WASTEWATER CERTIFICATION Training Course

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COMMON WASTEWATER TREATMENT TERMS

State Associations and Regulatory Agencies

AWWA	American Water Works Association
BPR	Florida Department of Business and Professional Regulation
FDEP	Florida Department of Environmental Protection
EPA	Environmental Protection Agency
FRWA	Florida Rural Water Association
FSAWWA	Florida Section of AWWA
FWPCOA	Florida Water & Pollution Control Operators Association
FWEA	Florida Water Environmental Association
NWFWMD	Northwest Florida Water Management District
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SRWMD	Suwannee River Water Management District
UF TREEO Center	University of Florida Center for Training, Researching, and Education for Environmental Occupation

Monitoring Parameters

BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
Cl_2	Chlorine
COD	Chemical Oxygen Demand
NH_3-N	Ammonia Nitrogen
NO_2-N	Nitrite Nitrogen
NO_3-N	Nitrate Nitrogen
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids

Abbreviations

Cu Ft	Cubic Foot
Cu M	Cubic Meter
Kg	Kilograms
L	Liter
Lbs	Pounds
Mg	Milligrams
mL	Milliliter
^oC	Celsius
^oF	Fahrenheit

Process Terminology

DO	Dissolved Oxygen
F/M Ratio	Food to Microorganism Ratio
GSA	Gould Sludge Age
MCRT	Mean Cell Residence Time
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
ORP	Oxidation/ Reduction Potential
OUR	Oxygen Uptake Rate
O & G	Oil and Grease
RAS	Return Activated Sludge
RBC	Rotating Biological Contactor
SA	Sludge Age
SDI	Sludge Density Index
SOUR	Specific Oxygen Uptake Rate
SRT	Solids Retention Time
SVI	Sludge Volume Index
WAS	Waste Activated Sludge

Miscellaneous

AWT, AWWT	Advanced Wastewater Treatment
BHP	Brake Horse Power
CFM	Cubic Feet Per Minute
CFR	Code of Federal Regulations
CFS	Cubic Feet Per Second
DMR	Discharge Monitoring Report
FAC	Florida Administrative Code
GPD	Gallons Per Day
GPM	Gallons Per Minute
GPS	Gallons Per Second
HP	Horse Power
MGD	Million Gallons Per Day
MG/L	Milligrams Per Liter
MOR	Monthly Operating Report
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly Owned Treatment Works
PPM	Parts Per Million
PSI	Pounds Per Square Inch
WRF	Water Reclamation Facility
WTP	Water Treatment Plant
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

COMMON WASTEWATER TREATMENT DEFINITIONS

ACID:
(1) A substance that tends to lose a proton.
(2) A substance that dissolves in water with the formation of hydrogen ions.
(3) A substance containing hydrogen which may be replaced with metals to form salts.
(4) A substance that is corrosive.
(5) A substance that may lower pH.

ACIDITY: The capacity of water or wastewater to neutralize bases. Acidity is expressed in milligrams per liter of equivalent calcium carbonate.

ACTIVATED SLUDGE: Sludge particles produced in raw or settled wastewater (primarily effluent) by the growth of organisms (including zoogleal bacteria) in aeration tanks in the presence of dissolved oxygen. The term "activated" comes from the fact that the particles are teeming with bacteria, fungi, and protozoa. Activated sludge is different from primary sludge in that the sludge particles contain many living organisms which can feed on the incoming wastewater.

ACTIVATED SLUDGE PROCESS: A biological wastewater treatment process which speeds up the decomposition of wastes in the wastewater being treated. Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or refused (returned to the aeration tank) as needed. The remaining wastewater then undergoes more treatment.

ADVANCED WASTE TREATMENT: Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. Typical processes include chemical treatment and pressure filtration. Also called tertiary treatment.

AERATION: The process of adding air to water. In wastewater treatment, air is added to refreshen wastewater and to keep solids in suspension. With mixtures of wastewater and activated sludge, adding air provides mixing and oxygen for the microorganisms treating the wastewater.

AEROBES: Bacteria that must have molecular (dissolved) oxygen (DO) to survive.

AEROBIC BACTERIA: Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as water molecules (H_2O), cannot be used for respiration by aerobic bacteria.

AIR LIFT: A type of pump. This device consists of a vertical riser pipe in the wastewater or sludge to be pumped. Compressed air is injected into a tall piece at the bottom of the pipe. Fine air bubbles mix with the wastewater or sludge to form a mixture lighter than the surrounding water which causes the mixture to rise in the discharge pipe to the outlet. An air lift pump works like the center of a stand in a percolator coffee pot.

ALGAE: Microscopic plants, which contain chlorophyll and live floating or are suspended in water. They also may be attached to structures, rocks, or other similar substances. Algae produce oxygen during sunlight hours and use oxygen during night hours. Their biological activities appreciably affect the pH and dissolve oxygen of the water.

ALIQUOT: Portion of a sample. Often an equally divided portion of a sample.

ALKALINITY: See Base.

ANAEROBIC: A condition in which atmospheric or dissolved molecular oxygen is *NOT* present in the aquatic (water) environment.

ANAEROBIC BACTERIA: Bacteria that live and reproduce in an environment containing no "free" or dissolved oxygen. Anaerobic bacteria obtain their oxygen supply by breaking down chemical compounds which contain oxygen, such as sulfate (SO_4^{2-}).

ANAEROBIC DIGESTION: Wastewater solids and water (about 5% solids, 95% water) are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen.

ANOXIC: Oxygen deficient or lacking sufficient oxygen.

BOD: **B**iochemical **O**xygen **D**emand. The rate at which organisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation. BOD measurements are used as a measure of the organic strength of wastes in water.

BACTERIA: Living organisms, microscopic in size, which usually consist of a single cell. Most bacteria use organic matter for their food and produce waste products as the result of their life processes.

BAFFLE: A flat board or plate, deflector, guide or similar device constructed or placed in flowing water, wastewater, or slurry systems to cause more uniform flow velocities, to absorb energy, and to divert, guide, or agitate liquids (water, chemical solutions, slurry).

BASE:
(1) A substance which takes up or accepts protons.
(2) A substance which dissociates (separates) in aqueous solution to yield hydroxyl ions (OH^-).
(3) A substance containing hydroxyl ions which reacts with an acid to form a salt or which may react with metals to form precipitates.
(4) A substance that may raise pH.

BIOMASS: A mass or clump of organic material consisting of living organisms feeding on the wastes in wastewater, dead organisms and other debris.

BIOSOLIDS: A primarily organic solid product, produced by wastewater treatment processes, that can be beneficially recycled. The word biosolids is replacing the word sludge.

BLANK: A bottle containing only dilution water or distilled water, but the sample being tested is not added. Tests are frequently run on a SAMPLE and a BLANK and the differences are compared.

BUFFER: A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.

BULKING: Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge does not settle properly. In the activated sludge process, bulking is usually caused by filamentous bacteria or bound water.

CAVITATION: The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.

CENTRIFUGE: A mechanical device that uses centrifugal or rotational forces to separate solids from liquids.

CHLORINATION: The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

CHLORINE DEMAND: Chlorine demand is the difference between the amount of chorine added to wastewater and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH or nature or amount of the impurities in the water.

Chlorine Demand, mg/L = Chlorine Applied, mg/L - Chlorine Residual, mg/L

CHLORINE REQUIREMENT: The amount of chlorine which is needed for a particular purpose. Some reasons for adding chlorine are reducing the number of coliform bacteria (Most Probable Number), obtaining a particular chlorine residual, or oxidizing some substance in the water. In each case, a definite dosage of chlorine will be necessary. This dosage is the chlorine requirement.

CLARIFIER: Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time during which the heavier solids settle to the bottom and the lighter material will float to the water surface.

COAGULANTS: Chemicals that cause very fine particles to clump (floc) together into larger particles. This makes it easier to separate the solids from the water by settling, skimming, draining or filtering.

COAGULATION: The clumping together of very fine particles into large particles (floc) caused by the use of chemicals (coagulants).

COLIFORM: A type of bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination. The human intestinal tract is one of the main habitats of coliform bacteria. They may also be found in the intestinal tracts of warm-blooded animals, and in plants, soil, air and the aquatic environment.

Fecal coliforms are those coliforms found in the feces of various warm-blooded animals; whereas the term "coliform" also includes various other environmental sources.

COLORIMETRIC MEASUREMENT: A means of measuring unknown chemical concentrations in water by *MEASURING A SAMPLE'S COLOR INTENSITY.* The specific color of the sample, developed by addition of chemical reagents, is measured with a photoelectric colorimeter or is compared with "color standards" using, or corresponding with, known concentrations of the chemical.

COMMINUTOR: A device used to reduce the size of the solid chunks in wastewater by shredding (comminuting). The shredding action is like many scissors cutting or chopping to shreds all the large influent solids material in the wastewater.

COMPOSITE: A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the rate of flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sample period.

CONFINED SPACE: Confined space means a space that:
(1) Is large enough and so configured that an employee can bodily enter and perform assigned work; and
(2) Has limited or restricted means for entry or exit; and
(3) Is not designed for continuous employee occupancy.

(Definition from the Code of Federal Regulations (CFR) Title 29 Part 1910.146.)

CROSS CONNECTION: A connection between a drinking (potable) water system and an unapproved water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross connection, or mixing, between the two water systems can occur. This mixing may lead to contamination of the drinking water.

DECHLORINATION: The removal of chlorine from the effluent of a treatment plant.

DENITRIFICATION:
(1) The anoxic biological reduction of nitrate-nitrogen to nitrogen gas.
(2) The removal of some nitrogen from a system.
(3) An anoxic process that occurs when nitrite or nitrate ions are reduced to nitrogen gas and nitrogen bubbles are formed as a result of this process.

DETENTION TIME: The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

DETRITUS: The heavy, coarse mixture of grit and organic material carried by wastewater. (also called grit).

DIFFUSED-AIR AERATION: A diffused air activated sludge plant takes air, compresses it, and then discharges the air below the water surface of the aerator through some type of air diffusion device.

DIFFUSER: A device used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.

DIGESTER: A tank in which sludge is placed to allow decomposition by microorganisms. Digestion may occur under anaerobic (more common) or aerobic conditions.

DISINFECTION: The process designed to kill or inactivate most microorganisms in wastewater, including essentially all pathogenic (disease-casing) bacteria. There are several ways to disinfect, with chlorination being the most frequently used in water and wastewater treatment plants.

DISSOLVED OXYGEN (DO): Molecular (atmospheric) oxygen dissolved in water or wastewater.

EFFLUENT: Wastewater or other liquid - raw (untreated), partially or completely treated - flowing *FROM* a reservoir, basin, treatment process or treatment plant.

ELUTRIATION: The washing of digested sludge with fresh water, plant effluent or other wastewater. The goal is to remove fine particles and/or the alkalinity in the sludge. This process reduces the demand for conditioning chemicals and improves settling or filtering characteristics of the sludge.

EQUALIZING BASIN: A holding basin in which variations in flow and composition of a liquid are averaged. Such basins are used to provide a flow of reasonably uniform volume and composition to a treatment unit. Also called a balancing reservoir.

ESTUARY: Body of water that is located at the lower end of a river and is subject to tidal fluctuations.

EVAPOTRANSPIRATION:
(1) The process by which water vapor passes into the atmosphere from living plants. Also called Transpiration.
(2) The total water removed from an area by transpiration (living plants) and by evaporation from soil, snow and water surfaces.

EUTROPHICATION: The increase of nutrient levels of a lake or other body of water; this usually causes an increase in the growth of aquatic animal and plant life.

FILAMENTOUS ORGANISMS: Organisms that grow in a thread or filamentous form. Common types are T*hiothrix* and *Actinomycetes.* A common cause of sludge bulking in the activated sludge process.

FLOC: Clumps of bacteria and particles or coagulants and impurities that have come together and formed a cluster. Found in aeration tanks, secondary clarifiers and chemical precipitation processes.

FLOCCULATION: The gathering together of fine particles after coagulation to form larger particles by a process of gentle mixing.

FORCE MAIN: A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.

FREEBOARD: The vertical distance from the normal water surface to the top of the confining wall.

GRAB SAMPLE: A single sample of water collected at a particular time and place which represents the composition of the water only at that time and place.

GRIT: The heavy material present in wastewater, such as sand, coffee grounds, eggshells, gravel and cinders.

GRIT REMOVAL: Grit removal is accomplished by providing an enlarged channel or chamber which causes the flow velocity to be reduced and allows the heavier grit to settle to the bottom of the channel where it can be removed.

HEADWORKS: The facilities where wastewater enters a wastewater treatment plant. The headworks may consist of bar screens, comminutors, a wet well and pumps.

HYDROGEN SULFIDE GAS (H_2S): A gas with a rotten egg odor. This gas is produced under anaerobic conditions. Hydrogen sulfide is particularly dangerous because it dulls the sense of smell so that it is unnoticeable after a prolonged period of time and because the odor is not noticeable in high concentrations. The gas is colorless, explosive, flammable, and poisonous to the respiratory system.

INFLOW: Water discharged into a sewer system and service connections from sources other than regular connections. This includes flow from yard drains, foundation drains and around manhole covers. Inflow differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.

INFLUENT: Wastewater or other liquid - raw (untreated) or partially treated - flowing *INTO* a reservoir, basin, treatment process or treatment plant.

MASKING AGENTS: Substances used to cover up or disguise unpleasant odors. Liquid masking agents are dripped into the wastewater, sprayed into the air, or evaporated (using heat) with the unpleasant fumes or odors and then discharged into the air by blowers to make an undesirable odor less noticeable.

MECHANICAL AERATION: The use of machinery to mix air and water so that oxygen can be absorbed into the water.

MICROORGANISMS: Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesired matter.

MIXED LIQUOR: When the activated sludge in an aeration tank is mixed with primary effluent or the raw wastewater and return sludge, this mixture is then referred to as mixed liquor as long as it is in the aeration tank. Mixed liquor may also refer to the contents of mixed aerobic or anaerobic digesters.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS): Suspended solids in the mixed liquor of an aeration tank.

MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS): The organic or volatile suspended solids in the mixed liquor of an aeration tank. This volatile portion is used as a measure or indication of the microorganisms present.

NPDES PERMIT: **N**ational **P**ollutant **D**ischarge **E**limination **S**ystem permit is the regulatory agency document issued by either a federal or state agency which is designed to control all discharges of pollutants from all point sources and storm water runoff into U.S. waterways. A treatment plant that discharges to a surface water will have a NPDES permit.

NITRIFYING BACTERIA: Bacteria that change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate).

OXIDATION: Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances.

PACKAGE TREATMENT PLANT: A small wastewater treatment plant often fabricated at the manufacturer's factory, hauled to the site, and installed as one facility. The package may be either a small primary or a secondary wastewater treatment plant.

PATHOGENIC ORGANISMS: Bacteria, viruses or cysts, which can cause disease (typhoid, cholera, dysentery) in a host such as a human. Also called Pathogens.

PERCOLATION: The movement or flow of water through soil or rocks.

POLYMER: Used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water.

PONDING: A condition occurring on trickling filters when the hollow spaces (voids) become plugged to the extent that water passage through the filter is inadequate. Ponding may be the result of excessive slime growths, trash or media breakdown.

PRECIPITATE:
(1) An insoluble, finely divided substance which is a product of a chemical reaction within a liquid.
(2) The separation from solution of an insoluble substance.

PRIMARY TREATMENT: A wastewater treatment process that takes the place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.

RAW WASTEWATER: Plant influent or wastewater *BEFORE* any treatment.

RECEIVING WATER: A stream, river, lake, ocean or other surface or groundwater into which treated or untreated wastewater is discharged.

RECIRCULATION: The return of part of the effluent from a treatment process to the incoming flow.

RETENTION TIME: The time water, sludge or solids are retained or held in a clarifier or sedimentation tank.

RISING SLUDGE: Rising sludge occurs in the secondary clarifiers of activated sludge plants when the sludge settles to the bottom of the clarifier, is compacted, and then starts to rise to the surface, usually as a result of denitrification.

SCREEN: A device used to retain or remove suspended or floating objects in wastewater. The screen has openings that are generally uniform in size. It retains or removes objects larger than the openings. A screen may consist of bars, rods, wires, gratings, wire mesh, or perforated plates.

SEPTIC: A condition produced by anaerobic bacteria. If severe, the wastewater produces hydrogen sulfide, turns black, gives off foul odors, contains little or no dissolved oxygen, and creates a high oxygen demand.

SEWAGE: The used water and water-carried solids from homes that flow in sewers to a wastewater treatment plant. The preferred term is WASTEWATER.

SHORT-CIRCUITING: A condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable since it may result in shorter contact, reaction or settling times in comparison with the theoretical (calculated) or presumed detention times.

SLUDGE:
(1) The settleable solids separated from liquids during processing.
(2) The deposits of foreign material on the bottoms of streams or other bodies of water.

SLUDGE DIGESTION: The process of changing organic matter in sludge into a gas or liquid or a more stable solid form. These changes take place as microorganisms feed on sludge in anaerobic (more common) or aerobic digesters.
SOLUBLE BOD: Soluble BOD is the BOD of water that has been filtered in the standard suspended solids test.

SOLUTION: A liquid mixture of dissolved substances. In a solution it is impossible to see all the separated parts.

STORM SEWER: A separate pipe, conduit or open channel (sewer) that carries runoff from storms, surface drainage, and street wash, but does not include domestic and industrial wastes.

SUPERNATANT: Liquid removed from settling sludge. Supernatant commonly refers to the liquid between the sludge on the bottom of an anaerobic digester and the scum on the surface. The liquid is usually returned to the influent wet well or to the primary clarifier.

SUSPENDED SOLID: Solids that either float on the surface or are suspended in water, wastewater or other liquids, and which are largely removable by laboratory filtering.

TOXIC: A substance which is poisonous to a living organism.

TOXICITY: The relative degree of being poisonous or toxic. A condition which may exist in wastes and will inhibit or destroy the growth or function of certain organisms.

TRANSPIRATION: See Evapotranspiration.

TURBID: Having a cloudy or muddy appearance.

VOLATILE SOLIDS: Those solids in water, wastewater or other liquids that are lost on ignition of the dry solids at 550°C.

WASTEWATER: The used water and solids from a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a wastewater treatment plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."

WEIR:
(1) A wall or plate placed in an open channel and used to measure the flow of water. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used.
(2) A wall or obstruction used to control flow (from settling tanks and clarifiers) to assure a uniform flow rate and avoid short-circuiting.

WET OXIDATION: A method of treating or conditioning sludge before the water is removed. Compressed air is blown into the sludge; the air and sludge mixture is fed into a pressure vessel where the organic material is stabilized.

WET WELL: A compartment or tank in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

ZOOGLEAL MASS: Jelly-like masses of bacteria found in both the trickling filter and activated sludge processes. See also Biomass.

SUMMARY OF PROCESSES

COLLECTION SYSTEM

Purpose

The purpose of a wastewater collection system is to collect and convey the wastewater from homes and industries in a community. The water carries the wastes in the form of either dissolved or suspended solids. Wastewater collection systems must be properly designed and constructed to provide a water velocity of around 2.0 ft/sec. Velocities that are too high can be detrimental to the operation and maintenance of a collection system. The collection system conveys the wastewater and solids to a treatment plant where the pollutants are removed before the treated wastewater is discharged to a body of water or onto land.

Collection System Components

A collection system normally contains the following components:

- Lateral Lines – carry wastes from homes and businesses.
- Main, or Trunk Lines – collect sewage from laterals.
- Manholes – allow main lines to join other main lines, and provide inspection and cleaning access.
- Gravity Sewer Lines – lines sloped to allow gravity to carry wastewater to a lower elevation, normally into a lift station.
- Lift (Pump) Stations – collect sewage from gravity sewer lines and use pumps to lift the sewage to a higher elevation, or into a treatment plant.
- Force Main – line carrying sewage from a lift station to a treatment plant. These lines are under pressure when the pump station is operating.

Collection System Problems Affecting Treatment

Problems associated with the collection system that will affect the wastewater treatment plant are rainwater inflow and infiltration (I & I) from cracks and holes in the pipe and joints causing high flows that will wash out the treatment plant process. If the gravity collection system is constructed with the incorrect flat slopes or the collection system design uses low-pressure sewers with the long force mains, septic conditions will be present causing major problems both in the collection system and at the treatment facility. Septic conditions will produce hydrogen sulfide which will deteriorate concrete pipe crowns (the top inside portion of the pipe) causing infiltration and corrosion of metal structures and electrical control panels. Septic conditions in the collection system cause low influent pH, odors and increased oxygen demand at the treatment plant.

Chemical Control of Hydrogen Sulfide (H_2S)

Numerous chemicals have been employed for control of sulfides in wastewater collection systems. Chemical addition can control sulfides by 1) chemical oxidation (chlorine); 2) sulfate reduction inhibition by providing an additional oxygen source; 3) precipitation (metal salts); or 4) pH control (strong alkalis). The addition of chlorine, hydrogen peroxide, iron salts, ferrous sulfate, nitrates and strong alkalis are ways to decrease or control hydrogen sulfide (H_2S).

Collection System Safety

When excavating sewers 5 feet or more in depth, cave-in protection is required. Types of cave-in protection include contouring, drag shields, shoring and sloping. The most practical and best cave-in protection is shoring.

When entering a confined space, such as a manhole, an approved man hoist, forced air ventilator, oxygen analyzer, hydrogen sulfide analyzer and explosive gas analyzer (methane gas) is required. If the oxygen in the atmosphere is less than 19.5% by volume, the confined space is considered dangerous and no entry is allowed until safe oxygen levels can be attained. The FIRST action to take when a person has been found unconscious in a confined space is to call for assistance. The main purpose of a confined space entry is to ensure that safety precautions and safe procedures are followed through so the previous scenario can hopefully be avoided.

Hydrogen Sulfide gas has a rotten egg odor and is the most common dangerous gas encountered in wastewater treatment. In low concentrations, H_2S can deaden your sense of smell and give a false sense of security. This gas can be fatal when concentrations are high enough to paralyze the respiratory system. Other gases that are encountered in collection systems include methane, oxygen (lack of), carbon dioxide and chlorine (used to control hydrogen sulfide) which can cause chemical pneumonia after exposure. (Sulfur dioxide used in the treatment plant can also cause chemical pneumonia after exposure.)

WASTEWATER FLOW

Purpose of Measuring Flows

Flow measurement is the determination of the rate of flow past a certain point, such as the inlet to the headworks structure of a treatment plant. Flow is measured and recorded as a quantity (gallons) moving past a point (primary device) during a specific time interval (seconds, minutes, hours or days). Thus we obtain a flow rate or quantity in millions of gallons per day (MGD). Flow should be measured in order to determine wastewater treatment plant loading and receiving stream loading and efficiency. These are permit requirements of the Florida Department of Environmental Protection (FDEP).

Types of Primary Devices

Parshall Flumes

A Parshall flume is one of the most common flow-measuring devices. Wastewater flows through a narrow place in an open channel. The flow can be determined by measuring the depth of flow with an ultrasonic device, float, or manually.

Weirs

Used in open channels and placed across the channel, weirs are made of thin materials and may have either a rectangular or V-notch opening. The flow over the weir is determined by the depth of flow going through the weir. A disadvantage in using the weir at the influent of the plant is that solids may settle upstream of the weir and cause inaccuracy, odors, and unsightliness.

Types of Flow Meters (Secondary Devices)

Flow meters or flow recording devices are called Secondary Devices. Different types of low-measuring devices include constant differential, head area, velocity meter, differential head and displacement. These methods are incorporated into the devices you may have at your plant. They are used to determine the flow through a Primary Device. It may be ultrasonic, a mechanical float type, or a magnetic flow meter installed in a pipe. Your WWTP may use hour meters at the main lift station to the treatment plant or at the effluent pump station to calculate the flow. Regardless of the type of flow measurement, all flow measuring devices must be calibrated annually and maintained to insure that the accuracy of the measurements is plus or minus 10% from the true flow.

Types of Wastewater

There are four types of pollution: organic, inorganic, thermal and radioactive. Most small treatment plants in Florida treat domestic waste. Domestic wastewater contains a large amount of organic waste. This is material which mainly comes from animal or plant sources. Bacteria and other small organisms can consume organic waste. Some organic industrial waste comes from vegetable and fruit packing, dairy processing, meatpacking, tanning (hides), poultry, oil, paper mills, wood, etc. Domestic wastewater also contains inorganic material. Inorganic material consists of sand, salt, iron, calcium and other materials which are only slightly affected by the action of bacteria or organisms.

Industrial Wastewater contains inorganic material such as heavy metals (chromium, copper, cadmium, lead, etc.), gravel and grit. The first indication that a strong toxic industrial discharge has entered the activated sludge plant is an increase in oxygen concentration in the aeration basin. This will happen because the microorganisms have been killed resulting in no oxygen being consumed.

There are two major types of wastewater that do not fit either the organic or inorganic classification:

- Thermal Waste - heated waste from cooling processes used by industry and thermal power stations.
- Radioactive Waste - usually controlled at the source, but could come from hospitals, research laboratories, Toxic Disposal Industries and Nuclear Power Plants.

If wastewater does not receive adequate treatment, large amounts of solids may accumulate on the banks of the receiving waters and also settle to the bottom of the receiving stream. The solids are not only unsightly, but the organic solids will cause oxygen depletion (which may result in fish kills) and be a source of odors.

Wastewater contains pathogenic organisms, which are bacteria, viruses or cysts than can cause disease. Well-known diseases found in wastewater are Typhoid, Cholera, Dysentery, Polio and Hepatitis (Jaundice). Disinfection using chlorine, bromine and ultraviolet light are some of the common ways to kill or destroy the pathogenic organisms.

PRELIMINARY TREATMENT

Preliminary treatment processes commonly consist of flow equalization, screening, shredding and grit removal to separate course material from wastewater being treated. Cans, bottles, scrap metal, rocks, egg shells, plastic products, rags and sand must be removed to prevent blockages of pipes, damage to pumps, excessive wear in pumps and chains, and filling of digesters and tanks.

Flow Equalization / Surge Basins

If your treatment plant experiences wide flow variations, these may often cause problems with treatment efficiency. High flow due to rainwater inflow and infiltration, or from a processing plant, is detrimental to all types of treatment (RBC's, trickling filters and activated sludge) but has the greatest impact on activated sludge process. Flow equalization tanks or surge tanks will help control a constant flow (if designed correctly) to the treatment plant, dilute strong organic wastewater and help neutralize highly acidic or alkaline (toxic) wastes. When using flow equalization tanks, aeration of the tank is highly recommended to prevent septic conditions from developing.

Bar Screens and Racks

Bar Screens are parallel bars that may be placed at an angle or vertically in a channel to catch large solids and debris. The spacing between the bars is 3/8 inch to 2 inches. The bar screen may be manually or automatically cleaned. To base the intervals between cleaning, the allowable head loss behind the bar screen should be a limit of 3 inches. Racks are parallel bars that are usually placed in a bypass channel. The spacing between the bars is usually 3 to 4 inches or more. They are manually cleaned due to their infrequent use.

The material that has been screened must be disposed of properly. Burial at an approved landfill or incineration are two common practices of disposal.

Moving or Rotating Screens

Moving or rotating screens continuously rotate through the wastewater stream and are mounted on a horizontal cylinder. The cylinder collects debris and dumps it into a collection trough. An advantage of rotating screens over stationary screens is that the rotating screens usually do not back up the incoming flow. Rotating screens are usually used in industrial waste treatment processes.

Comminution

Comminutors are devices that act both as a cutter and a screen. They reduce the size of solid chunks in the wastewater by shredding it with oscillating and stationary cutters. They shred the solids and leave them in the wastewater. Pieces of wood, plastic and metal are rejected and remain until they are manually removed. Until the debris is removed, the flow is restricted, thus creating a head loss downstream.

Maintenance

Daily maintenance for comminutors consists of checking for debris hung up in the cutting drums and bars, sharpening and adjusting the cutting blades, exercising the inlet and outlet gates, and inspecting travel and rotation of the cutting blades. If stringing pieces of rags are hanging from the slotted drum or a comminutor, this may indicate that the cutter may be worn or is out of adjustment. Do not apply solvents and lubricants on parts that will contact the wastewater because it will affect the downstream biological treatment processes. During high flows or sewer line maintenance the operator may need to place additional units in service. The operator may need to place bypass channels with bar racks into service and give prompt action to avoid a back up into collection system. Comminutors should be run continuously.

Grit Removal

Grit (sand, eggshells and ash) is the heaviest inorganic matter that is found in wastewater and will not break down. Grit is removed to prevent wear in pumps, blockage of pipes, and reduction in the capacity of the aeration and digester tanks.

PRIMARY TREATMENT

Primary Clarifiers

Primary clarifiers are located after preliminary treatment and before the secondary biological treatment process (activated sludge basins or trickling filters). The job of a primary clarifier is to remove as much settleable and floatable material as possible. The use of primary clarifiers in an activated sludge treatment plant is not desirable because of the new Federal 503 regulation on sludge digestion and sludge disposal. The primary clarifier settled sludge is wasted to the digesters, which puts a tremendous load of untreated volatile organic food to the digester. If the wastewater flows from preliminary treatment directly to the activated sludge treatment aeration basins, the volatile organic sludge would receive treatment before it is wasted to the digesters and can be treated much more easily. Primary clarifiers are normally always located before trickling filters and RBC's. The sludge from the bottom of a primary clarifier is usually denser than secondary sludge.

In the primary clarifier the horizontal velocity of flow is slowed down to a rate of 1.0 to 2.0 feet of travel per minute. This allows time for the solids to settle to the bottom and floatables to float to the surface. The effluent from a primary clarifier is usually cloudier than the secondary clarifier effluent because it has not received secondary treatment.

Well-operated primary clarifiers can remove approximately 60% of the influent TSS and about 40% of influent BOD.

The factors that will influence settling characteristics in a clarifier are temperature, short circuits, detention time, weir overflow rates, surface loading rates and solids loading rates. Toxic waste, storm flows and septic flows from collection system problems are some of the other factors that influence settling. Detention time, weir overflow rate, surface loading rate and solids loadings are four mathematical methods of checking the performance of clarifiers.

TEMPERATURE - As water temperature increases, the settling of particles increases due to the liquid becoming less dense. As water temperature decreases, so does the settling rate since the liquid density is increased.

SHORT CIRCUITS - As wastewater enters a clarifier the flow should be evenly dispersed across the entire section of the tank and should flow at the same velocity in all areas toward the discharge end. When the velocity is greater in some sections than others, short-circuiting may occur. The use of weir plates, port openings and proper design of the inlet channel will usually prevent this from occurring. Turbulence and stratification of density layers due to temperature or salinity may also cause short-circuiting. Temperature layers can cause short-circuiting when a warm influent flows across the top of cold water and vise-versa.

DETENTION TIME - Wastewater should remain in the clarifier long enough to allow sufficient settling for solid particles. Most clarifier detention times are 2.0 to 3.0 hours.

Primary Clarifier Problems

One of the most common problems with primary clarifiers can be attributed to poor sludge removal practices. Sludge must be removed from the clarifier on a regular basis to prevent gasification of the sludge and increased clarifier effluent TSS and BOD. Poor sludge removal practice can seriously affect downstream biological treatment processes such as trickling filters and RBC's.

Symptoms of poor sludge removal result in sludge rising to the clarifier surface and black, odorous (septic) wastewater in the primary clarifier. Attempts should be made to increase sludge pumping rates and inspect the sludge collection mechanisms. If scrapers or collection mechanisms become worn or break, sludge may not be removed efficiently.

Safety Around Clarifiers

All walkways should be kept clean and clear of obstructions. KEEP HOSES ROLLED UP. All clarifiers and aeration tanks should be provided with safety vests, lifelines with floatation rings, and safety poles.

SECONDARY TREATMENT

The Activated Sludge Process

Activated sludge is the secondary treatment process most commonly used at Florida's class D wastewater treatment plants. This process involves growing a culture of microorganisms in suspension with wastewater. The purpose is to allow the microorganisms to absorb dissolved organics, ingest suspended organics, and adsorb suspended waste particles. This converts normally nonsetteable waste into floc particles that are large enough to settle in the clarifying tanks.

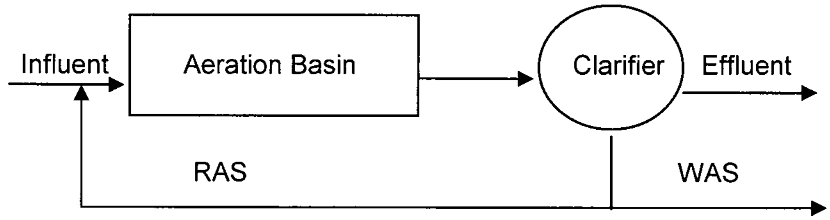
Types of Activated Sludge Processes

There are several types of modifications of the activated sludge process. The most common to Florida class D treatment plants is the extended aeration type plant. Types of activated sludge processes include:

(1) Contact stabilization
(2) Extended aeration
(3) Oxidation ditch
(4) Conventional activated sludge
(5) Step feed aeration
(6) Schreiber process
(7) Kraus process
(8) High rate activated sludge
(9) Pure oxygen activated sludge

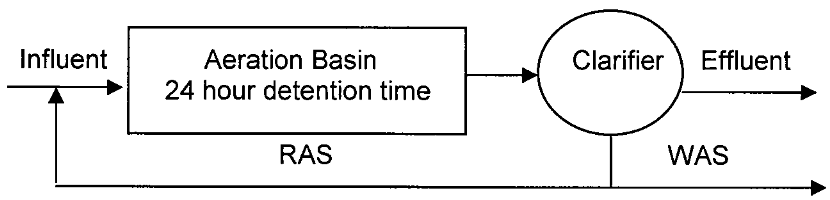
Common Activated Sludge Flow Schemes

Activated Sludge Modifications
Conventional Mode



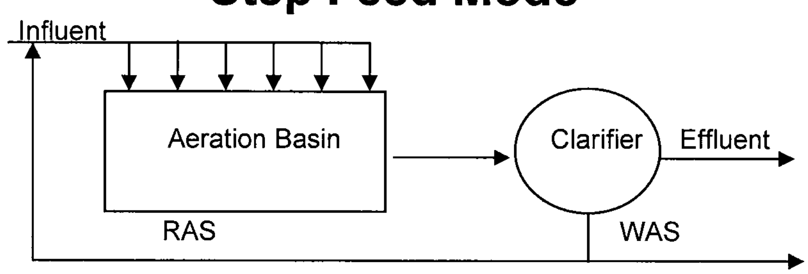
Plug flow design; 4-8 hour detention time;
F/M = 0.2-0.5 lbs BOD / lb MLVSS;
1000-3000 mg/L MLSS;
5-15 day SRT

Activated Sludge Modifications
Extended Aeration Mode



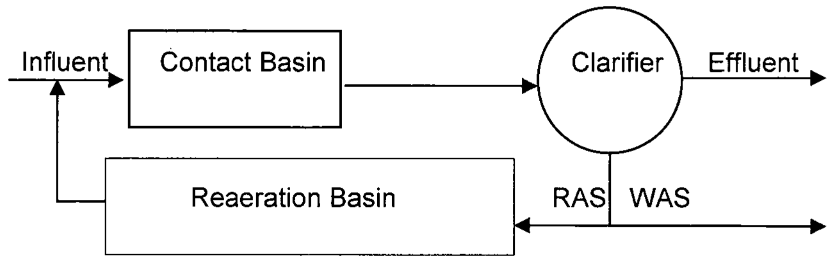
Complete mix; 18-30 hour detention time;
F/M = 0.05-0.15 lbs BOD / lb MLVSS;
2000-6000 mg/L MLSS;
20-30 day SRT

Activated Sludge Modifications
Step Feed Mode



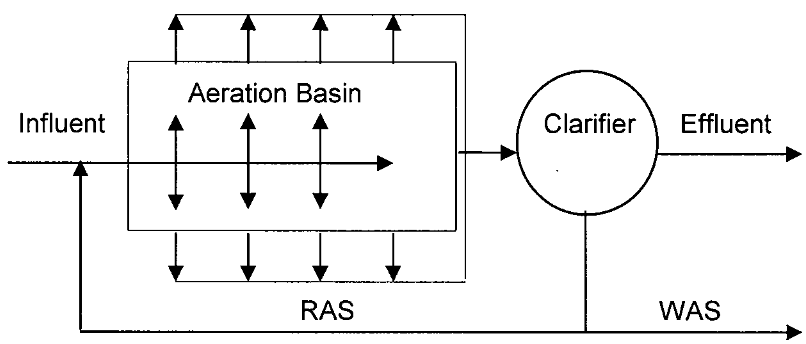
Plug flow design; 3-8 hour detention time;
F/M = 0.2-0.5 lbs BOD / lb MLVSS;
2000-3500 mg/L MLSS; 5-15 day SRT

Activated Sludge Modifications
Contact Stabilization Mode



Plug flow design; 4-8 hour detention time;
F/M = 0.2-0.5 lbs BOD / lb MLVSS;
1000-3000 mg/L MLSS;
5-15 day SRT

Activated Sludge Modifications
Complete Mix Mode



Not plug flow; 3-5 hour detention time;
F/M = 0.2-0.6 lbs BOD / lb MLVSS;
3000-6000 mg/L MLSS;
5-15 day SRT

In most activated sludge plants the operator has three ways to control his process: aeration rates, return sludge rates, and waste sludge rates. Adjustments of any three rates can affect the sludge age (SA), Solids Retention Time (SRT), food to microorganism ratio (F/M ratio), mean cell residence time (MCRT), solids inventory, Sludge Volume Index (SVI), or Mixed Liquor Volatile Suspended Solids (MLVSS) and then escalating to clarifier performance, microorganisms and regulated effluent quality and parameters. Activated sludge is a process of converting waterborne waste (wastewater) to a readily settleable biomass.

Food to Microorganism Ratio

The only way you can control the F/M ratio is controlling the amount of microorganisms you have in the activated sludge process. You cannot control the amount of food, but you can control the inventory of microorganisms (MLVSS) on hand. This is achieved by wasting activated sludge from the activated process at correct rates or not wasting at all while large amounts of BOD/COD (food) are entering the process. The F/M control technique for sludge wasting is best used in conjunction with the MCRT control technique. Control to a desired MCRT is achieved by wasting an amount of the aeration tank solids inventory that in turn provides an F/M ratio.

Typical ranges for F/M loading, in pounds of food (BOD) per pound of microorganisms (MLVSS)

	Conventional F/M	Extended Aeration F/M	High Rate F/M
BOD, lbs	0.1 - 0.5	0.05 - 0.1	0.5 - 2.5
COD, lbs	0.06 - 0.3	0.03 - 0.06	0.3 - 1.5

$$\text{F/M Ratio, lbs BOD / lb MLVSS} = \frac{\text{CBOD, lbs/day}}{\text{MLVSS, lbs}}$$

When the F/M ratio is low, you will have an older sludge that settles rapidly, which may leave a turbid effluent behind. Microorganisms that predominate include rotifers and nematodes (worms) and some stalked ciliates.

When the F/M ratio is in the proper range for your treatment plant, you will have a mixed liquor that produces a good settling sludge that leaves a clear effluent. Organisms that predominate may include stalked ciliates, rotifers and free-swimming ciliates. Filamentous organisms may also be present, but in numbers that only allow for the floc forming bacteria to build a strong, well developed floc particle.

When the F/M ratio is high, caused either by an increase of influent food to the plant or too much activated sludge was wasted or washed out, the sludge age is decreased resulting in a young sludge. This means that there are not enough microorganisms (bugs) to consume the available food. During this time, the predominant activated sludge microorganisms are free-swimming ciliates, flagellates, amoeba and some stalked ciliates that results in a young sludge. There is an abundance of volatile organic solids (CBOD) that accounts for the food value.

The problems associated with a great increase in the F/M ratio is that a sludge with poor settling characteristics is produced which can lead to sludge bulking in the clarifier. Effluent suspended solids will increase as well as effluent ammonia and BOD. The dissolved oxygen decreases in the aeration basin due to high oxygen demand of the increased organic loading. A young or under-oxidized activated sludge is formed that exhibits a high oxygen uptake rate and a slow settling rate.

To correct a high F/M ratio problem, decrease or stop the wasting of activated sludge to increase MLVSS in the aeration basin. When the MLVSS is increased, the sludge age also increases. This allows a sludge with better settling characteristics to be formed, and reduces the sludge bulking condition.

Mean Cell Residence Time (MCRT)

By using the MCRT process control method, an operator can control the organic loading (F/M). The MCRT expresses the average time that a microorganism will spend in the activated sludge process. For conversion of ammonia by activated sludge, the MCRT should be 4 days or longer. This is usually not a problem for extended aeration plants, which normally have a MCRT of 20 days or more. MCRT is best used along with the F/M control technique for sludge wasting.

$$\text{MCRT, days} = \frac{\text{MLSS under aeration, lbs}}{\text{Solids wasted*, lbs}}$$

*This includes solids intentionally wasted to digester and solids lost in effluent.

Sludge Age Control

Sludge age is another way to measure the length of time a particle of suspended solids has been undergoing aeration in the activated sludge process. Sludge age is based on a ratio between the pounds of solids in the aeration basin and the pounds of solids in the influent to the basin. When using sludge age as a control technique, the operator wastes just enough sludge to maintain the sludge age that produces the best quality effluent. Difficulties are experienced using the sludge age method when the BOD to solids ratio changes. If you monitor the BOD / SOLIDS ratio, you can adjust sludge age when the ratio changes. This can be done by increasing the sludge wasting rates.

$$\text{Sludge Age, days} = \frac{\text{lbs of influent solids}}{\text{lbs of solids (MLSS) under aeration}}$$

Sludge Bulking

One of the most common causes of repeated clarifier sludge bulking is a low sludge age or high F/M ratios. Slow down or stop wasting in this case until the ratio is corrected. To prevent bulking from occurring, carefully control the F/M ratio, sludge age, dissolved oxygen (DO) levels, aeration periods and filamentous growth. Bulking in the clarifier can cause an increase in effluent suspended solids and CBOD, increased fecal coliform counts, decreased chlorine residuals and solids entering the effluent disposal system.

There are many environmental conditions that can be contributed to a filamentous type bulking, too many to describe completely in this manual. Some of these conditions are: inadequate supply of nutrients (nitrogen and phosphorus) in the influent wastewater, septic influent wastewater, oil and grease entering the system, and low (DO) levels maintained in the aeration tank. When the proper conditions are present, filamentous organisms may begin to predominate and cause bulking in the secondary or final clarifier.

A hydraulically over-loaded treatment plant or clarifier will also cause bulking. When a facility's collection system allows rainwater I & I to enter, this will cause a hydraulic upset at the treatment plant. As the flows increase, the F/M ratio and sludge age change. If many solids are lost in a clarifier washout, this will also change the process conditions and can lead to bacterial sludge bulking.

There is another type of bulking that is commonly confused with bacterial (filamentous) bulking. This is caused by excessive solids concentrations in the aeration system. Poor or lack of sludge wasting to the digester is the cause of this condition. With too many solids in the system, the sludge will not settle properly in the clarifier. Clarifiers are designed to handle a certain solids loading at certain flow rates. When these conditions are exceeded, solids can no longer be held in the clarifier and will 'wash out' of the tank. So if you have a treatment plant that is already exceeding the recommended solids concentrations and a large amount of rainwater enters the collection system, your plant is susceptible to clarifier washout.

Ways of controlling sludge bulking include: controlling the process by using proper wasting techniques, controlling flows entering the WWTP, correcting inadequate nutrient loading, DO levels and septic influent conditions and excessive oil and grease entering the system. Sometimes chlorine can be used to bring filamentous conditions under control, but care MUST be exercised when adding any toxic substance to an activated sludge system. Having access to a microscope is the best way to diagnose a filamentous bulking condition. The progress of any control methods implemented should also be tracked.

Waste Activated Sludge (WAS)

One of the most important controls of the activated sludge process is the amount of activated sludge that is wasted. The amount of activated sludge that is wasted from the process affects all of the following items:

(1) Effluent quality
(2) Growth rate of the microorganisms
(3) Oxygen consumption
(4) Mixed liquor settleability
(5) Nutrient quantities needed
(6) Occurrence of foaming/frothing
(7) Possibility of nitrifying

Daily wasting of activated sludge is performed to maintain the correct or desirable food to microorganism ratio (this is the objective for wasting activated sludge). When the "bugs" eat or remove the BOD (the food value) from the wastewater, the amount of activated sludge (MLSS or MLVSS) increases. MLSS or MLVSS is an estimate of how many organisms are present in the aeration tank. This growth rate is controlled by wasting just enough activated sludge daily to keep the desired MLSS, MLVSS, F/M ratio or Sludge Age. This is called "steady state" condition. If you fail to waste the correct amount, you will unintentionally waste solids by losing suspended solids in the effluent. A gradual increase in the amount of fine solids over the weirs of the secondary clarifier is usually an indication that the WAS (wasting rate) is too low. There are several ways of wasting that an operator has control over. One is achieved by removing a portion of the return activated sludge daily from the clarifier and wasting it to the digester. You have to be careful to not waste too much because the sludge is concentrated in the clarifier. The other method is to waste MLSS from the aeration basins if the operator has this option. The operator can have more control of his MLSS in his basins since he is not wasting a concentrated sludge. The disadvantage is larger sludge handling facilities are required to handle the dilute MLSS. The most common method here in Florida is wasting a portion of the return sludge.

