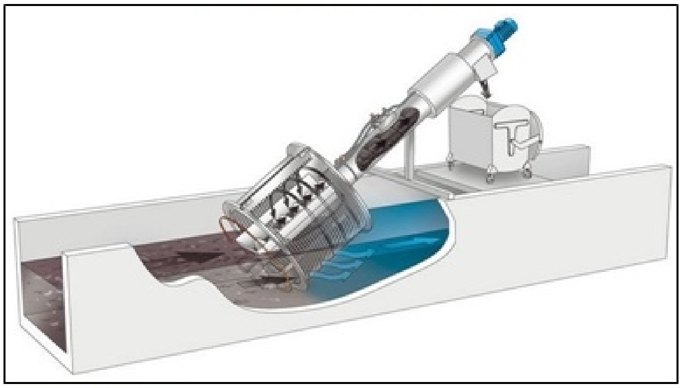
Figure 3.1.2.2

Mechanically Cleaned Bar Screen

Source: General Mechanical Works

Figure 3.1.2.3

Rotary Fine Screen



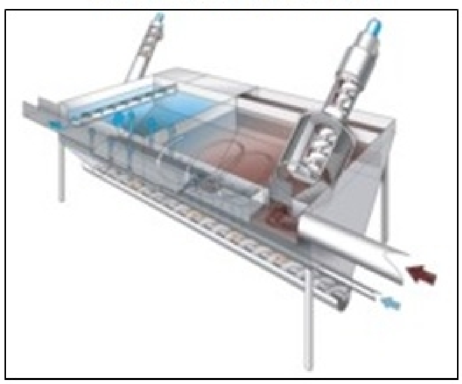
Source: ROTAMAT

3.1.3 Discuss how an aerated grit chamber works.

Raw wastewater is introduced into the end of an aerated grit chamber, which is typically rectangular in shape. Injected air creates a spiral flow of wastewater as it moves through the chamber. As the flow velocity diminishes along the tank, heavier grit particles gradually settle from the water. The settled solids are typically gathered at the tank bottom by a rake mechanism and removed by pumping.

Figure 3.1.3.1

Aerated Grit Chamber

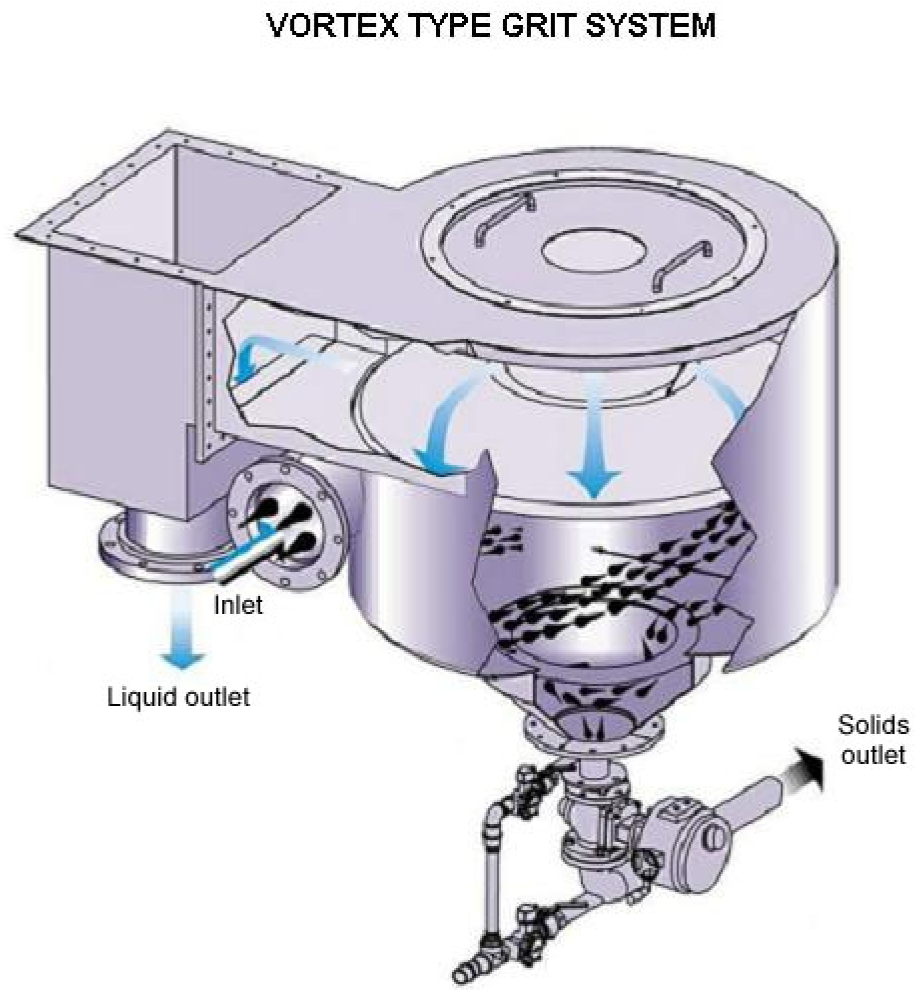


Source: Huber Technology

3.1.4 Discuss how a vortex-type (Pista®) grit chamber works.

Raw wastewater is introduced along the side of a cylindrical tank designed for vortex flow. The water and grit combination rotates slowly around the vertical access of the tank. The flow spirals gradually down the tank perimeter, allowing the heavier solids to settle to the tank bottom where they are then removed.

Figure 3.1.4.1



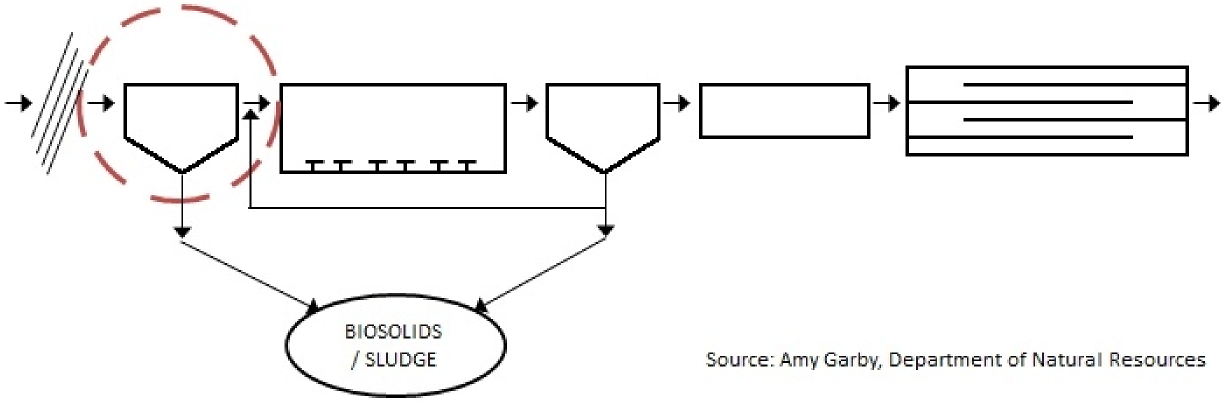
Section 3.2 - Primary Treatment

3.2.1 Discuss the primary treatment process.

The purpose of primary treatment is to settle wastewater solids and capture floatable substances [such as fats, oil, and grease (FOG)]. Some biochemical oxygen demand (BOD) is also removed in the settling of these solids. The solids that settle in primary clarifiers and the FOG skimmed off the surface are directly removed from the process.

Primary treatment commonly consists of circular or rectangular clarifiers. Sometimes dissolved air flotation (DAF) thickeners or other processes are used for primary treatment. Primary effluent containing soluble BOD and some suspended solids flows to a secondary biological treatment process for further treatment.

Figure 3.2.1.1



3.2.2 Describe common equipment used in primary treatment.

The purpose of primary treatment is to settle wastewater solids and capture floatable substances (such as FOG). Well-designed and operated primary facilities can expect removal efficiencies of 40% to 60% for suspended solids and 20% to 35% for BOD.

Common primary treatment units are rectangular clarifiers, circular clarifiers, and DAF.

Figure 3.2.2.1

RETANGULAR CLARIFIER

The flow enters one end of the tank, where a baffle directs it downward. The flow exits the other end of the tank over the effluent weir. Two chains run along the edges for the length of the tank. Flights (wooden or fiberglass boards) are attached between the chains, half submerged. A motor slowly moves the chains, and the flights push the scum to the end of the tank, where it is skimmed off. The chains then travel to the bottom of the tank where the flights push settled sludge to the other end of the tank, where the sludge is removed. The (relatively) clear liquid overflows to secondary treatment.

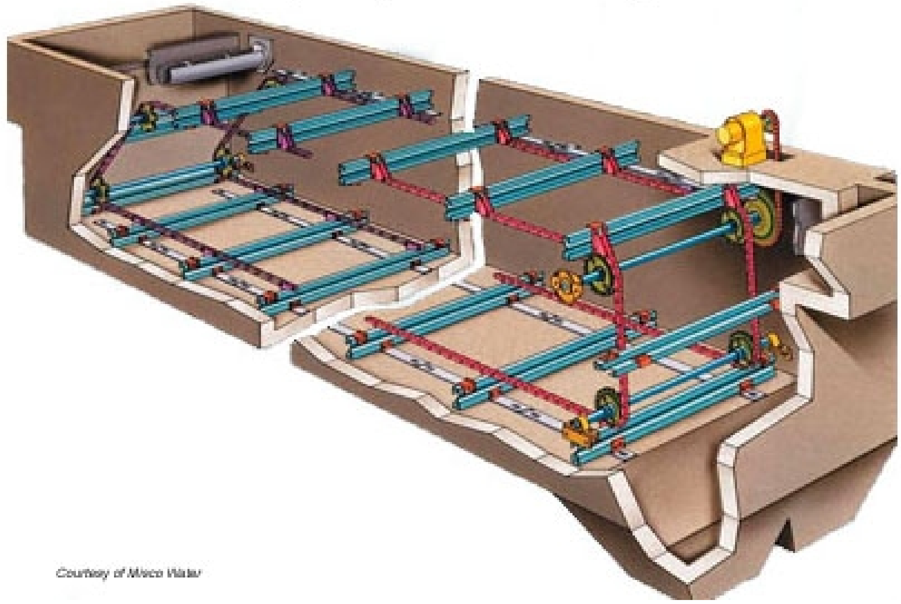


Figure 3.2.2.2

CIRCULAR CLARIFIER

The flow enters the center of the tank and is directed downward by a cylindrical baffle. The wastewater moves outward from the baffle to the overflow weir around the tank perimeter. A central drive unit moves the skimmer arm around the surface to a scum hopper, where scum is removed. The drive unit also moves a scraper arm around the bottom of the tank, pushing settled sludge to a sludge hopper, where sludge is removed. The (relatively) clear liquid overflows to secondary treatment.

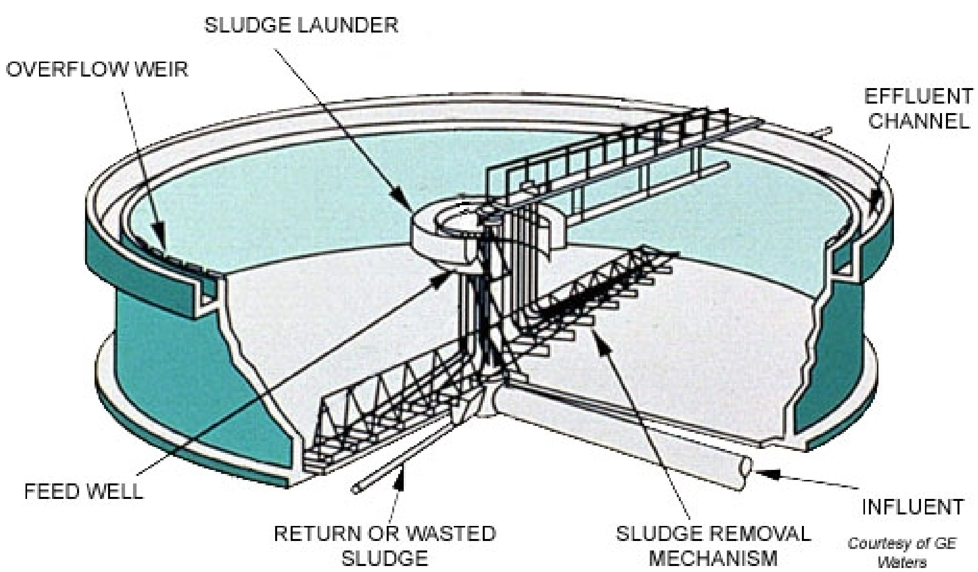
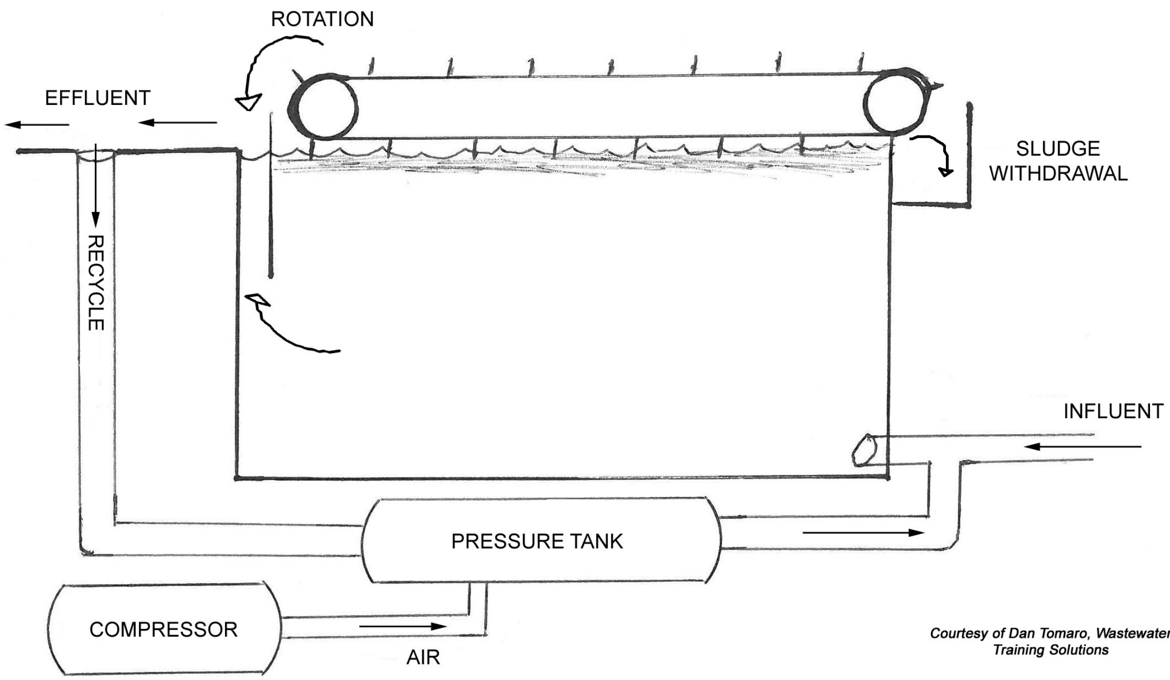


Figure 3.2.2.3

DISSOLVED AIR FLOTATION

Some industries use DAF for primary treatment. The wastewater is injected with air under pressure, and then enters the DAF tank. This releases tiny bubbles, which attach to sludge particles and float them to the surface. The layer of floating solids is skimmed off the tank, and (relatively) clear water flows out under a baffle.



Courtesy of Dan Tomaro, Wastewater Training Solutions

Section 3.3 - Secondary (Biological) Treatment

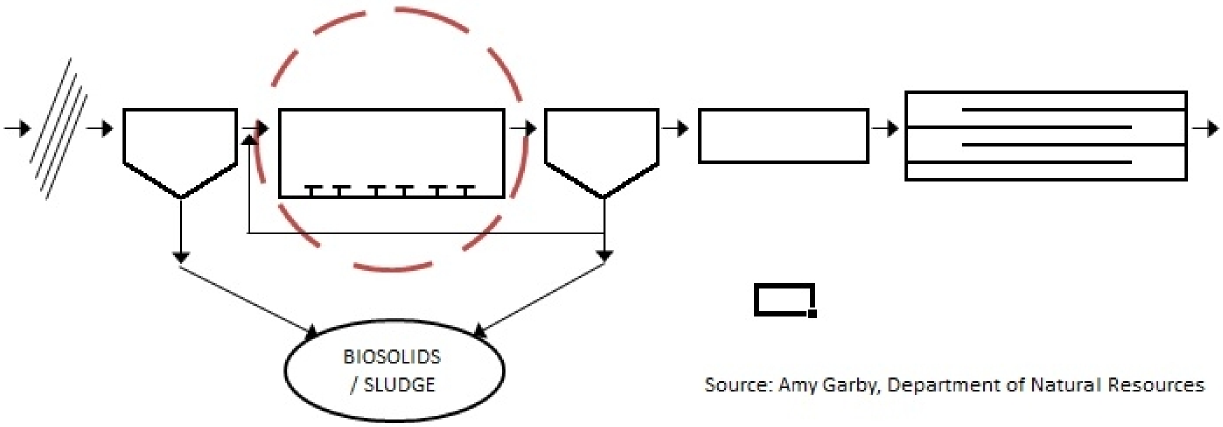
3.3.1 Discuss the secondary biological treatment process.

The purpose of secondary biological treatment is to remove dissolved and suspended organic material from wastewater to produce an environmentally safe treated effluent and biosolids or sludge.

A secondary treatment system can achieve overall biochemical oxygen demand (BOD) and suspended solids removal in the 85% to 95% range.

Secondary biological treatment consists of microorganisms (bacteria), either in mixed suspension in a basin or attached to a media of some type where the organic material is broken down and consumed by the microorganisms. Most secondary treatment processes require oxygen for the bacteria.

Figure 3.3.1.1



3.3.2 Discuss suspended growth systems (activated sludge).

Activated sludge is a suspension of wastewater and microorganisms in an aeration basin. The mixture of wastewater and microorganisms is referred to as mixed liquor suspended solids (MLSS). Aeration equipment provides dissolved oxygen (DO) to promote the growth of microorganisms that substantially remove organic material. Some common types of suspended growth processes are conventional and extended aeration activated sludge plants, oxidation ditches, and sequencing batch reactors (SBR). The reader is referred to the 'Biological Treatment – Suspended Growth Process Study Guide' for more detailed information about suspended growth processes.