During daily operation of an activated sludge plant you receive advanced warning of a high organic dump or spill, you should decrease the WAS rate to retain a greater amount of microorganisms in the system to consume the excess organic load and at the same time adjust the aeration rates (blowers) to 100% to meet the oxygen requirements of the bugs. Also the return activated sludge rate should be gradually increased during high organic loading.

Return Activated Sludge (RAS)

The purpose of returning activated sludge is to return the microorganisms from the clarifier back to the aeration basins to meet F/M ratios. There are two methods of return activated sludge rates; constant return rate or a return rate based on a percentage of the influent flow. There are a number of techniques which may be used to set the rate of sludge return flow. The most common are monitoring the depth of the sludge blanket, the settleability test approach and the sludge volume index (SVI) approach

The sludge blanket depth should be measured at the same time every day during peak flows. The blanket depth should be kept 1 to 3 feet from the bottom of the clarifier, or 25% of total clarifier depth.

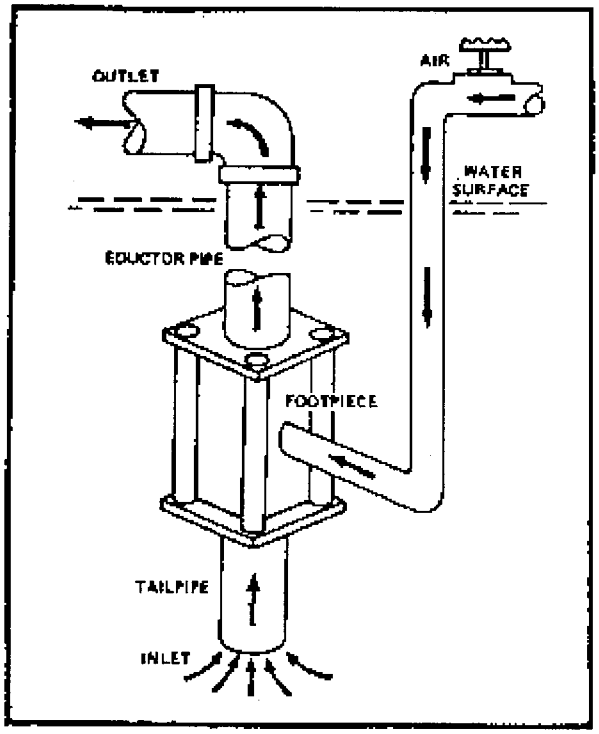
If the return activated sludge (RAS) rates are too low, there will not be enough microorganisms returned to the aeration basins to consume the influent waste or BOD. This can lead to sludge remaining in the clarifier too long and allowing the bugs to starve for oxygen resulting in denitrification.

Bubbles are formed (called gasification) and attach to the sludge flocs and float the sludge to the surface of the clarifier causing high effluent suspended solids. If there is sludge floating to the top of a primary or secondary clarifier, this may indicate that sludge is not being pumped at the correct rates. There will also be some odors and sludge carried over the clarifier weirs into the chlorine contact chambers.

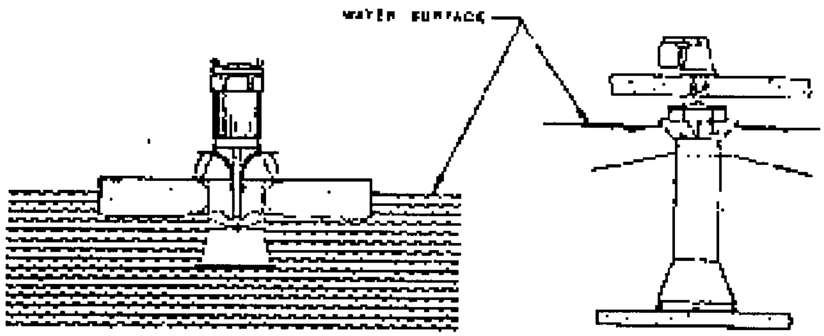
Increasing the RAS too much can lead to an increased hydraulic loading rate of the secondary clarifier. Since the RAS is pumped back into the aeration system, it increases the amount of flow received back at the clarifier. If this flow in combination with the influent flow to the WWTF exceeds the designed flow rate of the clarifier, a hydraulic washout can occur.

A typical class D package treatment plant uses an air-lift pump to remove settled sludge from the bottom of the clarifier and return it to the aeration tank. Control of RAS amounts is dependent on the rate of airflow to the pump. Setting the air rate too low can lead to clogging of the return sludge line. Closing the RAS in-line discharge valve will force the air supply out of the bottom of the RAS piping, hopefully unclogging the obstruction.

Air Lift Pump



Typical Floating and Platform Surface Aerators

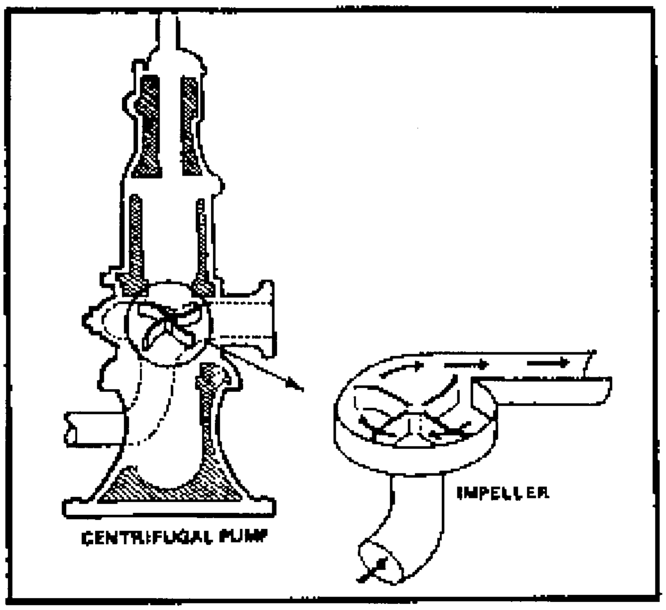


Activated Sludge Oxygen Requirements

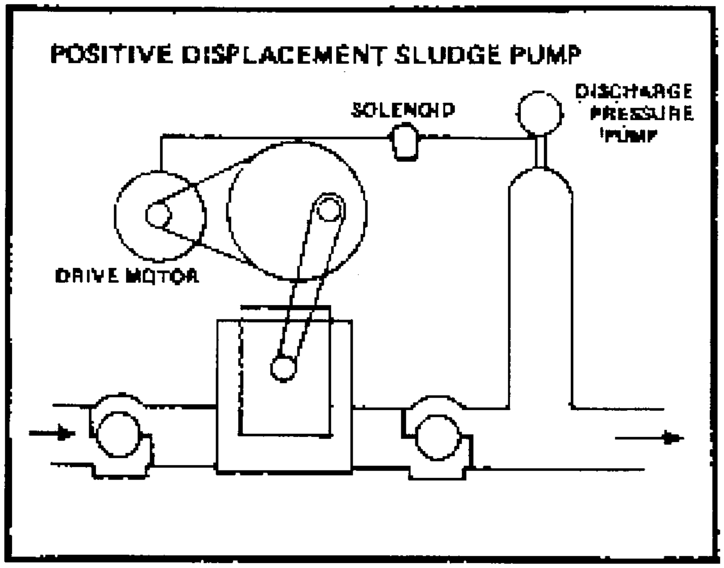
Aeration in the activated sludge basin mainly serves two purposes; to provide DO for the organisms and to mix or agitate the MLSS. DO levels can range from 0 to 3 mg/L depending on the kind of treatment plant, influent characteristics, oxygen uptake rate, aeration equipment condition and tank depth. For basic CBOD removal, approximately 1.5 pounds of oxygen is necessary to convert one pound of CBOD to carbon dioxide, water, and energy for microorganisms. About 4.5 pounds of oxygen is needed to convert one pound of ammonia to nitrate. Low DO can starve the organisms, changing the activated sludge age and settleability resulting in bulking and filamentous growth. Overaerated basins with excessive DO of 6 mg/L or more can shear the sludge floc, increase nitrate levels and waste energy. If laboratory tests indicate a high MLSS, low S.O.U.R. (specific oxygen uptake rate) and high effluent BOD, this is an indication that a toxic dump has happened killing the organisms, which in return do not use the oxygen or consume the BOD in the aeration basins.

Activated sludge treatment plants use a variety of methods to aerate the solids in the aeration tank. These methods include diffused aeration and mechanical aeration. In diffused air, a series of diffusers is placed on the bottom of the aeration tank and fed compressed air through a system of header pipes from a compressor or blower. The air then bubbles to the surface, causing a mixing effect and transferring oxygen to the MLSS. Mechanical aerators can be fixed to the structure of the WWTP or can float floating on the surface of the aeration tank. They rely on the transfer of oxygen to take place while they spray the MLSS through the atmosphere. Both aeration systems usually are controlled by a timer and run times are set by the amount of oxygen needed during certain times of the day. It is not uncommon to have a blower or mechanical aerator run most of the day (during peak loading times) and be off a majority of the night, when influent flows are low.

Centrifugal Pump



Positive Displacement Pump



Activated Sludge Microorganisms

The activated sludge process has two important types of indicator microorganisms: Protozoa (ciliates) and Metazoa (Rotifers, Nematodes). The protozoa feed on the bacteria and help produce a clear effluent. Protozoans are simple, single-celled organisms that use different ways of locomotion. Rotifers, multi-celled animals, are an indicator of a stable effluent. A healthy activated sludge that is producing a clear effluent will have balance of these types of indicator organisms. Zoogleal microorganisms (bacteria) that form the floc particles remove the majority of the BOD and make up the majority of the MLSS.

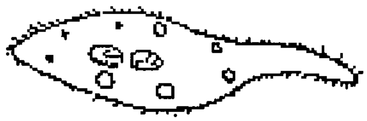
Three groups of protozoa are important to operators of activated sludge plants:

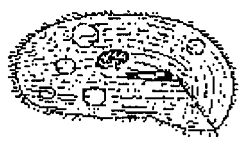
(1) Amoeba - Like in the movie 'The Blob'
(2) Flagellates - Use a whip-like tail called a Flagellum to propel themselves
(3) Ciliates - Have cilia or small hairs on their body to propel themselves or to feed

Activated Sludge Microorganisms

Amoeba- Common during plant start-up, not common in extended aeration plants

Flagellated Protozoa- Common during start-up. Common with young sludge





Bulk liquid type of free swimming ciliate- High energy, fast moving. Higher BOD levels.

Crawling type of free swimmer- Crawls on floc, scraping bacteria off. Lower energy, BOD reduced.

Carnivorous free swimmer- Consumes bacteria, flagellates and other protozoa. BOD levels low.

During start up or after an upset, amoeba and flagellates will predominate in the MLSS. The sludge age will be young, settling slowly and leaving straggler floc in the effluent.

A large number of stalked ciliates, with some free swimming ciliates and rotifers, will indicate a stable and efficiently operating plant that produces a good settling sludge and a high quality effluent.

An old sludge is indicated by predominance of rotifers and nematodes (worms). The sludge will settle at a high rate and leave pin floc in the effluent.

Rotifers can be identified by their feeding action: They attach themselves to a floc particle and extend themselves into the mixed liquor substrate. They use specially adapted cilia to form a whirling action in the liquid. This brings food particles into their reach so they can ingest it. They can be seen contracting and extending themselves, and will sometimes consume floc particles. An excessive amount of rotifers can consume large amounts of floc and cause a turbid effluent.

Nematodes are worm-like, multi-celled organisms that predominate when a sludge age is old. Nematodes can also cause a turbid effect due to their whip-like movements in the floc structures. Nematodes and Rotifers are commonly found in soil, and their numbers increase from rainwater I & I.

Filamentous Growth

There are many different types of filaments. Some causes are:

(1) Process guidelines out of adjustment (low DO, high F/M, low MCRT, low pH)
(2) Nutrient deficient wastewater (low carbon, nitrogen, phosphorus or iron)
(3) Toxic or septic influent wastewater (hydrogen sulfide)

Long filaments:

- Sphaerotilus Natans- associated with low DO's and/or high F/M ratios; cause bulking; sludge settles poorly.
- Thiothrix - grows well in the presence of sulfide ions in primary clarifiers, raw wastewater and aeration tanks with low DO's; cause bulking; sludge settles poorly.

Short filaments:

- Norcardia and Microthrix Parvicella – may not cause bulking but causes foam trapping - associated with foaming or frothing in aeration tanks and excess brown floating scum in secondary clarifier. The growth is associated with low DO's and/or F/M ratio, oil and grease in the influent can contribute.

To control filamentous bacteria, the best method would be to remove the initial cause of the problem. Filamentous bacteria are usually always present in the MLSS and help form the backbone structure of floc particles. Sometimes certain environmental conditions cause the filaments to grow and dominate the liquid. Inflow and infiltration entering the WWTF causing abnormally high hydraulic loading and washing out large amounts of MLSS is one such condition. High influent oil and grease is another source. Many small treatment plants receive waste from restaurants that do not pump out their grease trap, sending the grease to the WWTF. During periods of little or no flow to the plant, filaments proliferate due to the lack of food and nutrients necessary to the beneficial bacteria.

Ways of correcting filamentous growth:

- Supplementing the influent flow with cheap dog food
- Supplementing the MLSS with fertilizer
- Chlorinate the return activated sludge being careful not to over dose and kill your complete process
- Temporarily stopping aeration to create an anoxic condition in which the organisms go into an endogenous stage
- Waste sludge properly - many problems can be avoided by often and proper wasting

The typical growth pattern of bacteria is:

Lag phase - cells grow in size, not in numbers (young sludge);
Log phase - cells grow in numbers;
Stationary phase - population remains constant because there are as many cells dying as there are multiplying;
Death (endogenous) phase - there are more cells dying than there are multiplying (old sludge).

SECONDARY CLARIFIERS

Secondary Clarifiers are located after a biological process (secondary treatment) such as the activated sludge process or trickling filters. Secondary clarifiers are used after a trickling filter to settle out the sloughings from the filter media. Filter sloughings are quite high in BOD and will lower the effluent quality if not removed from the treated wastewater.

In the secondary clarifier the settled sludge will usually have a different appearance than the sludge collected in a primary settling tank. The sludge will usually be much darker in color, but should not be gray or black (septic). If the sludge is not pumped frequently from any clarifier, it will become septic and could rise and go over the weir. The sludge can be pumped to the primary clarifier or pumped directly to the digesters.

Activated Sludge Secondary Clarifiers

Secondary clarifier tanks that follow the activated sludge process are designed to handle large volumes of sludge. The following are ranges of loading rates for activated sludge secondary clarifiers:

Detention time -	2.0 to 3.0 hours
Surface loading -	300 to 1200 gpd/sq ft
Weir overflow -	5,000 to 15,000 gpd/lineal ft
Solids loading -	24 to 30 lbs/day/sq ft

The main goal of a secondary clarifier is to provide quiescent conditions to allow the activated sludge to settle. Activated sludge is normally a light sludge, with a density close to the surrounding liquid.

Most activated sludge secondary clarifiers are equipped with mechanisms capable of quickly returning the sludge (bacteria) back to the aeration basins healthy. The pumps used to remove sludge from these clarifiers are airlift type or centrifugal pumps, some with variable speed controls. Return sludge rates may range from 15 to 150 percent of the plant influent. If return rates are too high, turbulence in the tank can upset the sludge blanket. During a period of high flow caused by rain fall or periods of hydraulic overload, operators should decrease WAS (activated sludge wasting rate) and return sludge rates (RAS). This will retain the microorganisms in the aeration basins, for a quicker recovery. Hydraulic flow variations will have the most severe impact upon the activated sludge process.

The operator should monitor these six parameters:

(1) Level of sludge blanket in clarifier
(2) Concentration of suspended solids in clarifier
(3) Control and pacing of return sludge flows
(4) Level of turbidity in clarifier effluent
(5) Concentration of DO in the effluent
(6) pH

Treatment Plant Removal Efficiency Formula

The treatment plant performance, measured in percent removal, can be calculated using the following basic formula: $\frac{\text{In - Out}}{\text{In}} \times 100$

If the influent wastewater contains 250 mg/L of BOD and the effluent BOD is 5 mg/L the formula would be : $\frac{250 - 5}{250} (100) = 98\%$

The removal efficiency formula can be used to measure the efficiency of treatment units such as filters, clarifiers and digesters.

DISINFECTION

The most common practices for disinfecting wastewater effluent are chlorination, hypochlorination, chlorine dioxide, bromine chloride, ozone and ultraviolet light. Disinfection is necessary to reduce transmission of infectious diseases when human contact is probable. Disinfection differs from sterilization, since sterilization is the complete destruction of all living organisms in the wastewater and disinfection kills pathogenic (disease causing) organisms.

Domestic wastewater carries human pathogenic organisms excreted in the fecal discharges of infected individuals. The fecal coliform bacteria are tested for in the effluent and used as an indicator organism for the degree of disinfection. If there is fecal coliform present, this indicates that pathogenic organisms could be present which causes disease in humans. The organisms of greatest concern are the enteric (intestinal) bacteria, viruses, and intestinal parasites. Diseases that are spread through water are salmonellosis (including typhoid and paratyphoid fevers), cholera, gastroenteritis from enteropathogenic Escherichia coli, shigellosis (bacillary dysentery), and viral diseases caused by the infectious hepatitis virus. Pathogenic bacteria are destroyed or removed by the wastewater treatment plant process through the physical removal from sedimentation or filtration, natural die off in an unfavorable environment, and destruction through chemical treatment or during the disinfection process.

Chlorination

Chlorine is the most widely used wastewater disinfectant in the USA. Chlorine reacts very rapidly when mixed with water, and both hydrolysis and ionization occur. Environmental factors such as temperature, pH, alkalinity, suspended solids, biochemical and chemical oxygen demand, and ammonia nitrogen compounds cause side reactions called chlorine demand. This occurs before any disinfection takes place. Hydrogen sulfide, phenols, thiosulfate and ferrous iron will reduce chlorine effectiveness. When chlorine gas is mixed with water, hydrochloric and hypochlorous acid is formed.

Temperature affects chlorination. When the liquid temperature increases, the disinfection action of chlorine increases. When the temperature decreases, the disinfection action also decreases.

The lower the pH (<6), the higher the disinfection action due to the forming of hypochlorous acid from chlorine. The disinfection potential becomes 40 to 80 times greater.

Chlorine is available in 150 lb cylinders, 1 ton cylinders, and up to 90-ton railroad cars. These containers, under normal conditions of temperature and pressure, contain chlorine as a liquid form and a gas form. If you take chlorine from the bottom of the container, it will be liquid, but from the top of the container, it will be gas. One part of liquid chlorine will expand to 460 parts of chlorine gas.

Chlorine is 2.5 times heavier than air. The exhaust fans in chlorine equipment rooms should be located at floor level in the chlorine building. To locate chlorine leaks you should use a commercial ammonia/water mixture. The ammonia water can be put in a polyethylene squeeze bottle about half full and squeezed around the suspected leak area. When ammonia vapor comes in contact with chlorine, a white cloud of ammonia chloride is formed. An ammonia soaked rag wrapped around a stick will also do. Household ammonia is not strong enough. Never put water on a chlorine leak because the mixture of water and chlorine will increase the rate of corrosion at the leak. Be very cautious around a chlorine leak, the gas is very toxic and can cause respiratory arrest in low concentration. It is advised to get away from a serious chlorine leak and call the local fire department. They have the proper training and equipment to deal with a chlorine leak. A chlorine leak in the supply lines will appear with a green or reddish deposit, which is why chlorine supply lines are color-coded yellow, to expose the leak easier.

The maximum withdrawal rate on any type of chlorine cylinder is dependent on the temperature of the chlorine. The typical withdrawal rate for the 150 lbs cylinder is 40 lbs per day and 400 lbs per day from one ton containers. Withdrawing chlorine at rates greater than these can cause freezing of the cylinder and feed lines. Chlorinator rooms should have a heat source and maintain a temperature above a minimum of 55 degrees Fahrenheit.

Chlorine Formulas:

$$\text{Dosage, mg/L} = \frac{\text{Pounds of Chemical}}{(8.34\ \text{lbs/gal})\ (\text{Flow, mgd})}$$

Example: A chlorine scale indicated that during a 24 hour period, 5 pounds of chlorine fed. The flow during that same period was 14,000 gallons. What is the dosage of chlorine in mg/L?

$$\text{Dosage} = \frac{2\ \text{lbs Cl2}}{8.34 \times 0.014\ \text{mgd}} = 17.1\ \text{mg/L}$$

If the measured effluent residual of the effluent was 3.5 mg/L, then subtracting 3.5 from 17.1 gives us a chlorine demand of 13.6 mg/L. This means that the effluent demanded 13.6 mg/L of chlorine before a residual value could be met. Demand = Dosage - Residual

High effluent flow, high BOD, TSS or ammonia nitrogen levels can cause high chlorine demands. Elevated effluent pH, ammonia, nitrate, and sulfide can cause increased demand for chlorine.

Hypochlorination

This is the use of a dilute form of chlorine similar to bleach, but stronger. Commercially available and widely used at Florida's many class D and C WWTF's, hypochlorination is becoming the main type of wastewater disinfection.

This system uses a small chemical feed pump to feed a chlorine/water mixture from a barrel into the chlorine contact tank. The mixture is prepared on-site after adding a concentrated amount of chlorine to the barrel and topping it off with water. The pump feed rate is adjusted while the pump is running, and is dependent on the residual in the effluent.

The generation of hypochlorite on-site is becoming a popular upgrade to many small plants in Florida.

Hypochlorite can be made using equipment that uses a brine solution in conjunction with an electrical charge to generate the chlorine. Excess hypochlorite can be stored on-site and used when needed, provided it is stored properly.

Florida Administrative Code requires most Class D WWTF's to meet basic level disinfection requirements. Basic level disinfection requires that a chlorine residual of 0.5 mg/L shall be maintained at peak flow after 15 minutes of detention time. Chlorine contact chambers are designed to retain the treated wastewater in the tank long enough to give the applied chlorine time to disinfect. These tanks come in a variety of sizes and shapes and most will have a system of baffles to create a longer detention time. Proper mixing is also important for effective disinfection. A good chlorine residual and low fecal coliform count can measure the effectiveness of the whole disinfection system. Most Class D facilities must achieve an average monthly fecal coliform count of less than 200 colonies per 100 milliliters of effluent sample, and no more than 800 colonies in any one sample.

Dechlorination

The purpose of dechlorination is to protect small receiving streams and aquatic organisms from toxic levels of chlorine. Wastewater treatment plants use chlorine to kill fecal coliform to meet the permit limits and dechlorination (removal of the residual chlorine) protects receiving waters from harmful chlorine, which can kill aquatic organisms.

There are a few chemicals used in dechlorination:

(1) Sulfur dioxide - most commonly used
(2) Sodium sulfite
(3) Sodium metabisulfite
(4) Sodium bisulfate

Equipment used to feed and detect for sulfur dioxide leaks are similar to chlorine. Use an ammonia vapor dispenser or ammonia soaked swabs to locate leaks.

Disinfection Alternatives

Many small systems are getting away from the hazards of chorine and the associated equipment maintenance and costs. Some alternatives in use in Florida are ultraviolet light and ozonation. While these alternatives provide no residual chlorine to measure, fecal coliform results are used to ensure disinfection effectiveness.

AEROBIC SLUDGE DIGESTION

Process Description

Aerobic digestion tanks may be either round or rectangular, 5 to 20 feet deep, with or without covers. The tanks use aeration equipment (mechanical or diffused air) to maintain aerobic conditions. Each tank has a sludge feed line above the high water level of the tank, a sludge draw-off line at the bottom of the tank, and a way to draw off supernatant. Detention time depends on the origin of the sludge being treated.

Operation

Aerobic digesters are operated under the principle of extended aeration from the activated sludge process relying on the mode called Endogenous Respiration. Aerobic digestion consists of continuously aerating the sludge without the addition of new food, other than the sludge itself, so the sludge is always in the endogenous phase. Aeration continues until the volatile suspended solids are reduced to a level where the sludge is reasonably stable, does not create a nuisance or odors, and will readily dewater.

The greatest oxygen demand is exerted when sludge is first added, and the demand decreases as the sludge is mixed. DO levels in the tanks should be maintained at or above 1.0 mg/L.

Supernating / Decanting

In operation, a digester full of sludge is aerated for a length of time, and then the aeration is ceased. The sludge is allowed to settle for several hours and the clear liquid above the settled sludge blanket is then drawn off. This may be done with a submersible pump, or by displacement of the liquid with fresh waste sludge trickled into the digester tank. The clear liquid passes through an overflow line or port back into the aeration system. After several hours of this 'supernating' process (possibly overnight), the aeration is restarted. There may be some odor experienced after the aeration is restarted, but it will cease once the DO is re-established. Now there is room to waste more sludge into the digester. A rule of thumb regarding wasting rates is to not increase waste rates more than 10% per day. It is better to waste small amounts of sludge daily than to waste large amounts weekly or monthly. The activated sludge process receives less of a shock when wasting smaller amounts.

When sludge in the digester has been supernated several times, it may not be willing to readily settle when the aeration is turned off. This is an indication that the operator needs to remove the solids from the plant site. Calling a hauler to 'pump-out' the digester, or pouring sludge to sludge drying beds are common ways Class D plants deal with excess biosolids.

Aerobic digester supernatant is usually high in nitrate. It is best to return this supernatant to the plant during high or daily flow periods. Nitrate (NO_3) can be used by bacteria as an oxygen source and when added to the plant with a carbon source such as influent wastewater, these bacteria use the nitrate as a source of oxygen as they breakdown the BOD in the influent.

ANAEROBIC SLUDGE DIGESTION

Process Description

Anaerobic digestion is a continuous process of stabilizing waste sludge. Fresh sewage sludge is added continuously or at frequent intervals. The water separated from the sludge is normally removed as the sludge is added. Digested sludge is removed at less frequent intervals. The sludge is digested by bacteria that use the organic material as food, and give off the products carbon dioxide and methane gas.

Wastewater solids and water (about 5% solids, 95% water) are placed into a large tank where bacteria decompose the solids in the absence of dissolved oxygen. At least two general groups of bacteria act in balance: saprophytic bacteria and methane fermenters.

Anaerobic digestion is generally not found on package treatment plants. If the operator is responsible for maintaining a digester, the following EPA publication should be obtained for information on the basics and operation. (Operations Manual - Anaerobic Sludge Digestion, EPA Publication No. EPA 330/9-76-001.) Anaerobic digesters are mainly found in plants that have primary clarification, or settling tanks. These same clarifiers are often found at treatment plants with fixed media type secondary treatment units (i.e.: trickling filters, RBCs). Some large (>5 mgd) activated sludge facilities often have anaerobic digesters.

Operation

Anaerobic digesters degrade organic solids without the presence of dissolved oxygen. Facultative and strict anaerobic organisms break down the sludge-using sulfate as their oxygen source. This is similar to a septic condition, only in a controlled environment.

The digestion of the sludge is considered a two-step process. The first step is acid formation and the second is methane production. The sludge is digested by two different groups of bacteria living together in the same environment. One group is called saprophytic bacteria, which break down complex solids to volatile acids, the most common of which are acetic and propionic acids. The other group is called methane fermenters which break down the acids produced by the acid formers to methane carbon dioxide and water. Methane fermenters are not as abundant as acid formers and require strict living conditions.

The object of good digester operation is to maintain a suitable environment in the digester for growing populations of both acid forming and methane forming bacteria. One may do this by controlling the food supply (organic loading rate), volatile acid / alkalinity relationship, temperature and mixing. One must try to operate the anaerobic digester so that the rate of acid formation and methane formation is approximately equal; otherwise the reaction will be out of balance. The most common condition of imbalance is excess acid formation. This condition occurs when the methane formers fail to keep up with the acid formers. Efficient operation depends on keeping both types of organisms in proper balance.

Supernatant

Anaerobic digester supernatant is high in ammonia and BOD. A good rule of thumb is to return anaerobic digester supernatant during low flow or nighttime periods. This gives the treatment plant bacteria a source of food during times of low flow, and does not organically overload the plant during high flow conditions.

Volatile Acid/Alkalinity (VA/Alk) Ratio

This relationship of acid formers and methane formers is measured by the amount of volatile acid to the amount of alkalinity in the sludge. Alkalinity is the buffering capacity of a liquid to neutralize acids. Once alkalinity has been used, pH levels begin to drop.

The volatile acid/alkalinity ratio is measured in milligrams per liter (mg/L). Good digester operation occurs when the VA/Alk ratio is around 0.1 mg/L volatile acids to 1.0 mg/L alkalinity. The alkalinity should be around 2500-5000 mg/L as bicarbonate.

When the ratio starts to increase, corrective action must be taken immediately. If corrective action is not taken, the carbon dioxide content of the digester gas will increase, the pH of the sludge will begin to decrease and the digester will become sour or upset.

When the VA/Alk ratio reaches 0.3/1.0, close monitoring is necessary. Possible causes include pumping thin sludge to the digester, accidental overpumping, or withdrawing too much sludge. Solutions include thickening the raw sludge, decreasing the sludge withdraw rate, extending mixing times, checking and correcting sludge temperature, and adding seed sludge if possible.

When the VA/Alk ratio reaches 0.5/1.0, the carbon dioxide in the digester gas starts to increase. Proper gas mixture is approximately 70% methane and 30% CO_2. Trace gasses are present, such as hydrogen sulfide (H_2S), but in small quantities. When this happens, it is recommended to check thickness of raw sludge, mixing and temperature. Adding alkalinity in the form of lime based on amount of volatile acids is recommended.

When the VA/Alk ratio reaches 0.8/1.0, the pH will start to drop, and CO_2 increases to the point where the gas is not burnable (42-45% CO_2). A rotten egg odor (hydrogen sulfide) or rancid butter odor may be noted. Recommendations include a decrease in raw sludge loading, continue mixing and check temperatures. Adding alkalinity (lime) is recommended.

If volatile acid/alkalinity is not used as a process control tool and only pH is used, a digester can become upset before it is even recognized by the operator. By the time a decrease in pH is noted, the digesters can already be sour.

Digester Temperature

Anaerobic digesters can be operated in several different temperature ranges.

Psychrophilic: Cold temperature loving bacteria thrive here. This range is 50° F to 68° F. Temperature is basically the ambient temperature, and not much biological activity occurs below 50° F. Digestion takes place in 50 to 180 days. Not many of these digesters are in operation.

Mesophilic: This is the mid-range, between 68°F and 113° F. Optimum range is between 85° F and 100° F, with the ideal temperature of around 95° F. This is the so-called high-rate zone with digestion times ranging from 5 to 50 days.

Thermophilic: This is the high temperature zone and includes anything above 113° F, with 120° F optimum. Digestion times fall between 5 and 12 days. These are not very common due to high-energy requirements of maintaining high temps.

Temperature rule-of-thumb: Never change a digester temperature more than one degree per day. This allows the bacteria to adjust to the change in temperature.

Note:
Reference material used for this short summary is contained in The University of California, Sacramento "Operation of Wastewater Treatment Plants, Volume II, fourth edition, Chapter 12. For more information on digester operation, the student is encouraged to reference this manual.

SLUDGE DRYING BEDS

Sludge drying beds are used to dewater the sludge coming from the digester. The surface of the bed is either sand with gravel underdrain or the bed might be of asphalt. Sludge may be placed on the surface 6 to 18 inches deep, depending on the climate. The drying accomplished by evaporation and percolation of the moisture from the sludge. Removal of the dried sludge on the sand beds must be done by hand since heavy equipment will damage the underdrain. The underdrain is pumped back to the influent of the treatment plant. The dried sludge may be used as a soil conditioner and fertilizer. Some states have restrictions against placing the sludge on soil growing root crop vegetables; therefore, it is best to check with the regulatory agency first.

INFLUENT AND EFFLUENT SAMPLING AT WASTEWATER FACILITIES

Note: These sampling procedures are provided assuming that extractable organics, and/or volatile organic compound samples will not be collected. See DEP - QA-001/92 Chapter 4.0 for specific requirements for organic samples.

Grab Samples

- Obtain the sampling kit containing the bottles, chain of custody forms and additional preservatives from the laboratory.
- Gather sampling equipment. The equipment can be made of plastic, glass, teflon, or stainless steel.
- Before sample collection, clean all sampling equipment with a brush using hot water and Liquinox soap. Rinse thoroughly with tap water three to four times. Rinse with a 10-15% reagent grade hydrochloric acid. Do not use a nitric acid rinse if analyzing for nitrate or nitrogen compounds. Stainless steel equipment should not be rinsed in acid. Use analyte free water for the final rinse [most commonly used is de-ionized (DI) water]. An alcohol rinse is not necessary. DO NOT USE BLEACH FOR CLEANING PURPOSES.
- Disposable gloves are recommended for sample collection to protect personnel who collect the samples and to assure the integrity of the samples. Disposable gloves should be changed at each sampling location.
- Determine the correct location for sample collection. This is usually described in the permit for the facility. If there are questions about a representative sampling location, please contact the wastewater compliance section at the local Department of Environmental Protection office.
- Grab samples should be collected directly into the sample bottles whenever possible, particularly for fecal coliform. NOTE: Bottles with preservatives are the exception (see below). Rinse the sampling container with effluent except for fecal coliform samples. Pour the contents of the container downstream of the sampling locations. Collect the sample directly into the unpreserved container by submerging the container, top first, into the effluent. Point top of the bottle into the flow. After filling, pour out a few milliliters of sample to allow for air space for expansion, sample preservation, and mixing.
- If access to the sampling location is restricted, secure the bottle to a pole using a clip or other device and collect the sample directly into the bottle.
- Fecal coliform sample collection requires extra care. Make sure that sodium thiosulfate pill is not lost during sample collection.
- If collection directly into the bottle is not possible, an intermediate container may be used. The container must be thoroughly cleaned using the same procedures as for other sampling equipment. The container must be rinsed several times in the sample water. If the container is used for more than one sampling location and no metals and/or organics are being sampled, the container should

be rinsed with tap water between sampling points. At the next sampling location rinse the container several times in the sample water.

- Bottles with preservatives should be filled from an intermediate container so none of the preservative will be lost.
- Preservatives should be checked with narrow range pH paper to confirm that the samples are correctly preserved. Shake bottle thoroughly before performing the pH check. Do not dip the pH paper directly into the sampling container. Sample water may be poured directly onto the pH paper or a small amount of the sample can be poured into another container to check the pH. The small amount of the sample should be discarded after checking the pH.
- Keep the samples packed on ice for delivery to the laboratory.

Automatic Samplers

- Obtain the sampling kit containing the bottles, chain of custody forms and additional preservatives from the laboratory.
- The exterior and accessible interior portions of the automatic sampler should be washed with Liquinox soap and rinsed with tap water.
- All tubing should be visually checked. Tubing that has become discolored or has lost its elasticity should be changed. New pump tubing should be installed.
- If existing tubing is used, clean by flushing with hot water and Liquinox soap. Rinse with hot tap water. Then rinse with analyte free water. Re-install the tubing and cap both ends with aluminum foil.
- Disposable gloves are recommended for assembly of the unit at the sampling location and for dis-assembly to protect personnel who collect the samples and to assure the integrity of the samples. Disposable gloves should be changed at each sampling location.
- Check the permit for the facility to determine if samples are to be collected according to time or flow proportioned composite samples.
- A minimum of 100 milliliters should be collected each time the unit activates.
- Pack ice inside and around the sampler or set refrigerated units to 4 degrees Celsius.
- Collection line tubing should not be resting on the bottom or against the walls of the tank. Place the tubing in the turbulent zone. For influent samples, return sludge or other influences should not affect the sample.
- Check the timing and delivery of the automatic sampler by setting the unit for start up a few minutes later and use a graduated cylinder to measure the amount collected.
- For both influent and effluent samples, the automatic sampler purges the line each time samples are collected. Make sure the line does not contain any low areas where residuals would be retained in the line between sample collections.

For additional information, please see DEP – QA-001/92 Standard Operating Procedures for Laboratory Operations and Sample Collection Activities or visit web site: www.dep.state.fl.us/labs/libintro.htm

Also look for the next article discussing Record Keeping and Documentation Requirements.

pH CALIBRATION

- Be sure instrument is clean and in good operating condition. Must be automatic temperature compensating, or use a separate temperature probe along with pH probe.
- Set meter at Calibrate.

  Note: Always use fresh buffer when calibrating a pH meter!
- Use mid-range (7.00) buffer in a small, clean glass beaker, with stir bar on magnetic stirrer. Put probe in, allow to stabilize.
- After stabilization, read results, record reading. If not auto calibrating, set to 7.00 or whatever buffer is labeled. Record new setting.
- Note what expected range of sample should be, if sample is expected to be greater, that 7, use a 10.0 buffer solution for slope check. If sample is expected to be less than 7.00, use the 4.00 buffer.
- Read this buffer and record value. Adjust if necessary. Record the new value.

  Note: Rinse probe with DI water and blot tip dry between each buffer reading and each sample reading.
- If meter is type to show the slope reading, record the slope reading. If instrument is not reading proper slope, adjust to proper slope reading.
- Rinse probe after using the 10.00 or 4.00 buffer and return to the 7.00 buffer for a final reading check. Record reading.
- Probe may be stored in the 7.00 buffer.
- Proceed with reading samples.
- Read samples that were collected in the field.
- Be sure to rinse and blot probe in between reading samples.

FLORIDA DEPARTMENT OF ENVIORNMENTAL PROTECTION
WASTEWATER A, B, C & D FORMULA SHEET AND CONVERSION FACTORS 10-09

12 in= 1 ft	27 cu. ft. = 1 cu. yd.	1000 mg = 1 gm
3 ft= 1 yd	7.48 gal= 1 cu. ft.	1000 gm = 1 kg
5280 ft= 1 mi	8.34 lbs= 1 gal	1000 ml = 1 liter
144 sq. in. = 1 sq. ft.	62.4 lbs= 1 cu. ft.	2.31 ft water = 1 psi
43,560 sq. ft.= 1 acre	1 grain / gal= 17.1 mg/L	0.433 psi = 1 ft water
60 sec = 1 min	60 min = 1 hour	1440 min = 1 day
10,000 mg/L = 1%	454 gm = 1 lb.	43,560 sq. ft.= 1 acre

TEMPERATURE CONVERSIONS

C° to F° = C° x 1.8 + (32)

$$F^\circ \text{ to } C^\circ = \frac{(F^\circ - 32)}{1.8}$$

VELOCITIES and FLOW RATES

1. $$V = \frac{\text{distance, feet}}{\text{time, min}}$$

2. Q = V x A (Flow rate = velocity, ft / sec x area, sq. ft.)

DETENTION TIME

1. $$\text{Det. Time} = \frac{\text{tank cap. (gal) x (24 hours/day)}}{\text{rate of flow (gal / time)}}$$

PARTS PER MILLION / POUNDS

1. $$\text{mg/L} = \frac{\text{pounds of chemical}}{(\text{8.34 lbs / gal x MG})}$$

2. lbs = 8.34 lbs / gal x mg/L x MG

SEDIMENTATION AND LOADINGS

1. $$\text{Weir overflow, gal / day / ft} = \frac{\text{total flow, gal / day}}{\text{length of weir, ft.}}$$

2. $$\text{Surface loading, gal / day / sq.ft.} = \frac{\text{influent flow, gal / day}}{\text{surface area, sq. ft.}}$$

3. $$\text{Solids loading, lbs / day / sq. ft.} = \frac{\text{solids applied, lbs / day}}{\text{surface area, sq. ft.}}$$

4. $$\text{Efficiency, \%} = \frac{\text{(in) - (out)}}{\text{(in)}} \times 100\%$$

5. Hydraulic loading, gal / day / sq.ft. = $\frac{\text{flow rate, gal / day}}{\text{surface area, sq. ft.}}$

6. Trickling Filter Organic loading, lbs CBOD /day / 1000 cu. Ft. = $\frac{\text{CBOD applied, lbs /day}}{\text{vol. of media in 1000 cu. Ft.}}$

7. Soluble CBOD, mg/L = total CBOD, mg/L - (K x suspended solids, mg/L)
(where K = 0.5 to 0.7 for most domestic wastewaters)

8. RBC Organic Loading, lbs CBOD/day/1000 sq.ft. = $\frac{\text{soluble CBOD applied, lbs/day}}{\text{Surface area of media, 1000 sq.ft.}}$

ACTIVATED SLUDGE

1. SVI = $\frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$

2. SDI = $\frac{100}{\text{SVI}}$

3. Solids inventory, lbs = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs / gal)

4. Sludge age, days = $\frac{\text{solids under aeration, lbs}}{\text{solids added, lbs / day}}$

5. F/M = $\frac{\text{(inf CBOD, mg/L) x (Flow, MGD) x (8.34 lbs / gal)}}{\text{(Aeration tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs / gal)}}$

6. MCRT = $\frac{\text{solids inventory, lbs}}{\text{(effluent solids, lbs) + (WAS solids, lbs)}}$

7. WAS, lbs / day = $\frac{\text{(Solids inventory, lbs)}}{\text{MCRT, days}}$ - (Solids lost in effluent, lbs / day)

8. WAS flow, MGD = $\frac{\text{WAS, lbs/day}}{\text{(WAS, mg/L) x (8.34 lbs / gal)}}$

9. Change, WAS rate, MGD = $\frac{\text{(current solids inventory, lbs) - (desired solids inventory, lbs)}}{\text{WAS, mg/L x 8.34 lbs / gal}}$

10. Return sludge rate, MGD = $\frac{\text{(set. Solids, mL) x (flow, MGD)}}{\text{(1,000 mL) - (set. solids, mL)}}$

SLUDGE DIGESTION

1. Dry solids, lbs $= \dfrac{(\text{raw sludge, gal}) \times (\text{raw sludge, \% solids}) \times (8.34 \text{ lbs / gal})}{100\ \%}$

2. VS pumped, lbs / d $= \dfrac{(\text{ret. Sludge, gal / day})\ (\text{ret. sludge solids, \%})\ (\text{ret. sludge vol., \%})\ (8.34 \text{ lbs / gal})}{(100\%)\ (100\%)}$

3. Seed Sludge, lbs volatile solids $= \dfrac{\text{VS pumped, lbs VS / day}}{\text{loading factor, lbs VS / day / lb VS in digester}}$

4. Seed Sludge, gal $= \dfrac{\text{seed sludge, lbs volatile solids}}{(\text{seed sludge, lbs / gal}) \times \dfrac{(\text{solids \%})}{100\%} \times \dfrac{(\text{VS \%})}{100\%}}$

5. Lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs / gal)

6. Reduction of Volatile Solids, % $= \dfrac{(\text{in} - \text{out}) \times 100\%}{\text{in} - (\text{in} \times \text{out})}$

7. VS destroyed, lbs / day / cu. ft. $= \dfrac{(\text{VS added, lbs / day})\ (\text{VS reduction, \%})}{(\text{digester volume, cu. ft.})\ (100\%)}$

8. Gas production, cu. ft. / lb VS $= \dfrac{\text{gas produced, cu. ft. / day}}{\text{VS destroyed, lbs / day}}$

HORSEPOWER, FORCE, CHEMICAL PUMPS

1. Water HP $= \dfrac{(\text{flow, gal / min}) \times (\text{head, ft})}{3{,}960}$

2. BHP $= \dfrac{(\text{flow, gal / min}) \times (\text{head, ft.})}{(3{,}960 \times \text{Pump Efficiency, \%})}$

3. Motor HP $= \dfrac{(\text{flow, gal / min}) \times (\text{head, ft})}{(3{,}960) \times (\text{Pump Efficiency, \%}) \times (\text{Motor Efficiency, \%})}$

4. Upward force, lbs = 62.4 lbs / cu. ft. x ground water height over tank bottom, ft x area, sq.ft.

5. Side wall force, lbs $= (31.2 \text{ lbs / cu. ft.}) \times (\text{height, ft})^2 \times (\text{length, ft})$

6. Chemical sol=n, lbs / gal $= \dfrac{(\text{sol'n \%}) \times (8.34 \text{ lbs / gal})}{100\%}$

7. Feed pump flow, gal / day $= \dfrac{\text{chemical feed, lbs / day}}{\text{chemical solution, lbs / gal}}$

8. Scale setting, % $= \dfrac{(\text{desired flow, gal / day})\ (100\ \%)}{\text{maximum feed rate, gal / day}}$

9. Brake Horsepower = Hp $= \frac{\text{(Power to elec. motor) (Motor Eff.)}}{\text{.746 kw/Hp}}$

10. Pump Efficiency, % $= \frac{\text{Water Horsepower, Hp}}{\text{Brake Horsepower, Hp}} \times 100\%$

11. Total Dynamic Head, ft. = Static Head, ft. + Friction Losses, ft.

12. Static Head = Suction Lift, ft. + Discharge Head, ft.

LAB PROCEDURES AND MEASUREMENTS

1. TSS, mg/L $= \frac{\text{(RDD - DD)}}{\text{sample vol, mL}} \times \text{1 M}$

2. VSS, mg/L $= \frac{\text{(RDD - FDD)}}{\text{sample vol, mL}} \times \text{1 M}$

where: RDD = dried residue + dish + disc (filter), grams
DD = dish + disc, grams
FDD = fired residue + dish + disc, grams
1 M = 1,000,000

3. VSS, % $= \frac{\text{volatile solids, mg/L}}{\text{total suspended solids, mg/L}} \times 100\%$

4. CBOD sample size, mL $= \frac{\text{1,200}}{\text{estimated CBOD, mg/L}}$

5. Seed correction, mg/L, for 1 mL seed $= \frac{\text{seed initial D.O. - seedf final D.O.}}{\text{mL seed added}}$

6. CBOD, mg/L $= \frac{\text{[(initial DO - Final DO) - seed correction factor]} \times \text{(bottle volume, mL)}}{\text{sample volume, mL}}$

DISINFECTION

Chlorine Demand, mg/L = Chlorine Dosage, mg/L – Chlorine Residual, mg/L

Chlorine Dosage, mg/L = Chlorine Demand, mg/L + Chlorine Residual, mg/L

SUMMARY OF SOME DISEASES ASSOCIATED WITH WASTEWATER CONTAMINATED ENVIRONMENTS

Disease	Organism	Mode of Transportation
Bacillary Dysentary	*Shigella* spp.	Ingestion
Asiatic cholera	*Vibrio cholerae*	Ingestion
Typhoid Fever	*Salmonella typhi*	Ingestion
Tuberculosis	*Mycobacterium tuberculosis*	Ingestion
Tetanus	*Clostridium tetani*	Wound Contact
Infectious Hepatitus	Hepatitus A virus	Ingestion
Poliomyelitis	Polio virus	Ingestion
Common Cold	Echo virus	Inhalation

Wastewater Operator Exam Review

Florida Rural Water Association

Overview

- Collection Systems
- Rain Water I&I
- Wastewater Flow
- Preliminary Treatment
- Secondary Treatment

Collection Systems

- *Purpose*: Collect and convey wastewater from homes and industries
- *Sanitary Sewer*: Household (domestic) wastewater
- *Storm Sewer*: Conveys stormwater to DRA's
- *Combined Sewer*: Collects both sanitary and storm water

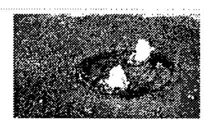
Collection System Components

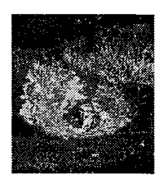
- Sanitary Sewer Main—Velocity of flow must be at least 2' per second
- Manholes—Distance between manholes 300-500'
- Laterals—Connects house to sewer main
- Force Main—Pumps sewage from lift station to plant

Collection System Problems

- Rainwater Inflow and Infiltration
- Flat Grades
- Bellies
- Tree Roots
- Manhole Deterioration
- Grease Accumulation

Collection System Problems





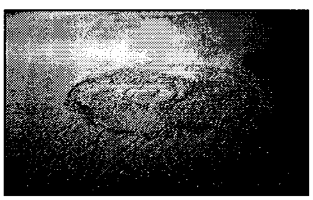
Rain Water Inflow and Infiltration (I&I)

- Enters collection system through cracks and holes in pipes, open cleanouts, cross connections, manholes
- Can cause hydraulic overload at WWTF, decreased capacity due to sand and grit accumulation, lift station pump failures and overflows, increased operating costs

Inflow

- Direct flow of water to sewer system

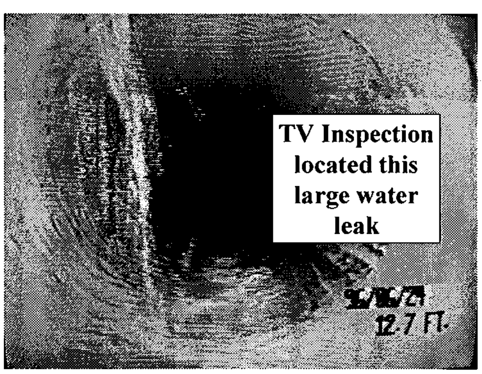
Example of Inflow



Improperly located manholes and poorly sealed manhole covers can add to high flows.

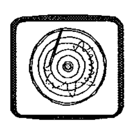
Infiltration

- Groundwater entering sewer pipes through cracks and openings



Is it Inflow or Infiltration?

- Record lift station run times and rainfall daily
- Compare rain event readings with dry weather readings to locate problem areas



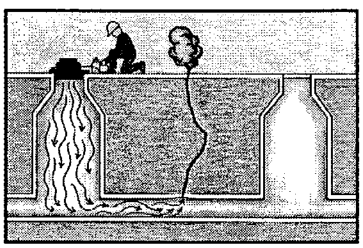
Rain Water I&I *(continued)*

- I&I studies include collection system inspection, smoke testing and televising sewer lines
- 10 three-inch open cleanouts adds up to a 30-inch hole in the collection system!
- A one-inch rainfall in one acre equals approximately 27,000 gallons of water!

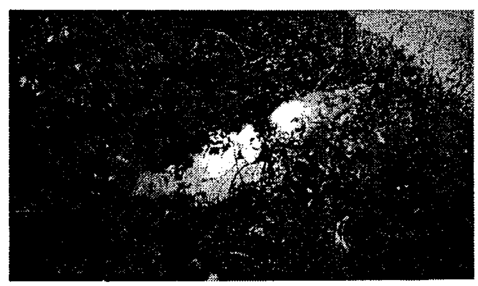
Smoke Blower

Smoke Testing

- Locates broken sewers
- Locates "lost" manholes



Smoke testing is one way of locating broken sewer pipes, like this one in a ditch.



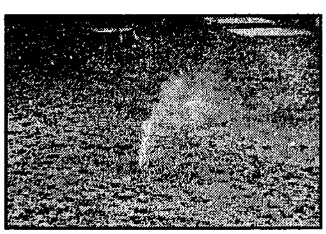
Excessive Hydraulic Loading

Cause: Inflow

⇩ Downspouts

⇩ Yard drains

⇩ Clean-outs

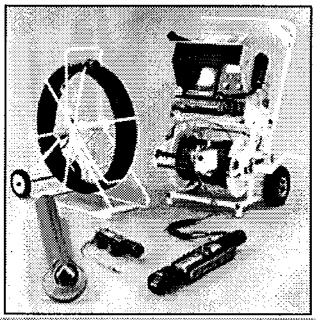


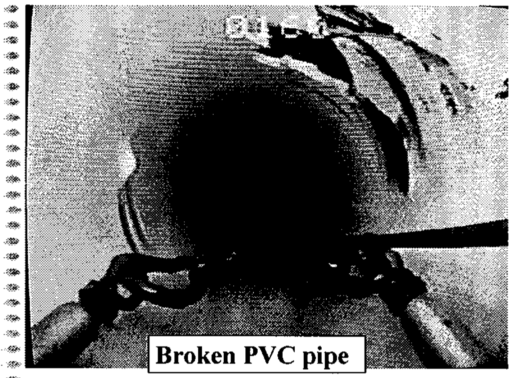
Excessive Hydraulic Loading

Cause: Inflow

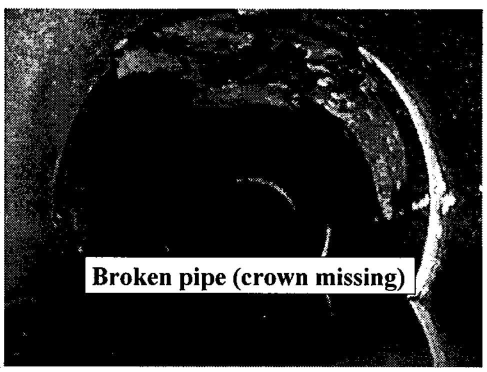
⇩ Storm drains

TV Inspection Equipment

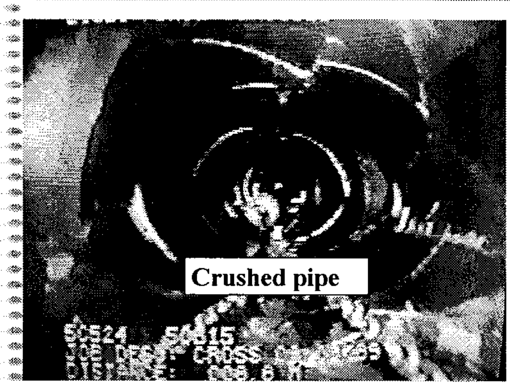




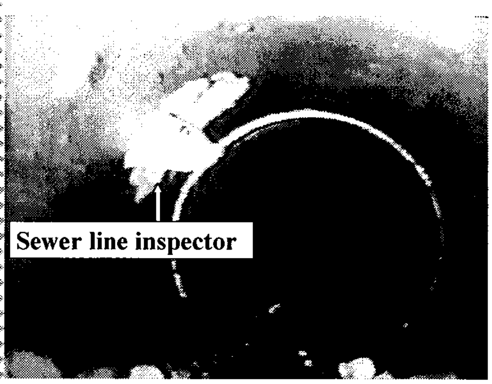
Broken PVC pipe



Broken pipe (crown missing)



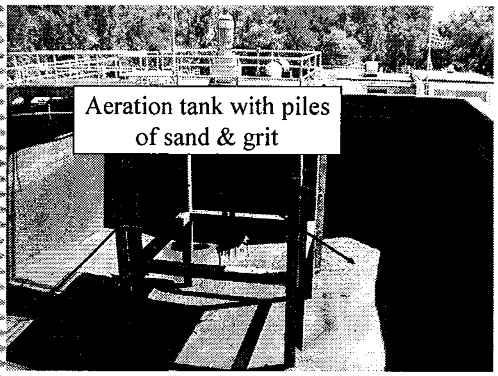
Crushed pipe



Sewer line inspector

What effect does grit have?

- Excessive wear on plant equipment
- Grit takes up valuable volume in tanks
- Excessive solids handling for grit removal



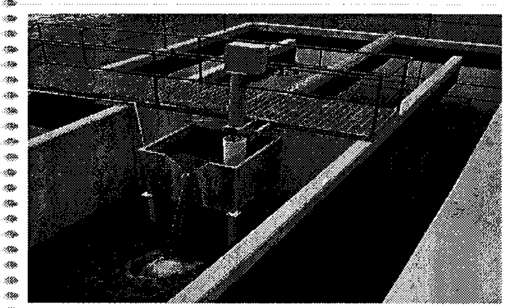
Bellies and Flat Grade Sewers

- Allows septic conditions to develop
- Allows formation of Hydrogen Sulfide (H_2S)
- Can cause low influent pH
- Causes odors
- Can increase oxygen demand at plant
- Can contribute to sludge bulking
- H_2S causes deterioration of manholes, pipes and lift stations

Wastewater Flow

- Flow is measured as a quantity (gallons) moving past a point (primary device) during a specific time interval
- Recording flow is required by DEP
- Recording flow @ plants 1 MGD are taken continuously.

Flow Measurement



Wastewater Flow

- Primary Devices: Weirs and Flumes
- *Secondary Devices*: Float Type, Ultrasonic, Bubbler, Magnetic, E.T. meters on pumps
- Secondary devices calibrated at least annually, a permit requirement of DEP

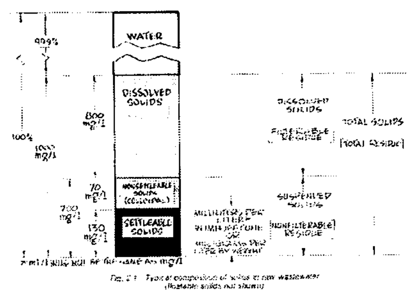
Wastewater Types

- *Organic*- mainly plant and animal waste
- *Inorganic*- sand, grit, iron, calcium
- *Thermal*- heated wastewater from industrial sources
- *Radioactive*- hospitals, research labs, toxic disposal industries, nuke plants

Wastewater Contents

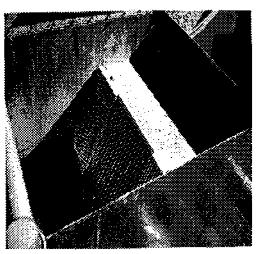
- Domestic waste is 99.9% water
- Contains pathogenic (disease causing) bacteria, viruses, cysts that can cause Typhoid, Cholera, Dysentery, Polio and Hepatitis
- Floatable, settleable, suspended, dissolved, colloidal solids

Raw Wastewater Solids Composition

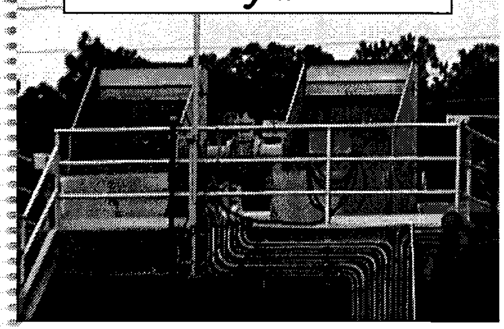


Preliminary Treatment

- Flow Equalization / Surge Basins
- Bar Screens and Racks
- Moving or Rotating Screens
- Grit Chambers / Channels



Preliminary Treatment



Preliminary Treatment

Unit processes include:

- Odor control
- Screening
- Grit removal

Odor Control

- Odor producing substances are small, mostly volatile molecules
- Most result from anaerobic decomposition of organic matter containing sulfur and nitrogen

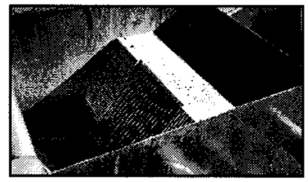
Odor Control, continued

Gases produced from wastewater decomposition:

- Hydrogen sulfide (H_2S)
- Ammonia (NH_3)
- Carbon dioxide (CO2)
- Methane (CH_4)

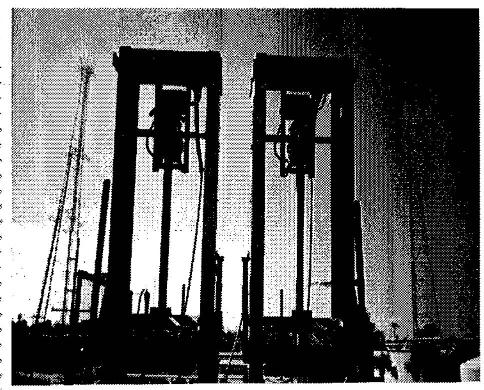
Barscreens and Racks

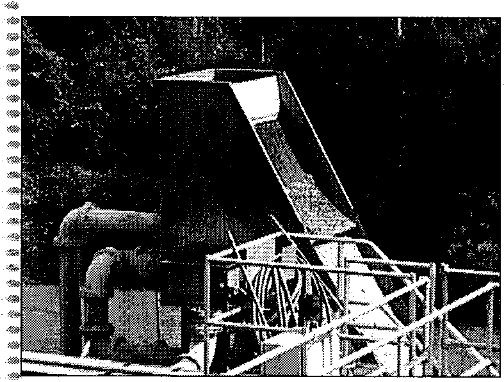
- Influent is screened to remove debris that can clog and damage downstream equipment



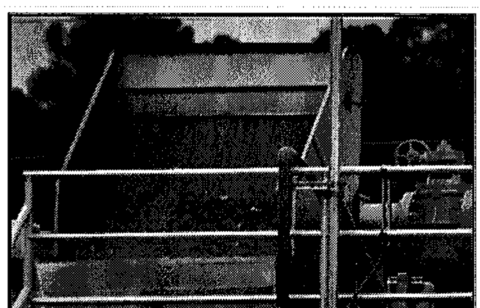
Barscreens and Racks

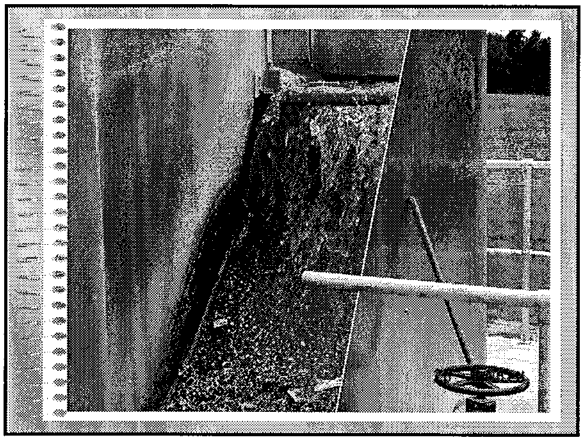
- Solids removed are referred to as screenings
- Consist of rags, roots, sticks, plastics and other large debris
- Must be placed in covered container and sent to approved landfill

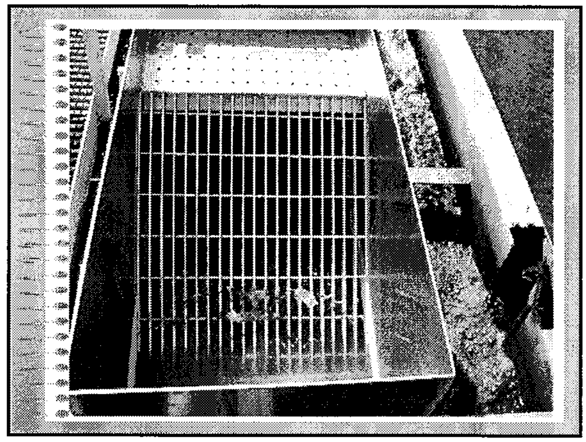


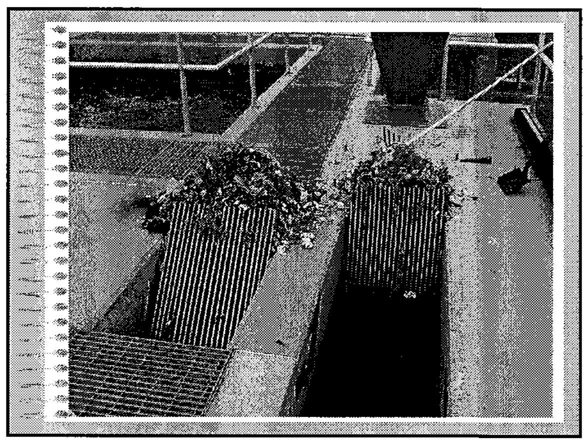


Hydroscreen in action



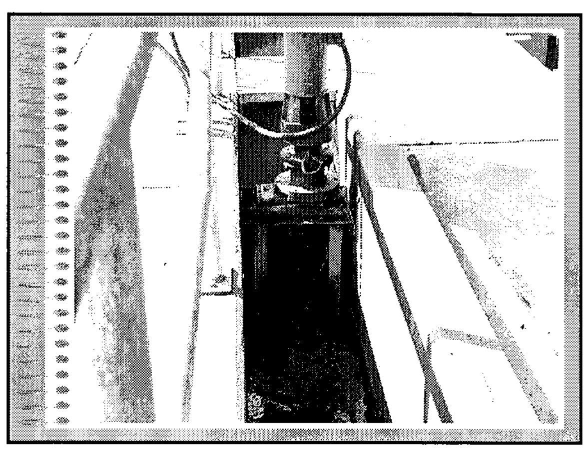






Influent grinding

- Comminutors and Barminutors grind or chop large solids
- Returns chopped solids to influent flow
- Shredded rags adversely affect downstream processes
- Not very common, slowly being replaced



Grit Removal

- Grit is removed to protect downstream equipment from its abrasive nature
- Grit consists of sand, gravel, pipe debris and eggshells
- Grit can plug pipelines, fill usable tank space, damage pumps and valves

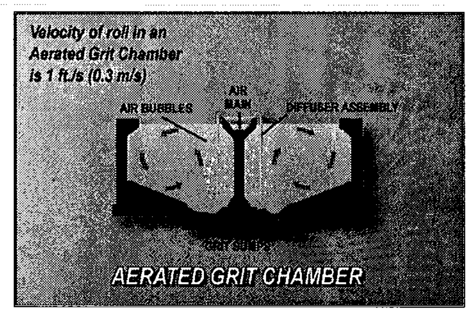
Volume of grit entering WWTP depends on following variables:

- Type of collection system (sanitary, combined)
- Material used in collection system construction
- Amount of street sand flushed into sewer
- Integrity of collection system
- Industrial waste containing grit from washing processes

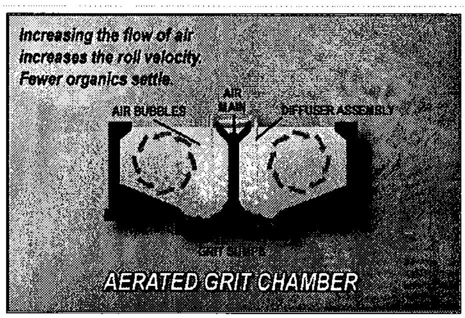
Grit removal

- A variety of equipment is used for grit removal
- Most grit removal techniques slow flow velocity to 1.0 fps to allow grit to settle

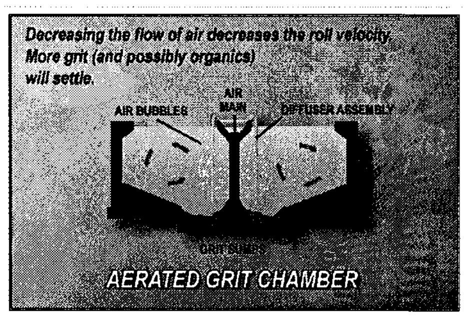
Aerated Grit Removal



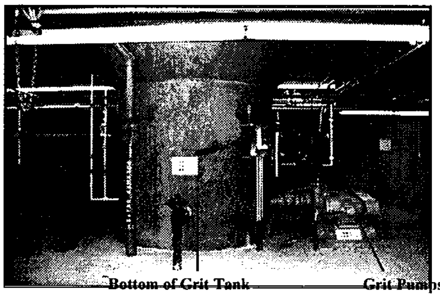
Aerated Grit Removal



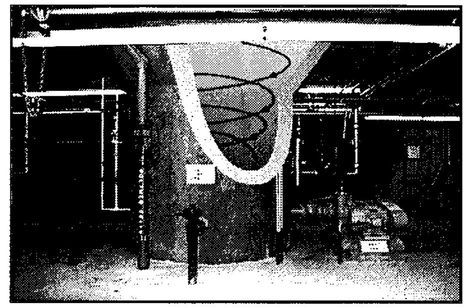
Aerated Grit Removal



Aerated Grit Removal



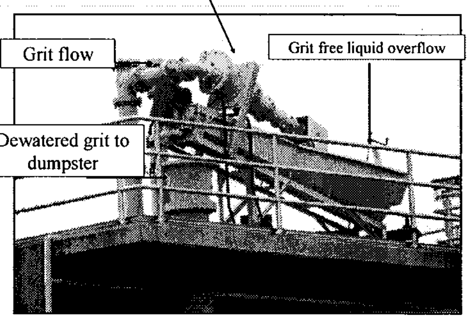
Aerated Grit Removal



Grit Pumping

- Grit pumps are typically recessed impeller centrifugal pumps
- Pumps are usually timer controlled
- Grit is pumped to a cyclone degritter or dewatering screen

Cyclone Degritter



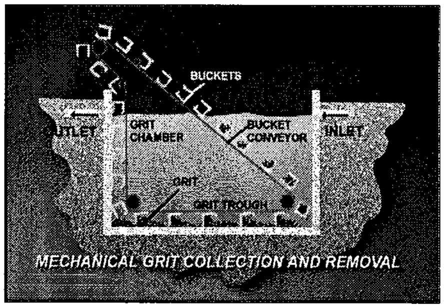
Mechanically Cleaned Chambers

- Most are rectangular shaped
- Most use a chain and flight system to move grit to a sump
- A bucket elevator or inclined screw lifts grit to a classifier or washer

Mechanically Cleaned Chambers

- Collectors operate at low speed, only fast enough to collect grit as it settles
- Run times of collectors depends on rate of grit accumulation
- Additional grit chambers should be placed on-line if grit loading exceeds that of on-line units

Mechanically Cleaned Chambers



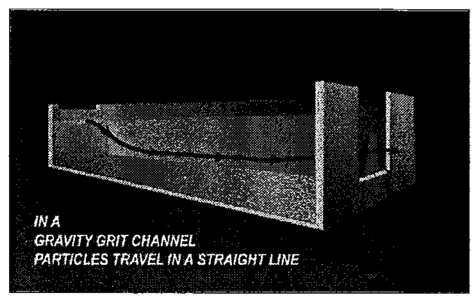
Grit channels

- Basically long channels that reduce flow velocity to 1.0 feet per second
- Use two or more channels
- One channel stays on-line, other channel off for draining and cleaning

Grit Channels

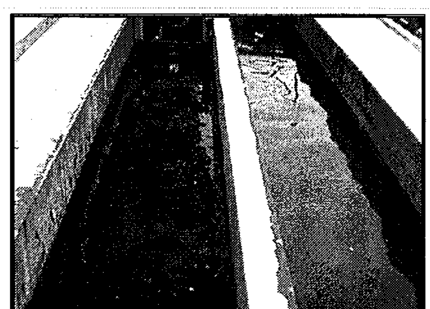
- Grit is manually removed (armstrong method)
- May be found as a back-up to a mechanical grit removal system

Grit Channels

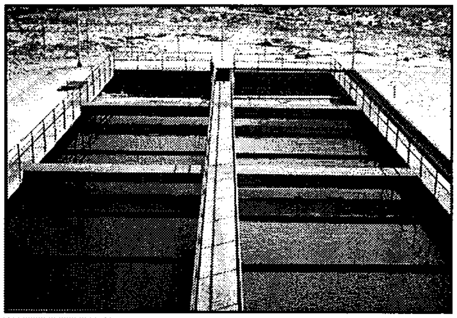


Grit Channels

Grit Channels



Primary Treatment



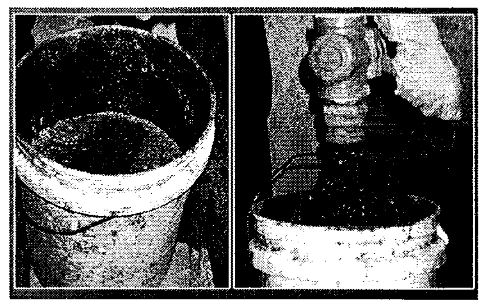
Why Primary Treatment?

- Primary treatment lessens the solids burden on secondary treatment processes
- Trickling filters / RBC's
- Activated sludge processes

Why Primary Treatment?

- Separates the settleable and floatable solids from waste stream

Primary Sludge



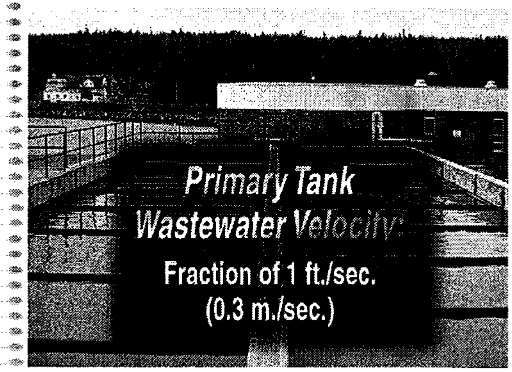
Primary Scum

Primary Removal Stats

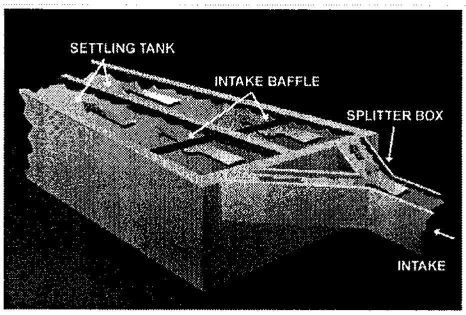
- Primary treatment can achieve 40-60% removal of influent TSS
- 25 –30% of influent BOD

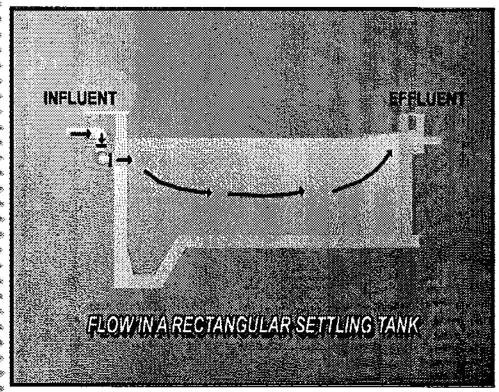
Primary Clarifier Design

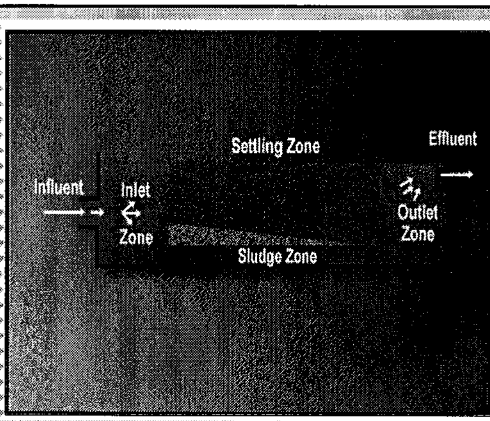
- Primary clarifiers can be rectangular or circular
- Designed to decrease influent flow velocity to allow for solids settling



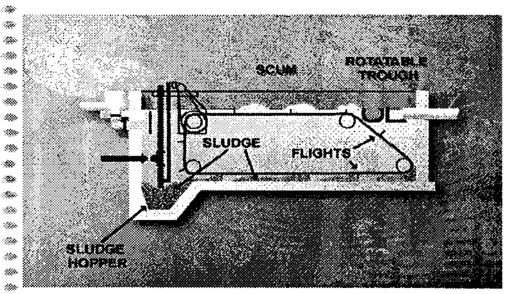
Slow the Flow



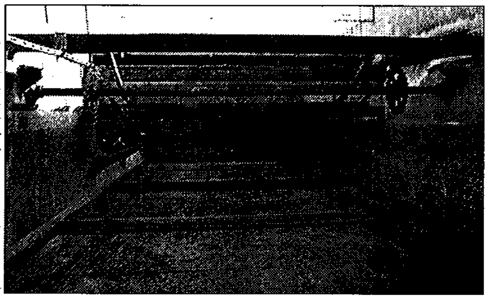




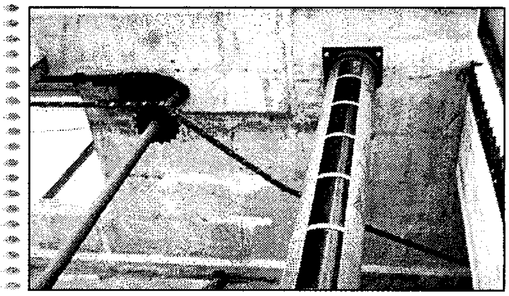
Rectangular Settling Tank



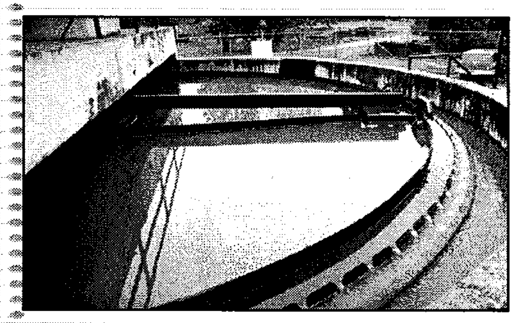
Chains and Flights



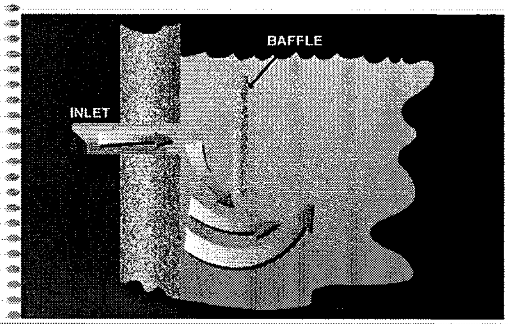
Scum Collection



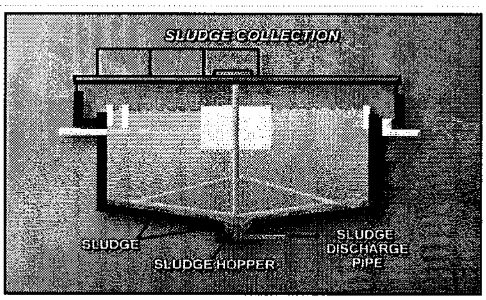
Circular Clarifier



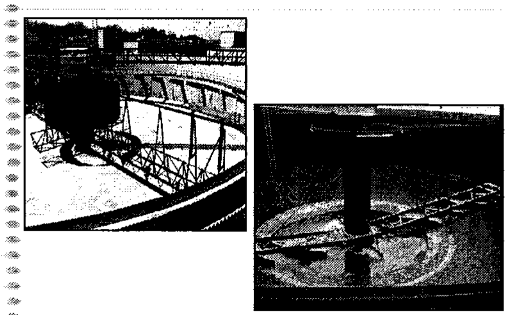
Slow the Flow



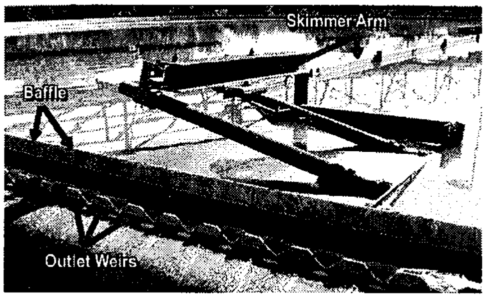
Circular Clarifier



Circular Clarifiers



Scum Collection



Factors Affecting Solids Removal

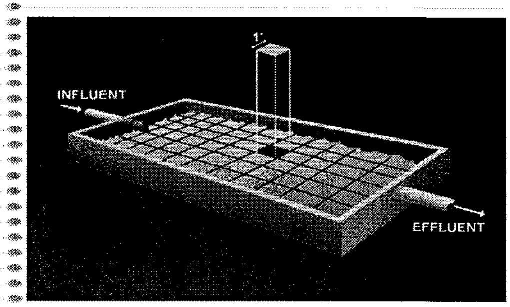
- Surface oveflow rates
- Detention time
- Tank configuration
- Wastewater characteristics
- Industrial contribution
- Temperature
- Particle characteristics

Hydraulic Loading Parameters

Surface Overflow Rate

- Tank surface area governs overflow rate
- Overflow rate varies with flow, since tank sizes are fixed
- Range = 800-1000 gal/ft^2/day

Surface Area, ft^2



Surface Area

$$\text{Surface area, gpd/sq ft} = \frac{\text{flow, gpd}}{\text{tank surface area, sq. ft.}}$$

Detention Time

- Time required for a unit of volume to pass entirely through the tank at a given flow rate.
- Should be sufficient to allow nearly complete removal of settleable solids
- Usually 1 to 2 hours

Detention Time

$$\text{Detention time, hrs} = \frac{\text{tank volume, gal} \times 24 \text{ hours}}{\text{flow, gpd}}$$

Particle Characteristics

- Dense particles settle faster than light ones
- Particles with large surface area:weight ratio settle slowly
- Irregularly shaped particles settle slowly

Temperature

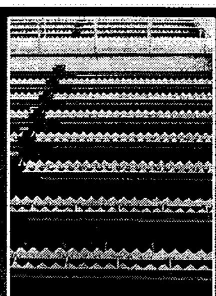
- Warm weather increases rate of biological degredation, increasing gasification
- Low viscosity of warm water tends to speed settling
- Cold temps slow settling

Industrial Wastewater

Industries may contribute:

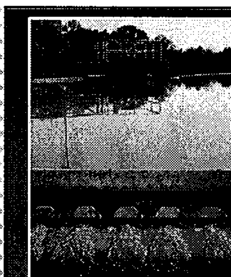
- Large, short term hydraulic surges
- Short term, high organic loading

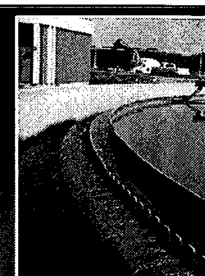
Effluent Weirs



Overflow weirs MUST be perfectly level to ensure good flow distribution and prevent short circuiting.

Effluent Weirs

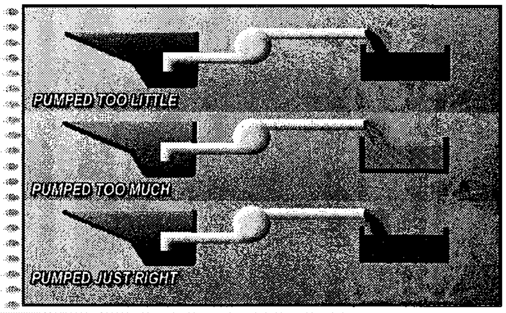




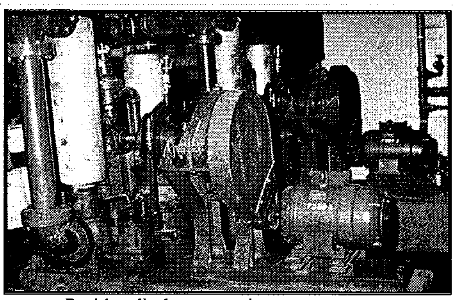
Primary Sludge Pumping

- Primary sludge should be withdrawn frequently, in small amounts
- Poor sludge pumping practice is most common operational error
- Can lead to septic conditions, high solids loading on secondary treatment units

Primary Sludge Pumping

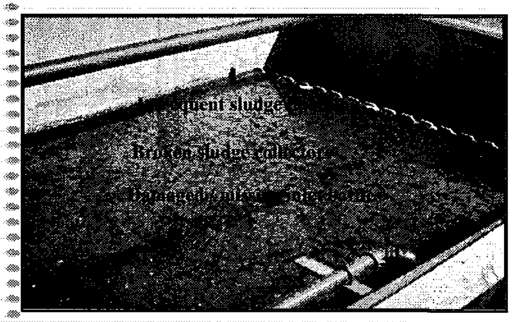


Primary Sludge Pumping



Positive displacement piston pumps

See Any Problems?



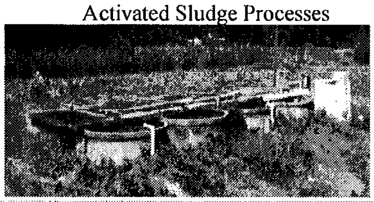
Secondary Treatment

BIOLOGICAL PROCESSES

Rotating Biological Contactors (RBCs)

Trickling Filters

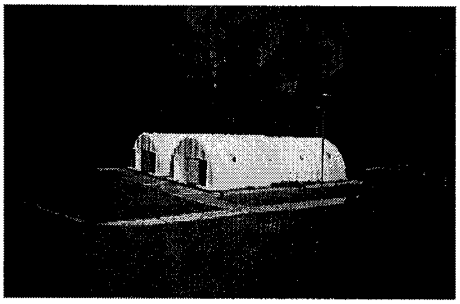
Activated Sludge Processes



RBCs and Trickling Filters

- Rotating Biological Contactors (RBCs) and Trickling Filters use bacteria that grow on media to treat wastewater
- These processes are located after primary clarifiers

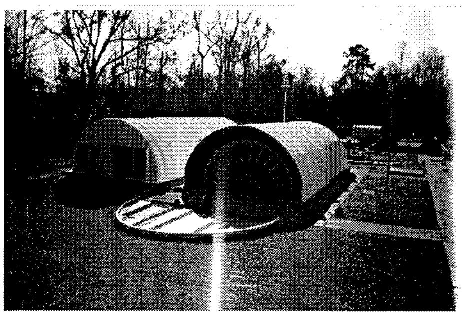
Rotating Biological Contactor



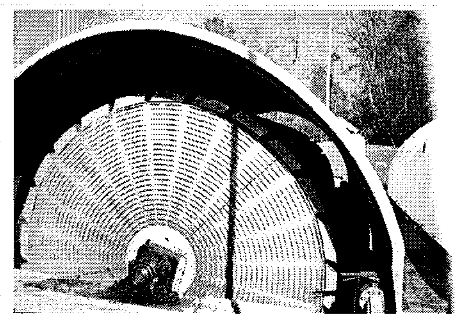
Rotating Biological Contactors

- RBC's can be ran in series or parallel

RBC



RBC



Rotating Biological Contactors

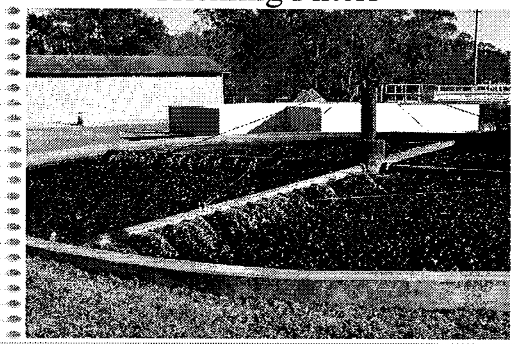
- RBC's are designed to rotate approximately 1 rpm
- D.O. is maintained between 1-3 mg/l

RBC

RBC Media

- Color of biomass growing on RBC media can indicate operating conditions.
  - White media indicates hydrogen sulfide condition.
  - Black media can indicate septic conditions in tank, or high organic loading.

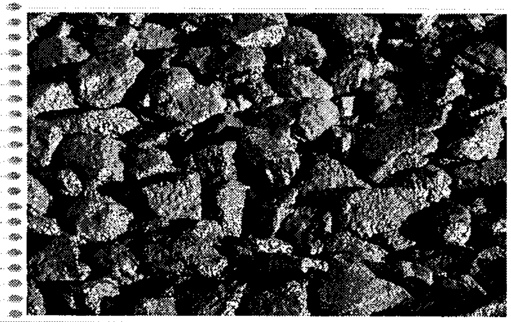
Trickling Filters



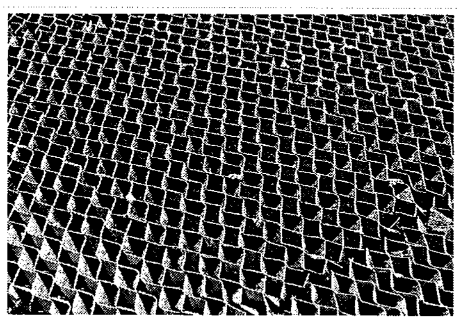
Trickling Filters

- Trickling filters use attached growth to treat wastes.
- Zoogleal (bacteria) growth continuously grows and sloughs off media.
- Sloughings flow to secondary clarifier.

Trickling Filters



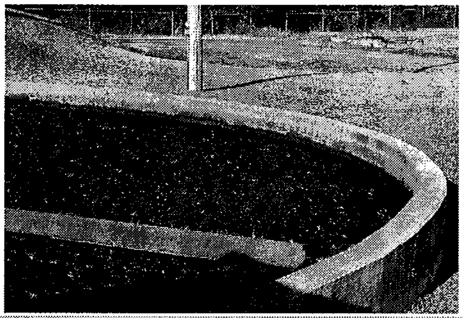
Trickling Filters



Trickling Filters

- Wastewater is collected in underdrains
- Use rotary distributors or fixed nozzle distributors
- Can use rock or plastic media
- Have vents to allow air circulation

Trickling Filters

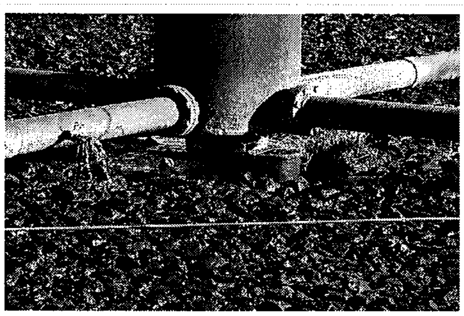


Trickling Filter Problems

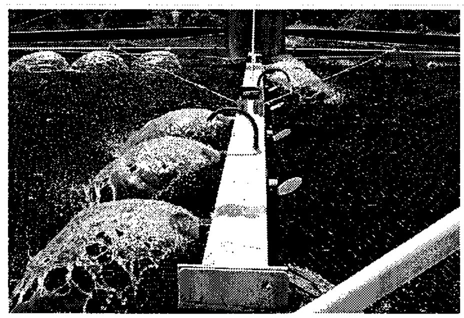
- Ponding
- Filter Flies

Flood the Filter !