3.3.3 Describe common equipment used in suspended growth secondary (biological) treatment.

Common equipment used in suspended growth secondary biological treatment are aeration tanks, blowers, diffusers, final clarifiers, and sludge pumps.

A. Aeration tanks
Aeration tanks are usually square, rectangular, or circular. They contain aeration equipment for providing oxygen to the microorganisms that live and grow in the tanks. Aeration equipment also provides mixing in the tank. The mixed suspension of wastewater, solids, and microorganisms in the aeration tank is commonly referred to as activated sludge. The activated sludge is measured as MLSS in milligrams per liter (mg/L).

B. Blowers
Mechanical blowers provide the air to the aeration tanks.

C. Diffusers
Diffusers disperse the air into the aeration tank, providing oxygen and mixing in the tank.

D. Final clarifiers
Final clarifiers follow the aeration basins and settle the MLSS. Clear effluent is discharged over and through weirs in the clarifier.

E. Sludge pumps

The settled solids in the clarifier can be returned back to the aeration tank or wasted from the treatment system by the pump(s). The pump(s) are known as the return activated sludge (RAS) or waste activated sludge (WAS) pump(s).

3.3.4 Discuss attached growth systems (rotating biological contactor (RBC), trickling filter, and biotower).

An attached growth system (some times referred to as a fixed-film process) utilizes microorganisms that are fixed in place on a solid surface (attached). As wastewater passes through and around the solid surface, the microorganisms remove the food (organic content) from the wastewater. This attached growth type aerobic biological treatment process creates an environment that supports the growth of microorganisms. Some common types of fixed-film processes are trickling filters, biotowers, and RBCs. The reader is referred to the 'Biological Treatment – Attached Growth Study Guide' for more detailed information about attached growth processes.

3.3.5 Describe common equipment used in attached growth secondary (biological) treatment.

Attached growth systems make use of microorganisms that attach themselves to a medium or substrate of some type. Common equipment used in attached growth systems such as trickling filters and biotowers are different types of media, pumps, distribution arm and piping, and underdrains. Common equipment used in attached growth systems such as RBCs are basins, shafts, circular plastic disks, motors, and drives and sometimes blowers and diffusers (for air driven shafts).

A. Pumps and distribution piping
After wastewater receives primary treatment, primary effluent is collected and pumps are used to convey the wastewater to a trickling filter or biotower distribution arm or to RBC basins for secondary biological treatment.

B. Media
The media is where biological organisms and bacteria attach themselves for treatment of the incoming wastewater. Trickling filter and biotower media most commonly consists of rock beds, gravel, or plastic (providing surface area for bacteria to grow) through which the wastewater flows. RBCs consist of closely spaced, circular plastic disks (providing surface area for bacteria to grow) that rotate on a shaft through the wastewater.

C. Underdrain system
After wastewater flows down through a trickling filter or biotower, it is collected in a drain where some of it is recirculated back through the media by pumps for further treatment. Because of temperature difference between outside air temperature and the temperature inside the filter, natural air drafts upward through the filter media providing oxygen.

D. RBC motors, drives, and shafts
The circular plastic disks of RBCs are on a shaft that is turned by a motor and drive system.

3.3.6 List and discuss the process control equipment used for monitoring an activated sludge plant.

A. DO meter
A DO meter is used to monitor aeration basin DO levels. Many plants have inline DO sensors to automatically control DO levels. If manual measurements are made, they should be taken in each aeration basin using a field DO probe.

B. Settleometer
A settleometer is used to monitor sludge settling characteristics in 30 minutes. A 1,000 mL beaker or cylinder is most commonly used. The MLSS sample for this test should be collected just before it goes to the final clarifier.

C. Sludge blanket finder
The sludge blanket finder is used to measure the depth of settled sludge in the bottom of a clarifier. A clear core sampler (Sludge Judge®) or an electronic device is most commonly used. Samples are usually collected before and after the scraper mechanism both near the well, midway, and near the sidewall. When and where the sludge depth is measured should be consistent each day.

D. Microscope
A microscope is used to observe the population and health of microorganisms living in an activated sludge system. The settled MLSS sample used for the 30-minute settling test can be used for the microscopic observation sample.

E. pH and temperature meter
A pH and temperature meter is used to measure pH and temperatures of wastewater entering the plant and the aeration basins.

F. Flow meters
Flow meters are used to measure influent, sidestream, RAS, WAS, and effluent flows.

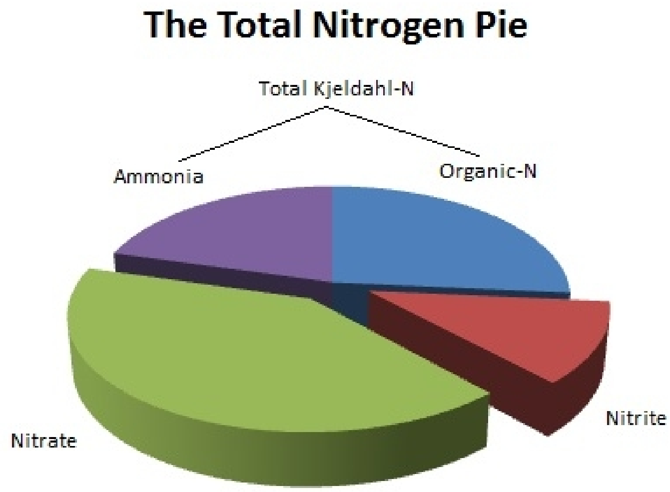
3.3.7 Describe the differences between nitrification and denitrification in wastewater treatment.

Nitrification is a biological process where nitrifying bacteria (nitrifiers) convert nitrogen in the form of ammonia (NH3) into nitrite (NO2-) and nitrate (NO3-) under aerobic conditions. Treatment plants that have ammonia limits on their permit will use nitrification to remove ammonia. Many plants that discharge to surface waters have ammonia limits to protect fish and aquatic life from ammonia toxicity.

Denitrification is a biological process where bacteria convert nitrate (NO3-) and nitrite (NO2-) to nitrogen gas (N2) under anoxic conditions. Treatment plants that have total nitrogen limits will use denitrification to remove nitrogen.

Plants that discharge to groundwater have total nitrogen limits to protect groundwater from nitrates. Plants that remove phosphorus biologically will also employ denitrification to remove nitrates that interfere with enhanced biological phosphorus removal (EBPR).

Figure 3.3.7.1



3.3.8 Explain why some treatment plants have to meet ammonia nitrogen limits.

Ammonia is toxic to fish and aquatic life, and its toxicity is dependent on temperature and pH. The actual limits for ammonia nitrogen are calculated based on stream flow, stream temperature, stream pH, and the type of fishery classification.

3.3.9 Explain why some treatment plants have total phosphorus limits.

Phosphorus is one of the key nutrients that contribute to eutrophication and excess algae and plant growth in rivers and lakes. The decomposition of excess plant matter reduces the level of DO in the receiving water which affects aquatic life.

3.3.10 Describe the role microorganisms have in the activated sludge process.

The principle role microorganisms have in the activated sludge process is to convert dissolved and particulate organic matter, measured as BOD, into cell mass. In a conventional activated sludge process, microorganisms use oxygen to break down organic matter (food) for their growth and survival. Over time, and as wastewater moves through the aeration basin, food (BOD) decreases with a resultant increase in cell mass (MLSS concentration).

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

The activated sludge wastewater treatment process must operate under proper environmental conditions to support a healthy, growing population of microorganisms. The operator must monitor the activated sludge process to ensure the right environmental conditions are being provided for the microorganisms. Efficient wastewater treatment plant performance will then be achieved.

A. Food

Incoming wastewater to a treatment plant provides the food that microorganisms need for their growth and reproduction. This food is mostly organic material. The more soluble the organic material is, the more easily microorganisms can use it. Since the amount and type of organic loading in the treatment plant affects the growth of the microorganisms, influent total BOD and soluble BOD are measurements an operator can make to determine the amount and type of incoming food for the microorganisms.

B. Flow
Incoming wastewater must flow through a treatment plant at a rate that allows the microorganisms sufficient time to consume the incoming food and to settle properly. High flows can shorten the time necessary for the full treatment of wastewater. Extremely high flows can wash microorganisms out of the plant through the final clarifier.

C. Oxygen
Conventional activated sludge is an aerobic process. Many bacteria in the activated sludge process need free oxygen (O2) to convert food into energy for their growth. For optimal performance, it is very important for an operator to be sure enough oxygen is being provided in the aeration tanks for the microorganisms (typically 1.0 to 3.0 mg/L). Aeration basin DO concentrations (mg/L) are measured continuously in many plants to ensure adequate oxygen is available.

D. Temperature
All biological and chemical reactions are affected by temperature. Microorganisms' growth and reaction rates are slow at cold temperatures and much faster at warmer temperatures. Most microorganisms do best under moderate temperatures (10 to 25°C). Aeration basin temperatures should be routinely measured and recorded.

E. pH
Biological and chemical reactions are affected by pH. Most microorganisms do well in a pH environment between 6.0 and 9.0. Acidic (low pH) or alkaline (high pH) conditions can adversely affect microorganisms' growth and survival. Operators measure both influent pH and aeration basin pH to ensure proper plant pH conditions.

F. Nutrients
Microorganisms need trace nutrients such as nitrogen, phosphorus, and some metals for their metabolism. Most incoming wastewater to a treatment plant, especially domestic sewage, contains an abundance of these trace nutrients. The ratio of BOD to nitrogen to phosphorus should be 100:5:1. Influent wastewater is measured to determine this nutrient ratio.

G. Toxicity
Incoming wastewater to a treatment plant may, at times, contain materials or compounds that are toxic to microorganisms. Depending on the concentration of toxic material, microorganisms could be destroyed or their metabolic rates affected, thus impairing the wastewater treatment plant efficiency.

3.3.12 Discuss the possible impacts of sidestreams or recycle flows back to the secondary process.

Sidestreams or recycle flows usually come from solids handling treatment or dewatering processes, such as decanting digesters or sludge storage tanks. Sidestreams may be high in 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 the 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 the permit limits phosphorus or ammonia, sometimes it is necessary to separately treat the sidestream.

3.3.13 List common sidestreams within a treatment plant.

The most common recycle streams are from:

A. Thickening and dewatering process
1. Gravity belt thickening filtrate
2. Centrifuge centrate
3. Gravity thickening supernatant
4. Dissolved air flotation (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

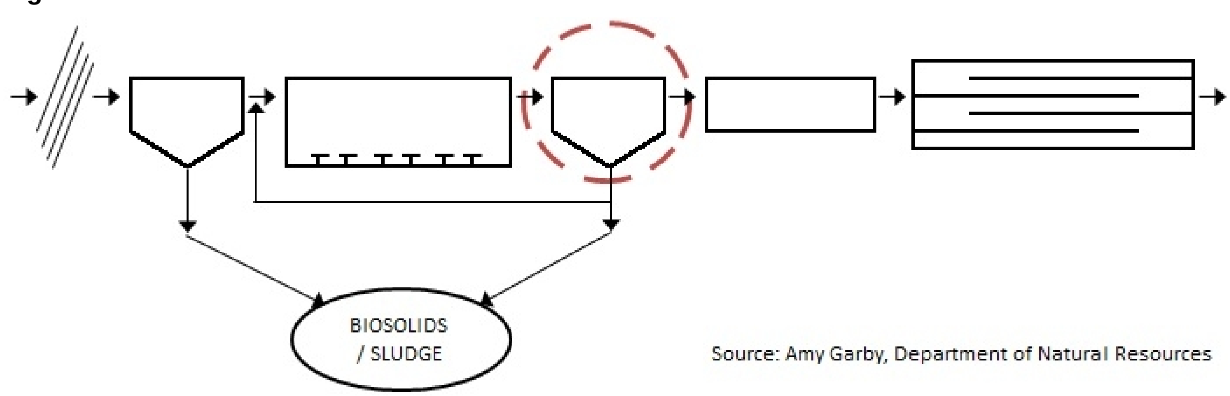
B. Stabilization and storage
1. Aerobic digester decant
2. Anaerobic digestion supernatant
3. Biosolids storage decant
4. Granular filter backwash

Section 3.4 - Final Clarification

3.4.1 Discuss the final clarification process.

The purpose of final clarification (consisting of final clarifiers) is to settle secondary biological treatment solids and discharge clear effluent. The settled solids can be returned [recycle activated sludge (RAS)] to the aeration tank or wasted [waste activated sludge (WAS)] for biosolids or sludge processing.

Figure 3.4.1.1



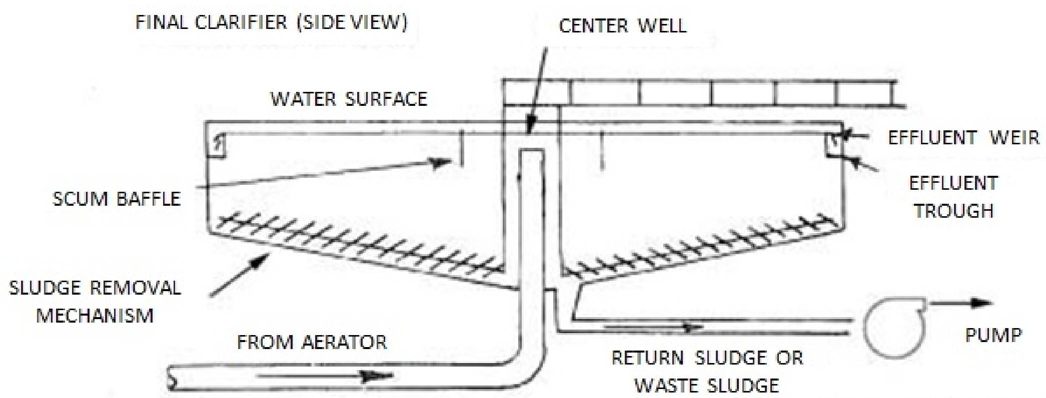
3.4.2 Explain the function of a final clarifier.

The final clarifier is a large basin or tank designed to allow organic solids to settle from effluents discharged from an attached growth process and/or activated sludge process. Hydraulic overloads or operational problems in the secondary system can cause major problems in the efficiency of the final clarifier, because the biologic solids to be removed have a density very close to that of water.

3.4.3 List the parts of a final clarifier.

A. Motor and drive system
B. Center stilling well
C. Skimmer
D. Scum skimmer
E. Scum beach
F. Baffles
G. Weirs
H. Effluent trough
I. Sludge collection and removal mechanism
J. RAS and WAS pumps

Figure 3.4.3.1



Source: Sacramento Operation of Wastewater Treatment Plants (Vol. II 6th Ed.)

3.4.4 Describe common equipment used in final clarification.

A. Motor and drive system
The motor and drive system is the device used to turn the surface skimmer and sludge collector.

B. Center stilling well
The center stilling well is the suspended column in the center of a clarifier which provides an area for mixed liquor flow to slow down and spread out.

C. Scum skimmer
The scum skimmer is the flat device at the surface of the clarifier which is moved by the drive system, to remove floating scum.

D. Scum beach and trough
The scum beach and trough are the equipment used to receive the collected scum.

E. Scum baffles
The scum baffles are the ring or plate at the clarifier's surface that prevents scum from entering the effluent trough.

F. Effluent weirs
Effluent weirs rest just below the clarifier surface allowing effluent to flow over and through into the trough.

G. Effluent trough
The effluent trough is the open channel on which the effluent weir is mounted and conveys the effluent.

H. Sludge collection and removal mechanism
The sludge collection and removal mechanism is an assembly and piping arrangement at the bottom of the clarifier moved by the drive system and used to gather and remove settled sludge.

I. RAS and WAS pumps
The RAS and WAS pumps return or waste the settled solids from the final clarifier.

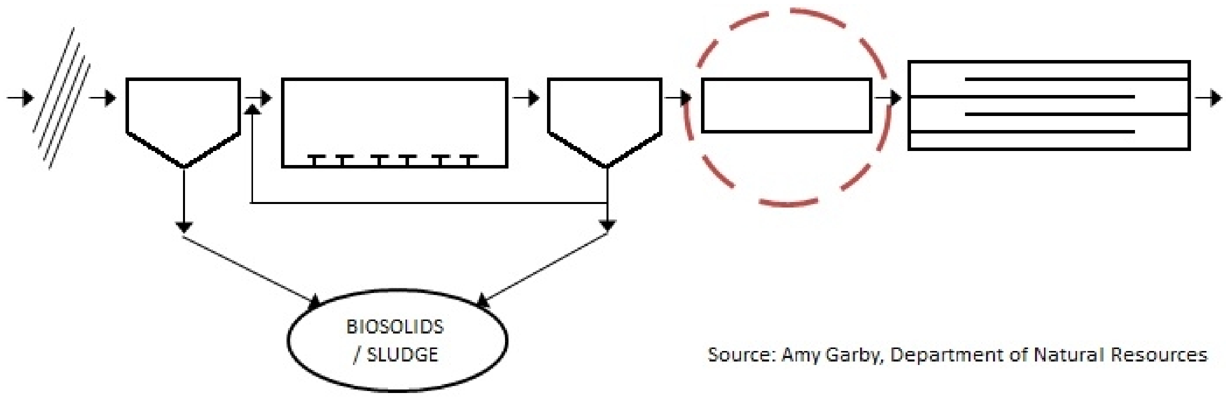
Section 3.5 - Tertiary Treatment

3.5.1 Discuss the tertiary treatment process.

The purpose of tertiary treatment is to provide advanced wastewater treatment beyond secondary biological treatment. It results in a very high quality effluent, extremely low in biochemical oxygen demand (BOD), suspended solids, and nutrients. Wastewater treatment plants that have discharge limits less than 10 mg/L of BOD and total suspended solids (TSS) or have very low phosphorus limits, usually need to provide tertiary treatment.

Tertiary treatment usually consists of a type of physical and/or chemical process. Sand or mixed media filters, cloth discs, membranes, or other treatment units can remove TSS and/or phosphorus to very low levels. Chemicals can also be used to precipitate some pollutants in the wastewater. Air stripping or activated carbon is sometimes used to remove volatile organic chemicals from the wastewater.

Figure 3.5.1.1



3.5.2 Describe common equipment used in tertiary treatment.

Currently, the most common method of tertiary treatment is granular filtration. The overall efficiency in removing pollutants by filtration could exceed 95% removal of suspended solids and phosphorus. Other less frequently used methods of tertiary treatment are carbon adsorption and physical chemical methods.