Trickling Filters



Trickling Filters



Activated Sludge

Activated Sludge

Most Common

- Conventional
- Complete Mix
- Step Feed
- Contact Stabilization
- Extended Aeration
- Oxidation Ditch

Activated Sludge
Conventional Mode

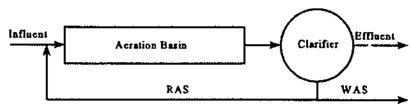


Figure 3-1: Conventional Activated Sludge

Plug flow design; 4-8 hour detention time;
F/M = 0.2-0.5 lb BOD/lb MLVSS;
1000-3000 mg/L MLSS;
5-15 day SRT

Activated Sludge
Complete Mix Mode

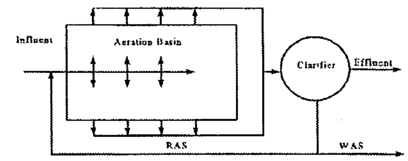


Figure 3-2: Complete Mix Activated Sludge

Not plug flow; 3-5 hour detention time;
F/M = 0.2-0.6 lbs BOD/lb MLVSS;
3000-6000mg/L MLSS; 5-15 day SRT

Activated Sludge
Step Feed Mode

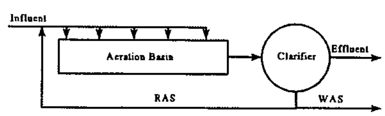


Figure 3-3: Step-feed Activated Sludge

Plug flow; 3-8 hour detention time;
F/M = 0.2-0.5 lbs BOD/lb MLVSS;
2000-3500 mg/L MLSS; 5-15 day SRT

Activated Sludge
Contact Stabilization Mode

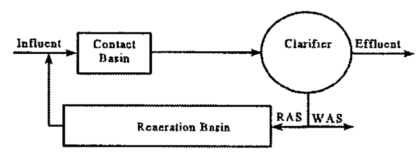


Figure 3-4: Contact Stabilization Activated Sludge

Plug flow pattern; 0.5-1.5 hr Detention time (contact);
F/M = 0.2-0.6 lbs BOD/lb MLVSS;
1000-3000 mg/L MLSS (contact); 5-15 day SRT

Activated Sludge
Extended Aeration Mode

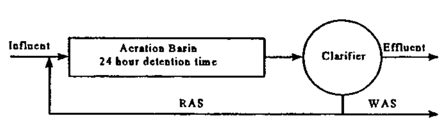
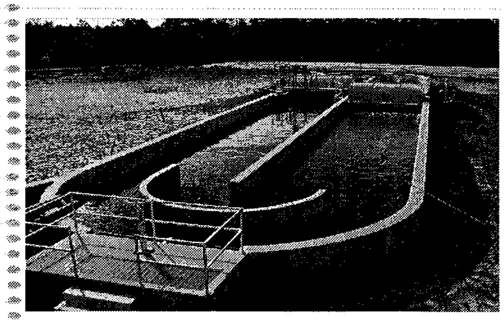


Figure 3-5: Extended Aeration Activated Sludge

Complete mix; 18-30 hour detention time;
F/M = 0.05-0.15 lbs BOD/lb MLVSS;
2000-6000 mg/L MLSS; 20-30 day SRT

Oxidation Ditch

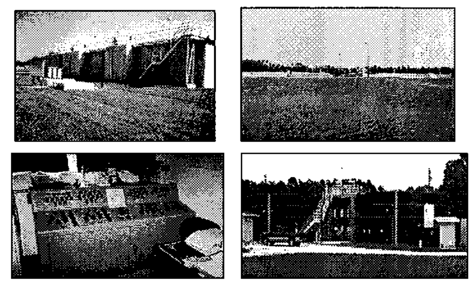


Activated Sludge

Other Modifications:

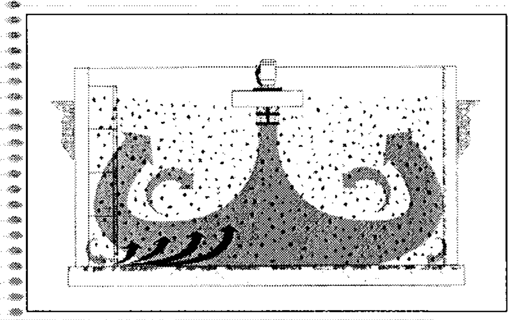
- Kraus Process
- High Rate
- Pure Oxygen
- Ludzack / Ettinger Process
- Wuhrman Process
- Sequencing Batch Reactor (SBR)
- Bardenpho process

SBR's of Today

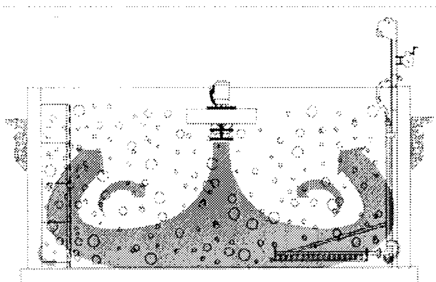


Principles of SBR Operation

Fill Stage



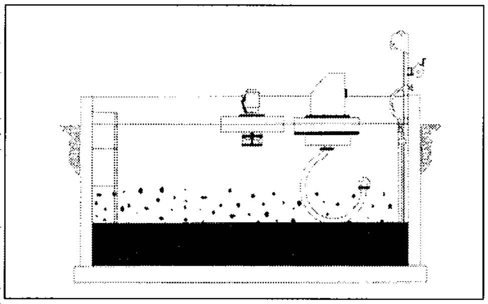
React Stage



React Stage

- Influent flow is terminated
- Mixing and aeration continue
- Intermittent operation of aeration system may continue to complete the nitrification/de-nitrification process or to conserve energy

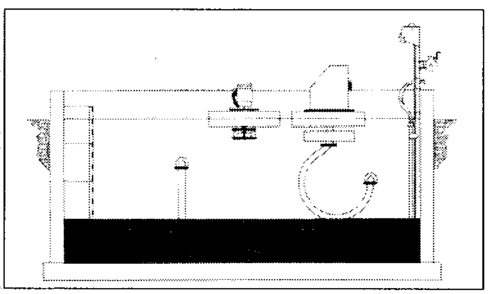
Settle Stage



Settle Stage

- Mixing and aeration cease
- Solids/liquid separation takes place under quiescent conditions

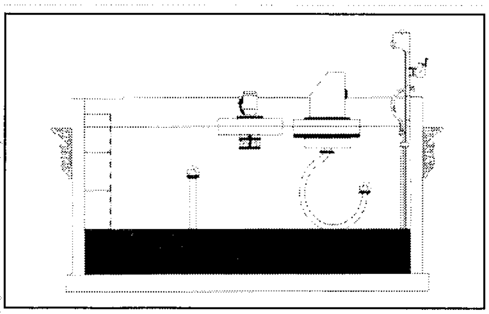
Decant and Sludge Waste



Decant and Sludge Waste

- The mixer and aeration remain off
- The decantable volume is removed by means of subsurface withdrawal
- A small amount of sludge is wasted each cycle
- The reactor is immediately available to receive the next batch of raw influent

Idle Stage

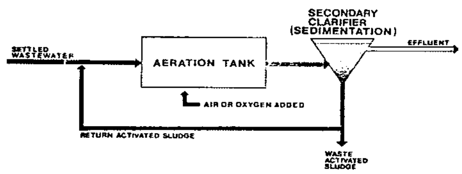


Idle Stage

- Occurs in multi-basin systems anytime that flow conditions are less than peak design flow
- Idle times will vary depending on actual flow conditions

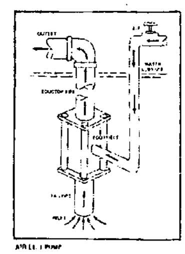
Activated Sludge Control Methods

- Return Activated Sludge (RAS)
- Waste Activated Sludge (WAS)
- Dissolved Oxygen (DO)



Return Activated Sludge (RAS)

- Return microorganisms back to aeration basins from clarifiers
- Constant Rate
- Flow Percentage Rate



Return Sludge Eductor Pipe

- RAS flow can be reduced by rags, thick sludge, sticks, cans, blankets, bicycle rims, tools, bumpers, cinder blocks, buckets, pipes, etc ...

If it can fall into the clarifier, it will clog the RAS piping!

Waste Activated Sludge (WAS)

The most important control of the activated sludge process

It affects the following:

- Effluent Quality
- Microorganism growth rate
- Oxygen uptake rate
- Settleability rates
- Nitrification rates
- Foaming / frothing

Waste Activated Sludge *(Continued)*

- Control Techniques: Constant MLSS/MLVSS F/M ratio, Sludge age (MCRT,SRT)
- Wasting can be intentional or unintentional.
- Wasting can be done from the aeration tank or a portion of the return sludge.
- Make waste changes gradually (10-15% per day) to avoid shock to system.

Dissolved Oxygen Requirements

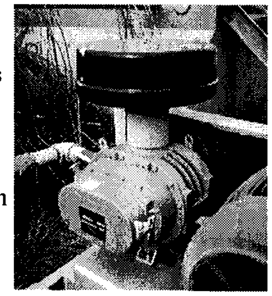
- Aeration serves two purposes:
  1. Provides DO (1-3 mg/l)
  2. Mixes MLSS
- High DO (>5.0) can shear floc, waste energy.
- Low DO (<0.5) can lead to bulking, poor effluent quality.

Dissolved Oxygen Requirements

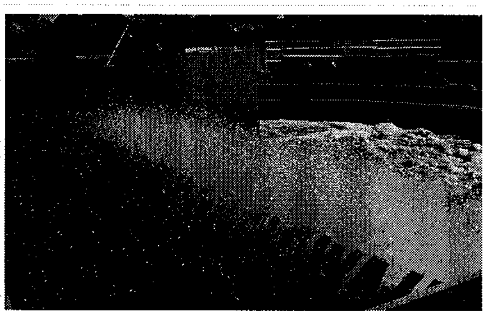
- 1.5 pounds of oxygen are required to convert 1 pound of BOD.
- 4.5 pounds of oxygen are required to convert 1 pound of ammonia.
- 2 approved methods of measuring DO are Winkler method & DO probe.

Aeration Methods

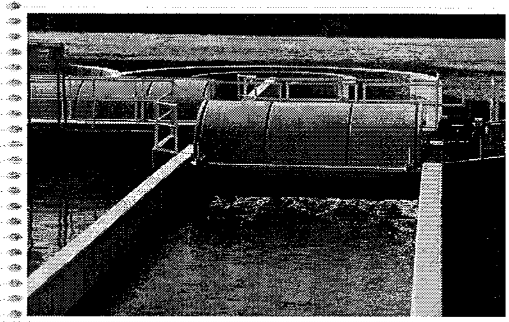
- Compressed air / Diffused aeration
  - Centrifugal blowers
  - Positive displacement blowers
- Mechanical aeration
  - Floating aerator
  - Fixed aerator



Brush rotors

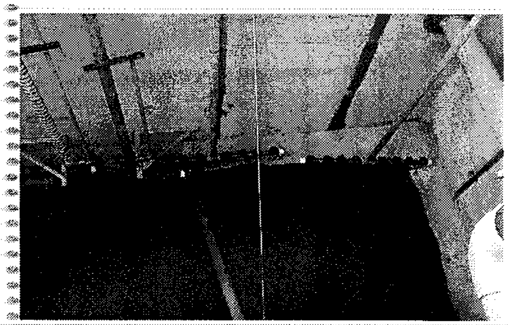


Brush Rotors

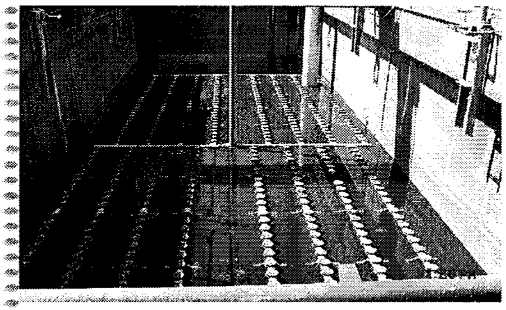


Brush rotors

Diffusers



Diffusers

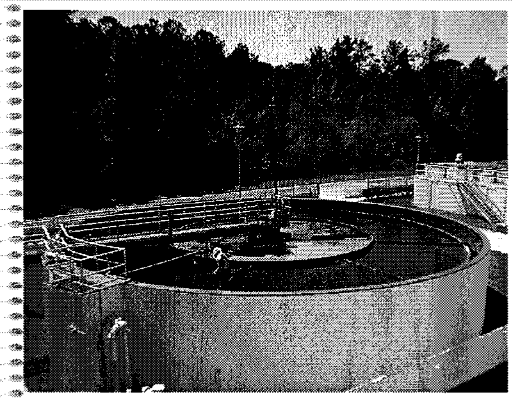


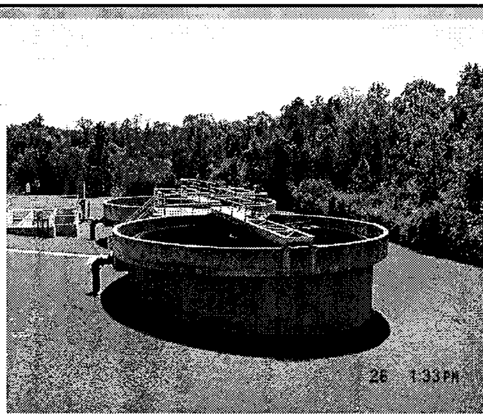
Diffusers

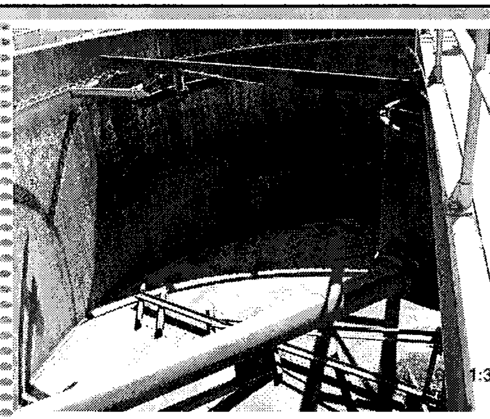
Activated Sludge Secondary Clarifiers

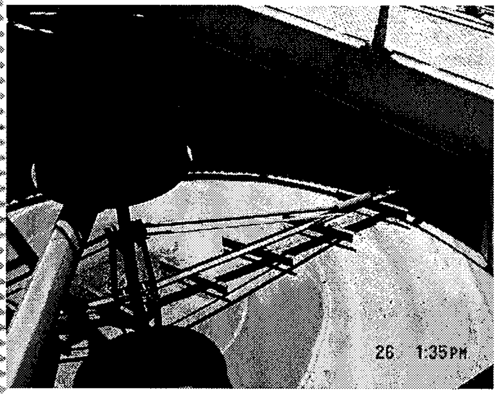
- Typical Loading Rates:
  - Detention Time - 2 to 3 hours
  - Hydraulic loading - 300 to 1200 gpd/sq.ft.
  - Solids loading - 20 to 30 lbs/day/sq.ft.
  - Weir overflow - 5,000 to 15,000 gpd/ft.

These are relative numbers, clarifiers vary between manufacturer and installation. Also, sludge quality changes these parameters.









Secondary Clarifiers *(continued)*

Monitor these parameters:

- Sludge levels (25% of total depth)
- MLSS concentrations
- Return sludge flows
- Turbidity of clarifier effluent
- DO in effluent
- Effluent pH

DISINFECTION

CHLORINE

Disinfection

- Disinfection - destroys pathogenic organisms
- Sterilization - destroys all organisms

Purpose of Disinfection

- Protect human beings and other animals from disease-causing pathogens
- These pathogens will threaten the quality of drinking water supplies, water-contact recreation areas and shellfish-growing areas

Disinfection Agents

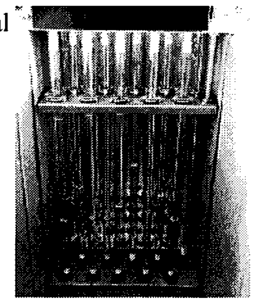
- Heat energy
- Radiant energy – UV
- Chemical Agents

Choosing a Disinfectant

- Process should be
  - economical
  - operationally practical
  - reliable
  - environmentally acceptable

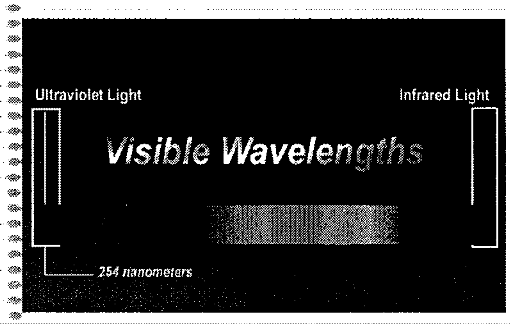
UV Disinfection

- High initial capital costs
- Must have low effluent TSS
- No residual to measure



UV equipment

Light Spectrum

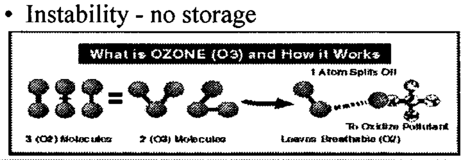


Chemical Agents

- Chlorine Gas or Liquid (Cl_2)
- Sodium or Calcium Hypochlorite
- Ozone (O_3)
- Chlorine Dioxide

Ozone

- Unable to measure residual
- Requires on-site generation
- Utilizes sensitive equipment which requires careful monitoring
- Instability - no storage



Choosing Chlorination

- Relatively low dosages
- Simple feed and control procedures
- Low cost compared to other substances

Chlorine in the United States

- Low cost can be contributed to the large total production of chlorine in the U.S.
- Wastewater facilities use about 5% of total chlorine produced

Chlorine Disadvantages

- Lasting toxic effect on aquatic life
- Toxic effect on human life
- Regulatory agencies placing tightening restrictions on storage and use (Risk management plan req'd for 2500 lbs)

Chlorine

- Liquid/gas chlorine (Cl_2) - pressurized containers that keep the chlorine in a liquid state
- Calcium hypochlorite [$Ca(OCL)_2$] - white powder
- Sodium hypochlorite (bleach) (NaOCL) - a pale yellow liquid

Physical and Chemical Properties

- Under normal atmospheric pressure at room temperature, chlorine is a yellow-green gas
- 2.5 times heavier than air
- Chlorine gas becomes a liquid at - 30° F
- Liquid to gas expansion ratio=460:1

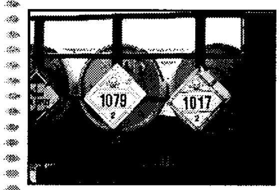
Physical and Chemical Properties

- Dry gaseous or liquid chlorine (less than 150 mg/L moisture) is 100% available chlorine
- Calcium hypochlorite 65 to 75% available chlorine

Physical and Chemical Properties

- Sodium hypochlorite is normally a 15% solution or 15% available chlorine - each 100 mL contain 15 grams of available chlorine or 150 g/L or 150,000 mg/L of available chlorine

Hazard



- Chlorine gas/liquid - extremely hazardous substance
- Calcium hypochlorite and sodium hypochlorite - hazardous substance
- Disinfection agents kill living organisms and tissue

Chlorination Methods

- Gas chlorination
- Liquid chlorination
- Hypochlorination

Chlorination Effectiveness

- Chlorine concentration and type
- Effluent pH
- Effluent temperature
- Contact time
- Effluent suspended solids

Reactions with Water

- When chlorine gas/liquid, sodium hypochlorite or calcium hypochlorite are added to water, hypochlorous (HOCl) or hydrochloric (HCl) acid is formed
- Higher pH makes Cl2 less effective

The Effect of Temperature on Disinfection Efficiency

- Disinfection happens quicker at higher water temperatures.
- However, disinfection strength is reduced at higher temperatures.

Contact Time

- Contact time is in many cases more important than dose
- For basic disinfection the State of Florida requires a minimum total chlorine residual of 0.5 mg/L after 15 minutes contact time at Peak Hourly Flow

Effluent Suspended Solids

- Effluent suspended solids normally consist of small nonsettleable or colloidal solids or settleable solids which have been hydraulically discharged
- Flocs consist of bacteria - some of these bacteria may be in the fecal coliform group or pathogenic
- The disinfectant may not penetrate the floc particle and may result in incomplete disinfection

Chlorine Demand

- Reducing agents (H_2S)
- Organic material
- Inorganic metals - Fe and Mn
- Nitrite (5:1 ratio)
- All react with chlorine and reduce it to the chloride ion
- No chlorine residual is realized

Forms of Chlorine

- Cl_2 existing in forms of hypochlorous acid and hypochlorite ion are defined as *free available chlorine*

Reactions of Hypochlorous acid with Ammonia

NH_3 + HOCl > NH_2Cl (monochloramine) + H_20

NH_2Cl + HOCl > NHCl2 (dichloramine) + H_20

NHCl2 + HOCl > NCl3 (nitrogen trichloride) + H_20

Formation of Combined Chlorine

- Monochloramine (NH_2Cl)
- Dichloramine ($NHCl_2$)
- Trichloramine (NCl_3)

Chlorine Residual

- Free Chlorine - aqueous chlorine, hypochlorite ion and hypochlorous ion
- Combined Chlorine - compounds formed by reactions of hypochlorous acid and ammonia (chloramines)
- Total Chlorine - sum of free and combined chlorine

Chlorine Relationships

- Chlorine Residual =

  Chlorine Dose - Chlorine Demand

Chlorine Demand

- The amount of chlorine that is not available because of side reactions
- The difference between chlorine dosage and chlorine residual

Feed Rate and Dosage

- Feed Rate - lb/day of Cl_2 applied
- Chlorine dose - the amount of chlorine that is added to the effluent
- Chlorine – expressed in mg/L

Chlorine Dosage (mg/L)

- Chlorine Dosage (mg/L) =

$$\frac{\text{Feed Rate (lb/day)}}{\text{Eff Flow, MGD} \times 8.34 \text{ lb/gal}}$$

Typical Chlorine Dosages
Wastewater

- Trickling Filters - 3 to 10 mg/L
- Activated Sludge - 2 to 8 mg/L

Maximum Draw-Off Rates

150 lb cylinders - approximately 40 lbs/day

1-ton containers - approximately 400 lbs/day

- Temperature of remaining chlorine decreases as the rate of withdrawal increases
- When temperature of chlorine is low enough it will not evaporate

Chlorine Use Limit

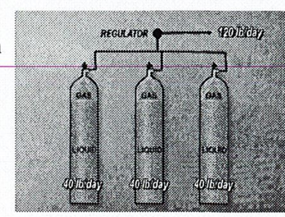
- 40 lb/day from each 150-lb cylinder
- 400 lb/day from each 1-ton container
- Temperature of remaining chlorine decreases as the rate of withdrawal increases
- When temperature of chlorine is low enough it will not evaporate

What happens when we try to feed more than these limits

CHLORINE ICING

Prevent Chlorine Icing

- When attempting to feed more than the allowable amount from any container, manifolding is required



Checks on Effectiveness

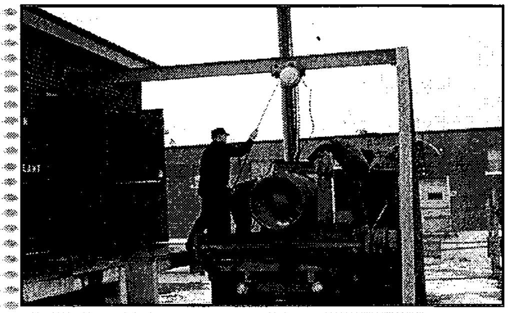
- Chlorine residual analysis - residual after a minimum contact time (i.e. for basic disinfection, 0.5 mg/L total chlorine residual after 15 minutes contact time at peak hourly flow)
- Concentration of Fecal Coliform Organisms
  - MPN -most probable number method
  - MF -membrane filter method

Effect on Treatment

- Disinfection
- Oxidizes solids further reducing BOD
- Oxidation of ammonia-N

A Look at Chlorine Equipment

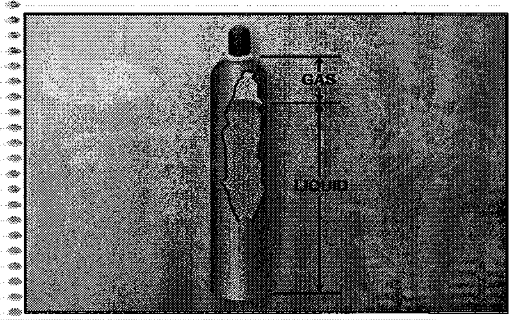
Hoisting a 1-Ton Container



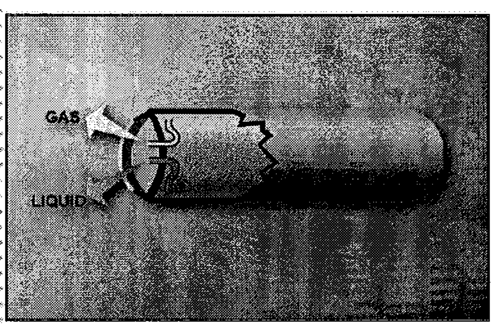
Chlorine Cylinders

- Fusible Plugs—designed to melt at 158-165 deg F.
- 6 Plugs on a ton cylinder
- 1 on a 150 lb cylinder

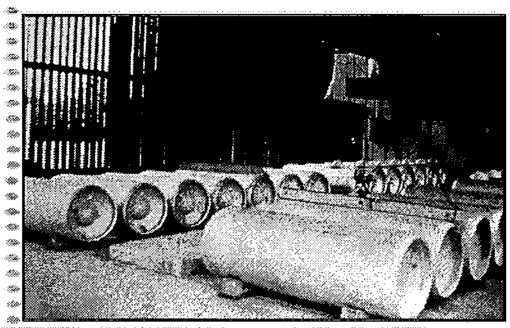
150 lb Chlorine Container



1-Ton Chlorine Container



Ton Container Storage

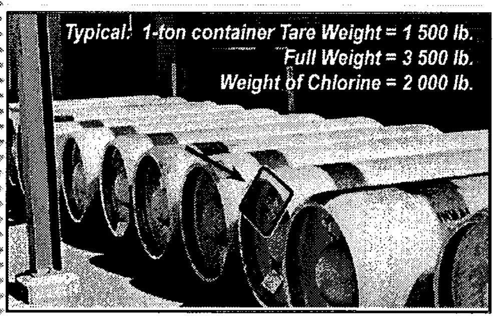


Chlorine Storage

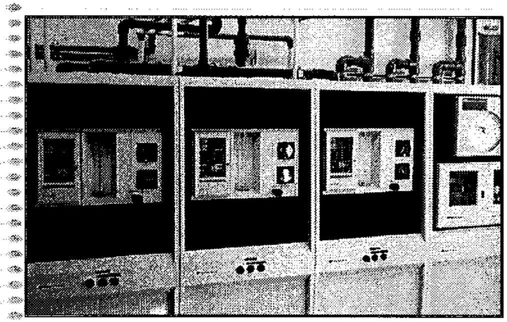
- Storage is limited to 2500 pounds at one site
- If exceeded a Risk Management Plan is required

Manifolding More Than One

Chlorine Weights



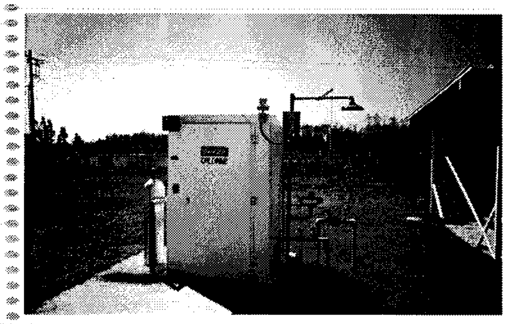
Chlorine Feed Equipment



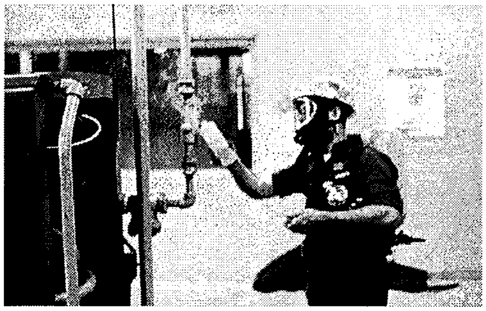
Disinfection Systems

Safety Hazards

Chlorine Safety



Detecting a Chlorine Leak

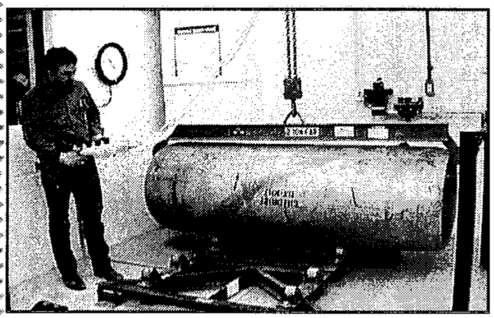


Effects of Chlorine on Humans

- Chlorine Concentrations

- 1 mg/l considered health haz
  2-3 mg/L detectable by smell
  25 mg/l immediate life hazzard
- 1000 mg/l rapidly kills

Safe Handling of 1-Tons



Understanding Activated Sludge Parameter Relationships

A look at how process parameters work together

Exam Preparation

- Important to know and understand how these parameters relate
- Applies to everyday operation of WWTP
- Simplifies troubleshooting

Floc Particles

- *Straggler floc*: As seen in settleometer or clarifier, about the size of half your pinky fingernail.
- Suspended, slow settling
- Large, irregularly-shaped, fluffy
- Young Sludge

Floc Particles

- *Pin-Floc:* As seen in settleometer or clarifier, small particles, about the size of a pin head.
- Leaves a turbid, cloudy appearance
- Sludge settles rapidly, rounded shape, grainy appearance
- Old Sludge

Foam Characteristics

- Young: White foam produced from low MLSS
- White, billowy, sudsy, crisp
- Large amounts of surfactants, plant start-up

Foam Characteristics

- Old: Dark foam produced from high MLSS
- Shiny, dark tan
- Dark and leathery as sludge gets older.
- Influent oil and grease contribute.

Indicator Organisms (bugs)

- Young: Amoebae and Flagellates
- Old: Rotifers and Worms
- Predominance of these bugs depends on sludge age

MLSS

- Young Sludge: Low mixed liquor
- Reasons
  - Plant start-up
  - Excessive solids washout
  - Excessive wasting
- Solutions
  - Stop or decrease waste rate
  - Control hydraulics through plant

MLSS

- Old Sludge: High mixed liquor
- Reasons
  - Poor sludge wasting practices
  - High organic and solids loading
- Solutions
  - Increase wasting
  - Haul sludge more frequently

Sludge Age / MCRT

- When MLSS is low, sludge age is young
- Reasons
  - Plant start-up
  - Solids washout
  - Excessive wasting
- Solutions
  - Slow or stop wasting

Sludge Age / MCRT

- When MLSS is high, sludge age is old
- Reasons
  - Poor wasting practices
  - Limited digester capacity
  - High organic/solids loading
- Solutions
  - Increase wasting

F/M Ratio

Amount of food, in pounds, available to a pound of MLVSS (bugs)

- High: Young Sludge
- Lots of food (CBOD) per pound of MLVSS (bugs)

F/M Ratio

Amount of food, in pounds, available to a pound of MLVSS (bugs)

- Low: Old sludge
- Limited amount of food (CBOD) per pound of MLVSS (bugs)

Sludge Volume Index (SVI)

- Young: High SVI (>300)
- Reasons
  - Plant start-up
  - Low MLSS
  - Excessive wasting
  - Solids washout

Sludge Volume Index (SVI)

- Old: Low SVI (<80)
- Reasons
  - Rapid-settling sludge
  - Small grainy particles

Sludge Settleability

- Young sludge: Slow settling
- Reasons
  - Supernate may be cloudy
  - Leaving stragglers
- Solutions
  - Reduce waste rate

Sludge Settleability

- Old sludge: Fast settling
- Supernate may be cloudy with pin point floc suspended
- Rapid settling leaves small stuff behind
- Increase sludge waste rate

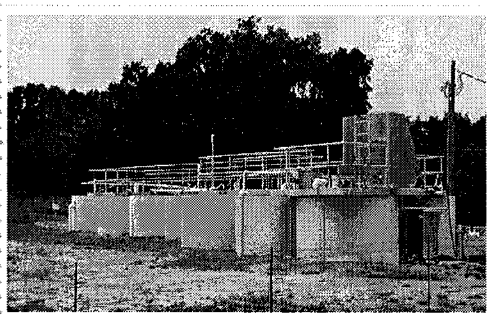
Waste Activated Sludge (WAS)

- The key to controlling the activated sludge process
- Most facilities don't waste sludge properly

One more

- One of the most common causes of repeated sludge bulking is a high F/M ratio, low sludge age
- What waste rate change would you make?

Activated Sludge Troubleshooting



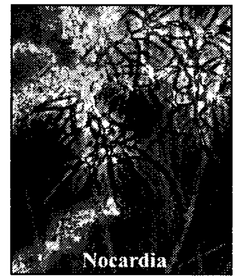
Typical Activated Sludge Problems

- Foams
- Excessive effluent suspended solids
- Excessive effluent BOD/NH_3
- Low effluent pH

Foam

Foaming Organisms

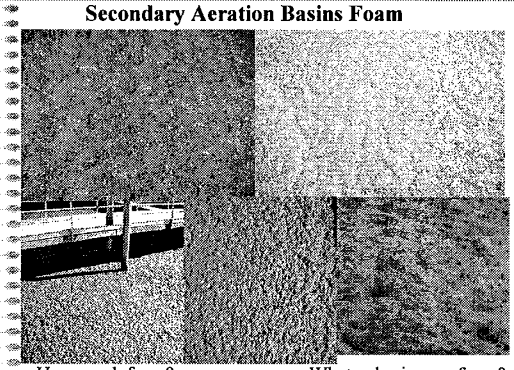
- Nocardia is hydrophobic and difficult to get rid of!
- Nocardia is the most common *SHORT* filament



Foam Types

- Pumice-like foam
  - Solids return from sludge processing
- Gray, thick, slimy foam
  - Nutrient deficiency
- Dark brown, thick, scummy foam
  - Old sludge, Nocardia

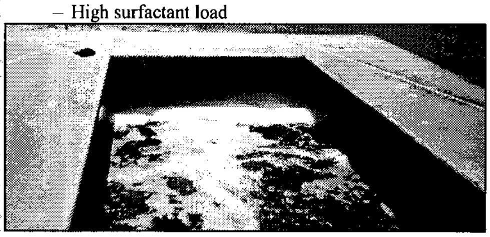
Secondary Aeration Basins Foam



How much foam? What color is your foam?

Foam Types

- Billowy white foam – Young Sludge
  - Plant start up
  - High surfactant load



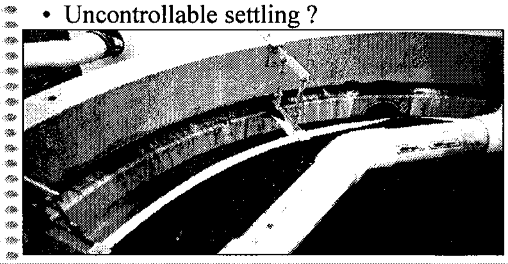
Foam Types

- Dark Brown, 'leathery' thick scummy foam
- High MCRT, low F/M Ratio, high MLSS
- Old sludge

Excess Effluent TSS

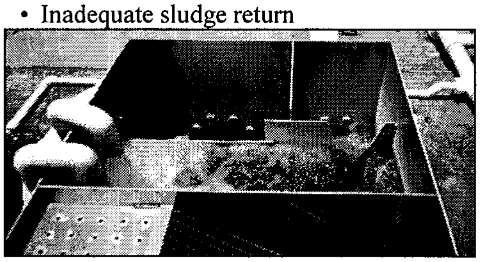
Blanket Washout

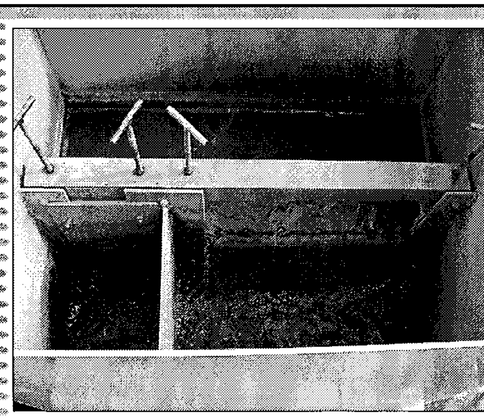
- Controllable settling ?
- Uncontrollable settling ?



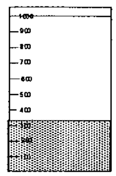
Controllable Settling

- Hydraulic overload
- Inadequate sludge return





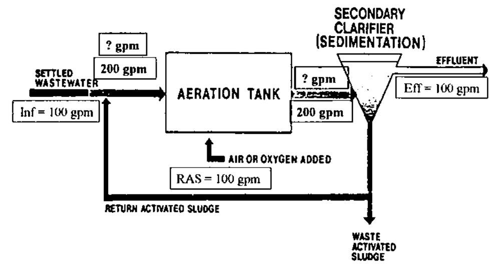
Controllable Settling



100 % MLSS

Good settling in an undiluted sample, but washout in clarifier, indicates hydraulic overload.

Controllable Settling

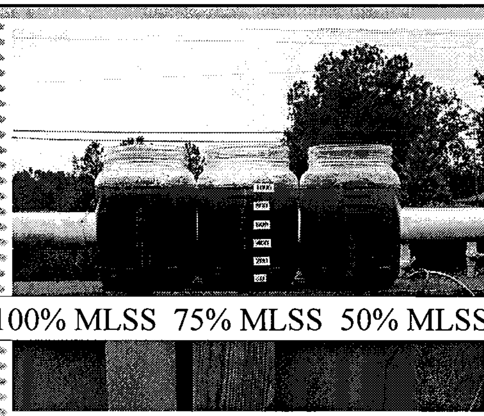


Diluted Settleability

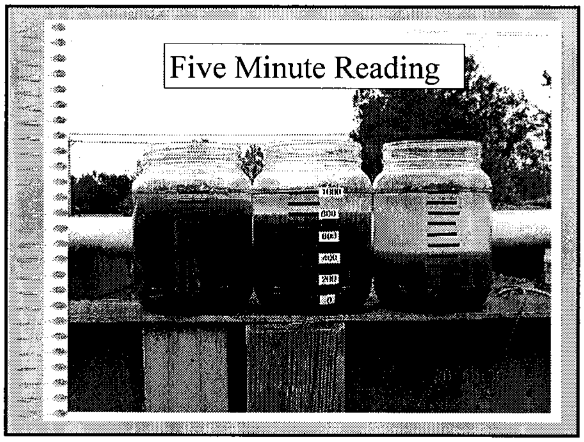
- A modification of the settleability test
- Uses different dilutions to simulate how sludge would settle if some of the solids were wasted

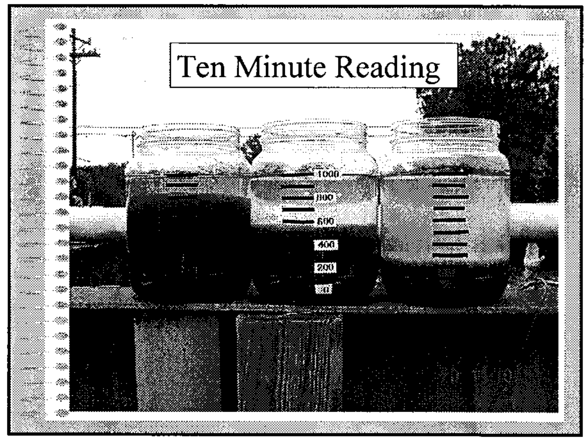
Diluted Settleability

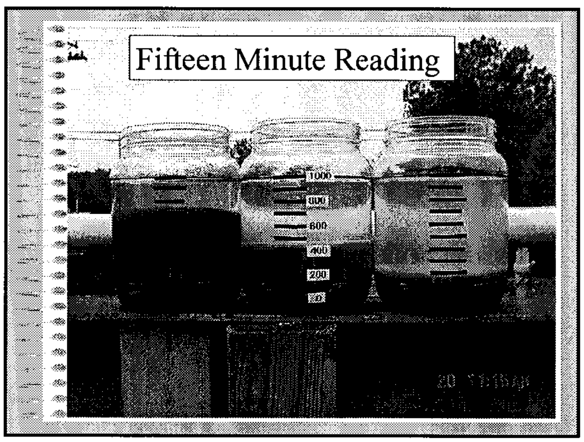
- Use clarifier effluent water for dilutions
- Don't use the garden hose laying at the plant for dilution water
- Keep conditions consistent with actual operation

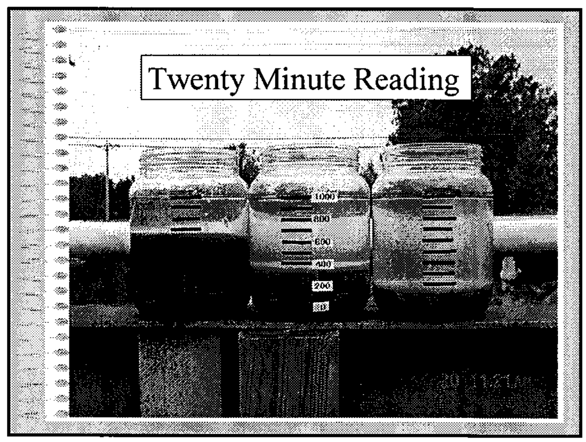


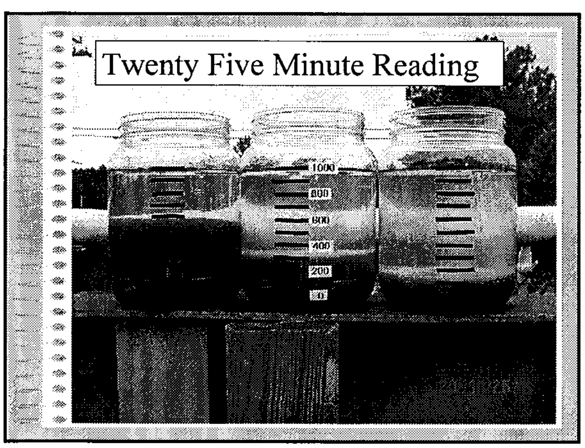
100% MLSS 75% MLSS 50% MLSS

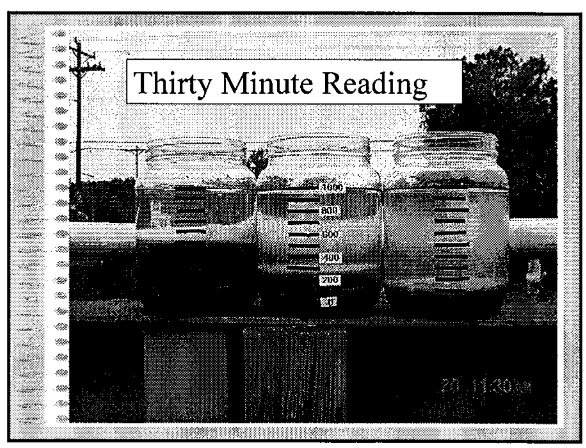

Five Minute Reading


Ten Minute Reading

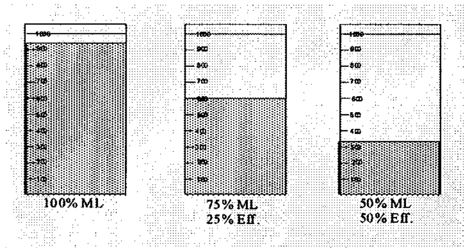

Fifteen Minute Reading


Twenty Minute Reading


Twenty Five Minute Reading


Thirty Minute Reading

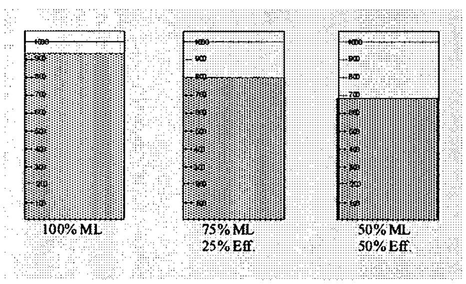
Good Settling with Diluted Settleometer



Good Settling with Diluted Settleometer

- Excess old sludge
- Glutted system
- Increase waste rates

Poor Settling with Diluted Settleometer



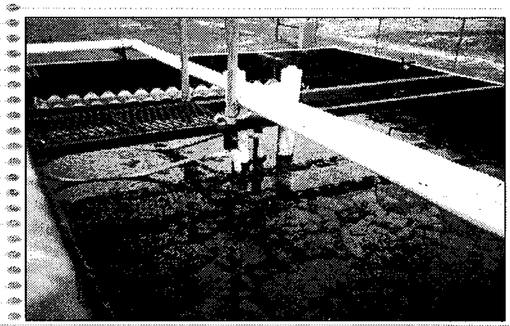
Poor Settling with Diluted Settleometer

- Slime Bulking
- Filamentous sludge (True Bulking)

Excess Effluent TSS

- Pop ups can wash out over weirs
- Reasons
  - Denitrification in clarifier
  - Septic sludge in clarifier

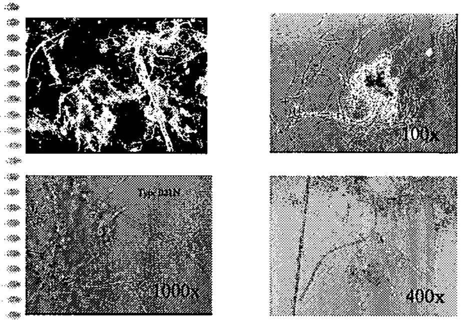
Excess Effluent TSS



Filamentous

- Low DO
- Low F/M
- Nutrient deficiency
- Sulfides
- Readily metabolized substrate
- Slowly metabolized substrate
- Surface seeding

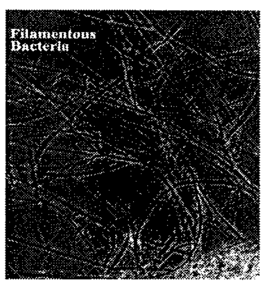
Magnification



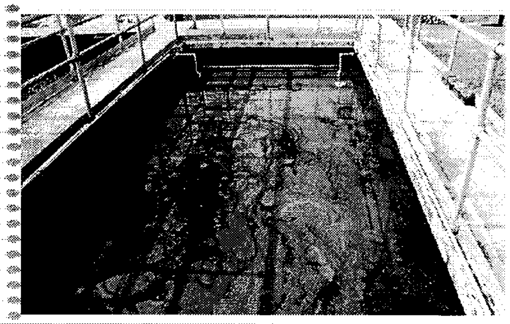
Filamentous

Low DO promotes low DO filaments:

1) Type 1701
2) *S. Natans*
3) *H. Hydrossis*
4) *M. Parvicella*



Individual Particle Washout



Individual Particle Washout

- Pin-floc
- Straggler floc
- Individual bacterial cells

Pin-floc

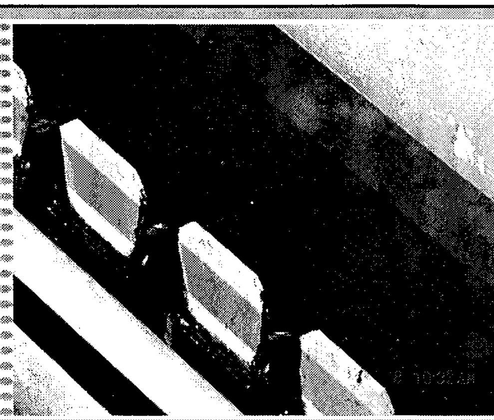
- High MCRT / Low F/M Ratio
  - Highly underloaded plant
  - Clarifier denitrification
- Solids recycle from solids processing
- Very small particles, about the size of a pin head

Pin-floc

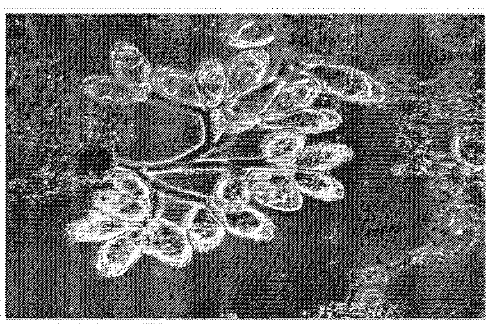
- Pin floc can lead to 'ashing' on the surface of clarifiers
- MLSS getting high, sludge getting old
- Increase wasting

Straggler Floc

- Associated with Low MCRT or High F/M Ratio
- Filamentous
- Non-filamentous
- Larger particles, about the size of a half fingernail

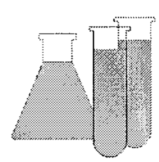


How Does Your WWTP Work?



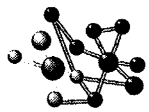
Chemical Requirement for Treatment

- DO, NO_3
- pH
- Alkalinity
- Nutrients



Nutrients

- Carbon
- Nitrogen
- Phosphorus
- Trace minerals



Ratio

BOD: Nitrogen: Phosphorus: Iron

100: 5: 1: 0.5

Types of Bugs, Critters & Microorganisms in *your* WWTP

- Bacteria
- Protozoa
- Metazoa
- Algae
- Fleas?
- Bears?!?

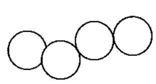
Bacteria:

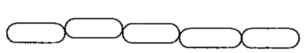
The Workhorses of Treatment

- Floc-forming (stick together)
- Filamentous (backbone of floc)
- Heterotrophic (utilize *organic* carbon)
- Autotrophic (utilize *inorganic* carbon)
- Aerobic (free dissolved oxygen)
- Anaerobic (anoxic and fermentation)
- Facultative (free DO or bound Oxygen - NO_3, SO_4)

Floc-Forming

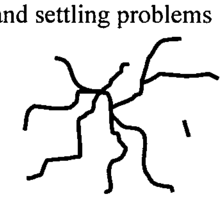
- Non-filamentous bacteria that stick together





Filamentous Bacteria

- Form backbone of good floc
- Excessive filaments can cause a bulking sludge and settling problems



Heterotrophic Bacteria

- Carbon source is organic – BOD
- Fast growing under proper conditions
- Facultative - function with free DO or bound oxygen (NO_3, SO_4)

Autotrophic Bacteria

- Carbon source is inorganic - carbonate and carbon dioxide
- Slow growing
- Require O_2 as an electron acceptor

Environments

- Aerobic - Free dissolved oxygen present
- Anoxic - No free dissolved oxygen present, but nitrate present
- Anaerobic - No free dissolved oxygen or nitrate present

Facultative Bacteria

- Can reproduce under aerobic or anoxic conditions
- Can utilize free dissolved oxygen or bound oxygen (nitrate)
- Will utilize free dissolved oxygen first

The Indicator Organisms

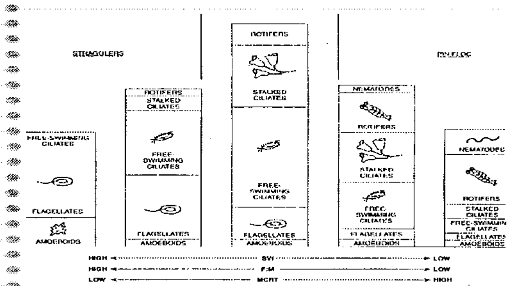


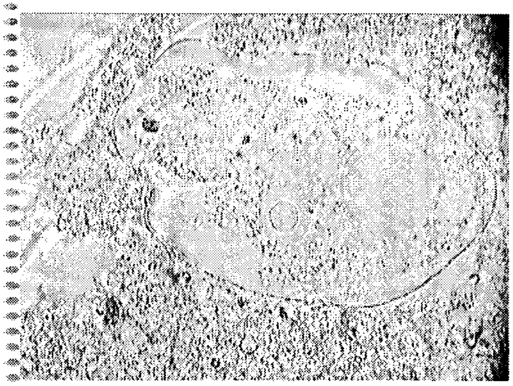
Fig 11.38 Population predominance vs. operational guidelines (Bar graph taken from EPA PROCESS CONTROL MANUAL FOR AEROBIC BIOLOGICAL WASTEWATER TREATMENT FACILITIES 1977)

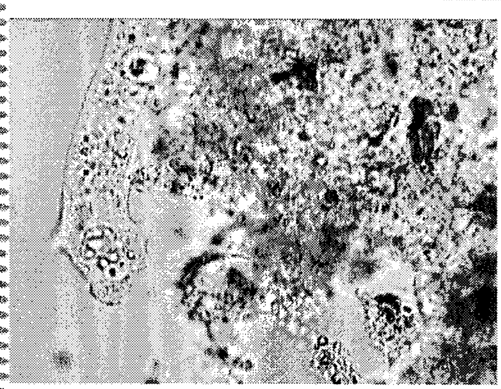
Indicator Organisms

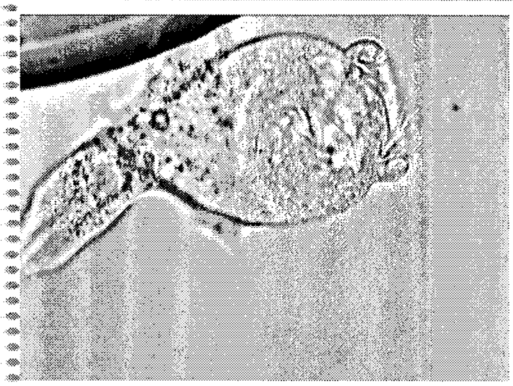
- While bacteria are performing the actual work of BOD and TSS reduction, we use certain protozoans as *indicators* to determine the degree of treatment.
  - Amoebae
  - Flagellates
  - Free Swimming Ciliates
  - Stalked Ciliates
  - Suctoria

Amoebae

- No distinct shape, since flow of cytoplasm continually changes shape
- Feed on bacteria and protozoa
- Found during plant start-up or toxic overload
- Poor biomass health when amoeba predominate
- Indicate young sludge

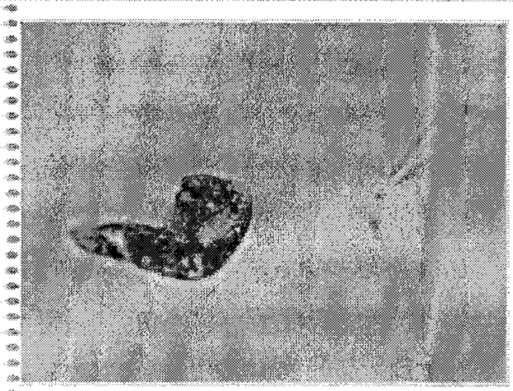






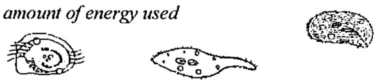
Flagellated Protozoa

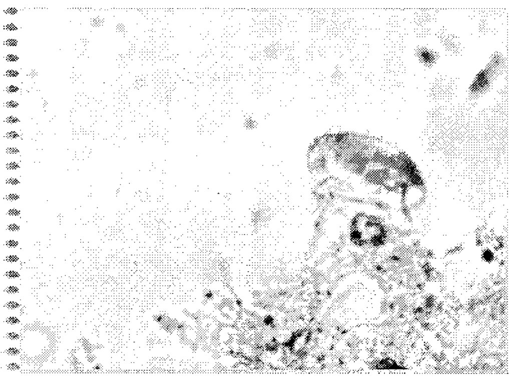
- Use a flagellum (whip-like tail) for locomotion
- Present during start-up or plant upset
- Feed on specific strains of bacteria
- Indicate young sludge
- High energy requirement
- Elevated CBOD in effluent

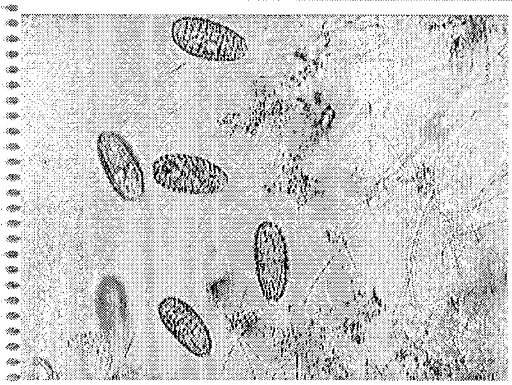


Free Swimming Ciliates

- Present during start-up or plant upset
- Bulk Liquid - *Have large 'mouths' to collect food in liquid, high energy requirements, higher BOD*
- Crawler - *Smaller 'mouths', crawls over floc to scrape bacteria off, less energy required, decreasing BOD*
- Carnivorous - *BOD limited, specialized diets, least amount of energy used*



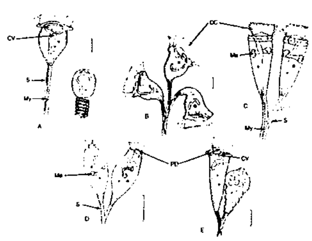




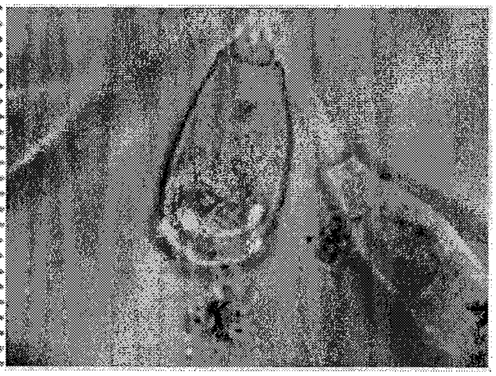
Stalked Ciliates

- Inverted bell shaped bodies mounted on a stalk which is attached to a substratum
- Conspicuous oral ciliiation located in the oral region of the body
- Low energy requirements, BOD reduced, improves effluent quality

Stalked Ciliates

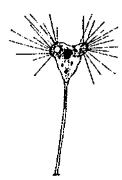


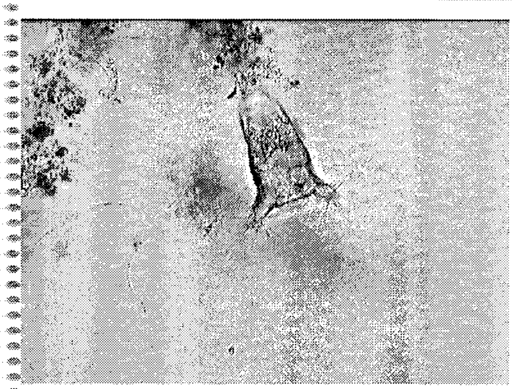
A Vorticella
B Carchesium
C Zoothanmium
D Opercularia
E Epistylis

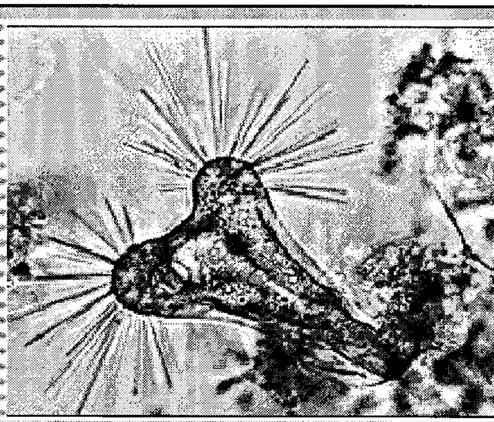


Suctoria

- Carnivorous protozoa
- Has hollow tentacles
- Feeds on small protozoa and bacteria
- Remains motionless
- Little energy exerted







Metazoa

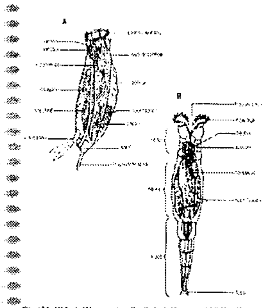
As with the protozoans, we use these Metazoans to indicate process stability and age.

- Rotifer
- Nematode
- Copepod
- Water mites
- Ostracod (seed shrimp)
- Tardigrade (water bear)
- Water fleas (Ceriodaphnia)
- Annelid (bristle worm)

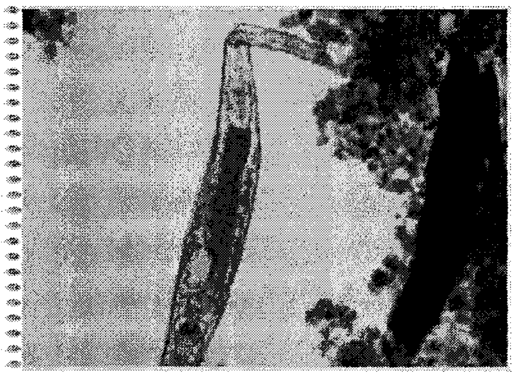
Rotifers

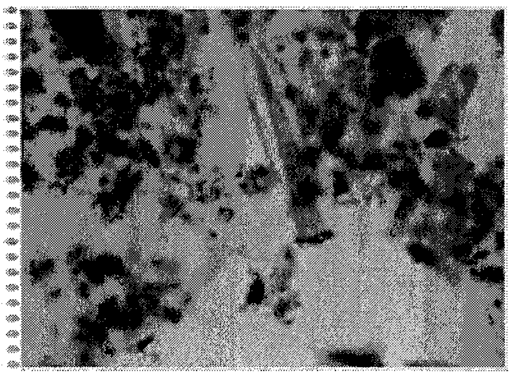
- Feed on bacteria and small protozoans
- Cilia on head resemble wheels
- Help keep bacterial population healthy
- Secrete mucus which aids in floc formation
- Strict aerobes
- Indicate process stability

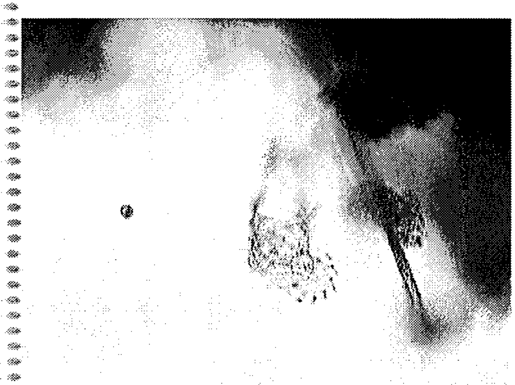
Rotifers



- The phylum Rotifera is divided into two classes:
  - Monogononta
  - Digononta
- Rotifers range in size from 40 to 500 microns and have an average life of 6 to 45 days

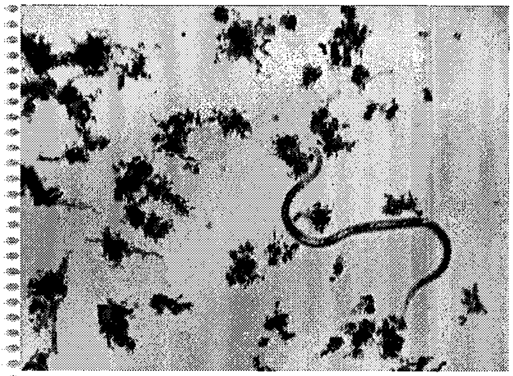






Nematodes

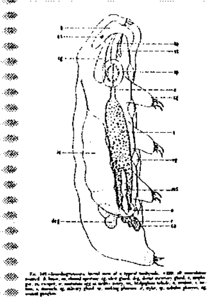
- Infest soils
- Common in trickling filters and RBC's
- Indicate old, over-oxidized sludge
- Will eat protozoans, rotifers and decaying plant and animal matter
- Whip-like motion may cause floc to break-up



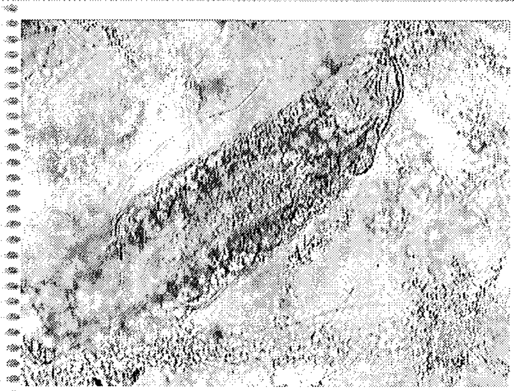
Tardigrades (Water Bears)

- Uncommon in most activated sludge systems
- Common in extended aeration systems
- Shed skin several times during lifetime
- Very sensitive to ammonia and other toxic substances
- Indicate a stable, well nitrified effluent

Tardigrades (Water Bears)

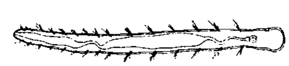


- Tardigrades are preyed upon by amoeboid protozoans, nematodes and each other.
- They have been discovered in lake bottoms 100 meters deep to mountain tops 6,000 meters high.



Annelids (Aeolosoma Worms)

- AKA Bristleworms
  - These aquatic earthworms feed on about anything including the MLSS solids used for secondary treatment. These can sometimes be seen as a red tint laying on the surface of the sludge blanket in a settleometer.

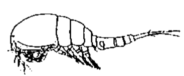


Other Metozoans

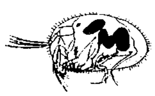
- Some other types of Metozoans are:
  - Ostracods
  - Copepods

  Water Mites
  Water Fleas
- These organisms are rare in activated sludge systems, but may be found in lagoon systems. If found in your system, they would indicate a stabile, non-toxic environment.

Other Metozoans



Copepod



Ostracod

Ceriodaphnia

How Do The Bacteria Eat?

- Adsorption
- Absorption
- Exocellular Digestion

Adsorption/Absorption

- Adsorption
  - Organisms contact and stick to food particles.
- Absorption
  - Dissolved nutrients are brought into the cell
  - Used for various growth and reproductive activities

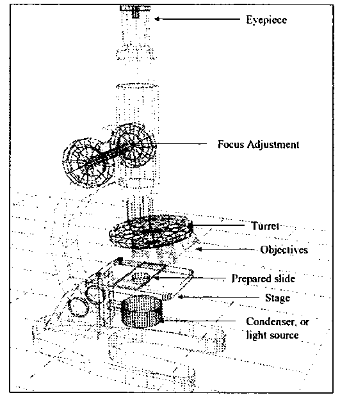
Exocellular Digestion

- Exocellular Digestion
  - Organisms secrete enzymes though cell walls
  - Enzymes begin dissolving the adsorped food
  - These enzymes aid in floc formation

Microscopes

Types of microscopes:

- Compound
- Dark field
- Phase Contrast
- Interference contrast
- Electron
- Fluorescent microscopy



Summary Q & A

- Who are the "workhorses of treatment"?
  - *Bacteria*
- We call protozoans "_____" organisms.
  - *Indicator*
- What organism has hollow tentacles?
  - *Suctoria*
- What is the "wheeled animal"?
  - *Rotifer*

Summary Q & A

- Organisms contact and stick to food particles by ______. *Adsorption*
- Enzymes producing and secreting to breakdown food particles is called ______? *Exocellular Digestion*
- Dissolved nutrients are brought into cell by ______. *Absorption*

Sludge Digestion

Principles of Operation

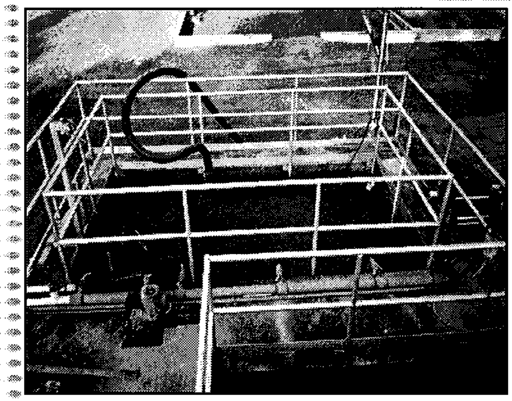
Troubleshooting and Correcting Problems

Purposes of Digestion

- Protect public health and the environment
  - Primary and secondary sludge both contain large amounts of biodegradable material, which must be stabilized before final disposal.
  - Digestion stabilizes biodegradable solids concentrated from wastewater.

Purposes of Digestion

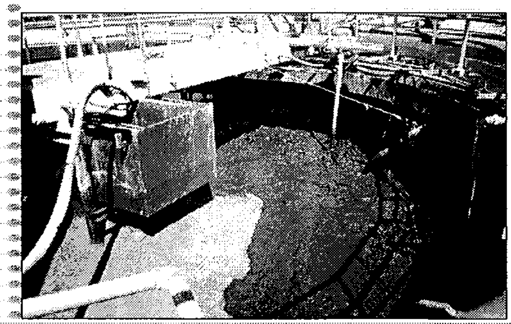
- Protect public health and the environment *(continued)*
  - Reduces possibility of sludge becoming a food source and breeding ground for disease-causing insects and rodents (vectors).
  - Makes sludge relatively inert, reduces odor and bacteria.



Purposes of Digestion

- Reduces cost of disposal
  - Digestion reduces volume and weight of sludge

Aerobic Sludge Digestion



Aerobic Sludge Digestion

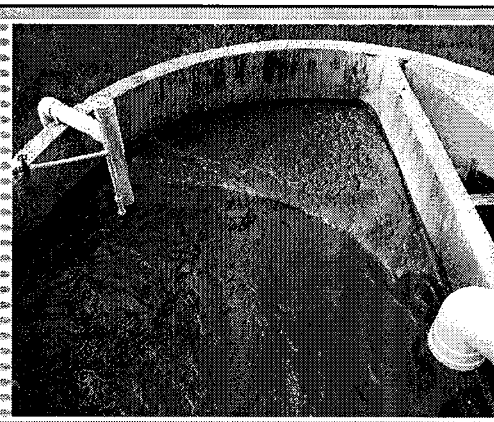
- Operates under Endogenous Respiration principle, similar to extended aeration.
- Sludge is aerated until volatile suspended solids are reduced to stable level, readily dewaters and does not create nuisance odors.
- "Digests" waste activated sludge, primary sludge and clarifier skimmings.

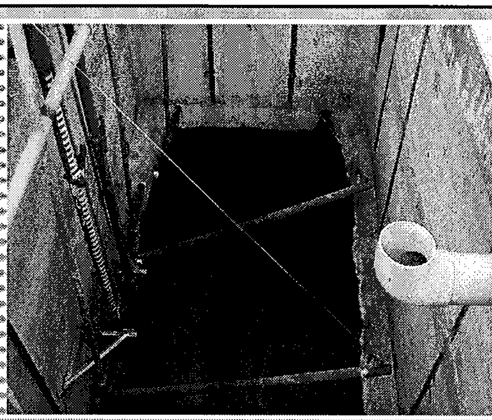
Aerobic Sludge Digestion

- Most common method of sludge digestion in Florida
- Low operating costs, easy operation
- No special training required by operators

Aerobic Sludge Digestion

- Supernating / Decanting
  - Aeration is ceased, sludge allowed to settle
  - Clear liquid (supernate) is drawn off, sent to aeration tank or head of plant
  - Aeration is restarted
  - Waste more sludge
  - Repeat process



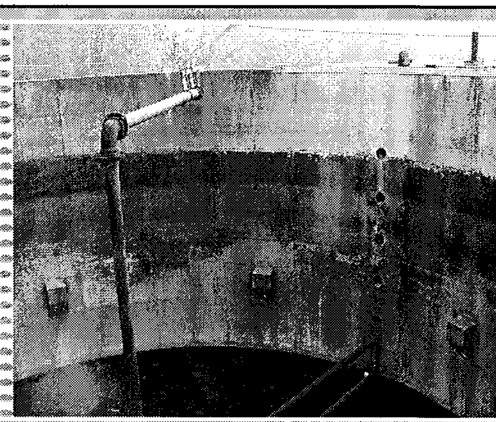


Aerobic Sludge Digestion

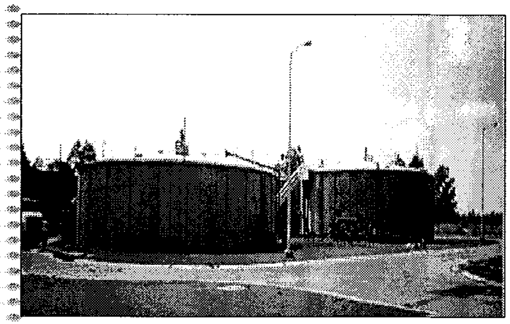
- Operational Controls
  - DO should be maintained at 1.0 to 2.0 mg/L
  - pH should be around 7.0
  - Monitor waste sludge flow and digested sludge withdrawal rates

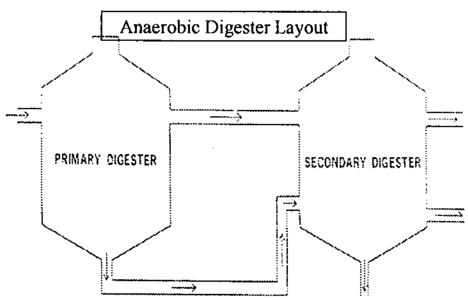
Aerobic Sludge Digestion

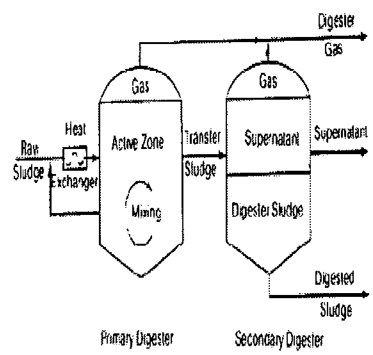
- Operational Concerns
  - Supernatant is usually high in nitrate.
    - Return aerobic digester supernatant during day time flow
  - A drop in digester pH usually indicates an increase in nitrification.
  - May be accompanied by large amounts of foaming and high DO levels.
    - Try reducing DO in digester, and/or add lime or sodium hydroxide to raise pH.



Anaerobic Sludge Digestion







Anaerobic Sludge Digestion

A multistage process

- Anaerobic digestion is accomplished in two stages …

Stage One

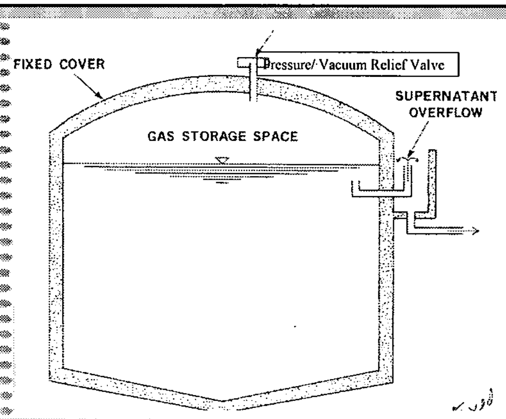
- Complex organics, cellulose, proteins and lipids are broken down into soluble (liquid) forms.
- These forms include organic fatty acids, alcohols, carbon dioxide and ammonia.

Stage One

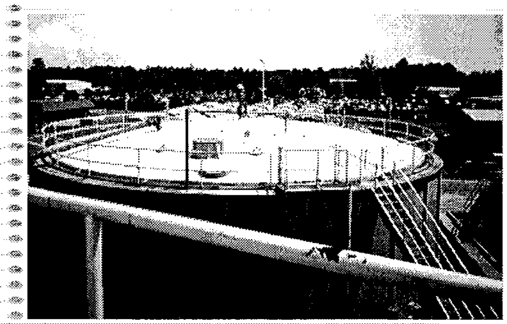
- Products of the first stage are converted to acetic acid, propionic acid, hydrogen, carbon dioxide and other organic acids.
- Microorganisms responsible for these conversions are referred to as acid formers (acetogenic bacteria).

Stage Two

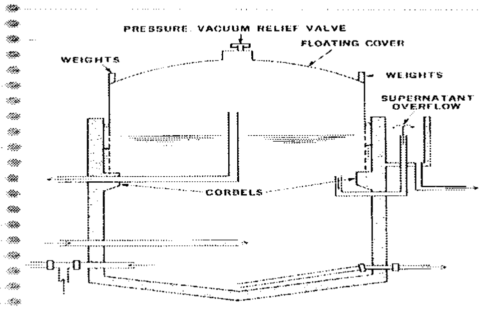
- Two groups of methane-forming bacteria begin work.
  - First group converts hydrogen and carbon dioxide to methane.
  - Second group converts acetate to methane and bicarbonate.



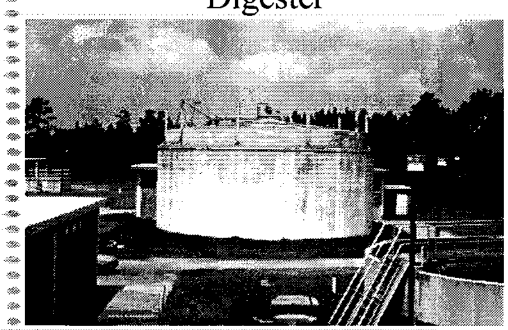
Fixed Cover Anaerobic Digester

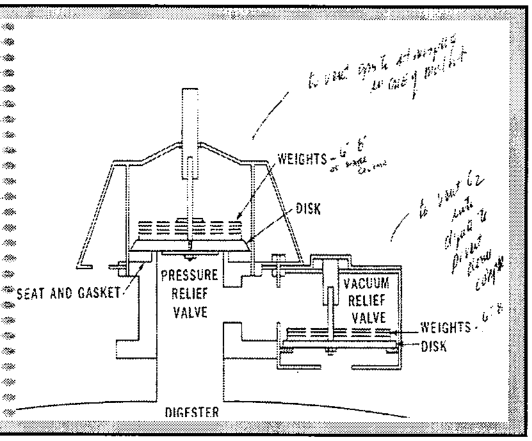


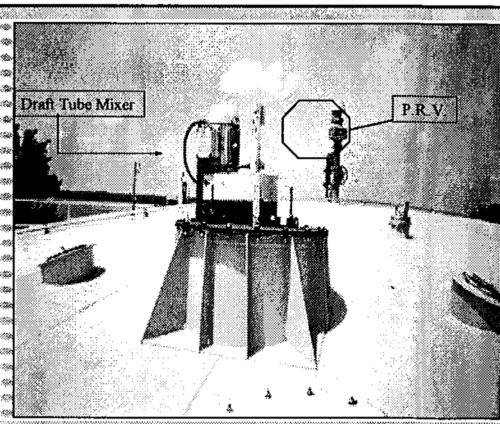
Floating Cover Digester



Floating Cover Anaerobic Digester

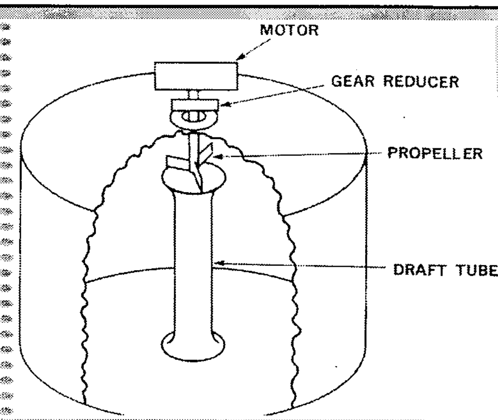


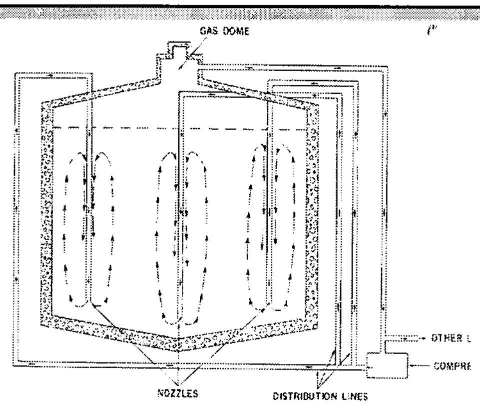


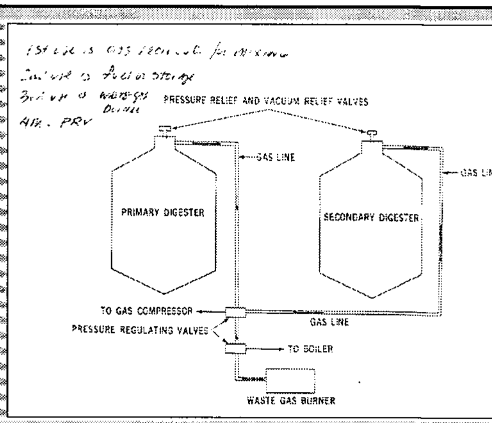


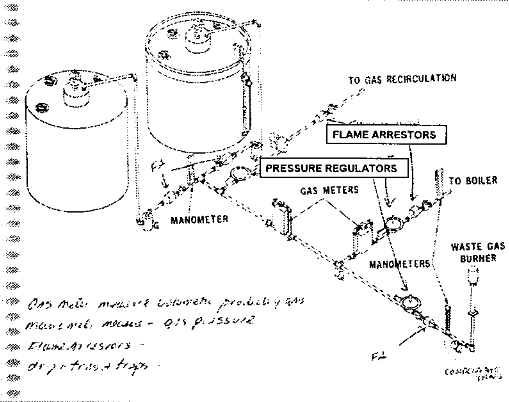
Anaerobic Sludge Digestion

- Digester Mixing
  - Mixing serves three purposes:
    - Keeps solids in suspension
    - Keeps grit from accumulating and scum layer from forming
    - Keeps sludge temperature uniform

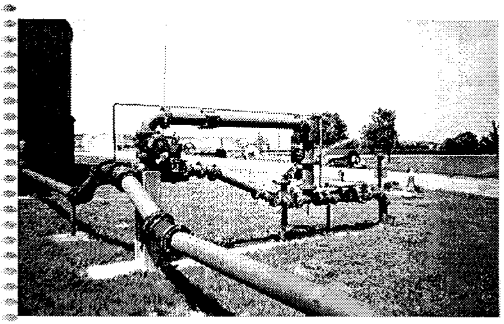




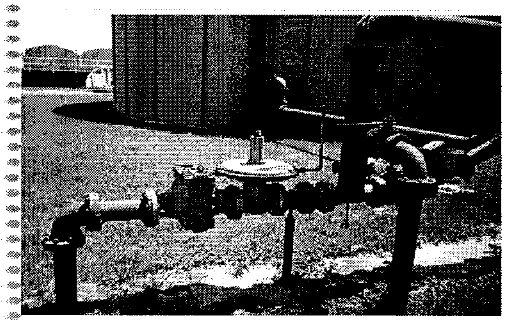




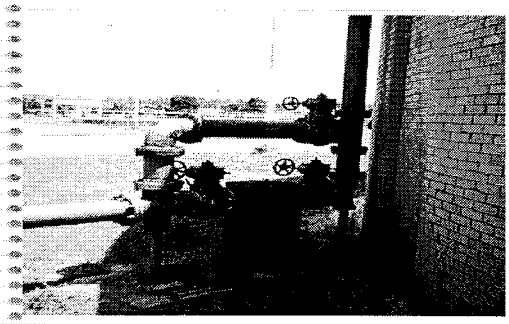
Methane Gas Piping



Methane Gas Piping

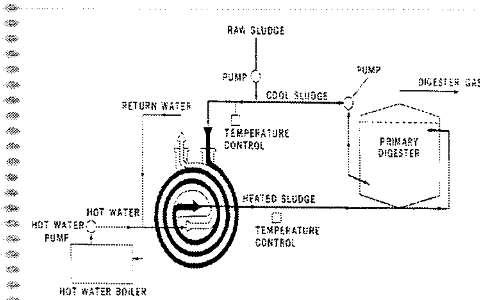


Methane Condensate Trap

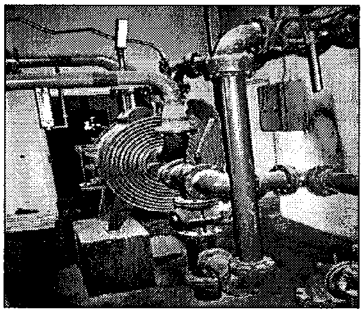


Methane Condensate Trap

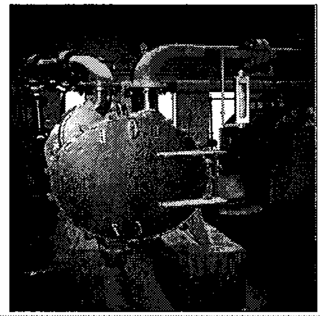
Digester Sludge Heating



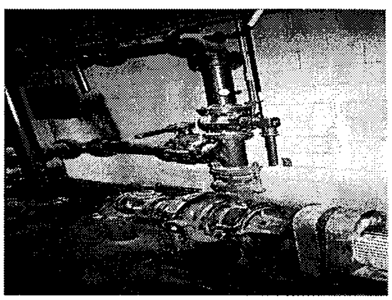
Sludge Heat Exchanger



Sludge Heat Exchanger

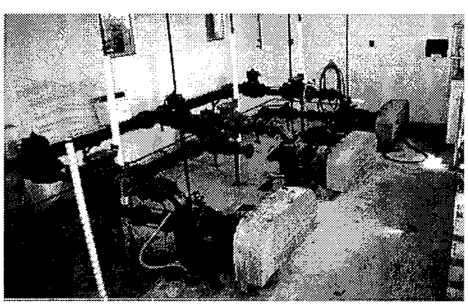


Sludge Recirculating Pump

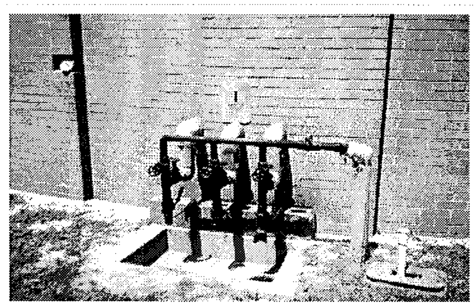


Methane-Fueled Boiler

Digester Sludge Transfer Pumps



Sludge and Supernatant Ports



Anaerobic Sludge Digestion

- Operational Controls
  - Never change digester temperature more than one degree per day.
  - Digester gas is normally 70% methane and 30% carbon dioxide.
- Digester gas and oxygen is ***very*** explosive!!!

Anaerobic Sludge Digestion

- Volatile acid/Alkalinity ratio is key to operation
  - When VA/Alk ratio gets out of balance, upset (sour) digester occurs.
  - When VA/Alk ratio rises, digester gas may be unburnable.
  - When VA/Alk ratio finally gets too high, pH begins to drop.
  - If pH is only process control tool used, digester can sour before operator is aware.

Anaerobic Sludge Digestion

- Volatile acid/alkalinity ratio
  - 0.1:1 - considered good balance
  - 0.3:1 - needs attention, keep mixing slow feeding
  - 0.5:1 - stop feeding, keep mixing, add some seed sludge
  - 0.8:1 - gas unburnable, pH drops. Stop feeding, keep mixing, add alkalinity
  - 1.0:1- Too late!

Anaerobic Sludge Digestion

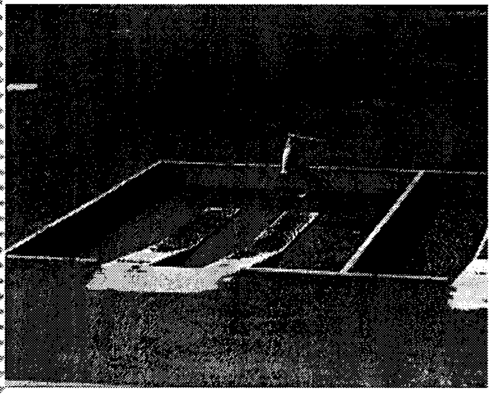
- Sour Digester Recovery
  - When digester becomes sour, several methods can be used to recover
    - Seed sludge from another digester can be used
    - Lime or soda ash can be added to raise pH

Anaerobic Sludge Digestion

- Digester Supernatant
  - Anaerobic digester supernatant is usually high in ammonia (NH_3) and BOD
  - Return anaerobic digester supernatant to head of plant during low flow periods

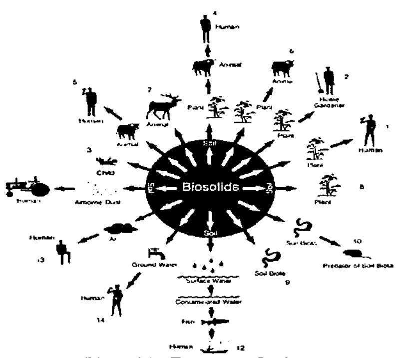
Rules

- In Florida, biosolids must meet either class A or B limits, as per EPA 40 cfr Part 503 and FDEP 62-640
- Must meet Pathogen Reduction requirements and Vector Attraction Reduction requirements
- Three methods to meet Pathogen limits, 10 ways to meet Vector Attraction Reduction limits



Pathogens and Vectors

- Fecal Coliform is the pathogen indicator
- Vectors are described as flies, mosquitoes, rats and other disease carrying organisms.
- All wastewater plants are considered generators of biosolids.