Common equipment used in filtration are:

A. Filtering system
Depending on the level of tertiary treatment needed, the filtering of very fine, suspended particles in the effluent is accomplished using mixed media (usually sand), cloth, or membranes. The filter captures fine particles from the wastewater as it passes, resulting in a very clear and high quality effluent.

B. Cleaning system
As fine particles are filtered from the wastewater, the particles eventually start to plug the filter media and cleaning becomes necessary. Backwashing effluent filters or cloth disks are done to re-open the filtering pore space to restore the performance of the filter. Membranes are subject to fouling and are cleaned using one or a combination of backwashing, air sparging, relaxation, and chemical clean-in-place.

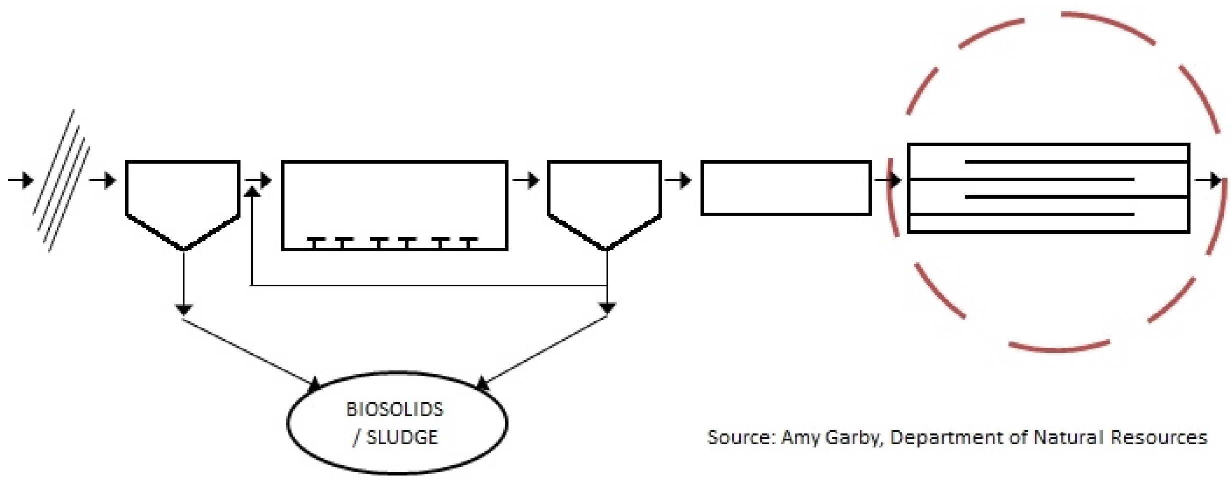
Section 3.6 - Disinfection

3.6.1 Discuss the disinfection process.

The purpose of disinfection of treated wastewater is to reduce the discharge of waterborne pathogenic organisms that cause illness. This is done to protect public health as related to surface drinking water supplies and recreational use of downstream areas. Seasonal disinfection provides disinfection during the months when recreational activities are using downstream areas.

Disinfection consists of either chlorination tanks or ultraviolet (UV) radiation units in Wisconsin.

Figure 3.6.1.1



3.6.2 Describe common disinfection processes.

A. Chlorination

The process of chlorination uses chlorine as a gas, solid, or as a liquid. Chlorine is added to the treated wastewater as the wastewater flows through the contact tank. The contact tank gives ample time for the chlorine to react with the wastewater, killing the pathogenic organisms. After the contact tanks, a chemical (usually sodium bisulfite or sulfur dioxide) is added to remove the excess chlorine. This removal is called dechlorination. Chemical feed pumps that are flow proportional are commonly used in feeding liquid chlorine (sodium hypochlorite, a stronger version of household bleach). When feeding chlorine as a gas, special equipment is used to create a vacuum which draws the gas into the treated wastewater.

B. UV radiation

The process of UV radiation uses ultraviolet light to destroy the pathogenic organisms' ability to reproduce. Treated wastewater enters a channel where a stack of several ultraviolet lamps are placed either in horizontal or vertical banks. These lamps need cleaning when they become fouled (dirty).

Figure 3.6.2.1

Chlorine Contact Tank

Figure 3.6.2.2

ULTRAVIOLET (UV) RADIATION

Sparta WWTP

Section 3.7 - Ponds and Lagoons

3.7.1 Discuss pond and lagoon systems.

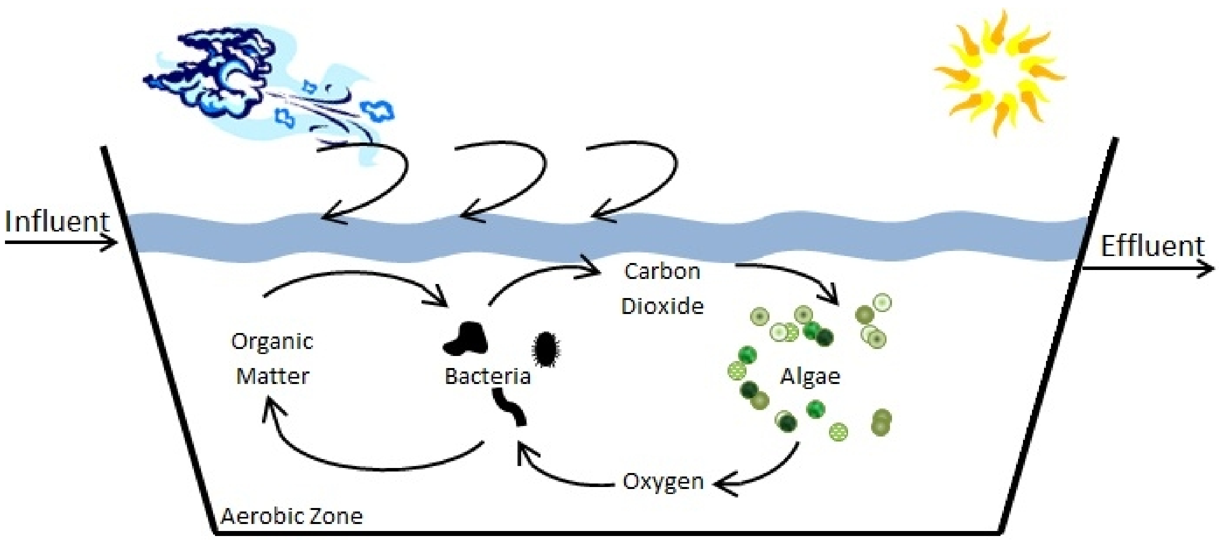
Pond and lagoon systems are earthen basins with a clay or synthetic liner to prevent leakage to groundwater. These systems are classified as secondary biological treatment and are an economical way to accomplish biological treatment. Pond systems are typically used for biochemical oxygen demand (BOD) and total suspended solids (TSS) removal when limits are 30 mg/L; however, when limits are more restrictive or include nutrient limits, mechanical treatment is necessary. The flow often goes through more than one pond in a series. Their large size provides a long detention time for the bacteria to break down the wastes. Due to their large size, pond systems are mostly used in small communities when land is available.

Wastewater is pumped into one end of the pond. On the other end, the flow exits through a control manhole, which may consist of stop logs or a telescopic valve, allowing the operator to control the pond depth. Most stabilization pond systems have a detention time of 150 days or greater and use more than one pond to effectively treat the wastewater.

3.7.2 Describe a stabilization pond system.

Stabilization ponds are large, non-aerated, and normally less than 10 feet deep. Algae growing in the ponds provide most of the oxygen to the bacteria to remove pollutants. Solids settle to the bottom of the pond and are further stabilized by bacteria.

Figure 3.7.2.1



3.7.3 Describe an aerated lagoon system.

Aerated lagoons can use surface aerators or subsurface diffusers to provide aeration and mix the wastewater. Aerated lagoons are usually deeper (more than 10 feet) and require shorter detention times (60 days) to effectively treat the wastewater. Aeration improves removal efficiency. Aerated lagoons are followed by non-aerated lagoons to allow settling of suspended solids before discharge.

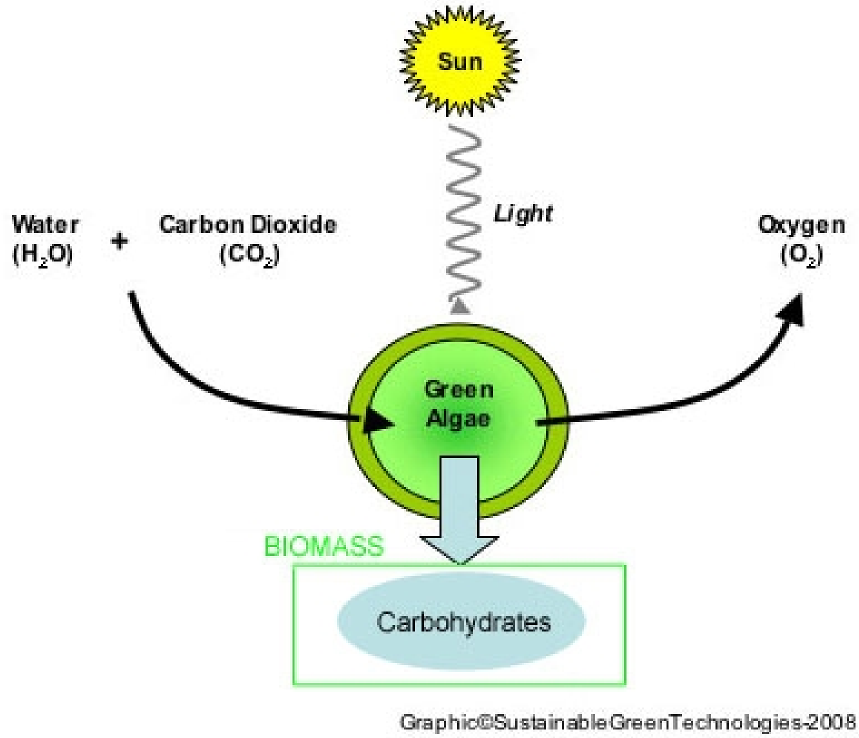
3.7.4 Discuss what photosynthesis is and how it aids the biological treatment of wastewater in stabilization ponds.

Photosynthesis is a natural, chemical process in which green plants (algae in ponds) containing chlorophyll use carbon dioxide in the presence of sunlight to produce carbohydrates for growth. In wastewater treatment ponds, photosynthesis releases oxygen as a byproduct, which is used to sustain the bacteria that stabilize the suspended organic material in wastewater.

Photosynthesis can be summarized by the equation:

Carbon dioxide + Water => Carbohydrate + Water + Oxygen
$CO_2 + 2H_2O \Rightarrow CH_2O + H_2O + O_2$

Figure 3.7.3.1



Section 3.8 - Equipment

3.8.1 Describe the types of pumps used in wastewater treatment.

Figure 3.8.1.1

Centrifugal Pump

A pump with an impeller that rotates in a casing to pump large volumes of liquid through a pipe. A centrifugal pump is the most commonly used wastewater pump. They are used most commonly for raw wastewater pumping; at lift stations, recirculation flows, for return activated sludge, waste activated sludge, and final effluent pumping.

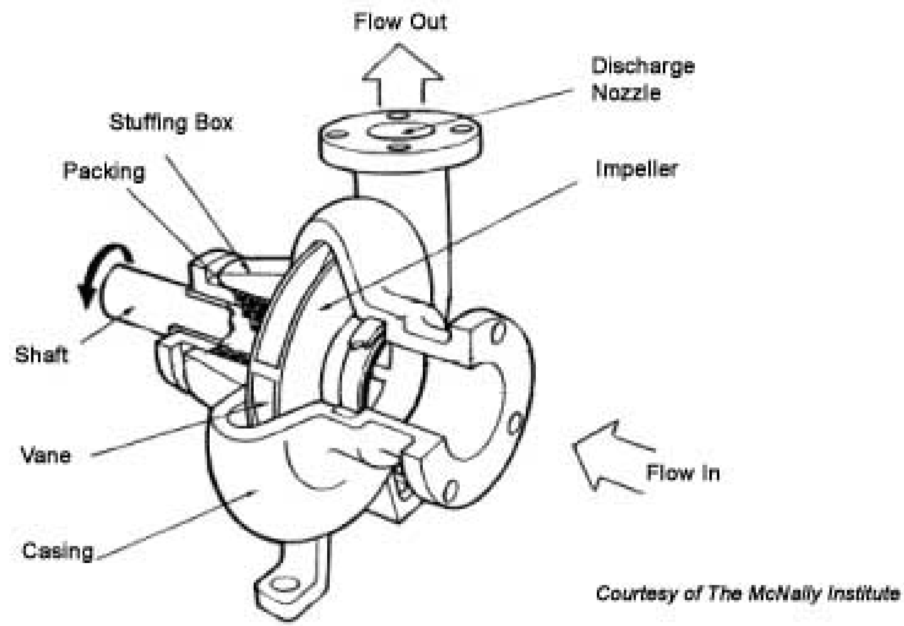


Figure 3.8.1.2

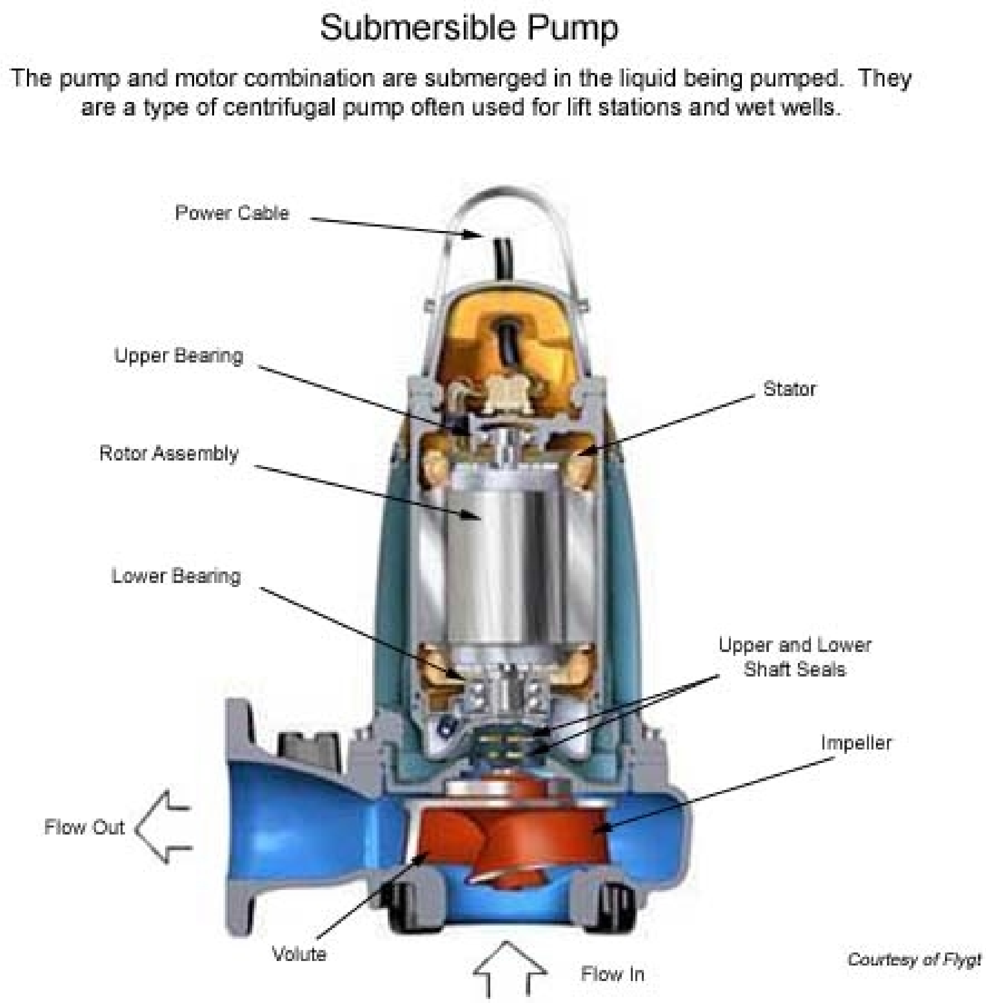

Submersible Pump
The pump and motor combination are submerged in the liquid being pumped. They are a type of centrifugal pump often used for lift stations and wet wells.
Power Cable
Upper Bearing
Stator
Rotor Assembly
Lower Bearing
Upper and Lower Shaft Seals
Impeller
Flow Out
Volute
Flow In
Courtesy of Flygt

Figure 3.8.1.3

Positive Displacement Piston Pump

This type of pump operates using a piston in a reciprocating motion to pump fluids (similar to piston in an automotive engine). These pumps are commonly used for pumping sludges.