Biosolids Exposure Pathways

Sludge Analysis

- All plants must also perform sludge analysis testing at least annually.
- This includes metals testing, nitrogen, phosphorus, potassium, total solids and pH tests

Florida Department of Environmental Protection

Rules

Objective

- Overview of DEP Rules for Domestic Wastewater
- Rules of Concern for Certified Operators

Florida Administrative Code

- Chapter 62-4 - Permits
- Chapter 62-302 - Surface Water Quality Standards
- Chapter 62-600 - Domestic Wastewater Facilities

Florida Administrative Code

- Chapter 62-601 - Domestic WWTP Monitoring
- Chapter 62-602 - Drinking Water and Domestic Wastewater Treatment Plant Operators
- Chapter 62-604 - Collection Systems and Transmission Facilities

Florida Administrative Code

- Chapter 62-610 - Reuse of Reclaimed Water and Land Application
- Chapter 62-611 - Wetlands Application
- Chapter 62-620 - Wastewater Facility Permitting

Florida Administrative Code

- Chapter 62-640 - Domestic Wastewater Residuals
- Chapter 62-650 - Water Quality Based Effluent Limitations
- Chapter 62-699 - Treatment Plant Classification and Staffing

Chapter 62-4

Permits

- General Prohibition
  - Facility shall not be operated, maintained, constructed, expanded, or modified without the appropriate DEP permit
- Procedure to Obtain Permits
  - Application shall be certified by a Florida Professional Engineer
  - Permit fees
    - Collection System Construction
    - WWTF Operation
    - Modifications (Revision)

Chapter 62-4

Permits

- Surveillance Fees for Surface Water Discharge
  - Annual fee due by January 15
- Permit Application Renewals
  - At least 180 days before expiration of current permit
- Mixing Zones
  - Limited, defined area allows some relief for effluent limits
    - Calculated by dilution

Chapter 62-302

Surface Water Quality Standards

- Classification of Surface Waters
  - Class I - Potable water supplies
    - Lake Okeechobee, Hillsborough River, Upper St. Johns River
  - Class II - Shellfish propagation or harvesting
    - Indian River, Matanzas River, Tampa Bay
  - Class III - Recreation, propagation of a healthy, well-balanced population of fish and wildlife
    - Most other surface waters

Chapter 62-302

Surface Water Quality Standards

- Outstanding Florida Waters, National Resource Waters
  - Receives highest protection
    - Surface waters in National Parks, Preserves, Memorials, Wildlife refuges and Wilderness Areas
      - Everglades National Park, Caloosahatchee Wildlife Refuge, Suwannee River
- Criteria for Surface Water Quality Classifications
  - Table of water quality limits

Chapter 62-600

Domestic Wastewater Facilities

- Definitions
  - General terms
  - Common parameters
  - Facility types
- Design Requirements
  - Fenced
  - Easy, dry, safe access for obtaining samples
- Planning for Expansion
  - Capacity Analysis Report
    - Must have accurate flow measurements

Chapter 62-600

Domestic Wastewater Facilities

- Operation and Maintenance Requirements
  - Operation by a certified operator
  - Equipment shall be maintained so as to function as intended
  - Permittee shall provide operating data to DEP
  - Permit, drawings, O&M manual and operating data shall be kept available for use by plant operators and inspection by DEP

Chapter 62-600

Domestic Wastewater Facilities

- Treatment Standards
  - Secondary/Advanced Treatment
    - Minimum treatment: 20mg/L $CBOD_5$ and 20 mg/L TSS
- Disinfection
  - Concentration and contact time at peak hourly flow
    - Minimum contact time 15 minutes at peak hourly flow
    - Minimum concentration
      - Basic disinfection - 0.5 mg/L
      - High-level disinfection - 1.0 mg/L, additional TSS control

Chapter 62-600

Domestic Wastewater Facilities

- Operation and Maintenance Manual
  - Must be on-site and current
  - Provide the operator with information and description regarding design, operation and maintenance
  - Revise to reflect any facility alterations or reflect experience resulting from facility operation

Chapter 62-600
Domestic Wastewater Facilities

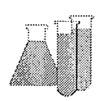
- O & M Performance Report
  - Included with new permit application
  - Evaluate physical condition and identify deficiencies
  - Prepared by engineer, operator and owner

Chapter 62-600
Domestic Wastewater Facilities

- Reporting, Compliance and Enforcement
  - Violations
    - Release or disposal without proper permit
    - Failure to maintain equipment
    - Planned bypassing of critical components without DEP notification
    - Submission of misleading, false or inaccurate info either knowingly or through neglect
    - Owner shall not allow or encourage operator to violate rules

Chapter 62-601
Domestic WWTP Monitoring

- Definitions
  - Lead or chief operator
- General Requirements
  - Submit reports by 28th of month for previous month



Chapter 62-601
Domestic WWTP Monitoring

- Sampling and Testing Methods
  - Methods must be approved by DEP and EPA
    - Field testing, sample collection and preservation, and laboratory testing
  - Laboratory must be certified by DOH for specified test
  - On-site tests may be run under direction of certified operator

Chapter 62-601
Domestic WWTP Monitoring

- Sampling Schedules, Locations, Methodology
  - Minimum schedule for sampling – Table
  - Grab samples, composite samples
  - Flow-proportioned samples taken @ hourly intervals

Chapter 62-602
Drinking Water and Domestic Wastewater Treatment Plant Operators

- Qualifications for Operator License
  - Class D
    - High school diploma or equivalent
    - Minimum 3 months experience or complete training course and 1 hour experience
  - Class C, B and A
    - High school diploma or equivalent
    - Minimum 1 year, 3 year, 5 year experience
    - Complete required training course
    - Must have previous level license for A and B

Chapter 62-602

Treatment Plant Operators

- Qualifications for Operator License *(continued)*
  - Must meet qualifications prior to submitting application
  - Exam (70% or better passing grade)
  - Experience (2080 hours = 1 year)
  - Training courses - residence or correspondence

Chapter 62-602

Treatment Plant Operators

- *New* Examination Fees
  - A, B, or C level: $100
    - $25 application fee (non-refundable)
    - $75 examination fee
  - D level: $75
    - $25 application fee (non-refundable)
    - $50 examination fee
  - Exam Review Fee
    - $75 to review incorrect questions
    - $10 to hand-score

Chapter 62-602

Treatment Plant Operators

- *New* License Fees
  - A, B, or C level: $100
    - $50 application fee (non-refundable)
    - $50 license fee
    - $75 renewal fee
  - D level: $50
    - $25 application fee (non-refundable)
    - $25 license fee
    - $50 renewal fee

Chapter 62-602

Treatment Plant Operators

- Renewal of Operator Licenses
  - Requires renewal every two years
  - Renewal notices sent to last known address
    - Failure to receive notice does not excuse licensee from timely renewal

Chapter 62-602

Treatment Plant Operators

- Renewal of Operator Licenses *(continued)*
  - CEU (Continuing Education Unit) documentation
    - Required for next renewal cycle
    - One CEU equals 10 hours of continuing education contact time
    - Two CEUs required for Class A or B renewal
    - One CEU required for Class C renewal
    - 0.5 CEU for Class D

Chapter 62-602

Treatment Plant Operators

- CEU documentation for double license
  - A portion of the CEUs must apply to each type of license
    - must be identified on the certificate
    - table of license levels and <u>hours</u> needed for double license

Chapter 62-602
Treatment Plant Operators

- Suspension and Revocation of Licenses
  - Suspension for up to 2 years
    - Submitting false data in license application
    - Cheating on exam
    - Incompetence in treatment plant operation
    - No re-test required to resume license

Chapter 62-602
Treatment Plant Operators

- Suspension and Revocation of Licenses *(continued)*
  - Permanent revocation
    - Fraud in the submission of documents for license
    - Falsified or misrepresented reports, logs, lab sheets
    - Negligence in treatment plant operation
    - Suspension of license more than twice
    - Short term revocation - complete course and take exam

Chapter 62-602
Treatment Plant Operators

- Duties of Operators
  - Submit required reports to permittee
  - Report to permittee and Department within 24 hours any:
    - Unsafe treatment plant operation
    - Unpermitted discharge
    - Major interruption in service

Chapter 62-602
Treatment Plant Operators

- Duties of Operators *(continued)*
  - Perform responsible and effective on-site management
  - Maintain operation and maintenance logs on site
    - Hard bound books with consecutive page numbers
    - Contain a minimum of three months of data
    - Partial electronic logging acceptable if approved by DEP

Chapter 62-602
Treatment Plant Operators

- Duties of Operators *(continued)*
  - O & M logs shall include the following:
    - Identification of plant
    - Signature and license number of operator
    - Signature of the persons making any entries
    - Date and time in and out
    - Specific operation and maintenance activities
    - Tests performed, samples taken (unless documented on lab sheet) and repairs made
    - Preventive maintenance and repair requests

Chapter 62-604
Collection Systems and Transmission Facilities

- Prohibitions
  - Deliberate introduction of stormwater
  - Acceptance of discharges without pretreatment
- Operation and Maintenance
  - Provide uninterrupted service
- Abnormal Events
  - Verbal notification within 24 hours, written report within 72 hours

Chapter 62-610

Reuse of Reclaimed Water and Land Application

- Rapid-Rate Land Application Systems
  - Rapid infiltration basins, absorption fields (percolation ponds, drainfields)
  - Effluent Nitrate limit = 12 mg/L
  - maintain ponds to control vegetation

Chapter 62-610

Reclaimed Water and Land App.

- Slow-Rate Land Application Systems - *Public Access*
  - Golf course, residential and food crop irrigation
  - TSS limit = 5 mg/L
- Slow-Rate Land Application Systems - *Restricted Public Access*
  - Spray irrigation (hay field)
  - TSS limit = 10 mg/L

Chapter 62-610

Reclaimed Water and Land App.

- Ground Water Recharge and Indirect Potable Reuse
  - Injection wells
  - Surface water augmentation for public water supply
- Overland Flow Systems
  - Sod farms, fodder crops
- Industrial Uses
  - Cooling water, wash-water or process water

Chapter 62-611

Wetlands Application

- Discharge Limits
  - Treatment wetland
    - Secondary treatment with nitrification
  - Receiving wetland
    - High level treatment 5-5-3-1
  - Total ammonia < 2 mg/L

Chapter 62-611

Wetlands Application

- Man-made Wetlands
  - Exempted from wetlands rule
  - Discharge must meet requirements
- Monitoring Requirements
  - Baseline monitoring
  - Nutrient monitoring
  - May request modification after 3 years

Chapter 62-620

Wastewater Facility Permitting

- General Prohibitions
  - Must have a permit to operate, construct or modify
- Renewals
  - Application must be submitted 180 days prior to expiration
- Recordkeeping
  - Maintain all records on site for 3 years

Chapter 62-620

Wastewater Facility Permitting

- Signatories to Permit Applications and Reports
  - Corporate officer
  - General partner or proprietor
  - Executive officer (city manager, public works director)
  - Authorized representative (must be documented)

Chapter 62-620

Wastewater Facility Permitting

- General Conditions for All Permits
  - All results must be reported and included in calculations
  - Must use certified laboratory for all tests
    - On-site tests for DO, pH and Cl2 may be performed under the direction of a certified operator

Chapter 62-640

Domestic Wastewater Residuals

- Provisions adopted from 40 CFR Part 503
- Applicability
  - domestic wastewater treatment facilities
  - residuals management facilities
  - septage management facilities
    - >10,000 gpd monthly average or 20,000 gpd in a single day

Chapter 62-640

Domestic Wastewater Residuals

- Permit Requirements
  - Valid permit and approved agricultural use plan
  - Responsibility for treatment and proper use
    - Permittee - unless applier has legally agreed
- Agricultural Use Plan (AUP)
  - Shall consider nutrient content of all residuals, reclaimed water, and other sources

Chapter 62-640

Domestic Wastewater Residuals

- Pathogen Reduction - Class A
  - Specific density requirements for fecal coliform or Salmonella in addition to one of six alternatives
  - Six alternatives
    - Examples: Thermal treatment, High pH - high temperature
- Pathogen Reduction - Class B
  - Three alternatives
    - Examples: Fecal coliform density, Process to Significantly Reduce Pathogens (PSRP), Equivalent PSRP

Chapter 62-640

Domestic Wastewater Residuals

- Vector Attraction Reduction
  - Ten options
    - Examples: Volatile solids reduction, SOUR test, lime addition, moisture reduction, soil injection or soil incorporation
- Monthly Distribution and Marketing Report
  - Class AA only
  - Sent to Tallahassee
  - Residuals monitoring report still applies

Chapter 62-640

Domestic Wastewater Residuals

- New Site
  - AUP along with permit application
  - Aerial maps
  - Soil conservation information
  - Pending site inspection
  - Liability agreement
  - Other pertinent information may be required (i.e. setbacks)
  - Cumulative metals loading rates
  - Site life determination
  - Nitrogen loading rate, Plant Available Nitrogen (PAN) determination, etc.

Chapter 62-640

Domestic Wastewater Residuals

- Site Requirements
  - Inspection
    - Piezometer
      - At least 2" in diameter, 36" deep and 24" above ground
      - Located at area where it is easy to see
      - Maintain water table readings ready for inspection
    - Aerial Maps
      - Scale zones
      - Crop type
      - Area of zone
      - Zone ID

Chapter 62-640

Domestic Wastewater Residuals

- Site Requirements
  - Setback Distances
    - To buildings - 300 feet if occupied
    - To water bodies - 1000 feet to Class I, 200 feet all other
    - To potable water wells - private is 300 feet, public is 500 feet

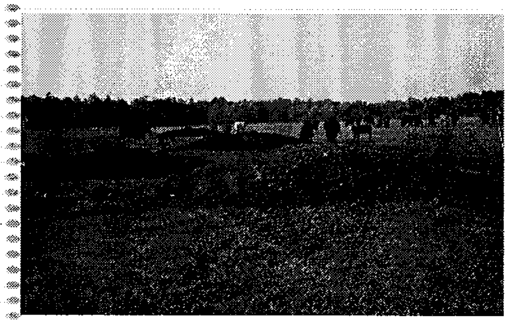
Chapter 62-640

Domestic Wastewater Residuals

- Site Requirements
  - Soil/residuals mixture must be pH 5.0 or greater
  - Runoff prevention
    - No application during rain that causes runoff or when soil is saturated
    - Topographic grades less than 8%
    - Topographic grades greater than 2% require a conservation plan. Contact the Soil Conservation Service at (904) 328-6522

Chapter 62-640

Domestic Wastewater Residuals



Chapter 62-650

Water Quality Based Effluent Limitations

- WQBEL Level I Process
  - Water body meets standards
- WQBEL Level II Process
  - Insufficient water quality data
  - Available assimilative capacity of water body is utilized

Chapter 62-699

Treatment Plant Classification and Staffing

- Classification and Staffing of Plants
  - Permittee shall employ certified operator as required

Chapter 62-699

Plant Classification and Staffing

- Additional Classification and Staffing Requirements
  - Operator shall be on call when plant is unattended
  - Daily checks shall be performed
  - Electric surveillance
  - Lead/chief operator shall be on duty each duty day

For More Information …

- www.dep.state.fl.us
  - For DEP Rules check side bar under Resources
- www.epa.gov
- contact your local district office:
  - Northeast District – Domestic Waste Section (904) 807-3300

Safety at WWTFs

Types of Hazards at the WWTF

- Physical injuries
- Infections/infectious diseases
- Confined space
- Oxygen deficiency
- Toxic or suffocating gases or vapors

Types of Hazards at the WWTF

… continued

- Explosive gas mixtures
- Electrical shock
- Noise
- Dusts, fumes, mists, gases, and vapors

Physical Injuries

Most common:

Cuts - Strains

Bruises - Sprains

Can be caused by improper lifting techniques or slippery surfaces

Falls from or into tanks, wet wells, or catwalks

Infections and Infectious Diseases

- General Definitions
  - Infection: The invasion of a host by an infectious microorganism.
  - Pathogenicity: The ability of an infectious agent to cause disease and injure the host.
  - Pathogenic organisms or "Pathogens": Bacteria, viruses, or cysts which can cause disease *(such as typhoid, cholera, dysentery)* in a host *(such as a human).*

Infections and Infectious Diseases

- Personal hygiene is the best protection against the risk of infections and disease.
- *Types:* Typhoid fever, Dysentery, Hepatitis and Tetanus
- Immunization shots are a necessity against Tetanus, Polio, and Hepatitis B.

Infections and Infectious Diseases

- There are many "Modes of Transmission" of infectious agents:
  - *Person-to-person:* This is the most common mode. By direct person-to-person contact, coughing, or sneezing.
  - *Waterborne:* From consumption of contaminated water.
  - *Foodborne:* Food contaminated from unsanitary practices during production or preparation.

Infections and Infectious Diseases

- Modes of Transmission *(continued)*
  - *Airborne:* Transmission of biological aerosols generated by WWTFs or by spray irrigation of wastewater effluents.
  - *Vector-borne:* Transmission by arthropods (fleas, insects) or vertebrates (cats, dogs)
  - *Fomites:* Pathogens transmitted by nonliving objects or fomites (clothes, utensils, toys).

Reference summary chart of some diseases associated with wastewater environments.

Infections and Infectious Diseases

- Pathogenic Bacteria Infections Include:
  - *Salmonella spp*: Acute Gastroenteritis, Typhoid Fever, Paratyphoid Fever, Salmonellosis.
  - *Shigella spp*: Shigellosis (bacillary dysentery)
  - *Vibrio spp*: Asiatic Cholera
  - *Clostridium spp*: Tetanus

Infections and Infectious Diseases

- Pathogenic Bacteria Infections Include:
  - *Mycobacterium*: Tuberculosis
  - *Yersinia*: Acute Gastroenteritis
  - *Escherichia coli (E-coli)*: Usually considered nonpathogenic, several strains may cause Gastroenteritis.

Infections and Infectious Diseases

- **Personal Protection**
  - *Gloves* Always wear a good, heavy duty rubber glove when cleaning bar racks, weirs, or while conducting any other scrubbing duty. Be sure there are no holes in them. Always wear gloves if your hands may come in direct contact with wastewater or sludge.
  - *Footwear* If you have to walk in sewage, wear rubber boots. Rubber boots will not soak up sewage fluids.

Infections and Infectious Diseases

- Personal Protection *(continued)*
  - *Hygiene* If you smoke or break for a snack, clean your hands first. Be sure to use a disinfectant soap.
  - Spray your shoes with a disinfectant or change your shoes before going home. Don't mix your work clothes with the family wash, and wash them in hot water.

Infections and Infectious Diseases

- Safety At The Plant Site
  - *DO NOT* store your lunch in the same refrigerator as sludge or any other wastewater samples. Freezing will not kill viruses, *only extremely high heat.*
  - When cleaning with a high pressure water hose (hose with nozzle), wear a full face shield and apron to stop any splash back.

Infections and Infectious Diseases

- Safety At The Plant Site *(continued)*
  - While conducting lab work, or when wearing latex gloves while sampling, consider doubling or tripling the glove. Latex is laced with five micron channels, the HIV virus is .1 micron in size and Hepatitis B is 1.5 microns in size.

Infections and Infectious Diseases

- Safety At The Plant Site *(continued)*
  - Bandages covering wounds should be changed frequently.
  - You should always wear long pants when climbing on or around a WWTF.

Confined Space

- Space that is large enough and configured so that an employee can enter and perform assigned work.
- Space that has limited or restricted means for entry or exit.
- Space that is not designed for continuous employee occupancy.

Confined Space

Examples of Confined Spaces

- Tanks
- Vessels
- Storage Bins
- Hoppers
- Vaults
- Pits
- Manholes
- Lift Stations

Oxygen Deficiency

- Low oxygen levels may exist in poorly ventilated areas where gases, such as hydrogen sulfide, gasoline vapor, carbon dioxide and chorine, may be produced or accumulated.
- *Hydrogen Sulfide and Chlorine* collect in low places because they are heavier than air.
- The weight of a gas is indicated by its specific gravity as it is compared to an equal volume of air.

Oxygen Deficiency

- The specific gravity of air is 1.0.
- Therefore, any gas with a specific gravity of >1 will sink to low lying places.

(Methane rises out of manholes because it's specific gravity is < 1. Therefore, it is lighter than air.)

Chlorine Facts

- When changing chlorine cylinders or handling chlorine, ALWAYS do the following:
  - Have a standby person present with a respirator available.
  - Remove the old lead washer from the pig-tail or chlorinator, use one new lead washer.
  - Have an emergency repair kit on-site and be familiar with how to use if BEFORE the need arises. Make sure the kit is complete and no tools or parts are missing.

Toxic or Suffocating Gases

- They originate from industrial waste dischargers, process chemicals, or decomposition of domestic wastewater.
- Become familiar with waste dischargers in your system.

Toxic or Harmful Chemicals

- Strong acids, bases, and liquid mercury are types of harmful chemicals that operators may encounter.
- All hazardous chemicals should be clearly labeled
- Health and safety data (MSDS) about the specific chemicals should be read before handling.

Explosive Gas Mixtures

- *Explosive Gases* develop in areas where air and methane, natural gas, manufactured fuel gas, hydrogen, or gasoline vapors mix.
  - Explosion-proof electrical equipment and fixtures should be used in these areas.
  - Explosions can be avoided by eliminating sources of ignition in these type areas. *(examples: influent bar screen rooms, gas compressor areas)*

Explosive Gas Mixtures

- Also, adequate ventilation should be provided

Note: **Methane and oxygen combined are highly explosive.**

Always use Non-Sparking tools when working around anaerobic digesters.

Electrical Shock

- *DO NOT* attempt electrical repairs unless you are qualified and know what you are doing.
- Ordinary 120 Volt electricity may be fatal.
- 12 Volts can cause injury.

Electrical Shock

- Any electrical system should be considered dangerous unless you know *for sure* it has been de-energized.
- Always use a lock-out tag-out procedure to prevent accidental re-energizing of power.

Noise

- Some WWTF equipment produce high noise levels. Ex: blowers
- Hearing protection devices should be used if you have to shout or cannot hear someone talking to you in a normal tone of voice.

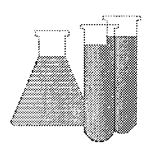
Dust, Fumes, Mists, Gases, and Vapors

- The ideal way to control diseases from breathing air contaminated with harmful dusts, fumes, mists, gases, and vapors is to prevent the atmospheric contamination from occurring.
- This can be achieved through *engineering control measures*. It is not always economically feasible, therefore *respirators should be provided/used* in these atmospheres.

References

- Operation of Wastewater Treatment Plants California State University, Sacramento, Volume II, Third Edition 1998.
- Wastewater Microbiology, University of Florida, Gainesville, Gabriel Bitton, 1994.
- Wastewater Engineering Treatment, Disposal, and Reuse, Metcalf and Eddy, Inc., Third Edition, 1991.

Laboratory Procedures and Chemistry



Agenda

- **Sample Collection**
  - Terminology
  - Procedures
- **Laboratory**
  - Safety
  - Terminology
  - Measurements

Sample Collection

- The result of any testing method can be no better than the sample on which it is performed.
- **Objective** - to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled to demonstrate compliance with regulatory requirements.

Sample Collection

- **Why?**
  - Used to control wastewater processes
    - Find problems before they become problems
    - Used for basic wastewater operations parameters
  - Used to monitor treatment effectiveness
    - Tests required by regulation
    - For determining effectiveness for budget issues

Sample Collection Terminology

- **Grab Sample** - a single sample collected at a particular time and place which represents the composition only at that time and place

- **Composite Sample** - a collection of individual samples obtained at regular intervals

Sample Collection Terminology

- **Flow Proportioned Sample** - a collection of individual samples obtained at regular intervals. Sample size based upon flow
- **Representative Sample** - a sample portion of material that is as nearly identical in content and consistency as possible to that in the larger body of material being sampled

Sample Collection Procedures

- **Most errors occur due to**
  - Improper sampling
  - Poor preservation
  - Lack of mixing during compositing and testing

Sample Collection Procedures

- **Proper sampling technique**
  - Have access to safe sampling location
  - Use clean and proper sampling equipment and containers
  - Collect a representative sample
    - Approved location and sample type (grab or composite)
    - Appropriate collection time and frequency

Sample Collection Procedures

- **Automatic samplers** - clean sample lines and verify proper programming
- **Sample containers & preservation**
  - Use type of container specified in method
  - Preserve as specified in method
  - Keep refrigeration $\leq$ 4 degrees C
  - Properly label all sample containers
  - Record sample collection time

Laboratory Safety

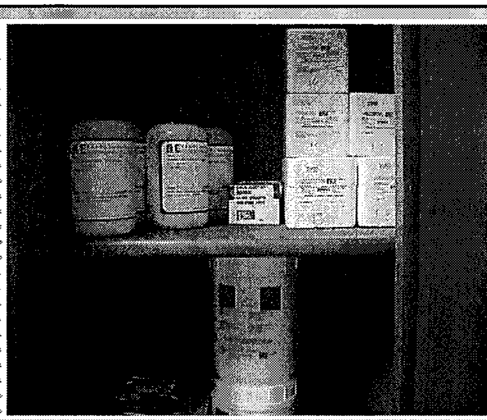
- Chemical hygiene plan
- Material Safety Data Sheets (MSDSs)
- Bloodborne pathogens
- Never pipet by mouth
- Always add acid to water
- PPE

Laboratory Safety

- **Corrosive Chemicals**
  - H_2SO_4 (Sulfuric Acid)
  - HNO_3 (Nitric Acid)
  - HCl (Hydrochloric Acid)
  - NaOH (Sodium Hydroxide)
  - KOH (Potassium Hydroxide)
  - Phenylarsine oxide

Laboratory Safety

- **Safety equipment in the laboratory**
  - Fume hood
  - Spill clean up kits
  - Safety eyewash and shower
  - Fire extinguisher
  - Fire blanket
  - First aid kit



Laboratory Terminology

- **Aliquot** - portion of a sample, usually an equally divided portion
- **Aseptic** - free from living germs, sterile
- **Buffer** - a solution or liquid that neutralizes acids or bases with minimal change in pH

Laboratory Terminology

- **Chain-of-Custody** - the ability to trace possession and handling of the sample from the time of collection through analysis and final disposition
- **Compound** - a pure substance composed of two or more elements
- **Element** - a substance which cannot be separated into its parts

Laboratory Terminology

- **Gram Molecular Weight** - molecular weight of compound in grams
- **Meniscus** - the curved surface of a column of liquid in a small tube
- **Molar (M)** - solution consists of one gram molecular weight of a compound dissolved in enough water to make 1 liter

Laboratory Terminology

- **Molecular weight** - the sum of the atomic weights of the elements in a compound
- **Normal (N)** - solution contains one gram equivalent weight of a compound per liter of solution

Laboratory Terminology

- **Quality Assurance** - a set of operating principles that, if strictly followed during sample collection and analysis, will produce data of known and defensible quality
- **Quality Control** - ability to produce credible results

Laboratory Terminology

- **Reagent** - a pure chemical substance that is used to make new products or is used in chemical test to measure, detect, or examine other substances
- **Solution** - a liquid mixture of dissolved substances
- **Titrate** - a chemical solution of known strength is added drop by drop until a change in the sample is observed (end point)

Laboratory Terminology

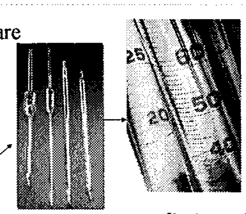
- **Volatile** - capable of being evaporated or changed to a vapor. In solids analysis, materials lost at 550 deg. C for 60 minutes in a muffle furnace.
- **Volatile acids** - fatty acids produced during digestion that are soluble in water and can be steam distilled at atmospheric pressure.

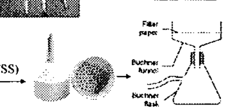
Laboratory Measurements

- **Metric**
  - Liter (volume) - L
  - Gram (weight) - g
  - Meter (length) - m
    - micro(T) = 1/1,000,000 or 0.000001 X
    - milli (m) = 1/1000 or 0.001 X
    - centi (c) = 1/100 or 0.01 X
  - Temperature
    - C° = 5/9 (F° - 32)
    - F°= C°(1.8) + 32

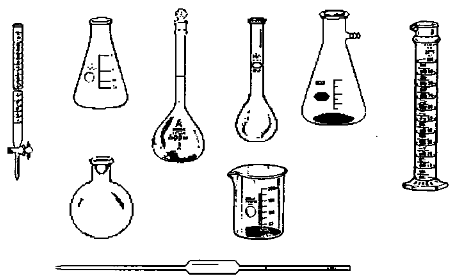
Laboratory Equipment

- Use of class "A" labware
- Burets
- Graduated cylinders
- Flasks
- Beakers
- Pipettes (Most Accurate)
- Crucibles
- Funnels (Buchner Funnel is used for TSS)

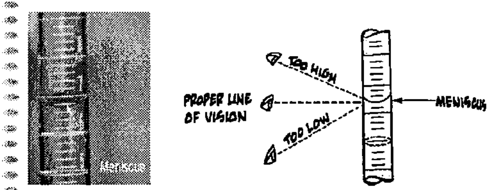




Laboratory Equipment



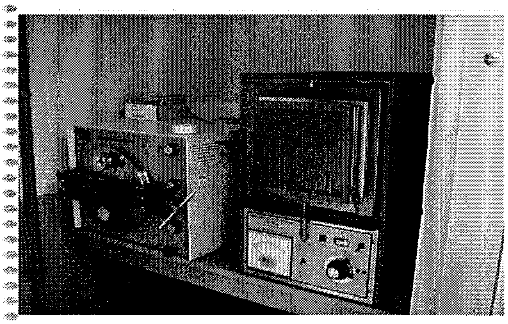
Laboratory Equipment



Laboratory Equipment

- Hot Plate
- Magnetic Stirrer
- Dessicator
- Drying Oven
- Muffle Furnace
- Water Bath
- Incubator
- Petri dishes

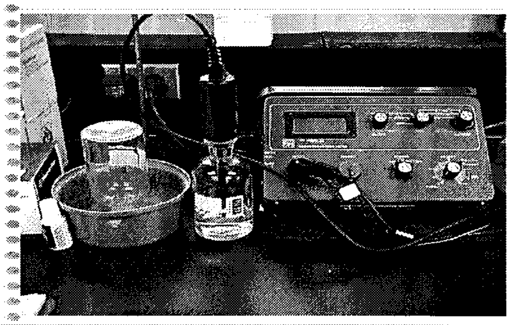
Laboratory Equipment



Laboratory Equipment

- Analytical balance
- Triple beam balance
- Ion meter (pH)
- Spectrophotometer
- D.O. meter
- Microscope
- Autoclave
- Fume hood

Laboratory Equipment



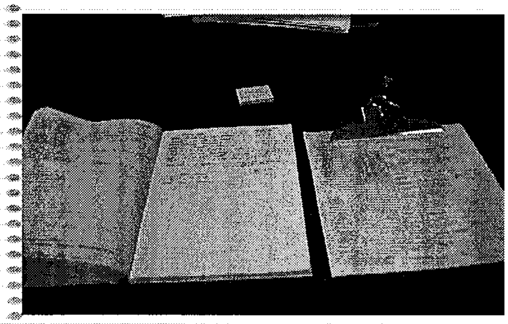
Laboratory Records

- **Bench sheets and notebooks**
  - Bench sheets must have all information required by DEP
    - Name of laboratory
    - Name of sampler(s)
    - Date & time of analysis
    - Date, time & location of sample
    - Method used
    - Name of technician performing analysis
    - Calculations used

Laboratory Records

- **Accurate, complete records are a must!**
  - Used to record data and arrange in orderly manner
  - All information must be recorded
  - If you make a mistake, one line & initial, no white out!
  - Keep accurate calibration and temperature logs
  - Make sure information is legible!

Laboratory Records



Laboratory Records

- **Quality Assurance/ Quality Control**
  - All certified labs must have a DEP approved QA Plan
  - Without good QA/QC, data is not considered reliable

Laboratory Analyses

- **Titrations**
  - Adding one solution to another until end point
- **Gravimetric**
  - Using weight to determine concentration

Laboratory Analyses

- **Electrode**
  - Using ion selective electrodes to measure
- **Spectrophotometer or Colorimeter**
  - Measure intensity of color at particular wavelength

Laboratory Analyses

- Carbonaceous Biochemical Oxygen Demand
- Total Suspended Solids
- Chlorine Residual
- pH
- Fecal Coliform

Laboratory Analyses

- **Carbonaceous BOD**
  - Disadvantage- results take 5 days to obtain
  - Bioassay
  - 5 day test at 20 deg. C
  - Nitrification inhibitor
  - Initial dissolved oxygen
  - Oxygen five days later
  - Calculate CBOD
  - Rate of oxygen-use expressed as mg/L

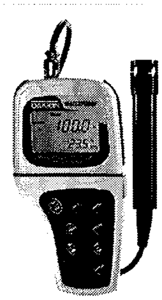
Laboratory Analyses

Laboratory Analyses

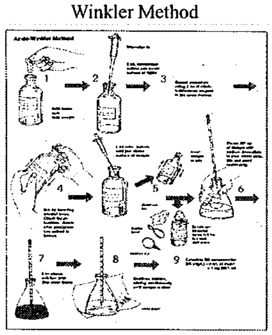
- **Total Suspended Solids (Total Non-Filterable Solids)**
  - Gravimetric method
  - Use fine filter to capture solids
  - Weigh clean filter
  - Pour sample through filter
  - Dry in drying oven at 103-105 C
  - Weigh again to determine mg/L

Dissolved Oxygen Analysis

DO Meter

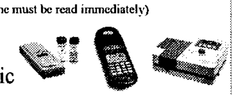


Winkler Method

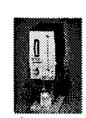


Laboratory Analyses

- **Chlorine residual** (Chlorine must be read immediately)



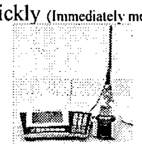
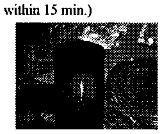
  - DPD Spectrophotometric
    - Use standards to calibrate meter
    - Add DPD reagent. Color intensity corresponds to residual chlorine (For Total Chlorine this takes 3 minutes)



  - Amperometric Titration
    - Uses electronic value to read chlorine level

Laboratory Analyses

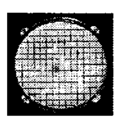
- **pH**
  - Meter or ion meter
  - Calibrate with at least 2 buffer solutions that bracket the expected range
  - Take reading immediately, pH can change quickly (Immediately means within 15 min.)

Laboratory Analyses

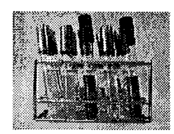
Laboratory Analyses

- **Fecal coliform**
  - Membrane Filter Method
    - Uses very fine porous filter to capture bacteria
    - Maintain sterile conditions during sampling and testing
    - Pour samples through filter
    - Place filter in petri dish with broth
    - Incubate 24 hours at 44.5 deg. C



Laboratory Analyses

- **Fecal coliform**
  - MPN Method (Most Probable Number)
    - Inoculate tubes of broth with several dilutions of sample
    - Calculate density based on number of tubes gas-negative and gas-positive



Additional Terminology

- **Bioassay** - measuring effect of biological process. Determining toxic effects by using live organisms.
- **Biomonitoring** - measuring effects of toxic substances
- **Biosurvey** - site survey upstream and down. Used to determine effect downstream

Additional Terminology

- **Facultative** - can survive in aerobic or anaerobic conditions
- **Oxidation** - addition of oxygen, removal of hydrogen (aerobic)

Additional Terminology

- **Reduction** - addition of hydrogen, removal of oxygen (anaerobic)
- **Surfactant** - surface active agent. Agent in detergents that has good cleaning ability.

WATER AND WASTEWATER MATH

CONVERSION FACTORS

- VOLUME :

CONVERSION FACTORS

- VOLUME :

7.48 gal = 1 cu ft

CONVERSION FACTORS

- VOLUME :

7.48 gal = 1 cu ft

7.48 gal/cu ft

CONVERSION FACTORS

- VOLUME :

7.48 gal = 1 cu ft

7.48 gal/cu ft

1 cu ft / 7.48 gal

CONVERSION FACTORS

- DENSITY OF WATER

CONVERSION FACTORS

- DENSITY OF WATER

8.34 LBS = 1 GAL

CONVERSION FACTORS

- DENSITY OF WATER

8.34 LBS = 1 GAL

8.34 LBS / GAL

CONVERSION FACTORS

- DENSITY OF WATER

8.34 LBS = 1 GAL

8.34 LBS / GAL

1 GAL / 8.34 LBS

CONVERSION FACTORS

- CONCENTRATION

CONVERSION FACTORS

- CONCENTRATION

CONCENTRATION MAY ALSO BE REFERED TO AS DOSAGE.

CONVERSION FACTORS

- CONCENTRATION

CONCENTRATION MAY ALSO BE REFERED TO AS DOSAGE.

1 ppm = 1 mg/l

GEOMETRY

- LENGTH

GEOMETRY

- LENGTH

SQUARE OR RECTANGLE

GEOMETRY

- LENGTH

SQUARE OR RECTANGLE

30 FT

10FT 10FT

30 FT

GEOMETRY

- LENGTH

SQUARE OR RECTANGLE

30 FT

10FT 10FT

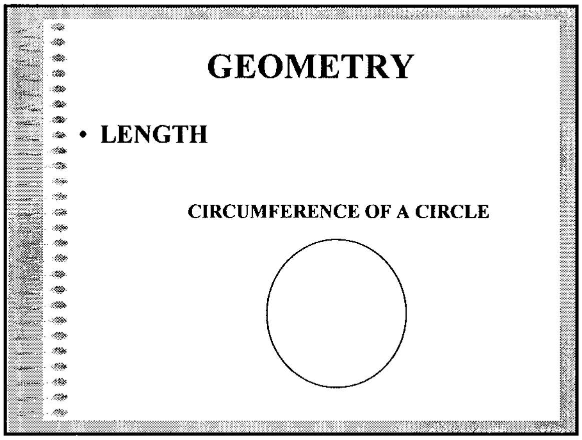
30 FT

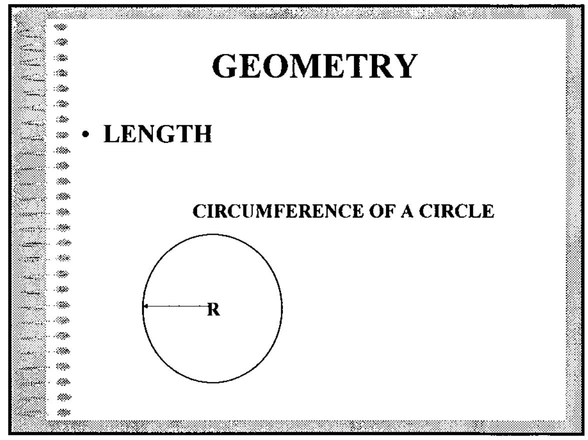
SUM OF ALL SIDES= 10+10+30+30=80 FT

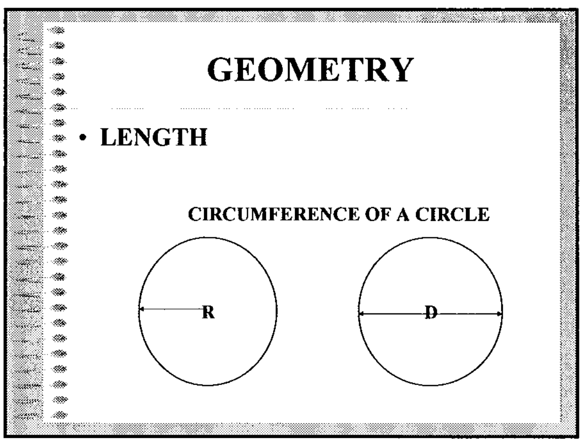
GEOMETRY

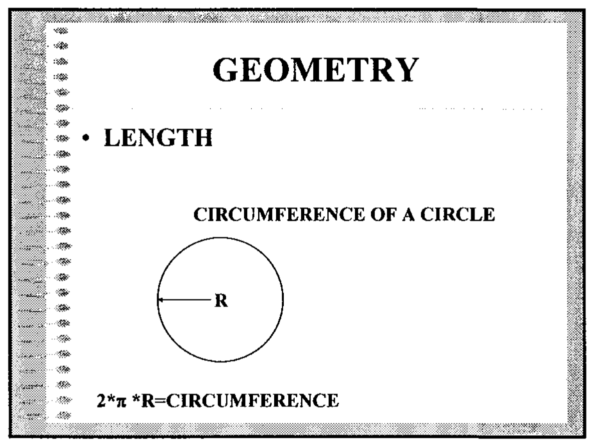
- LENGTH

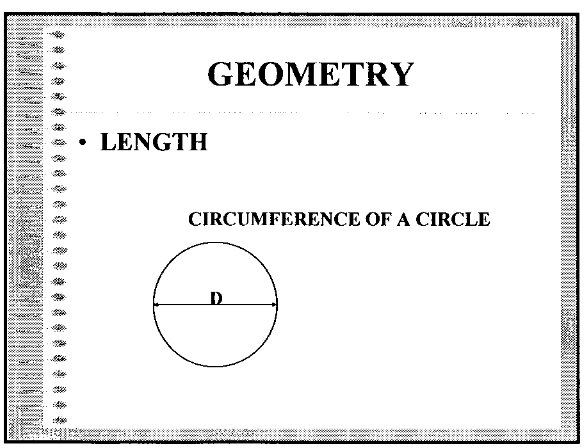
CIRCUMFERENCE OF A CIRCLE

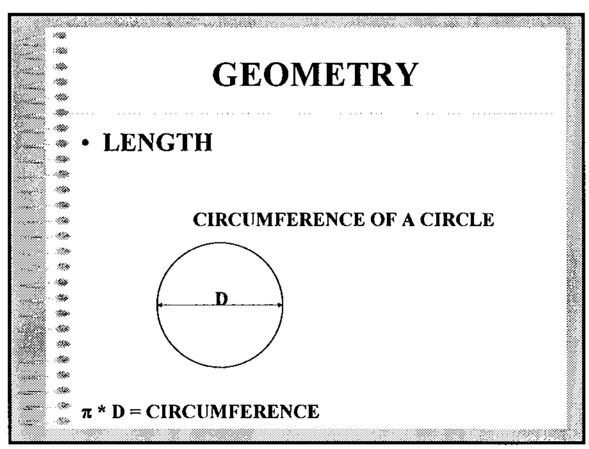

GEOMETRY
• LENGTH
CIRCUMFERENCE OF A CIRCLE


GEOMETRY
• LENGTH
CIRCUMFERENCE OF A CIRCLE
R


GEOMETRY
• LENGTH
CIRCUMFERENCE OF A CIRCLE
R
D


GEOMETRY
• LENGTH
CIRCUMFERENCE OF A CIRCLE
R
2*π *R=CIRCUMFERENCE


GEOMETRY
• LENGTH
CIRCUMFERENCE OF A CIRCLE
D


GEOMETRY
• LENGTH
CIRCUMFERENCE OF A CIRCLE
D
π * D = CIRCUMFERENCE

GEOMETRY

- AREA

GEOMETRY

- AREA

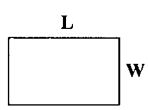
FT² OR SQ FT

GEOMETRY

- AREA

FT² OR SQ FT

AREA OF A RECTANGLE:



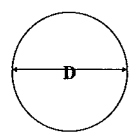
L * W= AREA

GEOMETRY

- AREA

FT² OR SQ FT

AREA OF A CIRCLE



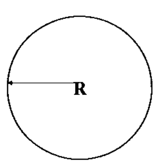
$(\pi * D^2)/4$

GEOMETRY

- AREA

FT² OR SQ FT

AREA OF A CIRCLE



AREA= $\pi * R^2$

GEOMETRY

- VOLUME

GEOMETRY

- VOLUME

  FT^3 OR CU FT

GEOMETRY

- VOLUME

  FT^3 OR CU FT

  VOLUME OF A RECTANGLE

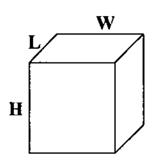
GEOMETRY

- VOLUME

  FT^3 OR CU FT

  VOLUME OF A RECTANGLE

  L * W * H = VOLUME



GEOMETRY

- VOLUME

  FT^3 OR CU FT

  VOLUME OF A CYLINDER

  $= [(\pi * D^2)/4] * H$

GEOMETRY

- VOLUME

  FT^3 OR CU FT

  VOLUME OF A CYLINDER

  $= [(\pi * D^2)/4] * H$

  $= \pi * R^2 * H$

GEOMETRY

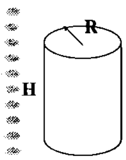
- VOLUME

  FT^3 OR CU FT

  VOLUME OF A CYLINDER

  $= [(\pi * D^2)/4] * H$

  $= \pi * R^2 * H$



AREA AND VOLUME PROBLEMS

AREA AND VOLUME PROBLEMS

CALCULATE THE AREA OF THE RECTANGLE

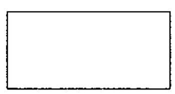
10 FT

20 FT

AREA AND VOLUME PROBLEMS

CALCULATE THE AREA OF THE RECTANGLE

10 FT

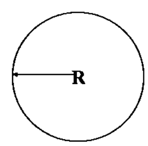


20 FT

L * W OR 10 * 20 = 200 SQ FT

AREA AND VOLUME PROBLEMS

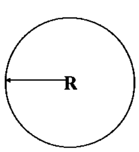
CALCULATE THE AREA OF THE CIRCLE



RADIUS = 20 FT

AREA AND VOLUME PROBLEMS

CALCULATE THE AREA OF THE CIRCLE

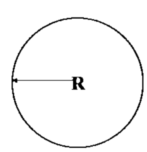


RADIUS = 20 FT

$= \pi * R^2$

AREA AND VOLUME PROBLEMS

CALCULATE THE AREA OF THE CIRCLE



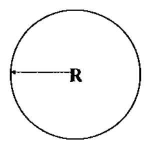
RADIUS = 20 FT

$= \pi * R^2$

$= 3.14 * 20 * 20$

AREA AND VOLUME PROBLEMS

CALCULATE THE AREA OF THE CIRCLE



RADIUS = 20 FT

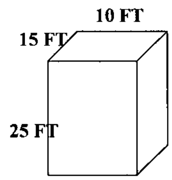
$= \pi * R^2$

= 3.14 * 20 * 20

= 1256 SQ FT

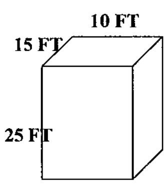
AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE RECTANGULAR TANK



AREA AND VOLUME PROBLEMS

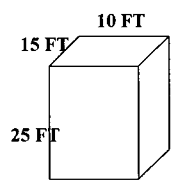
CALCULATE THE VOLUME OF THE RECTANGULAR TANK



L * W * H

AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE RECTANGULAR TANK

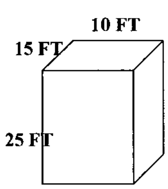


L * W * H

15 * 10 * 25

AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE RECTANGULAR TANK



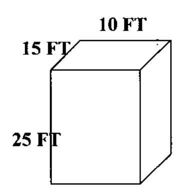
L * W * H

15 * 10 * 25

3750 CU FT

AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE RECTANGULAR TANK



L * W * H

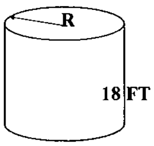
15 * 10 * 25

3750 CU FT OR

$3750 FT^3$

AREA AND VOLUME PROBLEMS

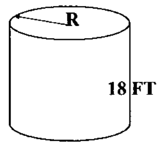
CALCULATE THE VOLUME OF THE CYLINDRICAL TANK



R = 30 FEET

AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE CYLINDRICAL TANK

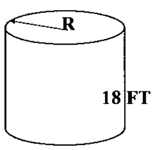


R = 30 FEET

3.14 * 30 * 30 * 18

AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE CYLINDRICAL TANK



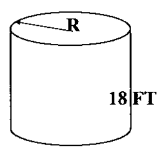
R = 30 FEET

3.14 * 30 * 30 * 18

= 50868 CU FT

AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE CYLINDRICAL TANK EXPRESSED IN <u>GALLONS</u>



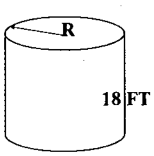
R = 30 FEET

3.14 * 30 * 30 * 18

= 50868 CU FT

AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE CYLINDRICAL TANK EXPRESSED IN <u>GALLONS</u>



R = 30 FEET

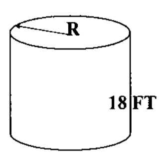
3.14 * 30 * 30 * 18

= 50868 CU FT

= 50868 * 7.48

AREA AND VOLUME PROBLEMS

CALCULATE THE VOLUME OF THE CYLINDRICAL TANK EXPRESSED IN <u>GALLONS</u>



R = 30 FEET

3.14 * 30 * 30 * 18

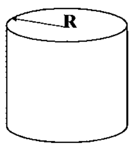
= 50868 CU FT

= 50868 * 7.48

= 380493 GALLONS

AREA AND VOLUME PROBLEMS

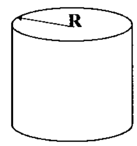
CALCULATE THE WEIGHT OF THE CYLINDRICAL TANKS CONTENTS IF IT IS WATER



= 380493 GALLONS

AREA AND VOLUME PROBLEMS

CALCULATE THE WEIGHT OF THE CYLINDRICAL TANKS CONTENTS IF IT IS WATER

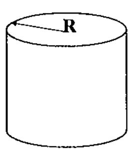


= 380493 GALLONS

= 380493 * 8.34

AREA AND VOLUME PROBLEMS

CALCULATE THE WEIGHT OF THE CYLINDRICAL TANKS CONTENTS IF IT IS WATER



= 380493 GALLONS

= 380493 * 8.34

= 3173309

LBS

GENERAL FORMULAS

DETENTION TIME,hr

GENERAL FORMULAS

DETENTION TIME,hr

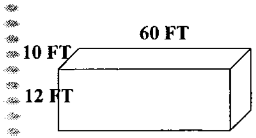
$$= \frac{(\text{TANK VOLUME, FT}^3) * (7.48\ \text{GAL/FT}^3) * (24\ \text{HR/DAY})}{(\text{FLOW, GAL/DAY})}$$

GENERAL FORMULAS

DETENTION TIME,hr

$$= \frac{(\text{TANK VOLUME, FT}^3) * (7.48\ \text{GAL/FT}^3) * (24\ \text{HR/DAY})}{(\text{FLOW, GAL/DAY})}$$

USING THIS FORMULA CALCULATE THE DETENTION TIME OF THIS TANK, WITH A DAILY FLOW OF 20,000 GAL/DAY.