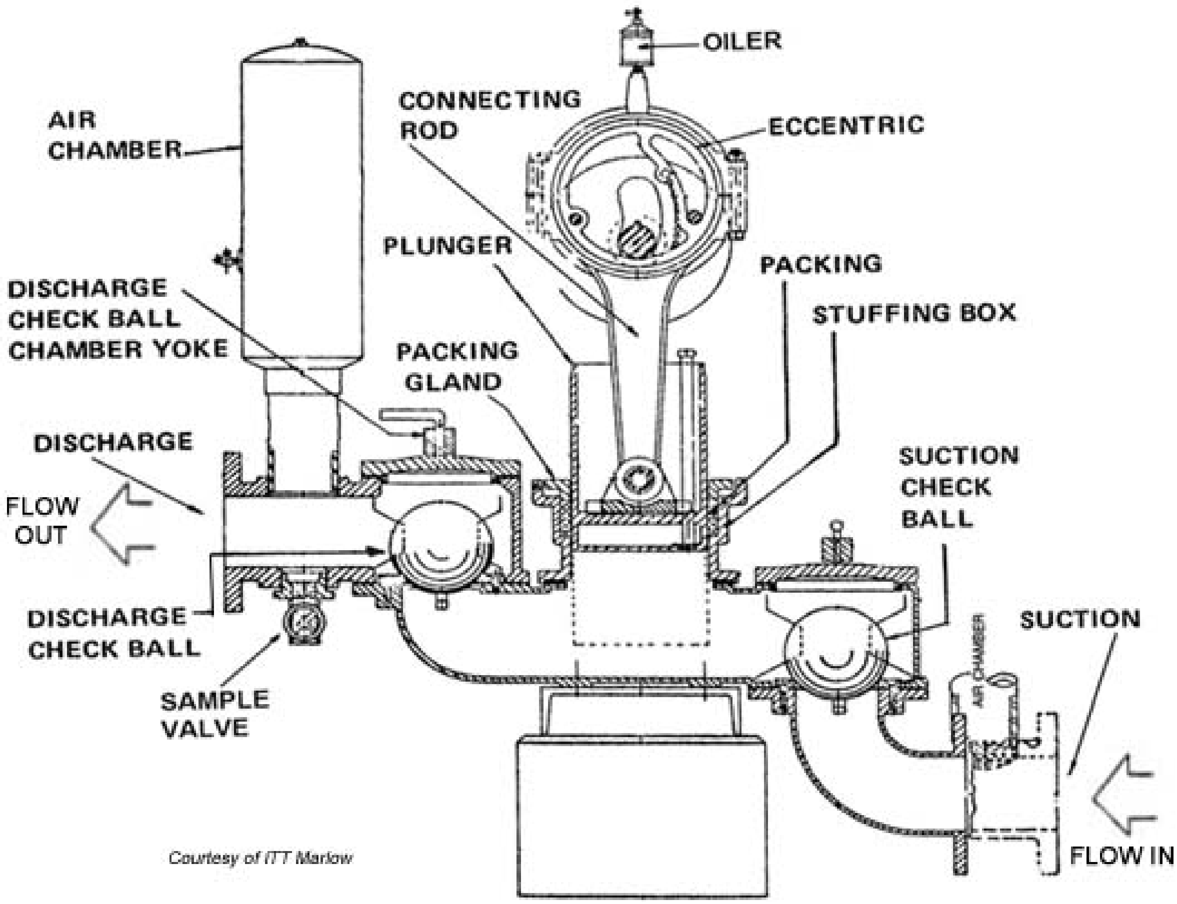


Figure 3.8.1.4

Courtesy of Megator & Gorger Company

Rotary Lobe Pump Cutaway

Rotary lobe pumps are used to pump both sewage and sludge. They are self-priming, valveless, positive displacement pumps. Two synchronized rotors rotating against each other create chambers between the lobes and pump casing. At the suction side the open chambers fill with the sewage or sludge. The sewage or sludge is displaced in the direction of the volume flow into the discharge side. When not operating, the rotors align and form a seal.

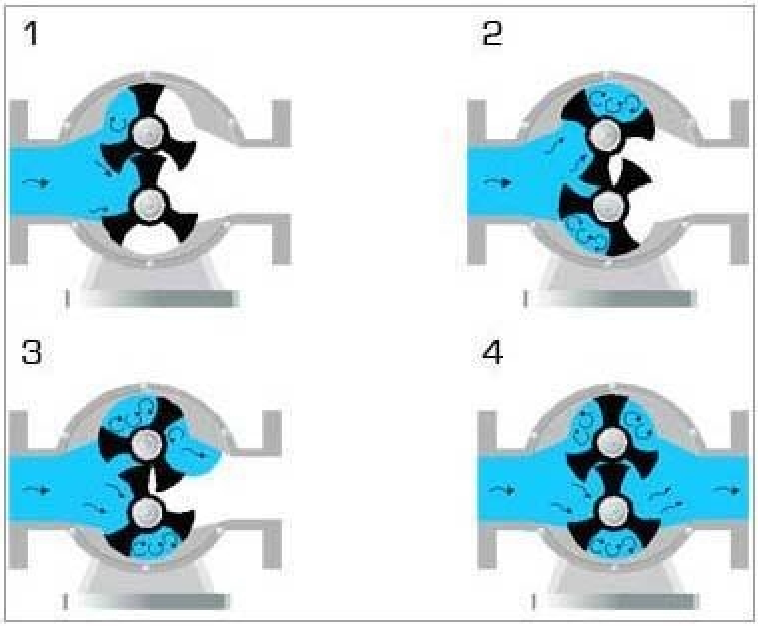


Figure 3.8.1.5

Peristaltic Pump

A small positive displacement pump commonly used for sampling and chemical addition.

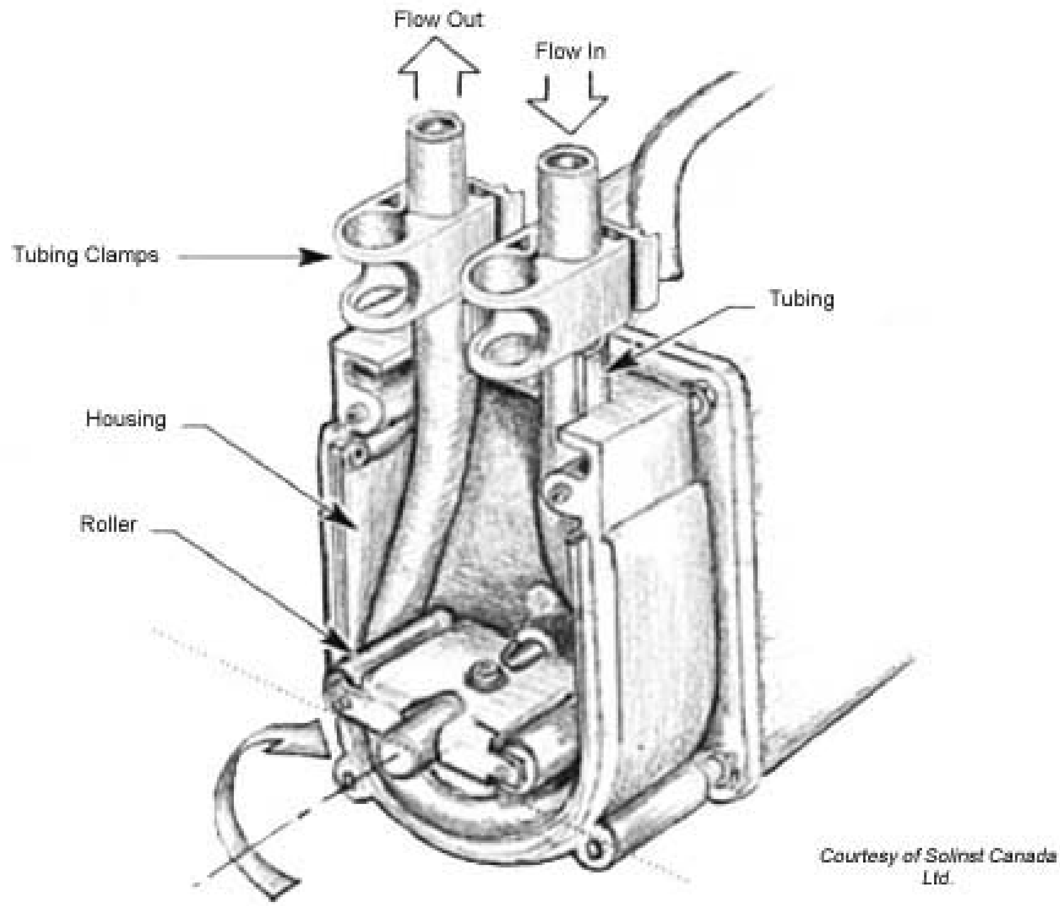


Figure 3.8.1.6

Progressive Cavity Pump

A fixed flow rate pump that turns a corkscrew shaped rotor inside a flexible rubber stator to transfer sludges. These pumps offer long life and reliable service as long as they don't run dry or with excessive grit.

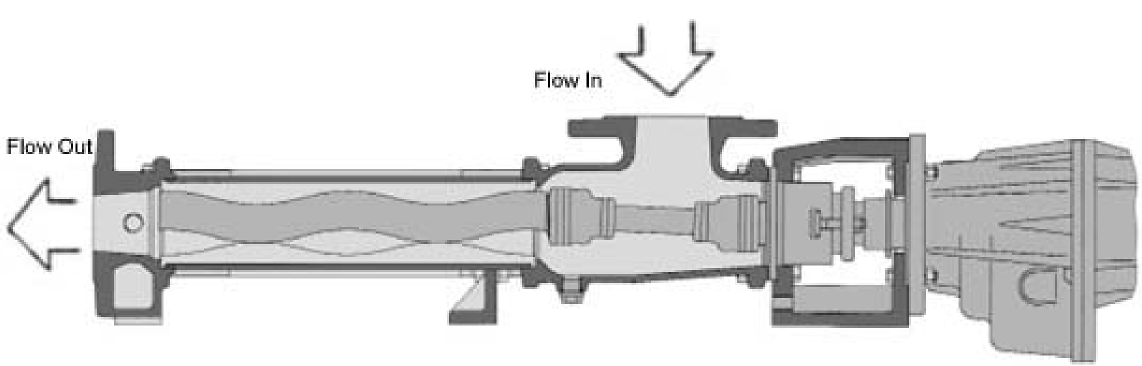
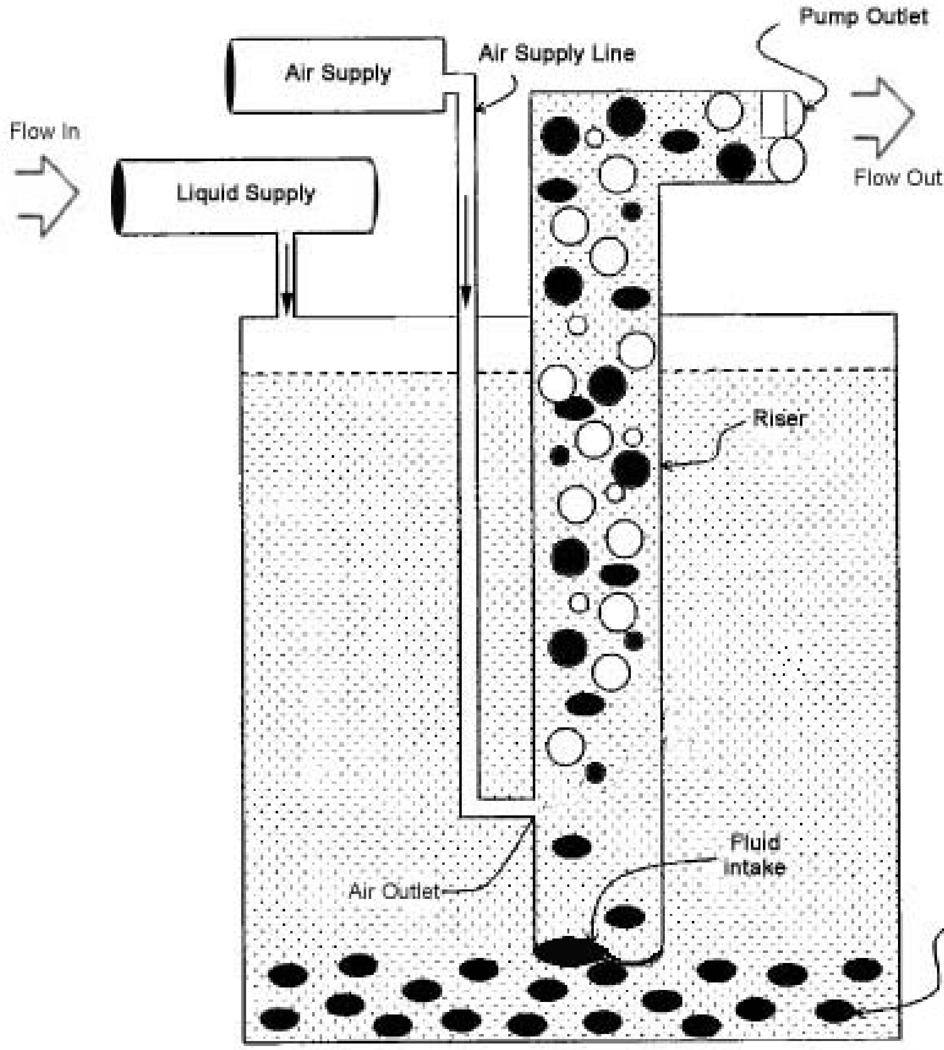


Figure 3.8.1.7

Airlift Pump

Airlife pumps are mostly used in small activated sludge plants to return and waste sludge from the system. They operate on the principle of water/air displacement. Airlift pumps are prone to plugging, especially at low return flow rates. Operators should closely monitor these pumps often to ensure sludge is being returned at all times.



Courtesy of Wikipedia and Amy Schmidt WIDNR

Figure 3.8.1.8

Diaphragm Pump

A diaphragm pump is a type of positive displacement pump. They differ from other positive displacement pumps in that the pumping mechanism is protected from the material being pumped. They are often used for adding chemicals or polymers. Larger diaphragm pumps are used for pumping sludge.

Chemical Metering Diaphragm Pump

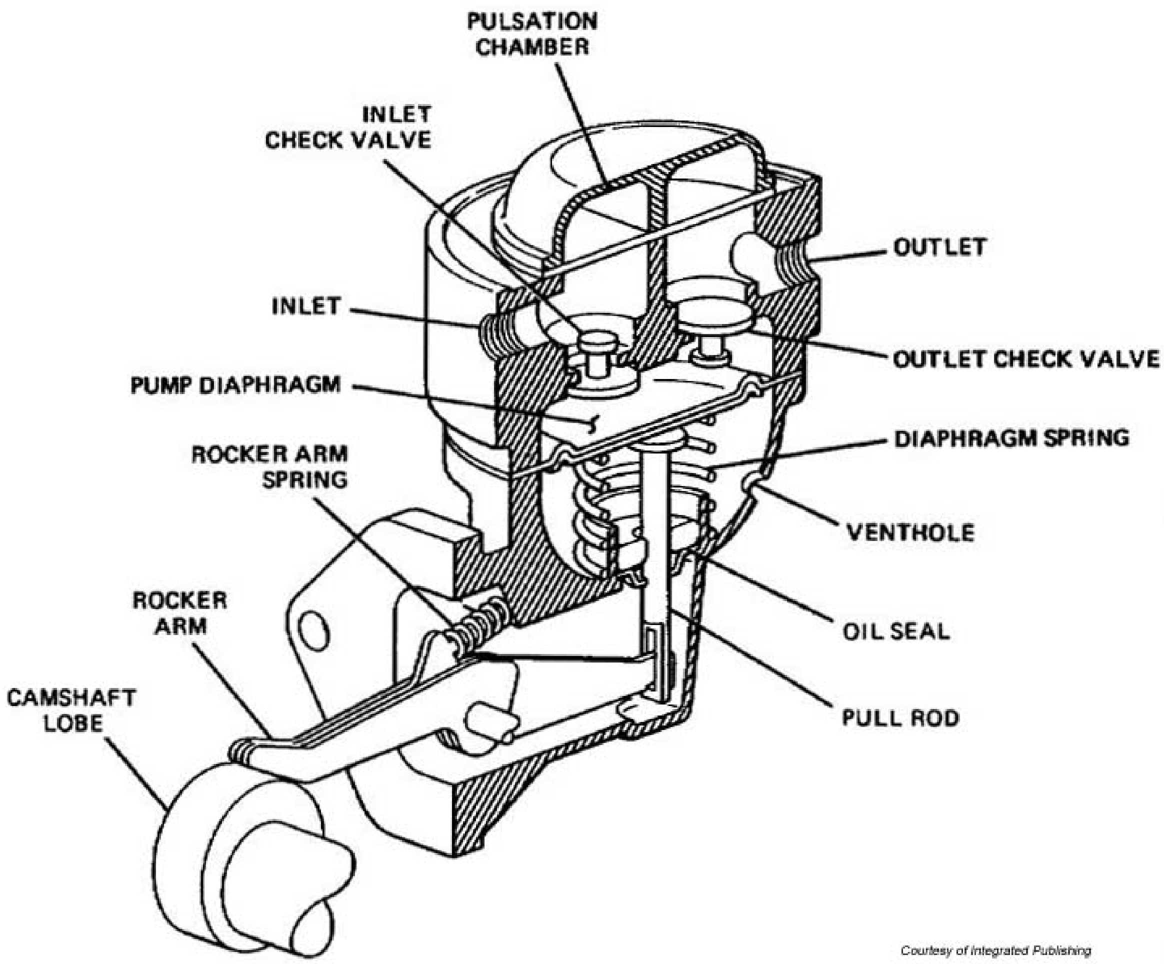
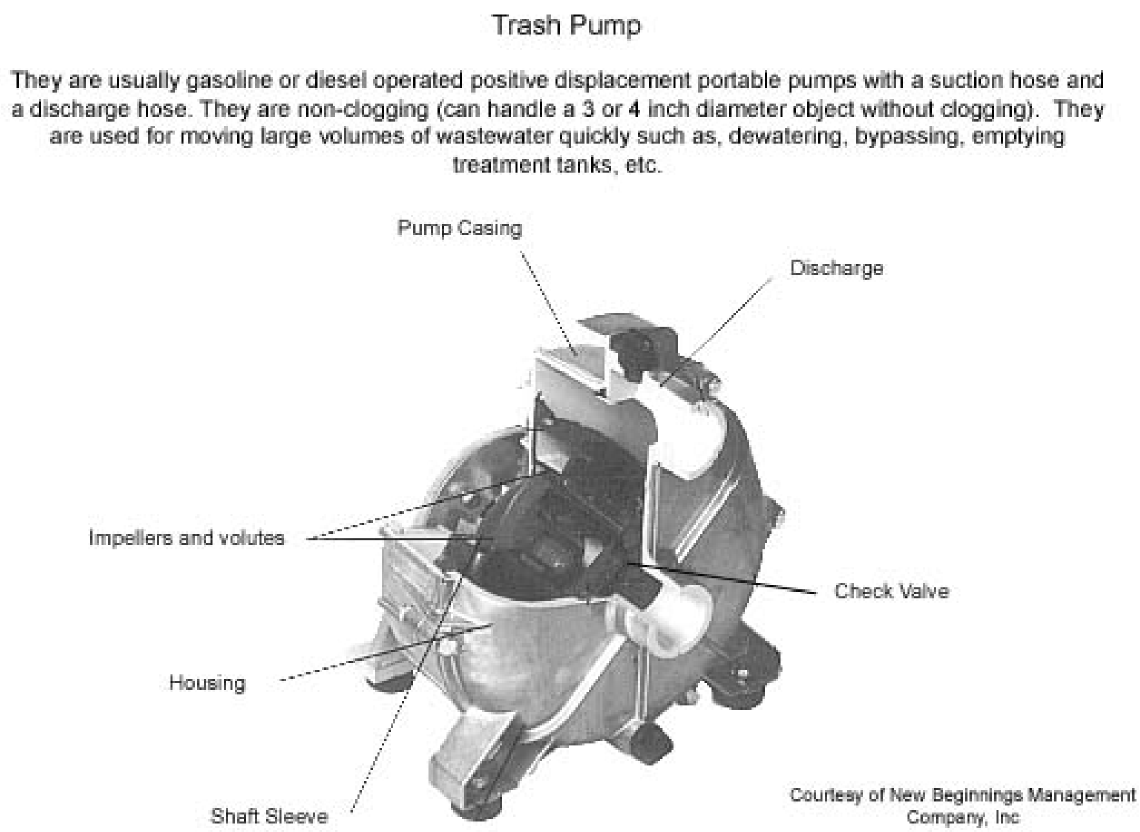


Figure 3.8.1.9



3.8.2 Describe the valves used in a wastewater treatment plant.

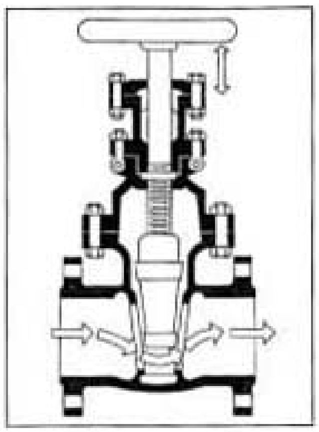
Valves are devices placed in piping systems to stop, regulate, divert, or change flow. Proper procedures for opening and closing valves must be followed to prevent personal injury and equipment damage. Valves used in wastewater treatment plants are:

Figure 3.8.2.1

MULTI TURN VALVES

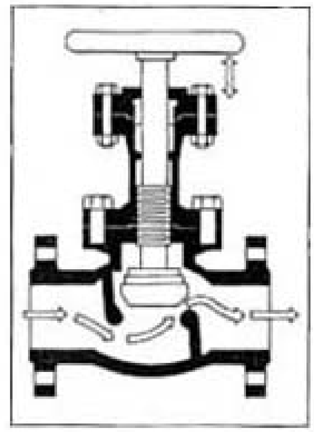
GATE VALVE

A gate valve is a general service valve used mostly for full open flow or no flow applications. This valve is closed using a gate or plate that slides the valve down to block the flow.