GENERAL FORMULAS

DETENTION TIME,hr

= (TANK VOLUME, FT³) * (7.48 GAL/ FT³) * (24 HR/DAY)
(FLOW, GAL/DAY)

$$\frac{(10 * 60 * 12) * 7.48 * 24}{20{,}000} = \frac{7200\ FT^3 * 7.48 * 24}{20{,}000}$$

= 64.6 HRS

GENERAL FORMULAS

PLANT EFFICIENCY

PLANT EFFICIENCY, % = (IN - OUT) * 100% / IN

GENERAL FORMULAS

PLANT EFFICIENCY

PLANT EFFICIENCY, % = (IN - OUT) * 100% / IN

EXAMPLE: RAW WATER COMING INTO THE PLANT HAS A TSS OF 120 MG/L, LEAVING THE PLANT AFTER FILTRATION IT IS 5 MG/L. WHAT IS THE EFFICENCY OF THE FILTER?

GENERAL FORMULAS

PLANT EFFICIENCY

PLANT EFFICENCY, % = (IN - OUT) * 100% / IN

EXAMPLE: RAW WATERCOMING INTO THE PLANT HAS A TSS OF 120 MG/L, LEAVING THE PLANT AFTER FILTRATION IT IS 5 MG/L. WHAT IS THE EFFICENCY OF THEFILTER?

$$\frac{(120 - 5) * 100\%}{120} = 95.8\%$$

GENERAL FORMULAS

PLANT EFFICIENCY

PLANT EFFICENCY, % = (IN - OUT) * 100% / IN

CAN ALSO BE USED FOR MANY OTHER APPLICATIONS:

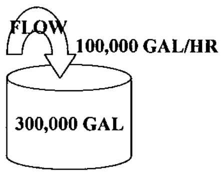
BOD
TSS
REMOVAL OF CHEMICALS

GENERAL FORMULAS

DETENTION TIME = TANK CAP. (GAL.) / RATE OR FLOW (GAL/TIME)

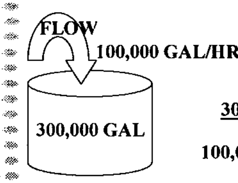
GENERAL FORMULAS

DETENTION TIME = $\frac{\text{TANK CAP. (GAL.)}}{\text{RATE OR FLOW (GAL/TIME)}}$



GENERAL FORMULAS

DETENTION TIME = $\frac{\text{TANK CAP. (GAL.)}}{\text{RATE OR FLOW (GAL/TIME)}}$



$\frac{\text{300,000 GAL.}}{\text{100,000 GAL/HR}}$ = 3 HOURS

GENERAL FORMULAS

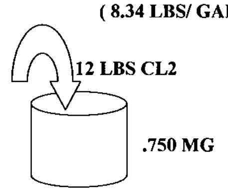
PARTS PER MILLION

MG/L = $\frac{\text{POUNDS OF CHEMICAL}}{\text{(8.34 LBS/ GAL * MG)}}$

GENERAL FORMULAS

PARTS PER MILLION

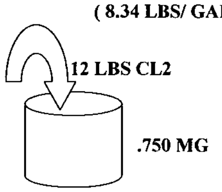
MG/L = $\frac{\text{POUNDS OF CHEMICAL}}{\text{(8.34 LBS/ GAL * MG)}}$



GENERAL FORMULAS

PARTS PER MILLION

MG/L = $\frac{\text{POUNDS OF CHEMICAL}}{\text{(8.34 LBS/ GAL * MG)}}$

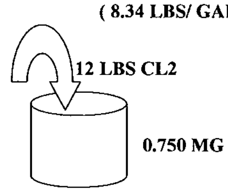


$\frac{\text{12 LBS}}{\text{8.34* .750}}$

GENERAL FORMULAS

PARTS PER MILLION

MG/L = $\frac{\text{POUNDS OF CHEMICAL}}{\text{(8.34 LBS/ GAL * MG)}}$



$\frac{\text{12 LBS}}{\text{8.34* 0.750}}$ = 1.9 MG/L

GENERAL FORMULAS

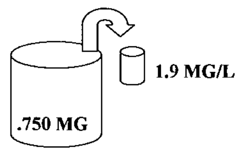
POUNDS

LBS = 8.34 LBS/ GAL * MG/L * MG

GENERAL FORMULAS

POUNDS

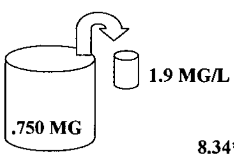
LBS = 8.34 LBS/ GAL * MG/L * MG



GENERAL FORMULAS

POUNDS

LBS = 8.34 LBS/ GAL * MG/L * MG

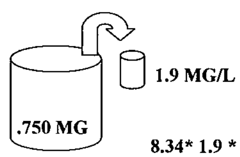


8.34* 1.9 * .750 =

GENERAL FORMULAS

POUNDS

LBS = 8.34 LBS/ GAL * MG/L * MG



8.34* 1.9 * .750 = 11.88 OR 12 LBS

ACTIVATED SLUDGE

SOLIDS INVENTORY, LBS

ACTIVATED SLUDGE

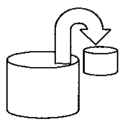
SOLIDS INVENTORY, LBS

SI , LBS = (TANK CAP. MG) * (MLSS, MG/L) * (8.34LBS/GAL)

ACTIVATED SLUDGE

SOLIDS INVENTORY, LBS

SI , LBS = (TANK CAP. MG) * (MLSS, MG/L) * (8.34LBS/GAL)



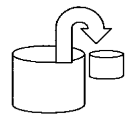
2800 MG/L MLSS

.500 MG

ACTIVATED SLUDGE

SOLIDS INVENTORY, LBS

SI , LBS = (TANK CAP. MG) * (MLSS, MG/L) * (8.34LBS/GAL)



2800 MG/L MLSS

.500 MG

.500 MG * 2800 MG/L * 8.34 LBS/GAL= 11676 LBS

ACTIVATED SLUDGE

SLUDGE AGE

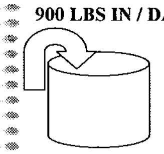
SLUDGE AGE, DAYS= SOLIDS UNDER AERATION, LBS / SOLIDS ADDED, LBS / DAY

ACTIVATED SLUDGE

SLUDGE AGE

SLUDGE AGE, DAYS= SOLIDS UNDER AERATION, LBS / SOLIDS ADDED, LBS / DAY

900 LBS IN / DAY



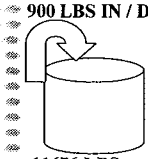
11676 LBS

ACTIVATED SLUDGE

SLUDGE AGE

SLUDGE AGE, DAYS= SOLIDS UNDER AERATION, LBS / SOLIDS ADDED, LBS / DAY

900 LBS IN / DAY



11676 LBS UNDER AERATION / 900 LBS ADDED / DAY

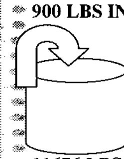
11676 LBS

ACTIVATED SLUDGE

SLUDGE AGE

SLUDGE AGE, DAYS= SOLIDS UNDER AERATION, LBS / SOLIDS ADDED, LBS / DAY

900 LBS IN / DAY



11676 LBS UNDER AERATION / 900 LBS ADDED / DAY =12.97 OR 13 DAYS

11676 LBS

ACTIVATED SLUDGE

- INFLUENT FLOW 0.500 MGD
- INF TSS 200 MG/L
- INF CBOD 250 MG/L
- AERATION TANK VOL. 0.300 MG
- MLSS 2800 MG/L
- EFF TSS 20 MG/L
- EFF CBOD 12 MG/L
- MLVSS 2600 MG/L
- WAS CONC. 5500 MG/L
- WAS 10,000 gal.

ACTIVATED SLUDGE

F/M

F = FOOD OR CBOD, MEASURED IN LBS.

ACTIVATED SLUDGE

F/M

F = FOOD OR CBOD, MEASURED IN LBS.

M = MICROORGANISMS MEASURED IN LBS.

MLVSS ARE THE BUGS

ACTIVATED SLUDGE

F/M =

<u>(INF CBOD, MG/L) * (FLOW, MGD) * (8.34 LBS/GAL)</u>
(AERATION TANK CAP.,MG) * (MLVSS,MG/L) * (8.34LBS/GAL

ACTIVATED SLUDGE

F/M =

<u>(INF CBOD, MG/L) * (FLOW, MGD) * (8.34 LBS/GAL)</u>
(AERATION TANK CAP.,MG) * (MLVSS,MG/L) * (8.34LBS/GAL

<u>250 MG/L * 0.500 MGD * 8.34 LBS/ GAL</u>
0.300 MG* 2600 MG/L * 8.34 LBS/GAL

ACTIVATED SLUDGE

F/M =

<u>(INF CBOD, MG/L) * (FLOW, MGD) * (8.34 LBS/GAL)</u>
(AERATION TANK CAP.,MG) * (MLVSS,MG/L) * (8.34LBS/GAL

<u>250 MG/L * 0.500 MGD * 8.34 LBS/ GAL</u> = .16
0.300 MG* 2600 MG/L * 8.34 LBS/GAL

ACTIVATED SLUDGE

MCRT

ACTIVATED SLUDGE

MCRT: **MEAN CELL RESIDENCE TIME**

ACTIVATED SLUDGE

MCRT: **MEAN CELL RESIDENCE TIME**

- **MCRT= SOLIDS INVENTORY , LBS / (EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)**

ACTIVATED SLUDGE

- **MCRT= SOLIDS INVENTORY , LBS / (EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)**

SI, LBS = TANK CAP MG * MLSSMG/L * 8.34 LBS GAL

EFF SOLIDS, LBS = FLOW MG * EFF TSS MG/L * 8.34LBS/GAL

WAS SOLIDS, LBS = WAS Q * WAS CONC. MG/L * 8.34 LBS/GAL

ACTIVATED SLUDGE

- **MCRT= SOLIDS INVENTORY , LBS / (EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)**

0.300 MG * 2800 MG/L * 8.34 LBS/GAL

0.500 MG * 20 MG/L * 8.34 LBS/ GAL +

0.010 MG * 5500 MG/L * 8.34 LBS/GAL

ACTIVATED SLUDGE

- **MCRT= SOLIDS INVENTORY , LBS / (EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)**

0.300 MG * 2800 MG/L * 8.34 LBS/GAL = 7005.6

0.500 MG * 20 MG/L * 8.34 LBS/ GAL + = 83.4 +

0.010 MG * 5500 MG/L * 8.34 LBS/GAL = 458.7

ACTIVATED SLUDGE

•MCRT= SOLIDS INVENTORY , LBS / (EFF SOLIDS, LBS) + (WAS SOLIDS, LBS)

0.300 MG * 2800 MG/L * 8.34 LBS/GAL = 7005.6

0.500 MG * 20 MG/L * 8.34 LBS/ GAL + = 83.4 +

0.010 MG * 5500 MG/L * 8.34 LBS/GAL = 458.7

$\frac{7005.6}{83.4 + 458.7}$ $\frac{7005.6}{542.1}$ = 12.92 OR 13 DAYS

Sprayfield Zones.

You operate an extended air plant that is rated at 750,000 Gallons per day. Your average daily flow is 300,000 gallons Per day. You discharge to a sprayfield that has 7 zones. Each Zone is 5 acres. You are allowed to apply 2 inches to a zone.

How long can you spray to a zone before switching zones?

Positive Displacement Pump.

You have a positive displacement pump that has an 8 inch bore and a 6 inch stroke. The pump runs at 89 RPM. How many gallons per stroke does it pump? How many gallons per minute does it pump.

How long will it take to raise the level of a digester 20% If it has a diameter or 20 feet and a height of 10 feet?

Drying Bed Rehab

You have a drying bed that measures 40 feet wide and 60 feet long. You are going to rehab the bed. You need to replace 6 inches of sand in the bed. Sand cost is $60.00 / cubic yard. How much will it cost to rehab the drying bed?

Water Horsepower

You have an effluent pump that pumps 250 gpm at 75 feet of head.

What is the Water Horsepower of the pump?

Brake Horsepower

You have an effluent pump that pumps 250 gpm at 75 feet of head. The Pump has an efficiency factor of .95.

What is the Brake Horsepower?

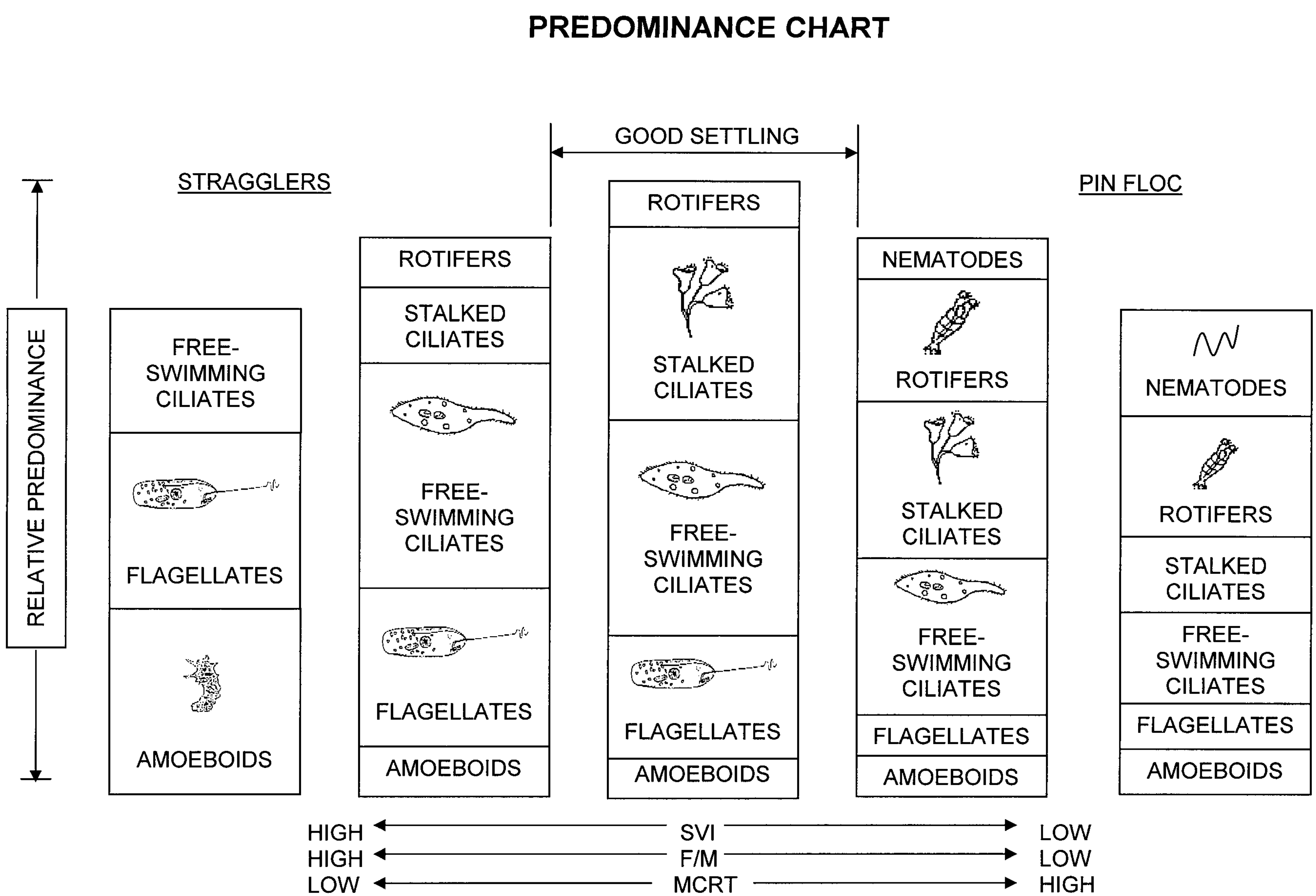


Fig. 11.38 Population predominance vs. operational guidelines (Bar graph taken from EPA PROCESS CONTROL MANUAL FOR AEROBIC BIOLOGICAL WASTEWATER TREATMENT FACILITIES, 1977)

KEY WORDS AND RELATIONSHIPS FOR ACTIVATED SLUDGE PROCESSES

Parameter	Young	Old
Floc Particle Size	***Straggler Floc***, large, fluffy, irregular shape	***Pin Floc***, round, small, granular
Foam Characteristic	White, ***billowy***, crisp	Shiny, ***dark tan***, greasy, ***dark leathery***
Indicator Organisms	***Amoebae, Flagellates***	***Rotifers, Worms*** (Nematode)
MLSS	***Low***, under-oxidized	***High***, over-oxidized
Sludge Age	***Low***	***High***
MCRT	***Low***	***High***
F/M Ratio	***High***, lots of food per bug	***Low***, not much food per bug
SVI	***High*** (>300)	***Low*** (<80)
Settling	***Slow***	***Fast, rapid***
Waste Sludge Rate	***Decrease***	***Increase***

GUIDE NO. 1- Aeration System Problems

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. Boiling action, violent turbulence throughout tank surface. Large air bubbles apparent.	A. Over aeration resulting in high D.O. and/or floc shearing.	1. Generally, D.O. should be in the range of 1.0 to 3.0 mg/L throughout the tanks.	1. Reduce air SCFM rate to maintain D.O. in proper range.
2. Uneven surface aeration pattern, Dead spots or inadequate mixing in some areas of tank.	A. Plugged diffusers.	1. Check maintenance records for last diffuser cleaning.	1. If diffusers have not been cleaned in the last 12 months, do so.
		2. Spot check diffusers in tank for plugging.	2. If several are plugged, clean all diffusers in tank.
	B. Under aeration resulting in low D.O. and/or septic odors.	1. Check D.O., should be in the range of 1.0 to 3.0 mg/L throughout tank.	1. Increase air SCFM rate to maintain D.O. in proper range.
		2. Check for adequate mixing in aeration tank.	2. Calculate SCFM of air per linear foot of diffuser. Adjust air SCFM to manufacturer's recommendation to maintain D.O. and mixing.

GUIDE NO. 1- Aeration System Problems (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
3. Excessive air rates being used with no apparent change in organic or hydraulic loading. Difficult to maintain adequate D.O.	A. Leaks in aeration system piping.	1. Check air pipes and joint connections; listen for air leakage or soap test flanges and watch for bubbling caused by leaking air.	1. Tighten flange bolts and/or replace flange gaskets.
	B. Plugged diffusers. Air discharging from diffuser header blow-off pipes causing local boiling to occur on the surface near diffuser header pipes.	1. Check maintenance record for last cleaning or diffusers. 2. Spot check diffusers in tank for plugging.	1. If diffusers have not been cleaned in last 12 months, do so. 2. If several are plugged, clean all diffusers in tank.
	C. Insufficient or inadequate oxygen transfer.	1. Check aeration system performance. a. Diffused aeration systems should provide 800 to 1500 ft^3 of air per pound of CBOD removed. b. Mechanical aeration systems should provide 1 to 1.2 pounds of oxygen per pound of CBOD removed.	1. Replace with more effective diffusers or mechanical aerators. 2. Add more diffusers or mechanical aerators.
	D. High organic loadings from in-plant side stream flows.	1. Check to see if organic loading from side streams contributes significantly to overall process loading.	1. If loadings are greater than 25%, optimize operational performance or upgrading of other in-plant processes will be required.

GUIDE NO. 2- Foaming Problems

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. White, thick billowing or sudsy foam on aeration tank surface.	A. Overload aeration tank (low MLSS) due to process start-up.	1. Check aeration tank BOD loading (lb/day) and the MLVSS in aeration tank. Calculate F/M ratio. Compare to the desired operating range.	1. After calculating the F/M and the MLVSS needed, stop wasting until the desired MLVSS is reached.
		2. Check secondary clarifier effluent for solids carryover. Effluent will look cloudy.	2. Maintain sufficient RAS rates to minimize solids carryover, especially during peak flow periods. Use mass balance or SSV to determine appropriate RAS rates.
		3. Check D.O. levels in aeration tank.	3. Try to maintain D.O. levels between 1.0 and 3.0 mg/L. Check to make sure adequate mixing is being provided.
	B. Excessive sludge wasting from the process causing overloaded aeration tank.	1. Check and monitor for trend changes occurring in the following. a. Decrease in MLVSS mg/L. b. Decrease in MCRT. c. Increase in F/M. d. D.O. levels maintained with lower air rates. e. Increased WAS rate.	1. Reduce WAS rate by not more than 10% per day until process approaches normal control parameters. 2. Increase RAS rate to minimize effluent solids loss. Maintain sludge blanket depth of 1 to 3 ft from clarifier floor.

GUIDE NO. 2- Foaming Problems (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
	C. Highly toxic waste, such as metals or bactericide, or colder wastewater temperatures, or severe temperature variations resulting in reduction of MLSS.	1. Take MLSS sample and test for metals, bactericides, and temperature.	1. Reestablish new culture of activated sludge. If possible, waste sludge from process without returning to other in-plant processes. Obtain seed from another plant, if possible.
		2. Monitor plant influent for significant variations in temperature, metals, etc.	2. Actively enforce Pretreatment Ordinance.
	D. Hydraulic washout of solids from secondary clarifier.	1. Check hydraulic detention time in aeration tank and surface overflow rate in secondary clarifier.	1. Refer to Guide No. 3, Observation 1
	E. Improper influent wastewater and/or RAS flow distribution causing foaming in one or more aeration tanks.	1. Check and monitor for significant differences in MLSS concentrations between multiple aeration tanks.	1. MLSS and RAS concentrations, and D.O.s between multiple tanks should be reasonably consistent.
		2. Check and monitor primary effluent and/or RAS flow rates to each aeration basin.	2. Modify distribution facilities to ensure equal influent wastewater and/or RAS flow rates to aeration basins.

GUIDE NO. 2- Foaming Problems (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
2. Shiny, dark-tan foam on aeration tank surface.	A. Aeration tank approaching underloaded (high MLSS) condition due to insufficient sludge wasting.	1. Check and monitor for trend changes which occur in the following: a. Increase in MLVSS mg/L. b. Increase in MCRT. c. Decrease in F/M. d. D.O. levels maintained with increasing air rates. e. Decrease in WAS rates.	1. Increase WAS rate by not more thank 10% per day until process approaches normal control parameters and a modest amount of light-tan foam is observed on aeration tank surface. 2. For additional checks and remedies refer to Guide No. 5 and 6. 3. For multiple tank operation refer to Observation 1, Probable Cause E.
3. Thick, scummy dark-tan foam on aeration tank surface.	A. Aeration tank is critically underloaded (MLSS too high due to improper WAS control program. Foam results from *Norcardia* sp.	1. Check and monitor for trend changes which occur in the following: a. Foam for presence of Norcardia. b. Increase in MLVSS mg/L, MCRT or decreased F/M. c. D.O. levels maintained by increasing air rates. d. Secondary effluent chlorine demand. e. Decrease in aeration tank effluent pH.	1. Increase WAS rate by not more than 10% per day until process approaches normal control parameters and modest amount of light-tan is observed on aeration surface. 2. For additional checks and remedies refer to Guide No. 5 and 7. 3. For multiple tank operation refer to Observation 1, Probable Cause E of this guide. 4. Do not let Norcardia foam recirculate through plant. Refer to Guide No. 4.

GUIDE NO. 2- Foaming Problems (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
4. Dark-brown, almost blackish sudsy foam on aeration tank surface. Mixed liquor color is very dark-brown to almost black. Detection of septic or sour odor from aeration tank.	A. Anaerobic conditions occurring in aeration tank.	1. Refer to Guide No. 1, Observation 2 and 3.	

GUIDE NO. 3- Solids Washout/ Billowing Solids

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. Localized clouds of homogenous sludge solids rising in certain areas of the clarifier. Mixed liquor in settleability test settles fairly well with a clear supernatant.	A. Equipment malfunction.	1. Refer to Guide No. 1, Observation 1-A, 2-A, and 2-B.	
		2. Check the following equipment for abnormal operation. a. Calibration of flow meters. b. Plugged or partially plugged RAS or WAS pumps and transfer lines. c. Sludge collection mechanisms, such as broken or worn out flights chains sprockets, squeegees, plugged sludge withdrawal tubes.	2. Repair or replace abnormal operating equipment.
		3. Check sludge removal rate and sludge blanket depth in clarifier.	3. Adjust RAS rates and sludge collector mechanism speed to maintain sludge blanket depth at 1 to 3 feet from clarifier floor.
	B. Air or gas entrapment in sludge floc or denitrification occurring.	1. Perform sludge settleability test and gently stir sludge when bubbles are released.	1. If the process is not nitrifying, refer to Probably Cause A above and Guide No. 7, Observation 2.
		2. If bubbles are released, check nitrate mg/L in secondary effluent to see is the process is nitrifying.	2. If the process is nitrifying, refer to Guide No. 5, Probably Cause A.

GUIDE NO. 3- Solids Washout/ Billowing Solids (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
	C. Temperature currents.	1. Perform temperature and D.O. profiles in clarifier.	1. If temperatures exceed 1 or 2 degrees between top and bottom of clarifier, use an additional aeration tank and clarifier if possible.
		2. Check inlet and outlet baffling for proper solids distribution in clarifier.	2. Modify or install additional baffling in clarifiers. 3. Refer to Probable Cause A-1 and A-2 above.
	D. Solids washout due to hydraulic overloading.	1. Check hydraulic detention time in aeration tank and clarifier, and surface overflow rate in clarifier.	1. If hydraulic loadings exceed design capability, use additional aeration tanks and clarifiers if possible. 2. Reduce RAS rate to maintain high sludge blanket depth in clarifier. 3. If possible, change process operation to sludge reaeration or contact stabilization mode. 4. Refer to Probable Causes B-1, B-2, and C-2 above.

GUIDE NO. 3- Solids Washout/ Billowing Solids (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
2. Localized clouds of fluffy homogenous sludge rising in certain areas of the clarifier. Mixed liquor settles slowly, leaving stragglers in supernatant.	A. Overloaded aeration tank (low MLSS) resulting in a young, low density sludge.	1. Check and monitor trend changes which occur in the following: a. Decrease in MLVSS, mg/L. b. Decrease in MCRT. c. Increase in F/M ratio. d. Lower air SCFM rate to maintain D.O. level.	1. Decrease WAS rates by not more than 10% over day to bring process back to optimum parameters.

GUIDE NO. 4- Bulking Sludge (EPA 1977, Jenkins 1986)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. Clouds of homogenous sludge rising and extending throughout the clarifier tank. Mixed liquor settles slowly and compacts poorly in settleability test but supernatant is fairly clear. Microscopic exam shows few filamentous organisms. Sudden increase in SVI.	A. Toxic materials present causing dispersed growth floc.	1. Check MLSS SOUR.	1. Enforce sewer ordinance.
	B. High F/M.	1. Monitor trends in MLVSS, MCRT, F/M aeration D.O., and influent BOD.	1. Use contact-stabilization, if possible. 2. Decrease WAS rate. 3. Decrease RAS rate. 4. Use setting aids.
2. Clouds of billowing homogenous sludge rising and extending throughout the clarifier. Mixed liquor settles slowly and compacts poorly in settleability test but supernatant is fairly clear. Microscopic exam slows numerous filamentous organisms extending beyond the floc into the free water.	A. Nutrient Deficiency.	1. Check available nutrient levels of influent and effluent. The ratio of influent BOD_5/N/P should be at least 100/5/1. Long MCRT sludges can be lower due to recycle of nutrients. Atypical influent high in sugars or other readily degradable BOD may require supplemental N. Effluent concentrations of total soluble inorganic $N \geq 0.2$ mg/L and soluble orthophosphate ≥ 0.2 mg P/L. 2. Check for filament types 021N, 0041, 0675 or *Thiothrix*.	1. Application of chlorine, hydrogen peroxide, or polymers is not recommended. 2. Supplement N deficiency by influent addition of aqueous ammonia or anhydrous ammonia. 3. Supplement P deficiency by influent addition of tri-sodium phosphate.

GUIDE NO. 4- Bulking Sludge (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
	B. Low aeration dissolved oxygen.	1. Check and monitor trend changes which occur in the following: a. Decrease in MLVSS mg/L, MCRT, increase in F/M ratio. b. Change in aeration D.O. levels, aeration equip't. c. Sudden SVI increase from normal, or decrease in SDI. d. Check for presence of filamentous bacteria, Type 1701, *Sphaerotilus natans*, or *Haliscomenobacter hydrossis*.	1. Decrease WAS rates by not more than 10% per day until process approaches normal operating parameters. 2. Increase aeration basin D.O. 3. Chlorinate RAS at 2 to 3 lbs/day/1000 lbs MLVSS until SVI improves. Taper back chlorine dose to maintain desired SVI.
	C. Low F/M bulking.	1. Check for excessive presence of *Microthrix parvicella*, *H. hydrossis*, *Norcardia*, Types 021N, 0041, 0675, 0092, 0581, 0961, 0803.	1. Increase WAS rate by not more than 10 % per day to meet a higher F/M. Maintain new F/M for 3 x MCRT to establish new microorganism distribution. 2. Change operation to provide anoxic selector at influent end of aeration or construct a mixed, anoxic selector tank. 3. Operate in a plug flow mode, providing very high OUR conditions at the head of the tank. 4. Remove aeration tankage from service.

GUIDE NO. 4- Bulking Sludge (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
	D. Wide fluctuations in raw influent pH or aeration tank pH less than 6.5.	1. Monitor influent pH continuously. Examine for the presence of fungi.	1. If influent pH is less than 6.5, conduct industrial survey to identify source. a. Enforce industrial pretreatment ordinance. b. Adjust pH by adding an alkaline agent such as caustic soda or lime to the aeration tank influent. 2. If fungi are present chlorinate RAS as described for filamentous bacteria.
		2. Check if process is nitrifying due to warm wastewater temperature or low F/M loading.	1. If nitrification is not required, increase WAS rate by not more than 10% per day to stop nitrification. 2. If nitrification is required, raise pH by adding an alkaline agent such as caustic soda or lime to the aeration influent.
	E. Septic wastewater.	1. Check for presence of *Thiothrix*, *Beggiatoa*, or Type 021N.	1. Add oxidizing agent, such as chlorine, hydrogen peroxide, or preaeration to the influent prior to the aeration tank.

GUIDE NO. 5- Sludge Clumping

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. Sludge clumps (from size of a golf ball to as large as a basketball) rising to and dispersing on clarifier surface. Bubbles noticed on clarifier surface. Mixed liquor in settleability test settles fairly well, however a portion of and/or all the settled sludge rises to the surface within four hours after lest is started.	A. Denitrification in clarifier.	1. Check for increase in secondary effluent nitrate level.	1. Increase WAS rate by not 10% per day to reduce or eliminate level of nitrification. If nitrification is required, reduce to allowable minimum.
		2. Check loading parameters.	2. Maintain WAS rates to keep process within proper MCRT and F/M ratio.
		3. Check D.O. and temperature levels in the aeration tank.	3. Maintain D.O. at minimum level (1.0 mg/L). Be sure adequate mixing is provided in the aeration tank.
		4. Check RAS rates and sludge blanket depth in clarifier.	4. Adjust RAS rate to maintain sludge blanket depth of I to 3 feel in clarifier. Ensure proper WAS rate is being maintained.
	B. Septicity occurring in clarifier.	1. Refer to Guide No. 1, Observation 2.	
		2. See 3 and 4 above.	

GUIDE NO. 6- Cloudy Secondary Effluent

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. Secondary effluent from clarifier is cloudy and contains suspended matter. Mixed liquor in settleability test settles poorly, leaving a cloudy supernatant.	A. MLSS in aeration tank low due to process start-up.	1. Refer to Guide No. 2, Observation 1.	
	B. Increase in organic loading.	1. Perform microscopic examination on mixed liquor and return sludge. Check for presence of protozoa.	1. If no protozoa are present, possible shock organic loading has occurred.
		2. Check organic loading on process.	2. Reduce WAS rate by not more than 10% per day to bring process loading parameters and increase RAS rates to maintain 1 to 3 foot sludge blanket in clarifier.
		3. Check D.O. level in aeration tank.	3. Adjust air SCFM rate to maintain D.O. level within 1.0 to 3.0 mg/L.
	C. Toxic shock loading.	1. Perform microscopic examination on mixed liquor and return sludge. Check for presence of inactive protozoa.	1. If protozoa are inactive, possibility of recent toxic load on process. 2. Refer to Guide No. 2, Observation 1-C.
	D. Overaeration causing mixed liquor floc to shear.	1. Perform microscopic examination on mixed liquor. Check for dispersed or fragmented floc and presence of active protozoa.	1. Refer to Guide No. 1, Observation 1-A.

GUIDE NO. 7- Ashing and Pinpoint/Straggler Floc

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. Fine dispersed floc (about tile size of a pinhead) extending throughout the clarifier with little islands of sludge accumulated on the surface afoul discharging over the weirs. Mixed liquor in settleability test settles fairly well. Sludge is dense at bottom with fine particles of floc suspended in fairly clear supernatant.	A. Aeration tank approaching underloaded conditions (high MLSS) because of old sludge in system.	1. Check and monitor trend changes which occur in the following: a. Increase in MLVSS mg/L and MCRT. b. Decrease in F/M ratio. c. D.O. levels maintained with increasing aeration rates. d. Decrease in WAS rates. e. Decrease in organic loading (BOD/COD in primary effluent).	1. Increase WAS rates by not more than 10% per day to bring process back to optimum control parameters for average organic loading.
		2. Check for foaming in aeration tank.	2. Refer to Guide No. 2 for any foaming which may be occurring ill aeration tank. 3. Adjust RAS rates to maintain sludge blanket depth of I to 3 feet in clarifier. 4. Refer to Guide No. I for additional observation.
2. Small particles ashlike material floating on clarifier surface.	A. Beginning of denitrification.	1. Stir floating floc on surface of 30-minute settling test.	1. If floating floc releases bubbles and settles, see Guide No. 5, Probable Cause A. 2. If it does not settle, refer to Probable Cause B below.

GUIDE NO. 7- Ashing and Pinpoint/Straggler Floc (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
3. Particles of straggler floc about ¼" or larger, extending throughout the clarifier and discharging over the weirs. Mixed liquor in settleability test, settles fairly well. Sludge does not compact well at the bottom with chunks of floc suspended in fairly clear supernatant.	A. Aeration tank slightly underloaded. (Low MLSS due to organic load change.)	1. Check and monitor trend changes which occur in the following: a. Decrease in MLVSS mg/L and MCRT. b. Increase in F/M ratio. c. Less aeration rate used to maintain D.O. d. Increase or decrease in organic loading (BOD/COD in primary effluent).	1. Decrease WAS rates by not more than 10% per day to bring process back to optimum control parameters for average organic loading.
		2. Check for foaming in aeration tanks.	2. Refer to Guide No. 2 for any foaming occurring in aeration tank. 3. Adjust RAS rates to maintain sludge blanket depth of 1 to 3 feet in clarifier. 4. Decrease aeration SCFM rates to maintain minimum D.O. of only 1.0 mg/L in aeration tank. Refer to Guide No. 1 for additional observation.

GUIDE NO. 8- Nitrification/ Denitrification

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. Nitrification problems- High effluent ammonia or TKN.	A. Influent alkalinity.	1. Check influent alkalinity. Need 7.1 mg/L of alkalinity for every 1 mg/L of ammonia oxidized into nitrate.	1. Addition of alkalinity (lime, sodium bicarbonate, sodium hydroxide).
	B. Influent pH.	1. Check influent pH. Optimum range is from 7.0 to 9.0.	1. Normally pH problems will be with low pH. Addition of alkalinity (lime, sodium bicarbonate, sodium hydroxide).
	C. Temperature.	1. Optimum range is from 30-35° C.	1. Monitor commercial/ industrial discharges for elevated temperatures.
	D. Dissolved Oxygen.	1. Typical guidelines are: Minimum 1.0 mg/L , Average $\geq$ 2.0 mg/L	1. Raise dissolved oxygen levels.
		2. 4.2 lbs of oxygen are required to oxidize 1 lb of ammonia to nitrate.	2. Check blower operation. It must deliver enough oxygen to nitrify.
	E. Sludge retention time (SRT).	1. There is a definite SRT to temperature relationship. The SRT must be higher at cooler temperatures due to reduced microbiological activity.	1. In cold weather increase SRT. Reduce wasting.
	F. Toxic influent.	1. Certain heavy metals and some organic chemicals are toxic to nitrifying organisms.	1. Be careful of pesticides, herbicides, cleaning compounds, antifreeze etc.

GUIDE NO. 8- Nitrification/ Denitrification (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
2. Denitrification problems- High effluent nitrates.	A. Anoxic conditions not being provided.	1. Nitrate is converted to nitrogen gasses by facultative organisms. If there is oxygen present, the organisms will utilize it rather than the nitrate.	1. Cycle blowers on and off or create an anoxic zone. 2. Reduce DO in oxic zone. 3. Lower DO in recycle.
	B. Lack of carbon source (soluble BOD).	1. A carbon source is needed for the denitrification reactions. The TBOD:TKN ratio should be 5 to 10.	1. Create the anoxic zone at the head of the plant utilizing raw wastewater as the carbon (food) source. 2. Provide additional carbon using methanol, waste sugars, etc.
	C. pH.	1. Check pH. The ideal pH for denitrification is 7.5- 8.5.	1. Adjust pH if necessary (lime, sodium bicarbonate, sodium hydroxide).
	D. Sludge Retention Time (SRT) and temperature.	1. Microbiological activity will decrease drastically as water temperature drops below 20° C. More organisms will be required to do the same amount of work.	1. Raise plant SRT during the late fall to early spring. Reduce wasting during cold months.

GUIDE NO. 9- Chlorination Problems

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
1. Inconsistent bleach feed.	A. Hypochlorite feed pump or tubing has accumulation of carbonate scale.	1. Hypochlorite feed pump or tubing.	1. Clean pump and tubing with a 5% HCL (Muriatic Acid) solution, then flush with water.
2. Low chlorine residual.	A. Improper dosage.	1. Hypochlorite feed rate.	1. Increase chlorine feed rate.
	B. Hypochlorite solution has deteriorated (light, heat, and time).	1. Length of time sodium hypochlorite has been stored and conditions of storage (i.e. in direct sunlight or in excessive heat).	1. Purchase only enough chlorine that you can sue within 30 days. Store sodium hypochlorite in shade.
	C. Destruction of chlorine residual by reducing compounds (Fe^{+2}, Mn^{+2}, H_2S and organic matter).	1. Check for solids escaping plant. If effluent TSS is high so may the content of organic matter. Check for Fe^{+2}, Mn^{+2}, and H_2S.	1. Eliminate sources if possible and/or Increase chlorine feed rate until desired residual is established. H_2S may be present if plant is septic. Fe^{+2} and Mn^{+2} may be in raw drinking water supply. Consider aeration of drinking water supply.
3. Poor fecal coliform kills.	A. Poor mixing.	1. Check injection point.	1. Move injection point to a turbulent area.
	B. Insufficient chlorine bleach dose.	1. Check chlorine bleach dose.	1. Increase chlorine bleach dose.
	C. Detention time- Chlorine contact chamber too small- shape of chlorine contact chamber.	1. Calculate detention time of chlorine contact chamber.	1. Chlorine contact chamber should be large enough to afford 15 minute contact time at the peak hourly flow rate.

GUIDE NO. 9- Chlorination Problems (Continued)

OBSERVATION	PROBABLE CAUSE	CHECK	REMEDIES
	D. Shape and piping allow short-circuiting.	1. Conduct a dye test to determine whether flow through chlorine contact tank is short-circuiting.	1. Add baffling to chlorine contact tank.
	E. Chlorine residual is in the form of chloro-organic compounds and chloramines.	1. Check total residual chlorine and free chlorine. If there is no free chlorine then all residual chlorine is in combined state. These compounds will disinfect, but not as efficiently as free chlorine.	1. Increase chlorine bleach dosage.
		2. Check for high effluent TSS. High TSS will blind disinfection action. Check sludge wasting rates.	1. Eliminate source of high effluent TSS. Adjust sludge wasting.
		3. Check pH.	1. As pH increases, disinfection efficiency decreases. Adjust chlorine bleach feed rate.
		4. Check water temperature.	1. As water temperature decreases, disinfection efficiency decreases. Adjust chlorine bleach feed rate.

Sample Exam Disclaimer

The short quizzes that follow are samples of what a student ***may*** see on a Florida Department of Environmental certification exam. ***In no way does passing this short quiz guarantee a person will pass the State certification test***. The answers to these questions may be found in the "FRWA Small Wastewater System Training Manual," in Operation of Wastewater Treatment Plants I & II, 2nd Edition, by Kerri, K., and presented at wastewater training sessions provided by Florida Rural Water Association.