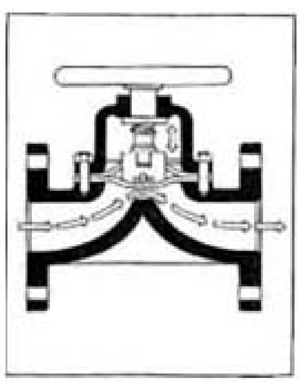
GLOBE VALVE

A globe valve is used for full flow or no flow applications as well as throttling clean water flows. This valve is closed by a flat or convex plug that is lowered onto a matching seat.



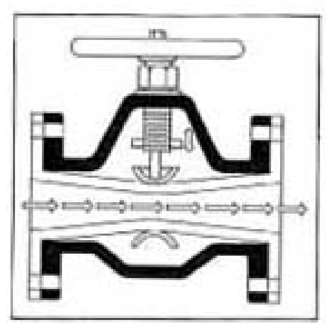
DIAPHRAGM VALVE

A diaphragm valve is often used for corrosive wastewaters. It is closed by a flexible diaphragm that is attached to a compressor. The diaphragm is lowered by the valve stem onto a weir, sealings, and shutting off the flow.



PINCH VALVE

A pinch valve is often used on sludge lines or wastewater with a high amount of suspended solids. The valve is closed by a flexible member in a valve that can be pinched close to shut off flow.



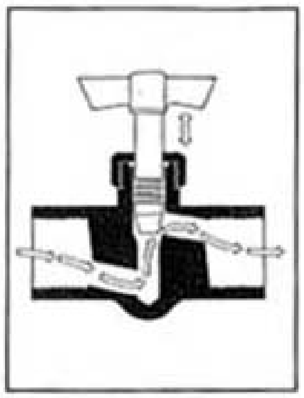
Courtesy of Water Engineering & Managment, Oct. 1988, Vol 135

Figure 3.8.2.2

QUARTER TURN VALVES

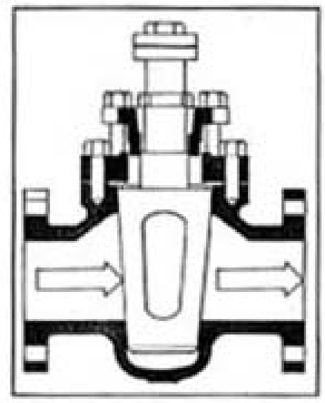
NEEDLE VALVE

A needle valve is used for regulating flow in small lines, such as instrument air lines or fuel lines. A rod with a cone shaped tip is raised and lowered relative to a seat, thus creating a certain size opening for which flow to pass.



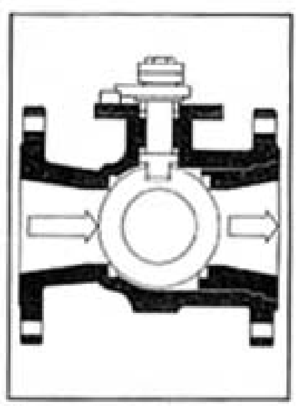
PLUG VALVE

A plug valve is used for on-off and some throttling application. It is closed by turning a cylindrical or tapered plug with a hole in the center. When open to allow full flow, the hole lines up directly with the flow path. A quarter turn in either direction blocks the flow.



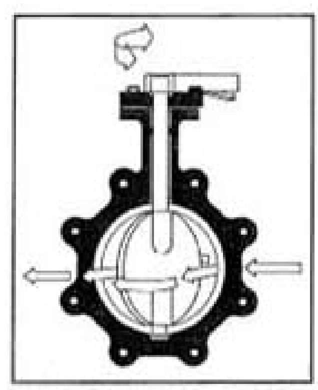
BALL VALVE

A ball valve is used for on-off and some throttling applications. It operates similarly to a plug valve but uses a rotating ball with a hole in the center. When open to allow full flow, the hole lines up directly with the flow path. When closed, the ball is rotated 90 degrees to block the flow.



BUTTERFLY VALVE

A butterfly valve is used for on-off and good for throttling applications. A butterfly valve regulates flow by turning a circular disk or vane. When open to allow for full flow, the vane is directly parallel to the flow. when closed, the vane is perpendicular to block the flow.



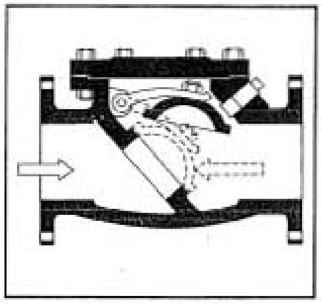
Courtesy of Water Engineering & Managment, Oct. 1988, Vol 135

Figure 3.8.2.3

SELF-ACTUATED VALVES

CHECK VALVE

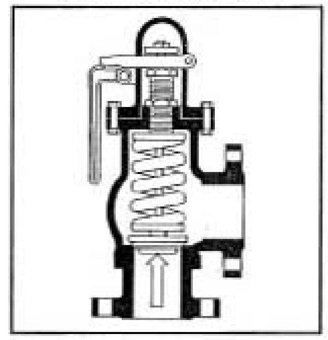
A check valve is used to allow flow in one direction. It operates by the flow in the desired direction opening the valve while flow backwards forces it closed.



Courtesy of Water Engineering & Management, Oct. 1988, Vol. 135

RELIEF VALVE

A relief valve is used to prevent excessive pressure. It operates by releasing pressure if the safety limit is exceeded. Once the pressure drops to a preset level, the valve closes again.



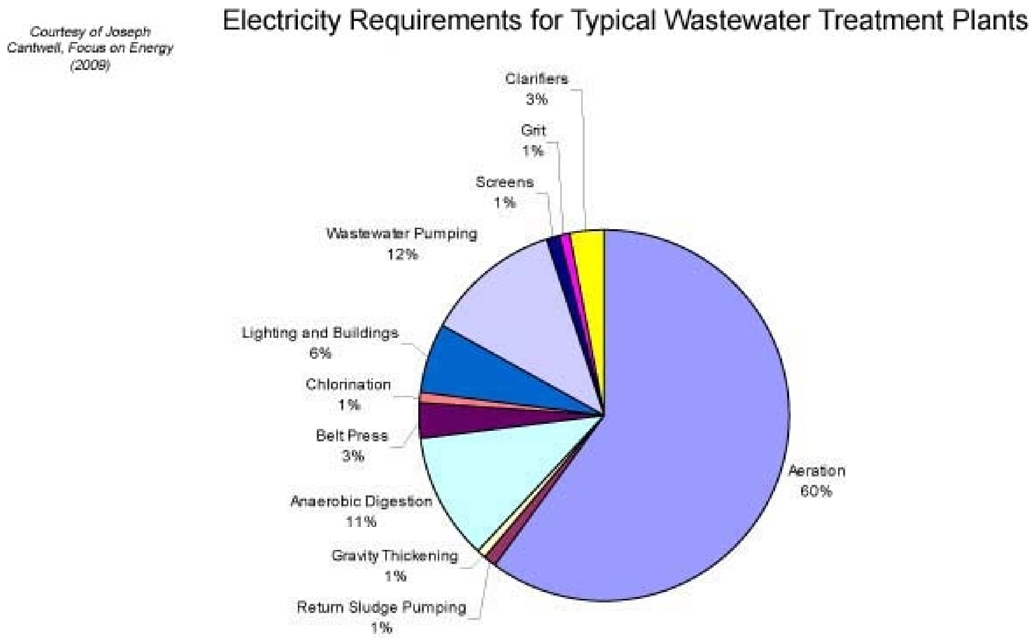
3.8.3 Describe wastewater treatment plant back-up power sources.

During power outages, treatment plants have generators to provide power to some or all of the plant. Generators are run by fuel and should be routinely operated to ensure their reliable operation during an actual emergency.

3.8.4 Discuss energy usage in a wastewater treatment plant.

The aeration system of a wastewater treatment plant uses the largest percentage (over 60%) of the energy in the treatment process. Wastewater pumping is another large energy user (12%) at a wastewater plant. Energy usage can be reduced with cost savings by having energy-efficient aeration systems, blowers, motors, and pumps.

Figure 3.8.4.1



3.8.5 List the basic components of an activated sludge system.

A. Aeration tanks
B. Blowers and diffusers or mechanical aerators
C. Clarifiers
D. Recycle activated sludge (RAS) and waste activated sludge (WAS) pumps

3.8.6 Describe the purpose of the aeration system.

The aeration system in the activated sludge process provides oxygen to the microorganisms and mixes the contents of the aeration basins. The mixing brings the wastewater pollutants into contact with the microorganisms to treat the wastewater and reduce the pollutants.

3.8.7 Describe aeration equipment used in a wastewater treatment plant.

A. Blowers
Blowers provide the air that is pumped through diffusers.

1. Centrifugal
A blower consisting of an impeller fixed on a rotating shaft and enclosed in a casing having an inlet and a discharge connection.

2. Positive displacement (PD)
A PD blower forces air to move by trapping a fixed amount, then displacing that trapped volume into the discharge pipe.

B. Diffusers

1. Fine bubble
Fine bubble diffusers are devices through which air is pumped and divided into very

small bubbles and used to introduce dissolved oxygen (DO) into the liquid. Fine bubble diffusers are normally disks or tubes with membranes or ceramic materials to create the bubbles and gentle mixing action.

2. Coarse bubble
Coarse bubble diffusers are devices through which air is pumped and divided into large bubbles transferred and dissolved into the liquid. Coarse bubble diffusers normally discharge air at a high rate and are installed to induce a spiral or cross roll mixing pattern.

C. Mechanical Aerators
The most common types of mechanical aerators utilize paddles or discs and spray or turbine mechanisms. By agitating the wastewater, air from the environment is introduced.

3.8.8 Describe instrumentation and controls used in a wastewater treatment plant.

A. Process probes and analyzers
Process probes, such as pH, total suspended solids (TSS), DO, turbidity, and temperature, are used throughout the treatment plant. Usually they are wired to an analyzer that sends data to a computer.

B. Supervisory control and data acquisition (SCADA)
SCADA is a computer program that is used solely for gathering the plant's operational data. The program shows different parts of the plant and what is happening in real time. An operator can see flows, DO levels, blowers, pumps, tank levels, probe readings, and other operational data. The data is stored within the program.

C. Programmable logic controller (PLC)
A PLC is a programmable electronic device that has inputs and outputs and is usually found in a control panel. For example, a PLC could control the liquid level of a tank by turning a pump on and off. An operator would program the PLC with set points to define the levels that the pump turns on and off.

D. Flow meters
Flow meters are used to measure the flow of liquids. Some areas of measurement include: influent, effluent, recycle streams, sludge pumping, septic stations, lift stations, and chemical feed systems. Flow meters are usually wired to a SCADA system that displays and stores flow data.

E. Alarms
Alarms notify operators of operational problems and emergencies. Alarms could be during the working day or programmed to notify operators after hours. An alarm can be triggered by a high or low water level, a high or low DO level in the aeration process, a malfunctioning pump, a high temperature reading on a pump, a problem at a lift station, etc.

Section 3.9 - Treatment Plant and Equipment Maintenance

3.9.1 Discuss the importance of having a wastewater treatment plant preventative maintenance program.

A. Minimize unanticipated breakdowns or emergency maintenance
B. Maximize operational consistent performance
C. Long-term cost savings
D. Prevent violations
E. Energy efficiencies

3.9.2 Describe a preventative maintenance system for wastewater treatment 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

3.9.3 Explain how to prevent grease and grit build-up in lift station wet wells.

To prevent grease and grit, control it at its source. This means having stringent pretreatment requirements in the sewer use ordinance and through a Grease Control Program. Monitor commercial and industrial sources to ensure good maintenance is performed on grease traps, oil separators, and any solids removal system.

3.9.4 Develope a routine lubrication maintenance schedule for all wastewater treatment equipment.

Lubrication is one of the most important preventative maintenance tasks at a treatment plant. The O&M manual specifies the type of lubricants and the frequencies of lubrication for each piece of equipment.

3.9.5 Discuss the importance of routine preventative maintenance of aeration basins and clarifiers.

Aeration basins and clarifiers should be emptied on a regular basis to:

A. Perform a detailed inspection of the structure, valves, and control gates
B. Clean out grit and settled solids
C. Maintain equipment and piping

When emptying aeration basins and clarifiers, an operator should be aware of structural and operational effects. Notify the Department of Natural Resources of scheduled maintenance activities as given in the standard conditions of the Wisconsin Pollution Discharge Elimination System (WPDES) permit.

3.9.6 List the items to include in a maintenance schedule for final clarifiers.

An operator should consult the O&M manual for the preventative maintenance schedule. Daily observations should be performed, including: checking for oil leaks, unusual vibrations or noises, scum collection, weirs, and floating solids. All maintenance and repairs should be documented.

3.9.7 List common critical maintenance tasks for pumps.

A. Lubrication
B. Amperage checks
C. Packing if leaking
D. Flushing water seals
E. Check for clogging

Follow the O&M manual for all specific maintenance tasks.

3.9.8 Discuss how to calibrate lift station pumps.

Calibrating pumps is a way to check on wear. Regular calibration also helps determine actual flow rates and whether any plugging or infiltration is occurring.

To calibrate pumps, first it is a must to find the drawdown distance, drawdown time, refill distance and refill time for each pump. Here is how:

A. Measure wet well length and width (for rectangular wells) or the diameter (for circular wells)

B. Allow the pump to come on and then record distance between the wastewater surface and a fixed object and the time until the pump shuts off. The distance between when the pump comes on and shuts off is called the drawdown distance. The time it takes is called the drawdown time.

C. Allow the pump to refill and then record the distance and time. The change in wastewater depth between when the pump shuts off and when it starts again is called the refill distance. The time elapsed is called the refill time.

D. Repeat A, B, and C several times to ensure similar results

E. Calculate the pump rate (see key knowledge 7.5.1)

For further information, refer to the 'MPCA Math Workbook for Collection System Operators'.

3.9.9 List common critical maintenance tasks for valves.

A. Exercise
B. Check for clogs (check valves)

Follow the O&M manual for all specific maintenance tasks.

3.9.10 List common critical maintenance tasks for motors.

A. Grease
B. Check temperature

C. Check amperage
D. Inspect for noise and vibration

Follow the O&M manual for all specific maintenance tasks.

3.9.11 List the informational content of a treatment plant O&M manual.

The Department of Natural Resources requires the following topics be in a treatment plant O&M manual:

A. General Information
B. Staffing
C. Records system
D. Laboratory
E. Safety
F. Security and emergencies
G. Utilities and electrical systems
H. Appendices
I. Process description, operation, and control (liquid and solids)
J. Sludge management
K. Maintenance
L. Recommended reference materials (manuals, books, and codes)

3.9.12 Explain cavitation, its cause, the sound, and how to handle it.

Cavitation occurs in wastewater systems when the vacuum pressure at any point in the system is lowered to the vapor pressure of the liquid. Under such conditions, vapor bubbles form and then collapse producing effects ranging from decreased efficiencies to equipment failure. Cavitation usually occurs in pumps, on impellers, or at restrictions in a flowing liquid and may occur as suction cavitation or discharge cavitation.

Cavitation can make a pump very noisy. This noise has been described as a popping sound, clattering, or similar to marbles rattling around in the pump. Operating the pump continuously under this condition can cause pitting of the impeller and corrosion. If cavitation is occurring, contact the consultant or pump service representative to determine the cause and corrective actions.

3.9.13 Discuss wastewater financial budgets in the operation, management, and upgrading of a wastewater treatment plant.

In the operation and management of a wastewater system there are four major separate budgetary items needed: Operation and Maintenance Budget, Capital Improvement Budget, Replacement Fund, and Debt Retirement. Revenues come from sewer use charges to support the operation, upgrading, and management of the treatment system. Sewer use charges should be reviewed every two years and adjusted as needed. Financial management information about the treatment plant and sewer system is reported to the Department of Natural Resources each year in the Compliance Maintenance Annual Report (CMAR).

A. Operation and maintenance budget
Sufficient funds must be available to cover the daily operational and maintenance expenses for the wastewater treatment plant and collection system, including salaries, electric bills for running all the equipment, lubricating pumps and drives, and cleaning sewer pipes.

B. Capital improvements budget or loan
Significant upgrading or improvement projects often require large expenditures of money. Utilities should establish a capital improvements budget to plan for future treatment plant needs. Sometimes it is not possible to save enough money for a project and in those cases there are a variety of funding methods available including grants, loans, and municipal bonds.

C. Replacement fund
Treatment plant equipment, such as pumps, motors, or aeration equipment, have projected lifespans and need to be replaced when reaching the end of their design life. A replacement fund with readily available funds allows an operator to replace old or worn out equipment during the useful life of the treatment works to maintain the capacity and performance for which the treatment works were designed and constructed.

D. Debt retirement
The large investment a community has to make in constructing and upgrading a wastewater treatment system often requires loans or bonds from a funding agency and/or financial institutions to be obtained and paid back over the terms of the loan.

Chapter 4 - Biosolids/Sludge - Processing, Handling, and Land Application

Section 4.1 - Thickening

4.1.1 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 those 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 that of water making them more difficult to settle than primary sludges. Secondary sludges are 75% to 80% volatile solids and contain bound water in the cells of the microorganism, making them difficult to dewater or thicken. Chemical additions can be used to enhance dewatering. The higher the volatile solids (organics) content, the more difficult the sludge is to dewater.

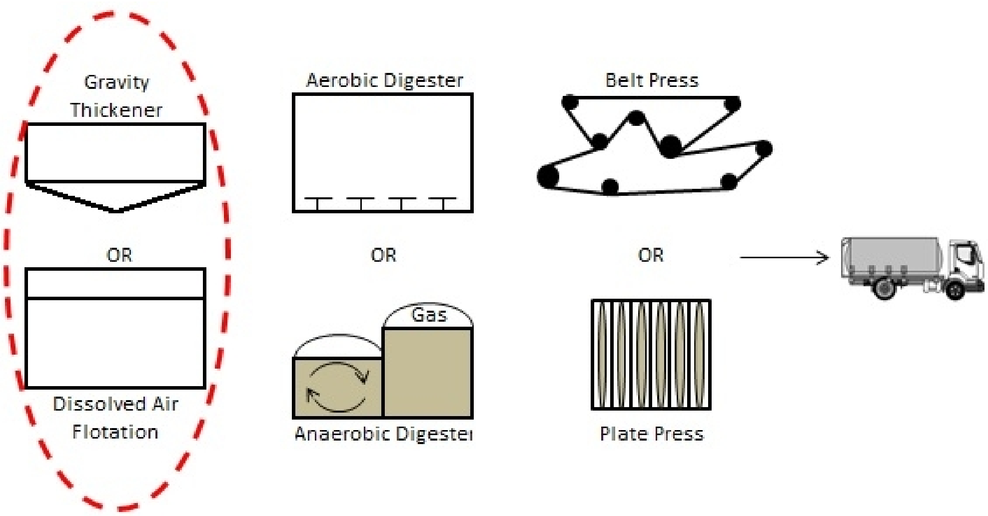
Both primary and secondary sludges should be as concentrated as possible by proper operation of clarifiers. At times, additional thickening is used to reduce the amount of water and volume loading on subsequent sludge treatment processes. Here, too, chemical additions can be used to enhance dewatering.

4.1.2 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% (5,000 mg/L) to 5.0% (50,000 mg/L) suspended solids. Sludge thickening further concentrates these solids from 3.0% (30,000 mg/L) to 6.0% (60,000 mg/L) to allow for further handling and processing.

Sludge thickening most commonly consists of gravity thickeners (settling tanks) 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, allow the sludge to settle, and thicken by decanting the clear liquid off the tank. Sludge drying beds can be used to thicken and store solids but are not as commonly used as they once were because of handling, odor issues, and space limitations at a treatment plant site.

Figure 4.1.2.1



4.1.3 Describe common biosolids and sludge thickening unit processes and how they work.

Sludge is thickened prior to being pumped to the digester or sludge storage. Common sludge thickening unit processes are:

A. Gravity settling thickener
Gravity thickening consists of a circular tank (usually with a conical bottom) fitted with collectors or scrapers at the bottom. Primary and/or secondary solids are fed into the tank through a center well, which releases the solids at a low velocity near the surface of the tank. The 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.

B. DAF
DAF thickens sludge by adding dissolved air under pressure and then releasing the air at

atmospheric pressure in a flotation tank or basin. The released air forms tiny bubbles which adhere to the suspended matter causing the suspended matter to float to the surface where it is removed by a skimming device.

Figure 4.1.3.1

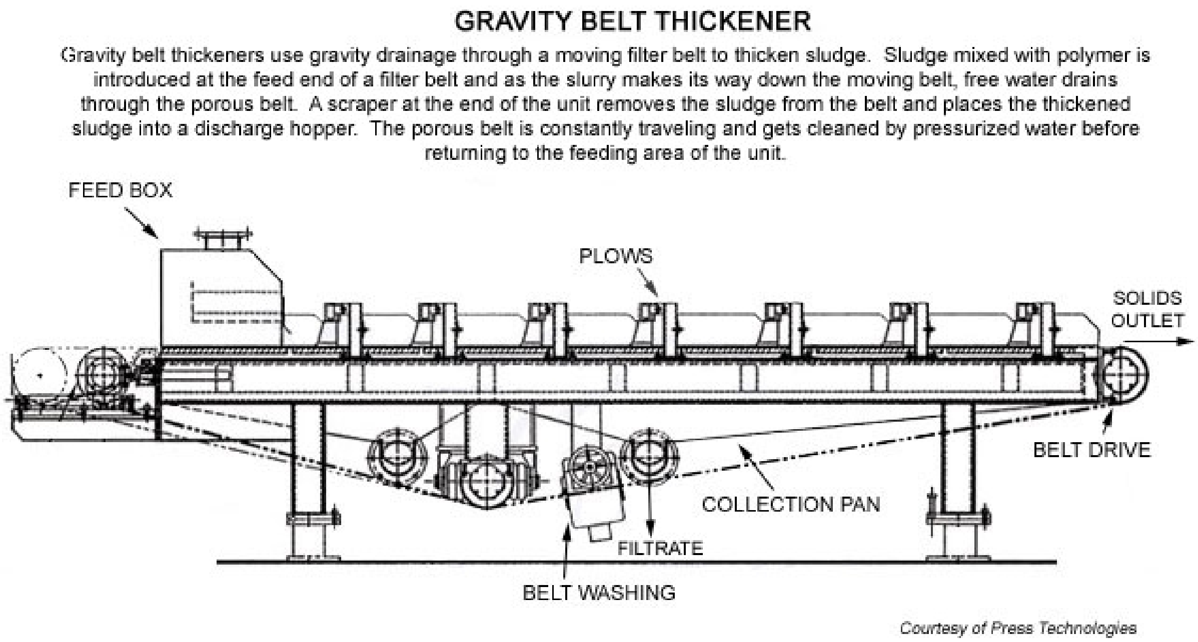
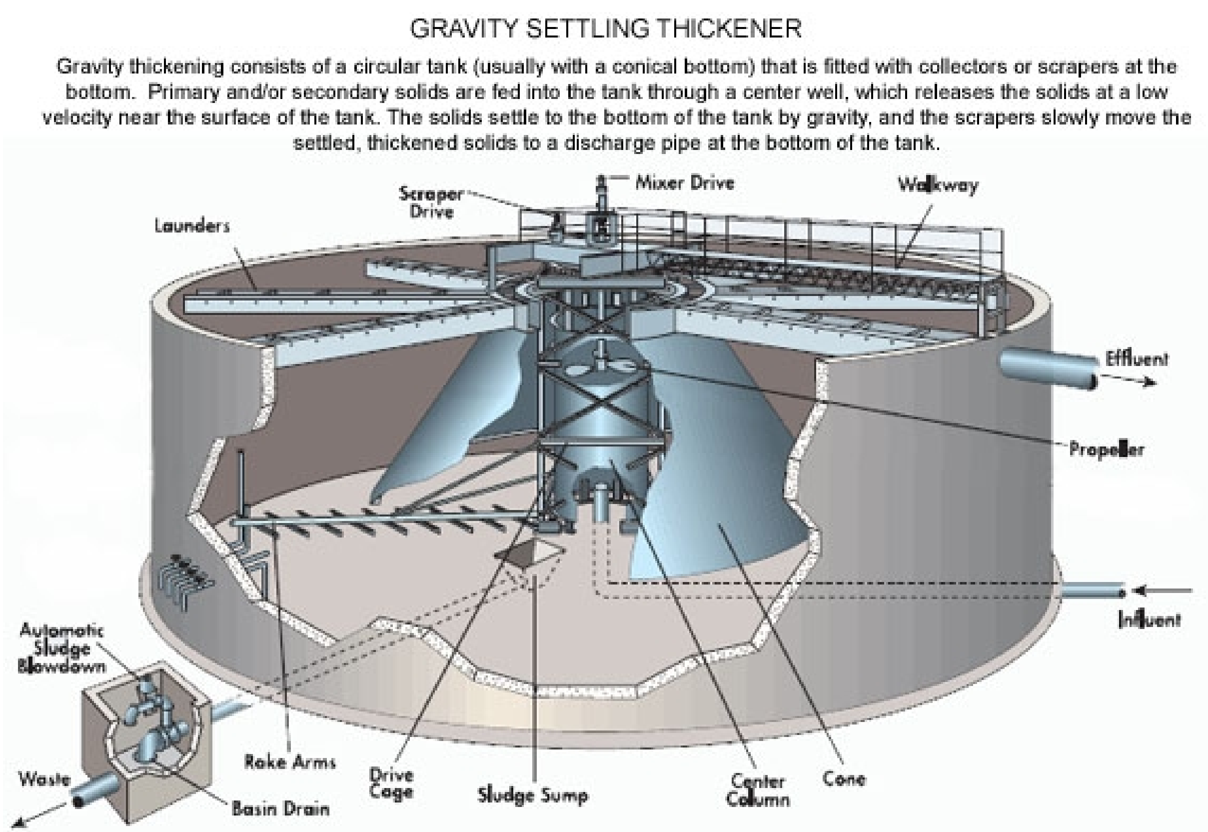


Figure 4.1.3.2



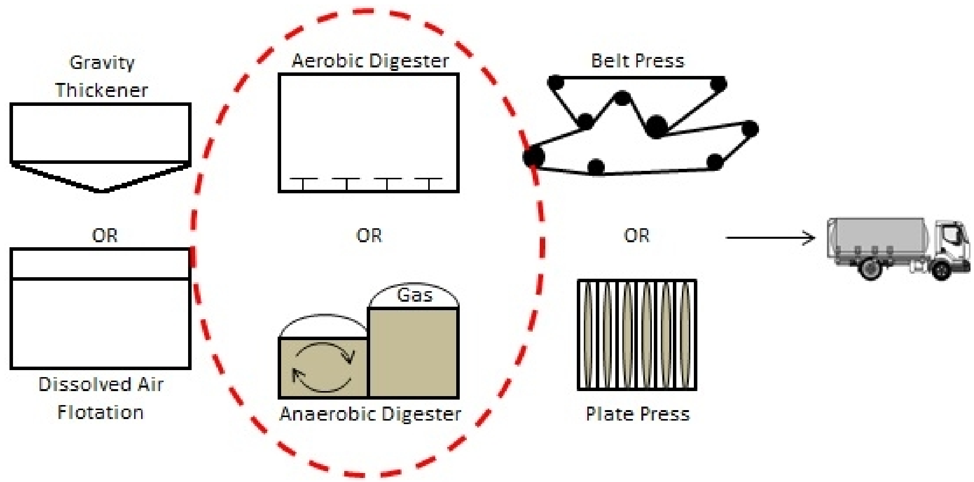
Section 4.2 - Treatment

4.2.1 Discuss the treatment of biosolids and sludges.

The purpose of sludge treatment, sometimes also referred to as sludge stabilization, is to reduce the pathogens (fecal coliforms) in the sludge and the attraction of vectors (flies, mosquitos, vermin, birds, etc.) that transmit diseases. The Department of Natural Resources establishes pathogen control and vector attraction reduction criteria in Wisconsin Pollution Discharge Elimination System (WPDES) permits that must be met before the sludge can be landspread.

Sludge treatment most commonly consists of aerobic or anaerobic digesters. Digesters utilize bacteria in the treatment of the sludge. Heat and chemicals can be used to treat sludges as well.

Figure 4.2.1.1



4.2.2 Discuss biosolids and sludge treatment processes used to significantly reduce fecal coliform bacteria and meet the pathogen control criteria.

Class B sludges are sludges that can be applied to agricultural lands. Adequate pathogen control for a Class B sludge is less than 2,000,000 colony forming units (cfu)/g or most probable number (mpn) fecal coliforms or by one of the following methods below. Certain sludge treatment processes are able to significantly reduce fecal coliform bacteria and meet these criteria in Wisconsin.

A. Anaerobic digestion
Sludge is treated in the absence of oxygen for a certain amount of time at a specific temperature. The time and temperature shall be between 15 days at 35°C to 55°C and 60 days at 20°C.

B. Air drying
Sludge is dried on sand beds or on paved or unpaved basins for a minimum of 3 months. During 2 of the 3 months, the average daily temperature has to be above 0°C.

C. Composting

Sludge is composted using a within-vessel, static-aerated pile, or windrow-composting method and the temperature of the sludge raised to 40°C or higher for 5 days. For 4 hours during the 5 days, the temperature in the compost pile has to exceed 55°C.

D. Alkaline stabilization
Lime is added to sludge to raise the pH to 12 for 2 hours of contact.

E. Process to significantly reduce pathogens (PSRP) equivalent
Sludge is treated in a process that is equivalent to a process to significantly reduce pathogens, as approved by the Department of Natural Resources. Many such processes are proprietary.

4.2.3 Describe how aerobic digesters work.

Aerobic digesters utilize microorganisms and oxygen to digest the remaining organic material in wasted sludge from the primary and secondary treatment processes. The detention time in an aerobic digester is sufficiently long to allow for most of 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 most of the time darker.

4.2.4 Describe how anaerobic digesters work.

Anaerobic digesters utilize microorganisms without oxygen to digest the remaining organic material in wasted sludge from the primary and secondary treatment processes. Anaerobic digesters are heated and covered. The process generates methane gas that can be recovered and used as an energy source in the treatment plant.

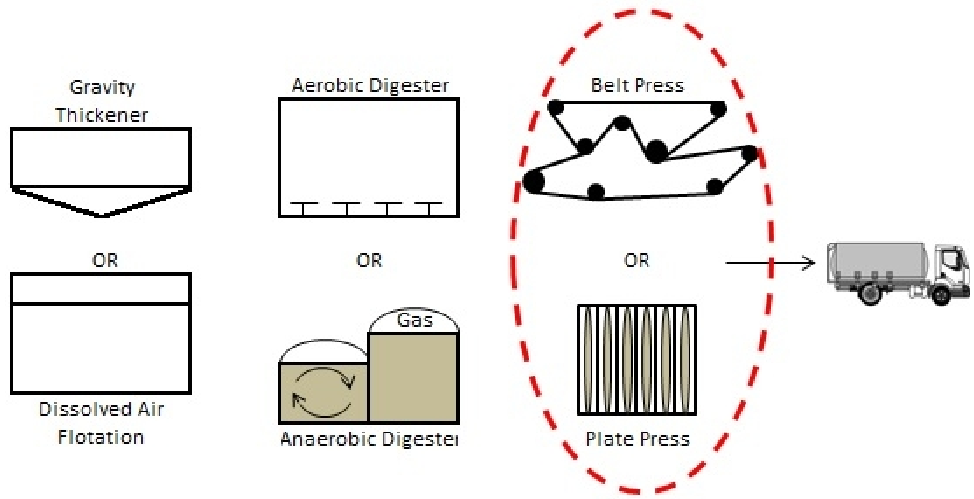
Section 4.3 - Dewatering

4.3.1 Discuss the dewatering of biosolids and sludges.

The purpose of dewatering biosolids and sludges is to significantly concentrate the solids and reduce the liquid content of the sludge. Dewatering reduces the sludge volume to be stored, transported, and landspread. Large treatment plants that generate large liquid volumes of sludge often use some type of sludge dewatering.

Sludge dewatering is done mechanically and most often consists of presses (belt or plates), vacuum filters, and centrifuges. Sludge can also be dewatered in sludge drying beds, reed beds, and other ways. Dewatered sludges are typically 15% to 30% solids and referred to as cake sludge. Cake sludge handling, transport, and land application is different than liquid sludge. Dewatered sludge is drier, thicker, and more solid and thus can be shoveled, moved using belt conveyors, and transported in dump trucks rather than pumper trucks.

Figure 4.3.1.1



4.3.2 Describe common mechanical biosolids and sludge dewatering units and how they work.

Figure 4.3.2.1

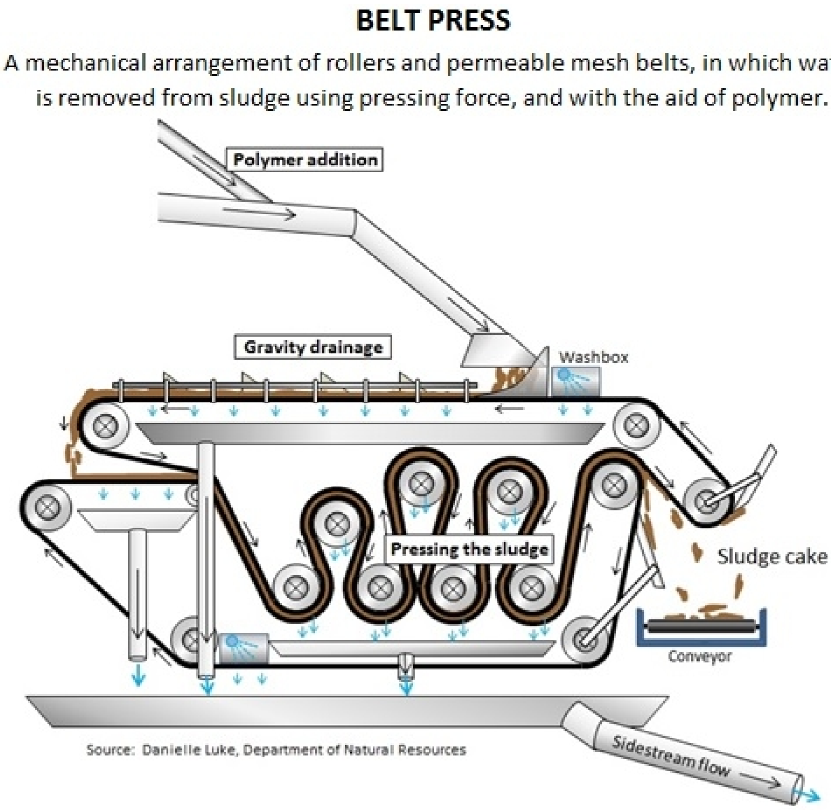


Figure 4.3.2.2

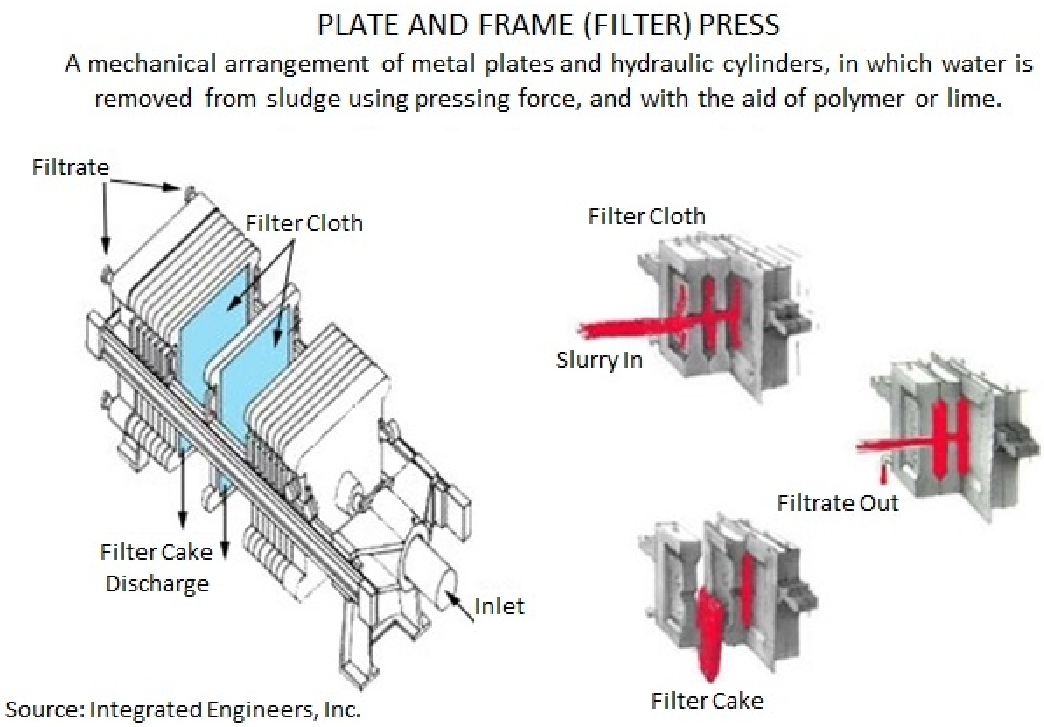
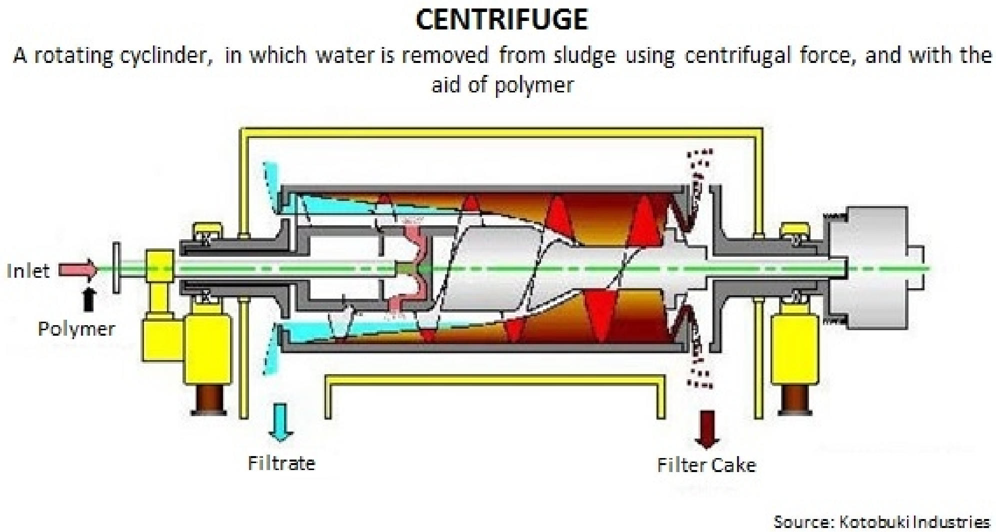


Figure 4.3.2.3

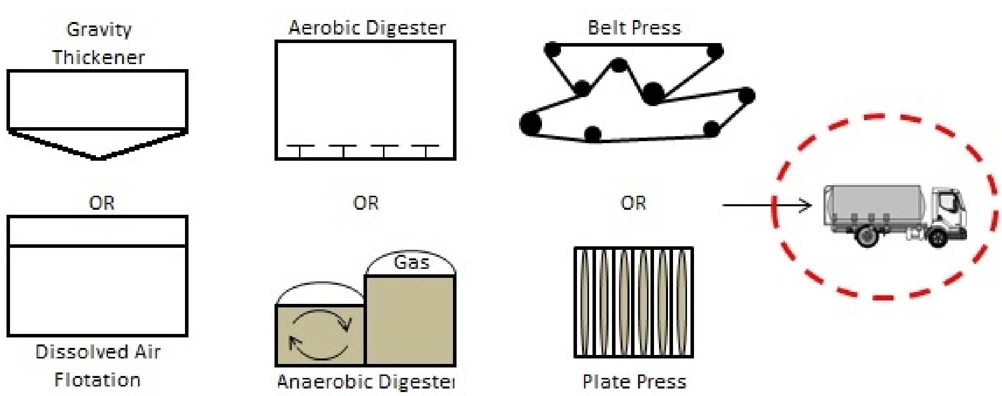


Section 4.4 - Land Application

4.4.1 List the common methods of sludge disposal.

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

Figure 4.4.1.1



4.4.2 List the two Wisconsin Administrative Codes regulating municipal and industrial sludge.

A. NR 204 Domestic sewage sludge management
B. NR 214 Land treatment of industrial liquid wastes, by-product solids and sludges

4.4.3 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). Recycling biosolids through land application is a sustainable management method to reuse nutrients and soil conditioners in place of commercial fertilizers and to avoid disposal in landfills.

Section 4.5 - Sampling and Reporting

4.5.1 Discuss sludge sampling and reporting prior to 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 and to protect public health and the environment. Industrial sludges must also meet certain criteria. 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 will leach down 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.

C. Pathogen densities
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, mosquitos, vermin, and birds that can carry and transmit diseases.

4.5.2 Compare activated sludge solids results expressed as milligrams per liter (mg/L) and percent solids.

In activated sludge aeration basins, mixed liquor suspended solids (MLSS) is expressed in mg/L. As solids are thickened and the concentration gets to 10,000 mg/L or above, the solids are then often expressed as a percent. Every 10,000 mg/L is 1% and can be expressed as follows:

10,000 mg/L = 1.0% solids
15,000 mg/L = 1.5% solids
20,000 mg/L = 2.0% solids
25,000 mg/L = 2.5% solids
30,000 mg/L = 3.0% solids

4.5.3 Discuss the records an operator must keep when biosolids and sludge are landspread.

A treatment plant operator has to maintain an application log for biosolids land applied each day when land application occurs. 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 applied with sludge on that day
C. Amount of sludge applied that day and amount per acre
D. Amount of nitrogen applied per acre
E. Method of application of the sludge (injection, incorporation, or surface application)

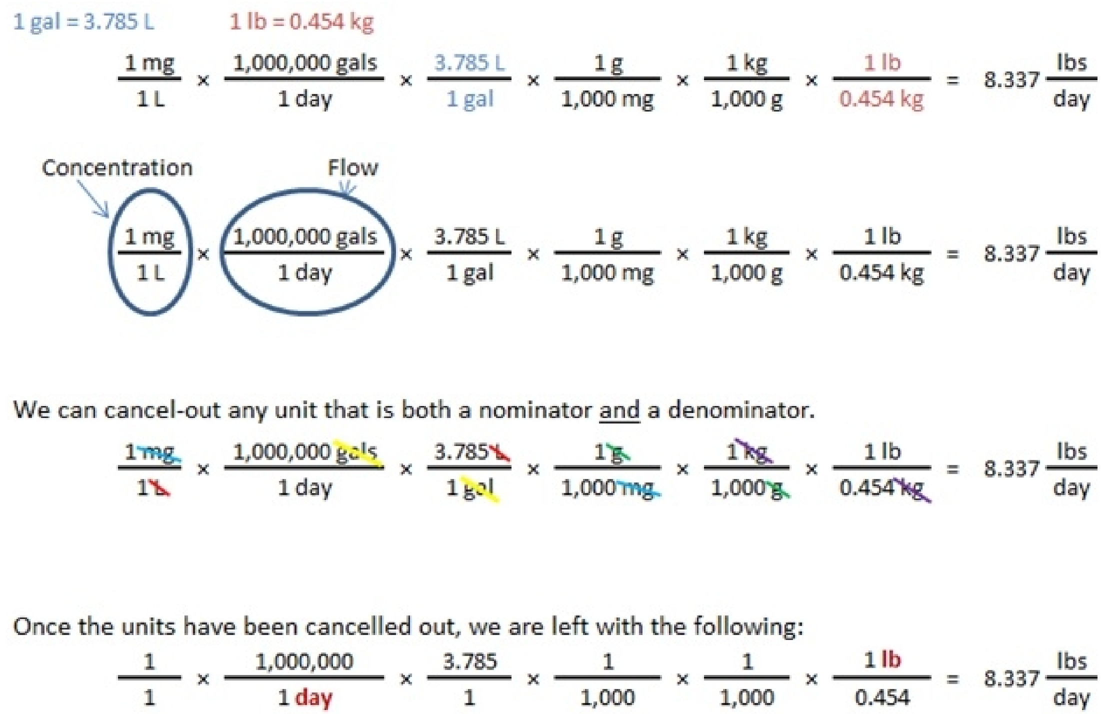
4.5.4 Discuss the pounds formula.

The purpose of the pounds formula is to convert mg/L of BOD, TSS, phosphorus, etc. into lbs/day. This formula is the most used formula in wastewater calculations.

The formula is:
lbs/day = flow (MGD) × concentration (mg/L) × 8.34

The number 8.34 is obtained by cancelling the units in the full formula using 1 mg/L for concentration and 1 MGD for flow (see figure below).

Figure 4.5.4.1



Chapter 5 - Effluent Discharge

Section 5.1 - Flow Monitoring

5.1.1 Explain effluent flow measurement.

Effluent flow measurement is required by the Wisconsin Pollution Discharge Elimination System (WPDES) permit at all wastewater treatment plants for measuring flows to the receiving water. It also is used for the operation of effluent flow-proportional composite samplers and for the pacing of chemical addition equipment. Effluent flow measurement equipment should be close to the end of the treatment plant. Treatment plants are typically equipped with an open channel flow measurement structure, which is fitted with a (primary) V-notch weir or Parshall flume. See key knowledge 2.4.2 for more information on these flow measurement devices.

5.1.2 Describe how daily flow measurements are recorded.

For Discharge Monitoring Reports (DMR), the day in which most of the flow is received is the date the flow should be recorded. For example, influent wastewater flow entering the plant is recorded and totaled from 7:00 am, July 14th to 7:00 am, July 15th. The total flow read the morning of July 15th is 475,000 gals. The operator would report this flow as the flow for July 14th. Flows should be recorded at about the same time each day. Flows are most commonly reported on DMRs in million gallons per day (MGD). In the example above, the flow would be recorded as 0.475 MGD.

Section 5.2 - Sampling

5.2.1 Describe a good sampling location and procedure for collecting representative effluent wastewater samples.

It is very important that the final effluent discharged from a wastewater treatment plant be sampled in a location where it is well mixed and represents the actual water being discharged to the receiving water. The sample should be collected using a flow-proportional composite sampler. Sample strainers or tubes should not lie on the bottom of a channel (where some solids may accumulate) or against any tank wall or in a corner (which may be stagnant zones). They should be suspended 1 to 2 feet below the water surface that has been well mixed or in a channel where it is mixed well, such as just before entering a flume or exiting a weir. The sampling strainer should be checked and cleaned regularly.

Often, an effluent sample is collected just prior to disinfection so the sample does not have to be seeded in the biochemical oxygen demand (BOD) test. If the sample is collected after disinfection, the BOD sample will have to be seeded with a very small amount of settled influent supernatant to reintroduce microorganisms to the BOD bottle.

5.2.2 Discuss samples and lab testing when sending to certified labs.

When sending samples to a certified lab one must make sure:

A. The lab is certified to perform the test needed.

B. The sample will get there in the appropriate time. For example: grab samples for pH cannot be sent out due to the holding time requirements and BOD samples must be tested at the certified lab no later than 48 hours after the last composite sample was taken.

C. The paperwork is filled out completely. Certified labs will provide a chain of custody form that has all the necessary data.

D. The samples are on ice when needed and that the temperature of the samples meets the specific requirements when they reach the certified lab.

5.2.3 List the information that must be recorded for effluent wastewater samples.

Automatic composite samplers must be refrigerated and maintained at a temperature of less than 6°C at all times without freezing. A thermometer immersed in a small capped bottle of liquid is usually kept in the sampler to check and record temperatures. A 24-hour flow-proportional composite sample is the common requirement. For Discharge Monitoring Reporting (DMR), the day on which most of the composite sample was taken is the date of the sample. A sampling log must be maintained at the automatic composite sampler and the following information recorded:

A. Sample identification
B. Date started
C. Time started
D. Date collected
E. Time collected
F. Sampler temperature
G. Operator initials
H. Comments

5.2.4 Describe how to set an automatic sampler.

An automatic sampler takes a series of small samples throughout the day and stores it in a large container. The large container is in a refrigerator to preserve the sample while collecting it. At the end of 24 hours, a 24-hour composite sample will be collected.

The Department of Natural Resources usually specifies flow-proportional composite samples, which means the automatic sampler receives a signal from a flow meter and takes a sample every so many gallons of flow.

In order to set up an automatic sampler to take a 24-hour flow-proportional sample, two settings need to be adjusted. The first setting determines the sample size (aliquot) and the second setting determines how often the sampler takes a sample (interval). During normal flows, for example, set up the sampler to take 100 samples per day with the container about half full at the end of the 24-hour period.

EXAMPLE:
An operator wants to take a 24-hour flow-proportional sample. The flow is 500,000 gals per day (gpd) and the sample container holds 20 liters.

SOLUTION:
The operator wants to take 100 samples per day with the container about half full at the end of the 24-hour period. 10 liters = 10,000 mL, so:
10,000 mL ÷ 100 samples = 100 mL/sample

The operator can set the sample size (aliquot) to 100 mL. To determine the interval, divide

the daily flow by the number of samples:
500,000 gpd ÷ 100 samples/day = 5,000 gals/sample

The operator can set the interval to 5,000 gals.

5.2.5 Discuss the water pollution concerns related to the discharge of insufficiently treated wastewater.

The discharge of insufficiently treated wastewater can affect fish and aquatic life in the receiving water course. These biological organisms are dependent on sufficient dissolved oxygen (DO) to live and the oxygen demand of the effluent can reduce or use up the oxygen present. Other concerns from wastewater discharges would include: toxics, deposition of suspended solids, and excessive growth of aquatic plants from the nutrients in the discharge.

Section 5.3 - Permitting and Reporting

5.3.1 List and describe what is in a Wisconsin Pollution Discharge Elimination System (WPDES) permit.

A WPDES permit allows you to discharge treated wastewater from a treatment plant to a specified receiving water or land area in accordance with the effluent limitations, monitoring requirements, and other conditions set forth in the permit. A WPDES permit contains the following sections:

A. Influent Requirements
The Influent Requirements section lists the specific influent sampling points and associated monitoring requirements at each point. It also provides how much flow and pollutants are coming into the plant.

B. Surface Water or Land Disposal Requirements
This section lists the specific effluent sampling points with associated monitoring requirements and effluent limitations at each point. This provides information on treatment efficiency and the amount and quality of the treated wastewater being discharged from the plant.

C. Groundwater Requirements (if applicable)
This section includes monitoring requirements and standards for a groundwater monitoring system.

D. Land Application Requirements
The Land Application Requirements section includes the specific sampling points and associated monitoring requirements and limitations at each point. It also provides information on the biosolids and sludge hauled from the plant and landspread.

E. Schedules of Compliance
The Schedules of Compliance section establishes a time schedule for any reports, upgrading construction requirements, or other actions to be met by the permittee.

F. Standard Requirements
The Standard Requirements section contains the more general requirements regarding wastewater reporting and monitoring, system operations, surface water discharge, and land application.

G. Summary of Reports Due
The end of the permit contains a table listing and summarizing all the reports that must be submitted and when they are due. Many operators copy this page and post it for ready reference.

5.3.2 Describe how water quality standards and limits are established in WPDES permits.

Some effluent limitations listed in a WPDES permit are derived from water quality based standards which vary depending on the receiving water. These limits are set to protect the water quality of the receiving water.

Other limits found in a WPDES permit are established based on the type of wastewater treatment plant processes and the amount of treatment they are technologically able to provide.

5.3.3 Describe a Discharge Monitoring Report (DMR).

A DMR is an electronic submittal required by the Department of Natural Resources, which includes routine monitoring data from a wastewater treatment plant primarily to determine compliance with permit limits. The monitored parameters and frequencies are outlined in the facility's WPDES permit. These reports are submitted electronically to the Department of Natural Resources on a monthly basis, although some facilities submit them quarterly. DMRs are due on the 15th of the following month.

Figure 5.3.3.1

Wastewater Discharge Monitoring Long Report

Facility Name: Activated Sludge Wastewater Treatment Plant
Contact Address: N 021 Filamentous Way
Flushing, WI 53000
Facility Contact: Mary Vorticella, Operator
Phone Number: (608)555-1234
Reporting Period: 01/01/2012 - 01/31/2012
Form Due Date: 02/15/2012
Permit Number: 0123456

For DNR Use Only

Date Received:
DOC:
FIN:
FID:
Region: South Central Region
Permit Drafter: Phillip A. Spranger
Reviewer: Amy M Schmidt
Office: Fitchburg

	Sample Point	701	701	001	001	001
	Description	INFLUENT	INFLUENT	EFFLUENT	EFFLUENT	EFFLUENT
	Parameter	66	457	211	66	457
	Description	BOD5, Total	Suspended Solids, Total	Flow Rate	BOD5, Total	Suspended Solids, Total
	Units	mg/L	mg/L	MGD	mg/L	mg/L
	Sample Type	24 HR FLOW PROP	24 HR FLOW PROP	CONTINUOUS	24 HR FLOW PROP	24 HR FLOW PROP
	Frequency	2/WEEK	2/WEEK	CONTINUOUS	2/WEEK	2/WEEK
Sample Results	**Day 1**					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					

5.3.4 Describe other reports required in WPDES permits submitted to the Department of Natural Resources.

In addition to the DMR, there are several other required reports listed in the WPDES permit. These include: the Compliance Maintenance Annual Report (CMAR), Whole Effluent Toxicity (WET), General Sludge Management, Sludge Characteristics, and Land Application reports. Compliance schedules in a WPDES permit may require other reports.

5.3.5 Discuss certifications needed at a wastewater treatment facility.

A. Operator Certification
Each WWTP must have an operator-in-charge (OIC). The OIC must be a DNR Certified Wastewater Operator. Different size plants and different types of treatments determine the type of operator certification required for that plant.

B. Lab registration or certification
Wisconsin state law requires that sampling and testing shall be performed by a certified or registered lab. A Registered lab runs tests for only their plant. A certified lab generally performs tests for any treatment plant.

5.3.6 Discuss the requirements for reporting a Sanitary Sewer Overflow (SSO).

Whenever there is an overflow occurrence at the treatment plant or from the collection system, the permittee must notify the Department of Natural Resources within 24 hours of initiation of the overflow occurrence by telephoning the wastewater staff in the regional office as soon as reasonably possible (by FAX, email, or voice mail, if staff are unavailable). In addition, the permittee shall within 5 days of conclusion of the overflow occurrence report pertinent SSO information in writing on a SSO reporting form provided by the Department of Natural Resources.

Chapter 6 - Safety and Regulations

Section 6.1 - Personal Safety

6.1.1 List prevalent diseases that can be contracted through wastewater exposure.

A. Gastroenteritis
B. Dysentery
C. Hepatitis B and C
D. Giardiasis
E. Upper respiratory illnesses

6.1.2 Identify potential toxic gases at a wastewater treatment plant.

A. Hydrogen sulfide
B. Methane
C. Carbon monoxide
D. Chlorine

6.1.3 Define personal protective equipment (PPE).

PPE is the protective clothing and other devices designed to protect an individual while in potentially hazardous areas or performing potentially hazardous operations. Examples of PPE include, but are not limited to: gloves, hard hat, steel-toed boots, safety glasses, and other appropriate clothing.

6.1.4 Define lock-out/tag-out.

Lock-out/tag-out is used to protect the operator from serious injury by ensuring that machinery remains completely off. The lock is placed on the power source in a way that prohibits the machinery from receiving the power necessary to run and includes a tag with the operator’s name performing the maintenance. Without a lock-out/tag-out system, the possibility exists that a machine will unexpectedly start-up, either because of stored energy not correctly released, being triggered by the control system, or through someone starting it without realizing maintenance is being performed.

6.1.5 Describe a potential safety hazard with anaerobic digesters.

A potential safety hazard with anaerobic digesters is the possibility of an explosive atmosphere being formed. If air is mixed with the methane gas from the digestion process, either in the digester or from any methane gas leak, any spark could cause a severe explosion.

6.1.6 Discuss precautions for entering tanks, vessels, or other confines space areas.

Owners of wastewater treatment plants should clearly define all confined spaces. Operators should know them and follow all confined space entry procedures. FOLLOW ALL CONFINES SPACE ENTRY PROCEDURES!

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

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

6.1.8 Discuss the importance of floatation 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 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. 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.

Section 6.2 - Chemical Safety

6.2.1 Discuss the importance of maintaining chemical delivery, storage, and usage records.

Some chemicals used in wastewater treatment plants are hazardous materials and must be identified. Safety Data Sheets (SDS) for each chemical are required to be kept onsite and readily available. In the event of a spill, the Department of Natural Resources must be contacted.

6.2.2 Discuss what should be done in the event of a chemical spill.

Any spill of hazardous material should be reported to the Department of Natural Resources within 24 hours and to the local emergency response agencies.

Section 6.3 - Management of Wastewater Treatment Plants

6.3.1 Discuss preventative spill measures and procedures when handling hazardous chemicals.

Storage tanks must have secondary containment that equals the volume of the storage tank. Place containment pails under potential leak points during unloading of delivery vehicles and when uncoupling fill lines. Inspect and maintain fill lines and valves. Inspect storage tanks and hardware for integrity. Pay attention to what is being done!

Provide onsite containment equipment such as absorbent booms, sandbags, etc. and seal the yard and storm drains to prevent offsite loss of chemical.

Chapter 7 - Calculations

Section 7.1 - Sampling

7.1.1 Given the average daily plant flow, calculate the programming of a flow-proportional sampler to collect the correct number and volume (mL) of samples.

GIVEN:

Average daily flow = 850,000 gals
24-hour composite volume desired = 5,000 mL
Sample container size = 10 L
Samples per day = 100

FORMULAS AND SOLUTION:
gpd = gallons per day

Flow interval (gals/sample) = average flow (gpd) ÷ # of samples/day
= 850,000 gpd ÷ 100 samples/day
= 8,500 gals/sample

Sample volume (mL) = 24-hour composite volume (mL) ÷ # of samples/day
= 5,000 mL ÷ 100 samples/day
= 50 mL

Section 7.2 - Flow Conversions and Flow Rate

7.2.1 Given a flow rate (gallons per day (gpd)), convert the flow rate to million gallons per day (MGD).

GIVEN:

Flow rate = 600,000 gpd

FORMULA AND SOLUTION:

Flow rate (MGD) = flow rate (gpd) ÷ 1,000,000
= 600,000 gpd ÷ 1,000,000
= 0.600 MGD

7.2.2 Given a flow rate (gallons per minute (gpm)), convert the flow rate to MGD.

GIVEN:

Flow rate = 500 gpm
1 day = 1,440 minutes

FORMULA AND SOLUTION:

Flow rate (MGD) = [flow rate (gpm) × 1,440 min/day] ÷ 1,000,000
= [500 gpm × 1,440 min/day] ÷ 1,000,000
= 0.720 MGD

Section 7.3 - Tank Areas and Volumes

7.3.1 Given the dimensions of a rectangular basin, calculate the volume (gallons).

GIVEN:

Basin length = 60 ft
Basin width = 20 ft
Basin depth = 10 ft
1 cubic foot = 7.48 gals

FORMULA AND SOLUTION:

Basin volume (gals) = [length (ft) × width (ft) × depth (ft)] × 7.48 gals/ft^3
= [60 ft × 20 ft × 10 ft] × 7.48 gals/ft^3
= 89,760 gals

7.3.2 Given the dimensions of a circular basin, calculate the volume (gals).

GIVEN:

Basin diameter = 30 ft
Basin depth = 10 ft
1 cubic foot = 7.48 gals

FORMULA AND SOLUTION:

Basin volume (gal) = [3.14 × (radius (ft))^2 × depth (ft)] × 7.48 gals/ft^3
= [3.14 × (15 ft × 15 ft) × 10 ft] × 7.48 gals/ft^3
= 52,846 gals

7.3.3 Given data, determine if an unused circular tank at a treatment plant can be used for 180 day sludge storage. The volume of sludge generated is 2,500 gallons per day (gpd) and the tank is 20 ft deep with a diameter of 50 ft.

GIVEN:

Tank depth = 20 ft
Tank diameter = 50 ft
Sludge wasted = 2,500 gpd

FORMULAS AND SOLUTION:

Sludge volume needed = sludge wasted (gpd) × sludge storage (days)
= 2,500 gpd × 180 days
= 450,000 gals

Tank volume = [3.14 × (radius (ft))^2 × depth (ft)] × 7.48 gals/ft^3
= [3.14 × (25 ft)^2 × 20 ft] × 7.48 gals/ft^3

= 293,590 gals

Since the sludge wasted is 450,000 gals and the tank is only 293,560 gals, the tank by itself is too small to be used for 180 days of storage.

7.3.4 Given data during wet weather, determine if a chlorine contact tank is of sufficient volume to meet a 30-minute detention time at peak hourly flow.

GIVEN:

Tank depth = 15 ft
Tank length = 20 ft
Tank width = 15 ft
Peak hourly flow = 35,000 gals/hr
Detention time needed = 30 minutes

FORMULAS AND SOLUTION:

Tank volume (gals) = [length (ft) × width (ft) × depth (ft)] × 7.48 gals/ft³
= [20 ft × 15 ft × 15 ft] × 7.48 gals/ft³
= 33,660 gals

Detention time (mins) = [tank volume (gals) ÷ flow rate (gals/hr)] × 60 mins/hr
= [33,660 gals ÷ 35,000 gals/hr] × 60 mins/hr
= 0.96 hrs × 60 mins/hr
= 57 minutes

Yes; the chlorine contact is able to meet the 30-minute detention time during wet weather peak hourly flow.

Section 7.4 - Pounds Formula

7.4.1 The pounds formula is one of the most commonly used formulas by operators. Given data, convert a pollutant concentration and flow to pounds per day.

GIVEN:

Influent biochemical oxygen demand (BOD) = 200 mg/L
Flow = 1.0 million gallons per day (MGD)

FORMULA AND SOLUTION:

Influent BOD (lbs/day) = influent flow (MGD) × influent BOD (mg/L) × 8.34
= 200 mg/L × 1.0 MGD × 8.34
= 1,668 lbs/day

7.4.2 Given data, calculate the BOD (lbs) entering the treatment plant each day.

GIVEN:

Influent flow = 0.845 MGD
Influent BOD = 320 mg/L

FORMULA AND SOLUTION:

Influent BOD (lbs/day) = influent flow (MGD) × influent BOD (mg/L) × 8.34
= 0.845 MGD × 320 mg/L × 8.34
= 2,255 lbs/day

7.4.3 Given data, determine the food to microorganism ratio (F/M) in the aeration basin of an activated sludge treatment plant.

In an activated sludge plant, the F/M ratio is the amount of food (BOD in lbs) relative to the amount of biomass (mixed liquor suspended solids (MLSS) in lbs) in the aeration basin.

GIVEN:

Influent flow = 0.125 MGD
Influent BOD = 280 mg/L
Aeration basin volume = 0.200 million gallons (MG)
Aeration basin MLSS = 2,100 mg/L

FORMULAS AND SOLUTION:

Incoming BOD (lbs) = influent flow (MGD) × influent BOD (mg/L) × 8.34
= 0.125 MGD × 280 mg/L × 8.34
= 292 lbs BOD

MLSS under aeration (lbs) = aeration basin volume (MG) × MLSS (mg/L) × 8.34
= 0.200 MG × 2,100 mg/L × 8.34
= 3,503 lbs MLSS

F/M ratio = incoming BOD (lbs) ÷ MLSS under aeration (lbs)
= 292 lbs ÷ 3,503 lbs
= 0.08 lbs

Section 7.5 - Pump Rate

7.5.1 Given the dimensions of a rectangular sewage wet well (ft), calculate the pump rate (gallons per minute (gpm)) for the given pumping drawdown. Assume influent flow is shut-off.

GIVEN:

Wet well length = 16 ft
Wet well width = 13 ft
Pumping drawdown = 1.75 ft
Pumping time = 6 mins
1 cubic foot = 7.48 gals

FORMULA AND SOLUTION:

Pump rate (gpm) = [length (ft) × width (ft) × drawdown (ft) × 7.48 gals/ft^3] ÷ pumping time (mins)
= [16 ft × 13 ft × 1.75 ft × 7.48 gals/ft^3] ÷ 6 min
= 454 gpm

7.5.2 Given the dimensions of a circular sewage wet well, calculate the pump rate (gpm) for the given pumping drawdown. Assume influent flow is shut-off.

GIVEN:

Wet well diameter = 8 ft
Pumping drawdown = 4.25 ft
Pumping time = 5 mins
1 cubic foot = 7.48 gals

FORMULA AND SOLUTION:

Pump rate (gpm) = [3.14 × (radius (ft))^2 × drawdown (ft) × 7.48 gals/ft^3] ÷ pumping time (min)
= [3.14 × (4 ft)^2 × 4.25 ft × 7.48 gals/ft^3] ÷ 5 min
= 319 gpm

7.5.3 Given data, calculate the size of an emergency (trash) pump needed to pump to a downstream manhole during a power outage at a lift station wet well to avoid a sanitary sewage overflow (SSO) or basement backup.

GIVEN:

Lift station wet well size = 10 ft × 10 ft
Wet well depth = 15 ft
Wet well fill time during storm = 10 mins
1 cubic foot = 7.48 gals

FORMULAS AND SOLUTION:

Wet well volume (gals) = [length (ft) × width (ft) × depth (ft)] × 7.48 gals/ft^3
= 10 ft × 10 ft × 15 ft × 7.48 gals/ft^3
= 11,220 gals

Sewage flow (gpm) = wet well volume (gals) ÷ fill time (mins)
= 11,200 gals ÷ 10 mins
= 1,120 gpm

Size slightly larger, so use at least a 1,500 gpm pump will need to be used to prevent a SSO or basement backup.

7.5.4 Given data, calculate the pump rate (gpm) of the lift station pump.

GIVEN:

Wet well diameter = 7 ft
Drawdown time = 250 secs
Drawdown distance = 1.33 ft
Refill time = 400 secs
Refill distance = 1.25 ft
1 cubic foot = 7.48 gals
60 secs = 1 min

FORMULAS AND SOLUTION:

Drawdown volume (gals) = 3.14 × (radius (ft))^2 × draw down (ft) × 7.48 gals/ft^3
= 3.14 × (3.5 ft)^2 × 1.33 ft × 7.48 gals/ft^3
= 383 gals

Refill vol. (gals) = 3.14 × (radius (ft))^2 × refill (ft) × 7.48 gals/ft^3
= 3.14 × (3.5 ft)^2 × 1.25 ft × 7.48 gals/ft^3
= 360 gals

Pump rate (gpm) = [drawdown vol. (gal) ÷ time (min)] + [refill vol. (gal) ÷ time (min)]
= [383 gals ÷ (250 secs ÷ 60 secs/min)] + [360 gals ÷ (400 secs ÷ 60 secs/min)]
= [383 gals ÷ 4.2 mins] + [360 gals ÷ 6.7 mins]
= 91 gpm + 54 gpm
= 145 gpm

Section 7.6 - Detention Time

7.6.1 Given data, calculate the detention time (hrs) for a clarifier.

GIVEN:

Volume of clarifier = 95,000 gals
Flow rate = 540,000 gallons per day (gpd)

FORMULAS AND SOLUTION:

Flow (gals/hr) = flow rate (gpd) ÷ 24 hrs/day
= 540,000 gpd ÷ 24 hr/day
= 22,500 gals/hr

Detention time (hrs) = volume (gals) ÷ flow (gals/hr)
= 95,000 gals ÷ 22,500 gals/hr
= 4.22 hrs

7.6.2 Given data, calculate detention time (hrs) for multiple clarifiers operating in parallel.

GIVEN:

Primary clarifiers = 2
Clarifier diameter = 80 ft
Clarifier depth = 12 ft
Average daily flow = 7.2 million gallons per day (MGD)
1 cubic foot = 7.48 gals
[NOTE: Both clarifiers receive equal flows]

FORMULAS AND SOLUTION:

Volume (gals) = # of clarifiers × [3.14 × (radius (ft))^2 × depth (ft) × 7.48 gals/ft^3]
= 2 clarifiers × 3.14 × (40 ft)^2 × 12 ft × 7.48 gals/ft^3
= 901,908 gals

Detention time (hrs) = tank volume (gals) ÷ flow rate (gals/hr)
= 901,908 gals ÷ (7,200,000 gpd ÷ 24 hrs/day)
= 901,908 gals ÷ 300,000 gals/hr
= 3 hrs

[NOTE: This can also be calculated by using the volume (gals) of 1 clarifier and dividing the flow by 2]

Section 7.7 - Percent Removal

7.7.1 Given data, calculate the percent removal of biochemical oxygen demand (BOD) in a wastewater treatment plant.

Wisconsin Pollution Discharge Elimination System (WPDES) permits require wastewater treatment plants remove at least 85% of the influent BOD and suspended solids. The intent of this permit condition is to ensure "the solution to pollution is NOT dilution".

GIVEN:

Influent BOD = 250 mg/L
Effluent BOD = 10 mg/L

FORMULA AND SOLUTION:

Percent (%) removal = [(infl. BOD (mg/L) - eff. BOD (mg/L)) ÷ infl. BOD (mg/L)] × 100
= [(250 mg/L - 10 mg/L) ÷ 250 mg/L] × 100
= (240 mg/L ÷ 250 mg/L) × 100
= 96%

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

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. WASTEWATER MICROBIOLOGY: A HANDBOOK FOR OPERATORS

Glymph, T. (2005). Wastewater Microbiology: A Handbook for Operators. Denver, CO: American Water Woks Association.

www.awwa.org

5. BASIC ACTIVATED SLUDGE PROCESS CONTROL: PROBLEM-RELATED OPERATIONS-BASED EDUCATION (PROBE)

Water Environment Federation (WEF). (1994). Basic Activated Sludge Process Control: Problem-Related Operations-Based Education (PROBE). Alexandria, VA: Water Environment Federation.

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6. AERATION: A WASTEWATER TREATMENT PROCESS

Water Pollution Control Federation, American Society of Civil Engineers. (1988). Aeration: A Wastewater Treatment Process. Alexandria, VA: Water Pollution Control Federation.

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7. A DROP OF KNOWLEDGE: THE NON-OPERATOR'S GUIDE TO WASTEWATER SYSTEMS

National Environmental Services Center on behalf of Rural Community Assistance Partnership, Inc. (2011). A Drop of Knowledge: The Non-operator's Guide to Wastewater Systems. Washington, DC: Rural Community Assistance Partnership, Inc (RCAP).

www.rcap.org

8. MATH WORKBOOK FOR COLLECTION SYSTEM OPERATORS

Duerre, S., Ellefson, N., & Minnesota Pollution Control Agency. (2008). Math Workbook for Collection System Operators. MN: Minnesota Pollution Control Agency.

www.pca.state.mn.us

9. STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER

United States Environmental Protection Agency (USEPA). (2012). Standard Methods for the Examination of Water and Wastewater (22nd ed.). Washington, DC: American Water Works Association.

www.standardmethods.org

10. OSHA CFR 29 PART 1910

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

www.osha.gov

11. WISCONSIN ADMINISTRATIVE CODE SPS 332 PUBLIC EMPOLYEE SAFETY AND HEALTH

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

http://docs.legis.wisconsin.gov