Class D Wastewater
Sample Questions

1. What is not run on raw influent wastewater?
   a. CBOD
   b. Fecal Coliform
   c. Suspended Solids
   d. pH

2. What disease is not considered to be conveyed or transmitted by untreated wastewater?
   a. Amoebic Dysentery
   b. Hepatitis
   c. Malaria
   d. Cholera

3. What effect will the addition of chlorine, acid, alum, carbon dioxide, or sulfuric acid have on the pH of wastewater?
   a. Neutralize
   b. Lower
   c. Increase
   d. Have no effect

4. Coliform bacteria are
   a. Algae
   b. Coagulant aids
   c. Indicators
   d. Sequestering agents

5. Which of these pH readings indicates an acidic wastewater?
   a. 3
   b. 7
   c. 9
   d. 12

6. Three waterborne diseases are
   a. Mumps, measles, colds
   b. Scarlet fever, pneumonia, hay fever
   c. Typhoid fever. dysentery, cholera
   d. TB, diphtheria, chickenpox

7. Which one of the following conditions increases chlorine demand?
   a. Alkalinity increase
   b. Increase in organic matter
   c. Increase in phosphate concentration
   d. pH increase

8. A chlorine leak can be detected by
   a. An explosimeter
   b. Checking the leak gauge
   c. Spraying water on suspected leaks
   d. A white cloud in presence of ammonia fumes

9. Turbidity in wastewater is caused by
   a. Finely divided suspended material
   b. Dissolved calcium
   c. Hardness
   d. Color

10. Dark tan and shiny foam is produced when
   a. F/M ratio is too low
   b. Insufficient aeration tank capacity
   c. Young sludge
   d. RAS rate inappropriate

11. The pH of wastewater
   a. Always increases as acid concentrations increase
   b. Always increases when wastewater becomes septic
   c. Is measured on a scale of 0 to 14
   d. Is measured on a scale of 0 to 100 mg/L

12. Which of the following conditions are likely to have been caused by biological activity that is prompted by long, sluggish flow in a flat grade sewer line?
   a. Concrete and metal corrosion
   b. Oxygen deficiency in manholes, sewers, and wet-wells
   c. Toxic gas production
   d. All of the above

13. Sand, silt, and grit are composed of what kind of matter?
   a. Colloidal
   b. Inorganic
   c. Organic
   d. Volatile

14. Which of the following statements is NOT indicative of fresh wastewater?
   a. Contains some dissolved oxygen from the water supply
   b. Is being decomposed by facultative bacteria
   c. Is blackish in color, with rotten egg odor
   d. Is turbid with solids in suspension

15. How much does a gallon of water weigh?
   a. 9.34 lbs
   b. 8.34 oz
   c. 7.5 lbs
   d. 8.34 lbs

16. Organic solids in wastewater are
   a. Generally of vegetable and animal origin
   b. Inert and not subject to decay
   c. Mostly floatable solids
   d. Always settleable solids

17. The purpose of primary sedimentation is to remove
   a. Pathogenic bacteria
   b. Roots, rags, cans, and large debris
   c. Sand and gravel
   d. Settleable and floatable material

18. One cubic foot of water contains how many gallons?
    a. 2.31 gallons
    b. 7.48 gallons
    c. 8.34 gallons
    d. 10 gallons

19. The seepage of groundwater into sewer lines through cracks and open joints is called
    a. Inflow
    b. Infiltration
    c. Sanitary sewage
    d. A blessing in disguise

20. The direct flow of rainwater into a sewer line through ground level openings and breaks is
    a. Inflow
    b. Infiltration
    c. Industrial sewage
    d. Sanitary sewage

21. ____________ is the most common and prevalent odorous gas associated with domestic wastewater collection systems.
    a. Chlorine
    b. Hydrogen sulfide
    c. Carbon dioxide
    d. Methane

22. Which of the following factors could cause a demand for more DO (Increase in aeration rate) in an aeration tank?
    a. Increase in food (BOD) in the aeration tank influent
    b. Decrease in organic wastewater
    c. Increase in influent DO
    d. Increase in toxic substances

23. Chlorine is _________ times heavier than air
    a. 1.5
    b. 2.0
    c. 2.5
    d. 3.0

24. The liquid to gas expansion ratio of chlorine is
    a. 25 to 1
    b. 250 to 1
    c. 460 to 1
    d. 500 to 1

25. Gaseous chlorine is a
    a. Clear colorless gas
    b. White fog-like gas
    c. Greenish-yellow gas
    d. Greyish-white gas

26. In an aerator, a white billowing foam indicates
   a. The need to increase wasting
   b. The need to increase the return activated sludge rate
   c. The need to decrease wasting
   d. The need to stop the return activated sludge

27. In the aerator, the dissolved oxygen should be maintained at what level?
   a. 2.0 mg/L
   b. 5.0 mg/L
   c. 6.0 mg/L
   d. 8.0 mg/L

28. A low F/M ratio, high MCRT, low SVI, and high MLSS concentrations are all characteristic of
   a. A bulking sludge
   b. A young sludge
   c. An old sludge
   d. None of the above

29. A Class D operator shall not be the lead/chief operator of more than __________ wastewater treatment plant(s) at any time.
   a. 1
   b. 2
   c. 5
   d. 10

30. Where chlorine is used for basic disinfection, a total chlorine residual of at least 0.5 mg/L shall be maintained after at least _________ minutes contact time at maximum daily flow.
   a. 15
   b. 30
   c. 45
   d. 60

31. The operator must report to the FDEP any serious plant breakdown or malfunction within what time frame?
   a. 24 hours
   b. 48 hours
   c. 12 hours
   d. Immediately

32. The recommended storage temperature for preserving samples is
   a. 21 °C
   b. 4 °C
   c. 60 °F
   d. 32 °F

33. Employee hazards you might encounter around a treatment facility would be
   a. Noxious or toxic gases
   b. Physical injuries
   c. oxygen deficiency
   d. All of the above

34. Chlorine gas is
    a. Colorless
    b. Heavier than air
    c. Nontoxic
    d. Odorless

35. Chlorine is primarily used to
    a. Disinfect
    b. Prevent corrosion
    c. Raise pH
    d. Stabilize organics

36. The exhaust fan inlet in a chlorinator room and/or chlorine storage room should be taken from
    a. Anywhere - the location is not important
    b. At floor level
    c. Close to the entrance
    d. In the ceiling

Class C Wastewater
Sample Questions

1. The first step in anaerobic digestion is called
   a. Acid formation
   b. Stabilization
   c. Methane formation
   d. Alkalinity formation

2. pH is the measure of
   a. Amount of an acid
   b. Intensity of basic or acidic condition of a liquid
   c. Acidity
   d. Alkalinity

3. The second stage of anaerobic digestion is called
   a. Acid formation
   b. Stabilization
   c. Methane formation
   d. Pathogenic formation

4. The two primary gases formed in the anaerobic digestion process are
   a. Nitrogen and oxygen
   b. Methane and oxygen
   c. Methane and water
   d. Methane and carbon dioxide

5. One liter of liquid chlorine can evaporate and produce how many liters of chlorine gas?
   a. 100
   b. 250
   c. 460
   d. 490

6. Samples taken for pH measurement should be
   a. Refrigerated
   b. Tested as soon as possible
   c. Allowed to warm to room temperature
   d. Preserved with H_2SO_4

7. What is the desired DO level in the first stage of an RBC ?
   a. 1 to 3 mg/L
   b. 0.5 to 1.0 mg/L
   c. 5 to 10 mg/L
   d. Unimportant since an RBC is in the air

8. Packing glands on centrifugal pumps should be
   a. Tightened until no water flows from around the shaft
   b. Tightened to 25 foot pounds of torque
   c. Tightened enough to allow a leak of one drip per second
   d. Tightened enough to allow a leak of one drip per minute

PROBLEM: Plant effluent coliform count fails to meet required standards for disinfection. Chlorine residual is adequate. Disinfectant supply not a problem.

9. Probable cause:
   a. Capacity of chlorinator too low
   b. Too many solids in effluent
   c. Contact time too short
   d. Chlorine demand too high

10. In a well operated activated sludge plant, when the RAS rate is decreased but the WAS rate remains constant, the expected conditions would be

	RAS CONC	WAS CONC	MLSS CONC	F/M RATIO	MCRT
a	decrease	decrease	decrease	increase	decrease
b.	decrease	decrease	increase	decrease	increase
c.	increase	increase	decrease	decrease	increase
d.	increase	increase	decrease	increase	decrease

11. In an activated sludge plant, if the DO in the aeration tank suddenly decreases and the aerators are not the problem, what is the most probable cause?
   a. F/M Ratio decreased
   b. Increased organic load
   c. Denitrification
   d. MCRT too long

12. The most important adjustments to the activated sludge process are made by adjusting
   a. Aeration, pH and RAS
   b. Aeration, pH and WAS
   c. RAS, WAS and aeration
   d. pH, RAS and WAS

PROBLEM: Classic sludge bulking occurring in the final clarifier of a conventional activated sludge plant. Indicators include solids pouring over the weirs, excessive floc observed at the surface, and a homogenous sludge blanket appearing throughout the clarifier. Sludge in settling test settles slowly leaving a cloudy effluent.

13. Probable cause
   a. Over-oxidized sludge
   b. Hydraulic washout
   c. Young sludge
   d. SVI too low

14. Necessary check
   a. Weir over flow rate
   b. Determine effluent suspended solids concentration
   c. Calculate sludge age
   d. DO in aeration tank

15. Best solution
   a. Reduce MLSS
   b. Reduce DO
   c. Maintain SVI at 80 or less
   d. Reduce sludge wasting

PROBLEM: Excessive white foam in the aeration tank

16. Probable cause
    a. pH too high
    b. MLSS too low
    c. Waste temperature too high
    d. WAS too low

17. Necessary check
    a. Temperature
    b. MLSS
    c. pH
    d. DO

18. Best solution
    a. Lower pH
    b. Decrease solids
    c. Increase MLSS
    d. Reduce waste temperature

PROBLEM: Good settling in the 30 minute settleability test. Excessive floc billowing in the clarifier and washing out.

19. Probable cause
    a. Hydraulic overload
    b. High pH
    c. BOD removal too high
    d. Excessive CBOD

20. Necessary check
    a. pH
    b. DO and settleable solids
    c. Clarifier overflow rate
    d. BOD

21. Best solution
    a. Lower aeration tank effluent weirs
    b. Increase RAS
    c. Add chlorine to RAS
    d. Reduce clarifier loading rates

22. In most activated sludge treatment plants, the major cause of repeated sludge bulking is
    a. Low F/M loading rates and high MCRT
    b. High F/M loading rates and low MCRT
    c. Low F/M loading rates and low MCRT
    d. High F/M loading rates and high MCRT

23. What happens in the stabilization (reaeration) tank in the contact-stabilization process?
    a. Adsorption of the activated floc
    b. Adsorption of waste material by microorganisms
    c. Agglomeration of the activated floc
    d. Digestion of the waste material collected by microorganisms

24. A problem associated with trickling filters is
   a. Bulking
   b. Protozoans
   c. Ponding
   d. Liquefaction

PROBLEM: Operational data is given below for a conventional activated sludge treatment plant:

Influent flow: 0.500 mgd
Influent CBOD: 199 mg/L
Influent TSS: 221 mg/L
Aeration tank volume: 350,000 gal
MLSS: 4200 mg/L
MLVSS: 3150 mg/L
Settleability results: 30 min= 360 ml/L
Settleability results: 60 min= 330 ml/L

RAS ss: 12600 mg/L
RAS vss: 9450 mg/L
RAS flow: 160%
WAS flow: 6433 gpd
Effluent TSS: 45 mg/L
Effluent VSS: 36 mg/L
Effluent CBOD: 20 mg/L

25. Calculate the MCRT
   a. 10 days
   b. 11 days
   c. 14 days
   d. 16 days

26. Calculate the F/M Ratio
   a. 0.09 lbs/lb MLVSS
   b. 0.10 lbs/lb MLVSS
   c. 0.12 lbs/lb MLVSS
   d. 0.15 lbs/lb MLVSS

27. Calculate the aeration tank detention time
   a. 0.3 hours
   b. 0.6 hours
   c. 13.0 hours
   d. 16.8 hours

28. Calculate the SVI
   a. 58
   b. 86
   c. 116
   d. 150

29. A trickling filter plant has an influent CBOD of 250 mg/L and an influent TSS of 260 mg/L. The plant effluent has a CBOD of 12 mg/L and a TSS of 15 mg/L. Calculate the removal efficiency of the treatment system.
   a. 93% CBOD and 97% TSS
   b. 95% CBOD and 94% TSS
   c. 94% CBOD and 95% TSS
   d. 99% CBOD and 99% TSS

30. What is the chlorine dosage if the chlorinator is feeding 120 lbs/day and the average daily flow is 3.5 mgd?
   a. 4.1 mg/L
   b. 8.9 mg/L
   c. 12 mg/L
   d. 23 mg/L

31. What is the chlorine demand for the question above if the residual is 1.3 mg/L?
   a. 1.7 mg/L
   b. 2.0 mg/L
   c. 2.8 mg/L
   d. 7.6 mg/L

32. In a properly operating facultative pond, algae live on carbon dioxide and nutrients during the day, and at night produce carbon dioxide. This has what effect on the pH?
   a. pH increases during the day, and decreases at night
   b. pH decreases during the day, and increases at night
   c. pH stays the same no matter what time of day
   d. Carbon dioxide has no effect on pH

33. A pond operating depth of _____ is recommended to prevent excessive weed and cattail growth.
   a. Less than one foot
   b. Less than three feet
   c. At least three feet
   d. Pond depth doesn't matter to weeds

34. An aerobic pond is a pond that
   a. Has DO distributed throughout the entire contents all the time
   b. Has no DO throughout the entire content of the pond
   c. Has an upper portion of DO, and a anaerobic bottom layer
   d. Requires no additional source of oxygen

35. Excessive odors are noticed around the primary clarifier. Bubbles are seen throughout the clarifier, and sludge is rising to the surface. What is the cause?
   a. Sludge decomposing in tank
   b. Wastewater entering clarifier is gray, with a musty odor
   c. PH of influent wastewater is 6.5 to 7.0
   d. DO of influent wastewater is too high

36. What is the necessary check of the problem described in question 35?
   a. Clarifier influent pH
   b. DO of the influent wastewater
   c. Sludge collection mechanism
   d. Lift station operation

37. A _________ is designed to deliver an accurate volume of sample or reagent when testing wastewater in a laboratory?
   a. Beaker
   b. Flask
   c. Pipet
   d. Graduated cylinder

38. The largest sources of error found in laboratory results are usually caused by:
   a. Representative sampling
   b. Sufficient mixing during sample compositing
   c. Poor preservation techniques
   d. H_2S in sample

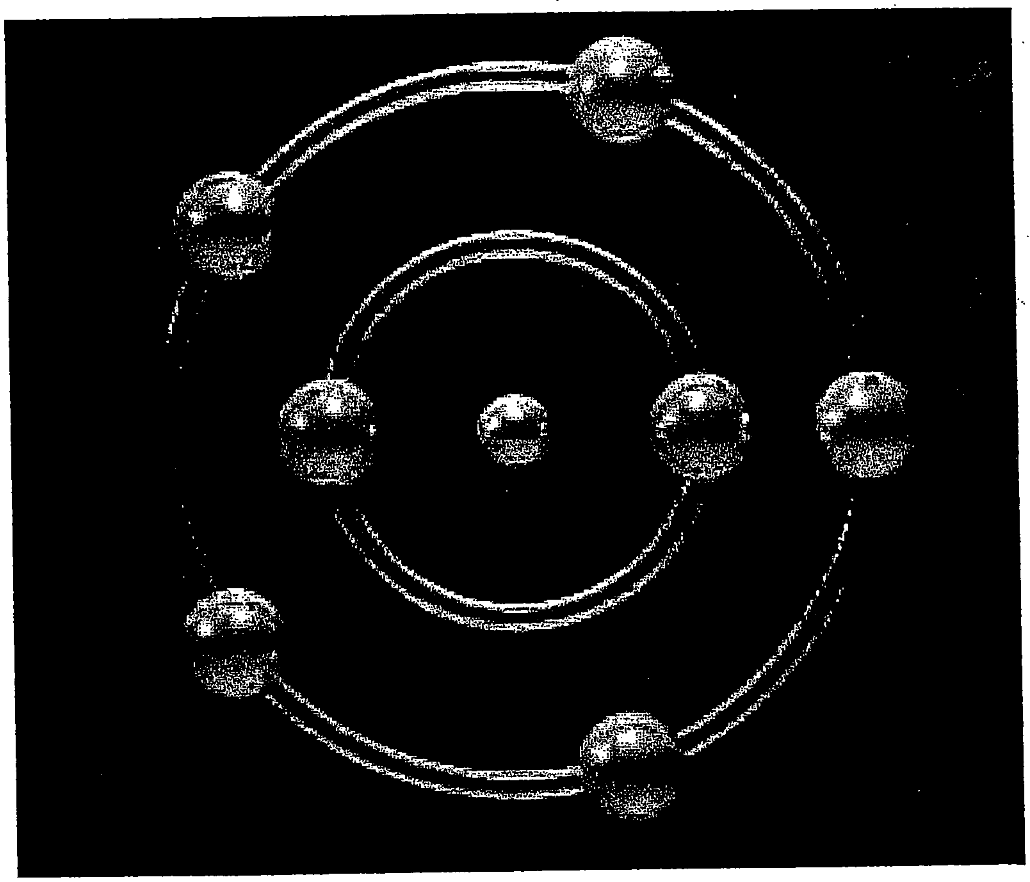
Answer Key to Class D Wastewater Sample Questions

1.	B	19.	B
2.	C	20.	A
3.	B	21.	B
4.	C	22.	A
5.	A	23.	C
6.	C	24.	C
7.	B	25.	C
8.	D	26.	C
9.	A	27.	A
10.	A	28.	C
11.	C	29.	A
12.	D	30.	A
13.	B	31.	A
14.	C	32.	B
15.	D	33.	D
16.	A	34.	B
17.	D	35.	A
18.	B	36.	B

Answer Key to Class C Wastewater Sample Questions

1.	A	20.	C
2.	B	21.	D
3.	C	22.	B
4.	D	23.	D
5.	C	24.	C
6.	B	25.	C
7.	A	26.	A
8.	C	27.	D
9.	C	28.	B
10.	D	29.	B
11.	B	30.	A
12.	C	31.	C
13.	C	32.	A
14.	C	33.	C
15.	D	34.	A
16.	B	35.	A
17.	B	36.	C
18.	C	37.	C
19.	A	38.	C

NITROGEN CONTROL IN WASTEWATER TREATMENT PLANTS



A manual prepared for the

Florida Department of Environmental Protection

by

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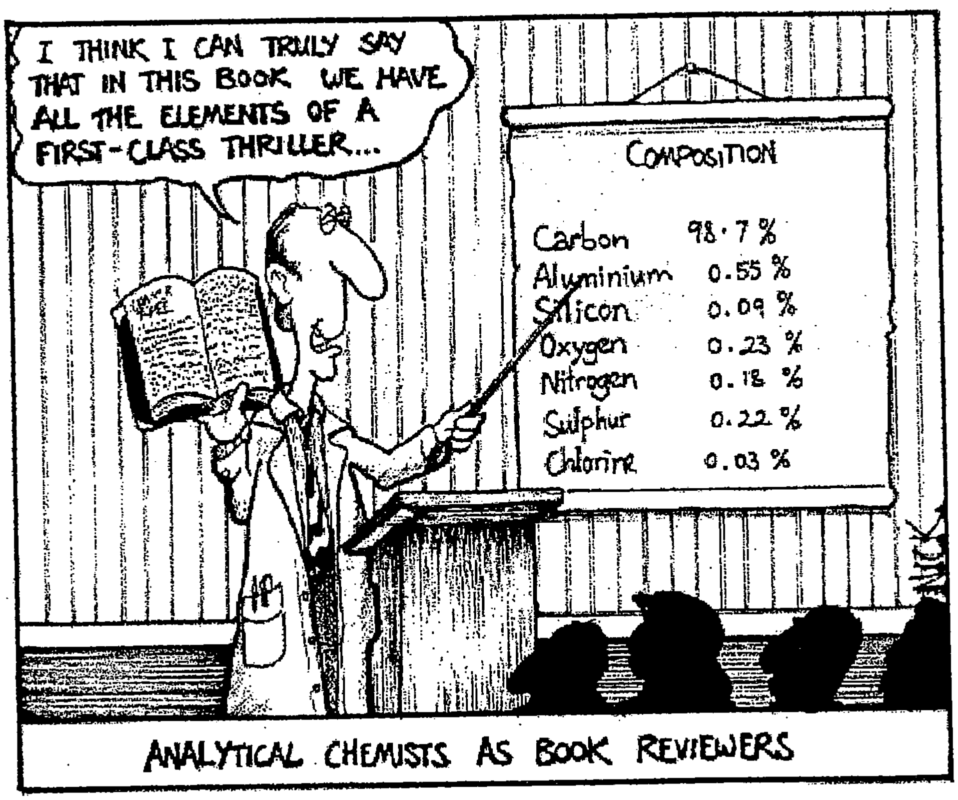
Introduction

This manual is designed to assist operators and owners of small wastewater treatment plants in understanding the role that nitrogen plays in the daily operation of their treatment facilities. It is also designed to help in preparing for State of Florida Department of Environmental Protection (FDEP) wastewater operator certification exams. This manual is a cooperative effort between the FDEP and the Florida Rural Water Association.



General Information on Nitrogen

What is nitrogen?

- Nitrogen was discovered in 1772 by Daniel Rutherford in Scotland
- Nitrogen gas makes up nearly 80% of the air we breathe
- Nitrogen gas is not toxic
- Nitrogen compounds such as ammonia (NH_3) are toxic in high concentration
- Nitrogen containing compounds like cyanide (CN^-) are lethal in very small amounts

Forms of nitrogen in water

- Ammonia (NH_3 as a gas or NH_4^+ ions)
- Organic nitrogen (urea, fecal material)
- Nitrate (NO_3^-) and nitrite (NO_2^-)
- Total Kjeldahl Nitrogen (TKN) is the combination of ammonia and organic nitrogen

Why remove nitrogen from wastewater?

In its various forms, nitrogen can deplete dissolved oxygen in receiving waters, stimulate aquatic plant growth, exhibit toxicity toward aquatic life, present a public health hazard, and affect the suitability of wastewater for reuse purposes. Wastewater effluents containing nutrients such as nitrogen and phosphorus can cause eutrophication, the excessive growth of plant and/or algae blooms in lakes, streams and rivers.

Nitrate is a primary contaminant in drinking water and can cause a human heath condition called Methemoglobinemia (blue babies). This is due to the conversion of nitrate to nitrite by nitrate reducing bacteria in the gastrointestinal tract. Oxidation by nitrite of iron in hemoglobin forms methemoglobin. Since methemoglobin is incapable of binding molecular oxygen, the result is a bluish tinge to the skin and suffocation or death may occur if left untreated. The maximum contaminant level (MCL) for nitrate in drinking water is 10.0 mg/L.

Typical effluent permit limits for nitrogen compounds in wastewater effluent vary, but all are based on location of final effluent discharge. A wastewater plant that discharges to a spray field may not have a limit on nitrogen while a plant that discharges to percolation ponds may have an effluent nitrate limit of 12 mg/L. A treatment plant that discharges to a nearby stream or river may have a total nitrogen limit of 3 mg/L, or a unionized ammonia limit of 0.2 mg/L.

In order to achieve these limits, we must operate treatment plants to not only remove CBOD and TSS, but to convert nitrogen compounds to less noxious forms. This requires operators to use processes that they may not be entirely familiar with. Many new package plants are being built with anoxic tanks, which require different process control methods than a basic extended aeration treatment plant. If a wastewater treatment plant does not have an anoxic tank, cycling the aeration blowers on and off may be needed to create an anoxic zone or time to denitrify in the aeration tank. These concepts will be discussed further in the following sections.

Nitrogen in Wastewater Treatment

Depending on environmental variables such as temperature and pH, nitrogen enters a treatment plant in various forms.

AMMONIFICATION

Beginning at the house connection to the main sewer line, nitrogen is mostly in the form of organic nitrogen. Through a process called hydrolysis, organic nitrogen begins conversion to ammonia or ammonium. The form of nitrogen depends on pH and temperature. When the pH of the wastewater is acidic (<6.9) or neutral (7.0), the majority of the nitrogen is ammonium (NH_4^+). When the pH increases over 8.0, the nitrogen is mostly ammonia (NH_3). Typically by the time the wastewater enters the treatment plant, most of the organic nitrogen has been converted to ammonium.

NITRIFICATION

Nitrification is the biological conversion of ammonium to nitrate nitrogen, and is a two-step process. First, bacteria known as *Nitrosomonas* convert ammonia and ammonium to nitrite. Next, bacteria called *Nitrobacter* finish the conversion of nitrite to nitrate. The reactions are generally coupled and proceed rapidly to the nitrate form; therefore nitrite levels at any given time are usually low.

These bacteria known as "Nitrifiers" are strict aerobes, which means they must have free dissolved oxygen to perform their work, and are only active under aerobic conditions. It requires approximately 4.6 pounds of oxygen for every pound of ammonia converted to nitrate. The growth rate of nitrifiers is affected by the concentration of dissolved oxygen (DO), and at DO less than 0.5 mg/L the growth rate is minimal. Typical operational guidelines call for a minimum DO concentration of 1.0 mg/L at peak flow and an average daily DO concentration of 2.0 mg/L. For nitrification to proceed the oxygen should be well distributed throughout the aeration tank and its level should not be below 2.0 mg/L.

The process of nitrification produces acid. This acid formation lowers the pH of the MLSS and can cause a reduction of the growth rate of nitrifying bacteria. The optimum pH for *Nitrosomonas* and *Nitrobacter* is between 7.5 and 8.5 and nitrification stops at pH at or below 6.0. Approximately 7.14 pounds of alkalinity (as $CaCO_3$) are destroyed per pound of ammonia oxidized to nitrate.

Water temperature also affects the rate of nitrification. Nitrification reaches a maximum rate at temperatures between 30 and 35 degrees C (86°F and 95°F). At temperatures of 40°C (104°F) and higher, nitrification rates fall to near zero.

Sludge Age and Mixed Liquor levels are also integral components in the nitrification process. When performing sludge age calculations (MCRT or SRT) to determine the detention time required for nitrification, the capacity of the oxic (aerated) portion of the plant should be used. Since anoxic or fermentation basins are not aerated and nitrifying organisms are strict aerobes, the capacity of these basins should not be included in calculations for oxic SRT. Extended aeration (package type) wastewater plants are more capable of nitrification than contact-stabilization and other activated sludge systems due to the high sludge age and long periods of aeration.

Toxicity and sources of inhibition to microorganisms present problems to operators and nitrifying organisms. Some of the most toxic compounds to nitrifiers include cyanide, thiourea, phenol and heavy metals such as silver, mercury, nickel, chromium, copper and zinc. Some of these compounds can enter a wastewater treatment plant from landfill leachate and septage. Nitrifying bacteria can also be inhibited by free forms of their own substrate. Nitrite oxidizing bacteria are sensitive to free nitrous acid, and ammonia oxidizing bacteria are sensitive to free ammonia. Increased levels of free ammonia can decrease nitrifier growth rates. Some treatment plants that may have increased influent organic nitrogen and ammonia levels include plants that serve Department of Transportation highway rest areas and wastewater plants serving schools.

DENITRIFICATION

Denitrification is an anaerobic respiration process in which nitrate serves as the electron acceptor. In simpler terms, denitrification occurs when oxygen levels are depleted and nitrate becomes the primary oxygen source for microorganisms. When bacteria break apart nitrate (NO_3^-) to gain the oxygen (O_2), the nitrate is reduced to nitrous oxide (N_2O), and nitrogen gas (N_2). Since nitrogen gas has low water solubility, it tends to escape as gas bubbles. These gas bubbles can become bound in the settled sludge in clarifiers and cause the sludge to rise to the surface.

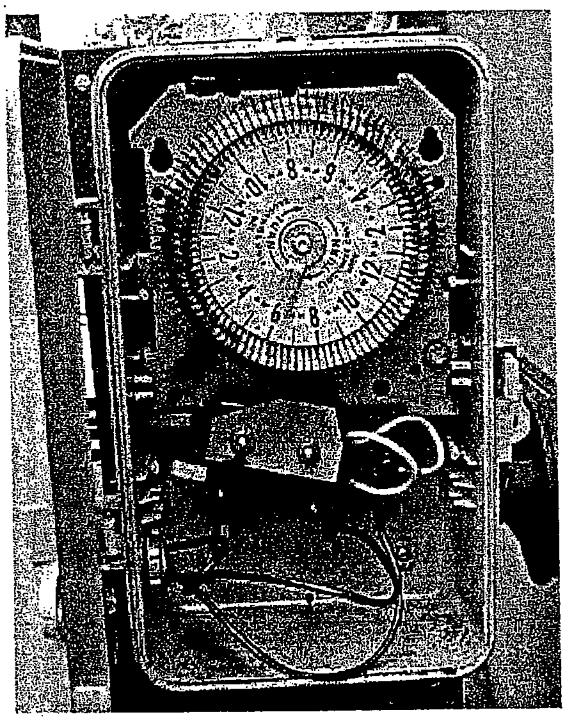


Figure 1 Blower Control Timer

Denitrification Process Description

There are several ways to force bacteria to perform the work of denitrification. The processes may be designed specifically for nitrification/denitrification using anoxic tanks (selectors) or may use timers (Figure 1) controlling aeration blowers to turn blowers on and off.

The Modified Ludzack-Ettinger process (Figure 2) is designed to use nitrate produced by the aeration zone as an oxygen source for facultative bacteria in the breakdown of raw wastewater in the anoxic basin. The first process in the treatment train is a pre-anoxic basin where influent wastewater, return sludge from the clarifier, and nitrate-rich mixed liquor pumped from the effluent end of the aeration tanks are mixed together. The influent wastewater serves as the carbon source for bacteria, return activated sludge from the clarifier provides microorganisms, and the anoxic recycle pumps provide nitrate as an oxygen source.

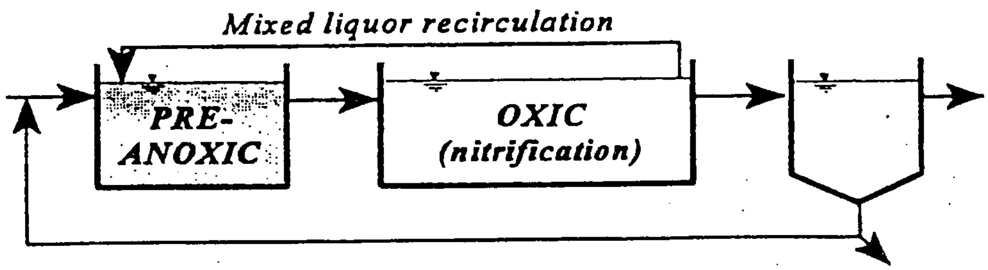


Figure 2 Modified Ludzack-Ettinger process

The anoxic basin is mixed, but not aerated. Mixers can be floating mechanical type or submersible motors fitted with propeller type mixers.

The Wurhman Process places the anoxic basin after the nitrification zone (Figure 3). This process relies on nitrate produced in the preceding aeration tank as the oxygen source. Facultative bacteria that make up a majority of the MLSS perform the work of denitrification.

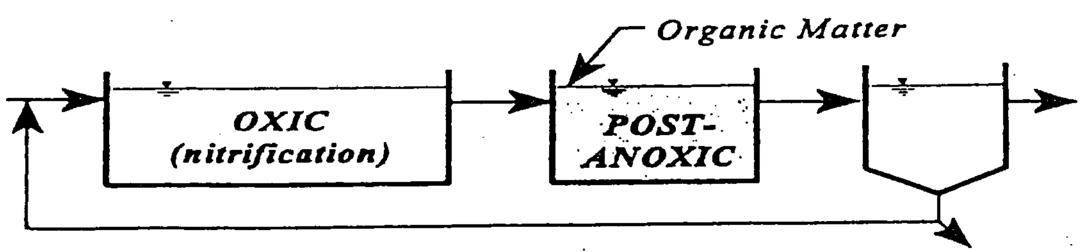


Figure 3 Wurhman Process

In order to drive the denitrification process, organic matter is added to the anoxic basin. Since most of the organic matter present in raw wastewater has been consumed through the aeration tank by aerobic and facultative bacteria, a supplement must be added to the anoxic basin. Sources of organic matter are discussed in following sections. The anoxic basin is mixed, but not aerated. Many facilities employ a reaeration zone after the anoxic basin to release nitrogen gas bound in the sludge, and freshen the mixed liquor before it enters the clarifier.

When a small plant is required to meet nitrate limitations according to the operating permit, but was not originally designed to meet these limits, an alternative method must be employed. These methods may require cycling the aeration blowers on and off to provide a time for bacteria to enter an anoxic period. This time period can be monitored and blower run times (Figure 1) are set using process control methods discussed in later sections of this manual.

Conditions Required for Effective Denitrification

Conditions that affect the efficiency of denitrification include nitrate concentration, anoxic conditions, presence of organic matter, pH, temperature, alkalinity and the effects of trace metals.

Since denitrifying bacteria are facultative organisms, they can use either dissolved oxygen or nitrate as an oxygen source for metabolism and oxidation of organic matter. If dissolved oxygen and nitrate are present, bacteria will use the dissolved oxygen first. This will occur since dissolved oxygen is readily available and yields more energy to the organisms. Therefore it is imperative to keep dissolved oxygen levels as low as possible in anoxic basins or timed anoxic cycles. Excessive aeration in basins designed as anoxic is possible through aerated return sludge (air lift type RAS), excessive splashing of liquid streams into anoxic basins, and air diffusion being used for tank mixing instead of using mixing pumps or mixing devices.

Another important aspect of denitrification is the presence of organic matter to drive the denitrification reaction. Organic matter may be in the form of raw wastewater, food-processing wastes, or chemical sources such as methanol, ethanol, acetic or citric acid. When these sources are not present, bacteria may depend on internal (endogenous) carbon reserves as the organic matter. This matter is released during the death phase of organisms, and may not be a consistent enough source of carbon to drive the denitrification to completion. Whatever organic source is used to drive the denitrification reaction, it should be fed consistently and at a rate to keep denitrification levels maximized. Conversely, it is important to avoid raising effluent CBOD values and avoid spending excessive money on organic sources such as methanol.

An advantage of denitrification is the production of alkalinity and an increase of pH. Approximately 3.0 to 3.6 mg of alkalinity (as CaCO3) is produced per milligram of nitrate reduced to nitrogen gas. Optimum pH values for denitrification are between 7.0 to 8.5.

Temperature affects the growth rate of denitrifying organisms, with greater growth rate at higher temperatures. Denitrification can occur between 5 to 30°C (41°F to 86°F), and these rates increase with temperature and type of organic source present. The highest growth rate can be found when using methanol or acetic acid. A slightly lower rate using raw wastewater will occur, and the lowest growth rates are found when relying on endogenous carbon sources at low water temperatures.

Denitrifying organisms are generally less sensitive to toxic chemicals than nitrifiers, and recover from toxic shock loads quicker than nitrifiers.

Problems That Nitrogen Can Cause

Rising sludge

Rising sludge ('pop-ups') are particles or chunks of sludge floating to the surface of the clarifier. The sludge can be carried over the effluent weir, which results in elevated effluent TSS levels. The sludge is carried to the surface by bubbles of gas formed in the sludge blanket at the bottom of the clarifier or from sludge hung up on the walls of the clarifier. The gas may be either nitrogen or hydrogen sulfide gas (H_2S) formed from the biological decomposition of the sludge.

Some differences of the gas can be used to determine if the sludge is denitrifying or going septic at the bottom of the tank. Pop-ups caused by nitrogen are usually light brown to brown in color, and have no odor when broken up by a hose or cleaning brush. When pop-ups are caused by septic conditions, a classic "rotten egg" odor is noticeable when the sludge is hosed down or otherwise broken up, due to release of the hydrogen sulfide gas. The pop-ups are usually dark brown to black in color.

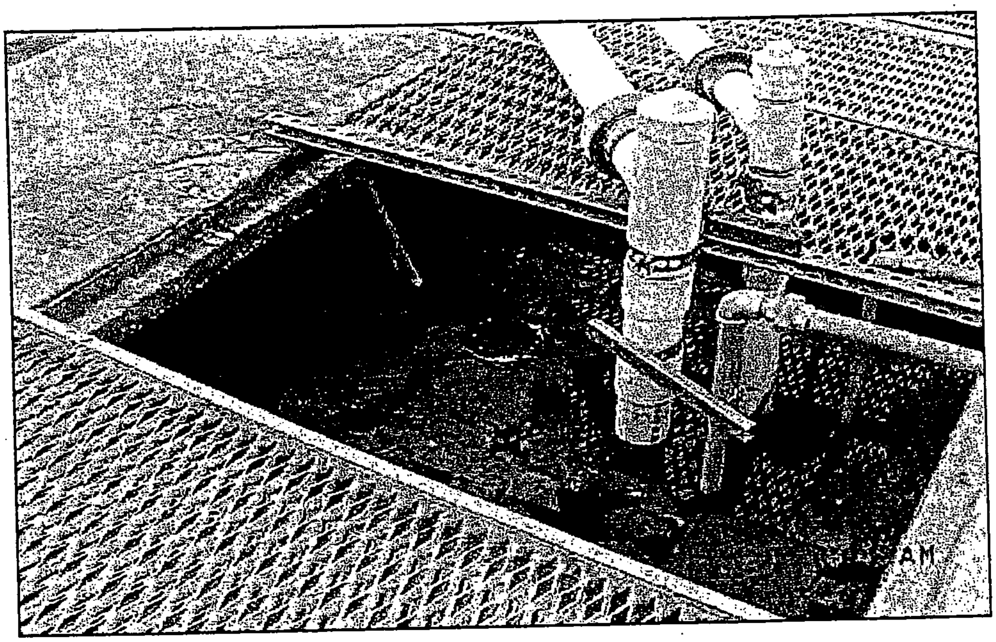


Figure 4 Pop-ups

Denitrification in the clarifier is the most probable cause of the rising sludge in the example shown in Figure 4. To remedy this situation, an increase in sludge wasting rates by no more than 10% per day, will help reduce or eliminate the degree of nitrification. Waste sludge rates should be maintained to keep the process within proper MCRT and F/M ratios. Maintaining a minimum DO at peak flow (1.0 mg/L) while ensuring that proper mixing is still being provided may also help. Adjust RAS rates to maintain a sludge blanket depth of 1 to 3 feet (or 25% of depth) in clarifier. Brushing or otherwise pushing settled solids in the clarifier to RAS hoppers on a regular basis will help reduce rising sludge due to denitrification or septicity occurring in clarifier. See troubleshooting guide #5 in appendix of this manual.

Ashing

Ashing on the surface of clarifiers is the result of very small particles of sludge bound to gas bubbles rising to the surface. These particles form small 'islands' of thin sludge that floats on the clarifier surface, and looks similar to ash (Figure 5). Ashing may also be accompanied by fine, dispersed floc extending throughout the clarifier (pin floc). Ashing is an indication that the aeration system is approaching an old sludge condition, or high MLSS levels. It also indicates that denitrification is beginning in the clarifier. See trouble-shooting guide #7 in appendix of this manual.

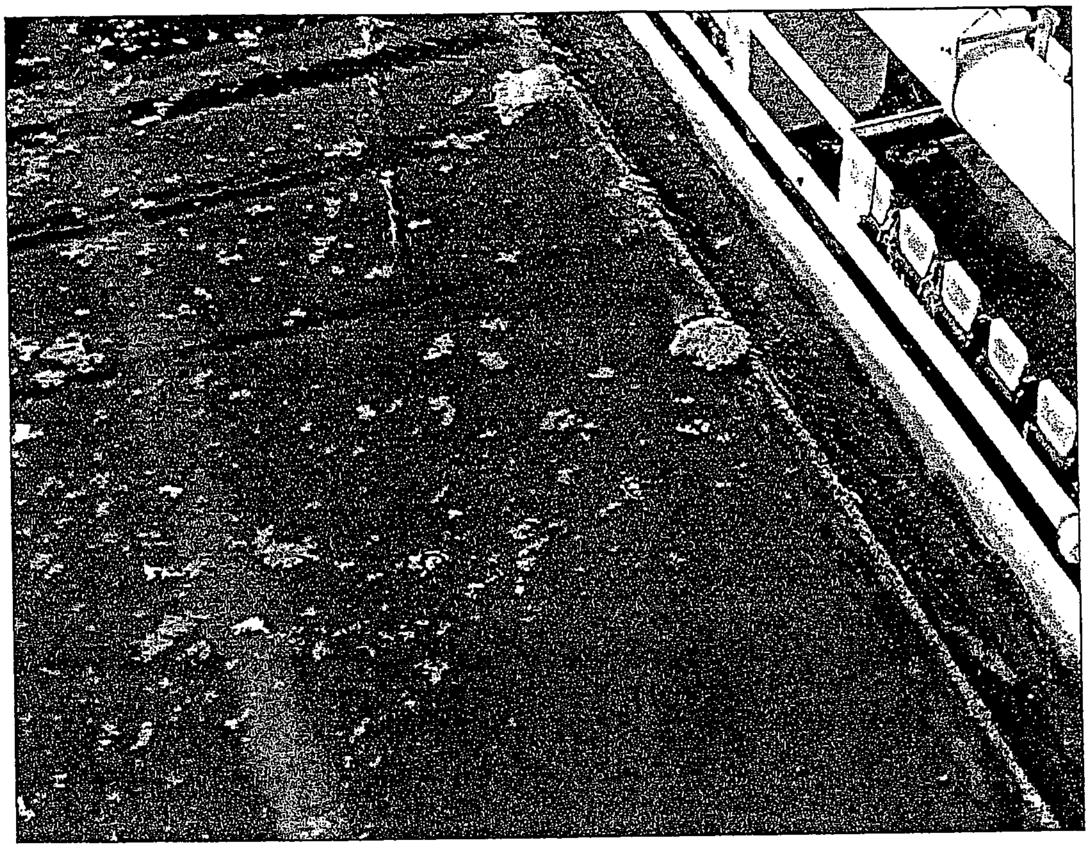


Figure 5 Ashing

When ashing and pin floc are noticed by the operator and determined to be from denitrification; an increase in sludge wasting is recommended to bring the process back into control. If the ashing can not be reduced by stirring or hosing the floating floc particles and the particles float back to the surface, then the cause may be traced to excessive amounts of grease in the mixed liquor. The grease may appear as small white particles floating on the clarifier surface.

Foam/Scum

Foam on the surface of clarifiers can be the result of several problems, including oil and grease entering the plant. A shiny, dark tan foam on aeration tank and clarifier surface means that the system is approaching an under-loaded condition (high MLSS) due to insufficient or lack of sludge wasting.

An excessive amount of grease and oil entering a wastewater treatment plant is a problem for many facilities. Improper or lack of grease trap pumping and deliberate dumping of waste grease down drains can be a food source for *actinomycetes,* a type of short, branched filamentous bacteria. Once these bacteria become predominant, a thick, dark-tan scum forms on the aeration tank and clarifier surface. The effluent quality deteriorates as the bacteria grow. Two types of bacteria can cause such problems, and once they proliferate, they are very difficult to get rid of. Nocardia and Microthrix Parvicella are two foam causing bacteria groups.

Foam or light scum from nitrification is an intermediate step between ashing and pop-ups (Figure 6). This type of scum occurs when a system has a high sludge age, and denitrification has begun in the clarifier. See troubleshooting guide #2 in appendix of this manual.

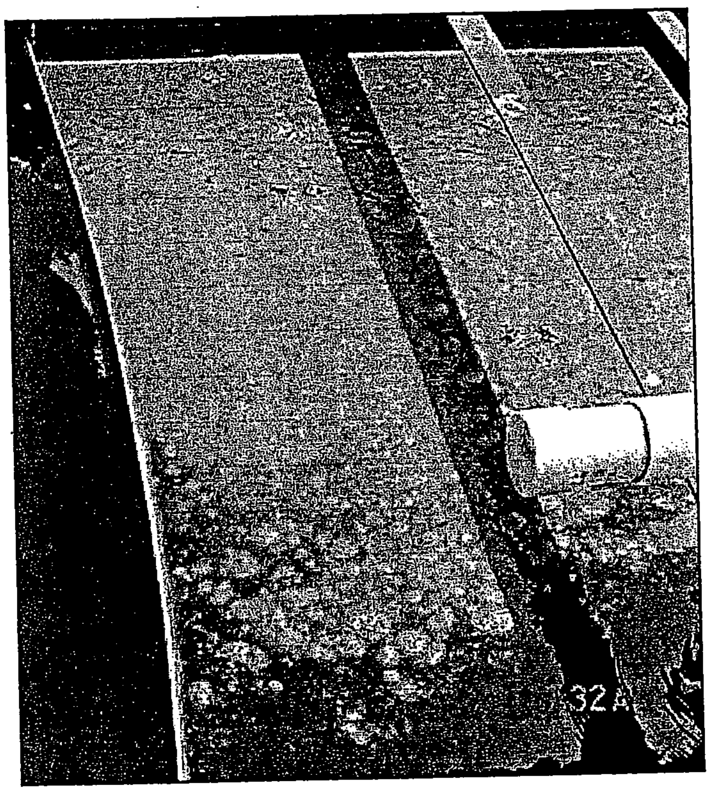


Figure 6 Light scum

For additional assistance in troubleshooting nitrification/denitrification problems, please refer to troubleshooting guide #8 located in the appendix of this manual.

Methods of Controlling Nitrogen

There are several ways to monitor the treatment process to determine the degree of nitrification and denitrification.

Sludge settleability

One of the least costly and easiest ways to check the process is a settleability test. A grab sample of well-mixed aeration tank mixed liquor is taken at the last point accessible where the aeration mixed liquor leaves the basin before entering the clarifier. This sample is allowed to settle. If a portion or all of the sludge rises to the surface within four hours of pulling the sample, denitrification is the probable cause.

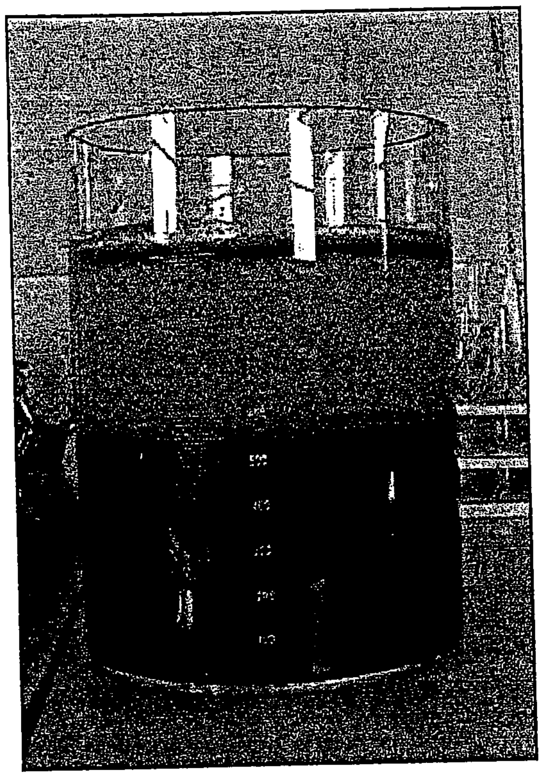


Figure 7 Settleometer

Settleability tests can be run using inexpensive mason jars, plastic containers or more elaborate Settleometers (Figure 7). These can be purchased through laboratory and utility supply companies. Whatever type container is used, it should have a wide mouth and hold at least one liter. Graduated cylinders are not generally acceptable for settling tests.

Nitrogen series testing

A colorimeter is a helpful tool in determining the degree of nitrogen removal and process stability. Testing the effluent for ammonia, nitrite and nitrate can help the operator determine how well the system is working. There are several brands of colorimetric instruments on the market, which vary in price (Figure 8).

It is important to note that monitoring for only one nitrogen parameter does not give a true indication of the removal of nitrogen. Since nitrate is the end result of nitrification, a low nitrate result could mean that the facility successfully nitrified and then denitrified, or it may indicate that the process did not complete nitrification. It is important to monitor the complete nitrogen series for proper process control. This would include testing for ammonia, nitrite and nitrate.

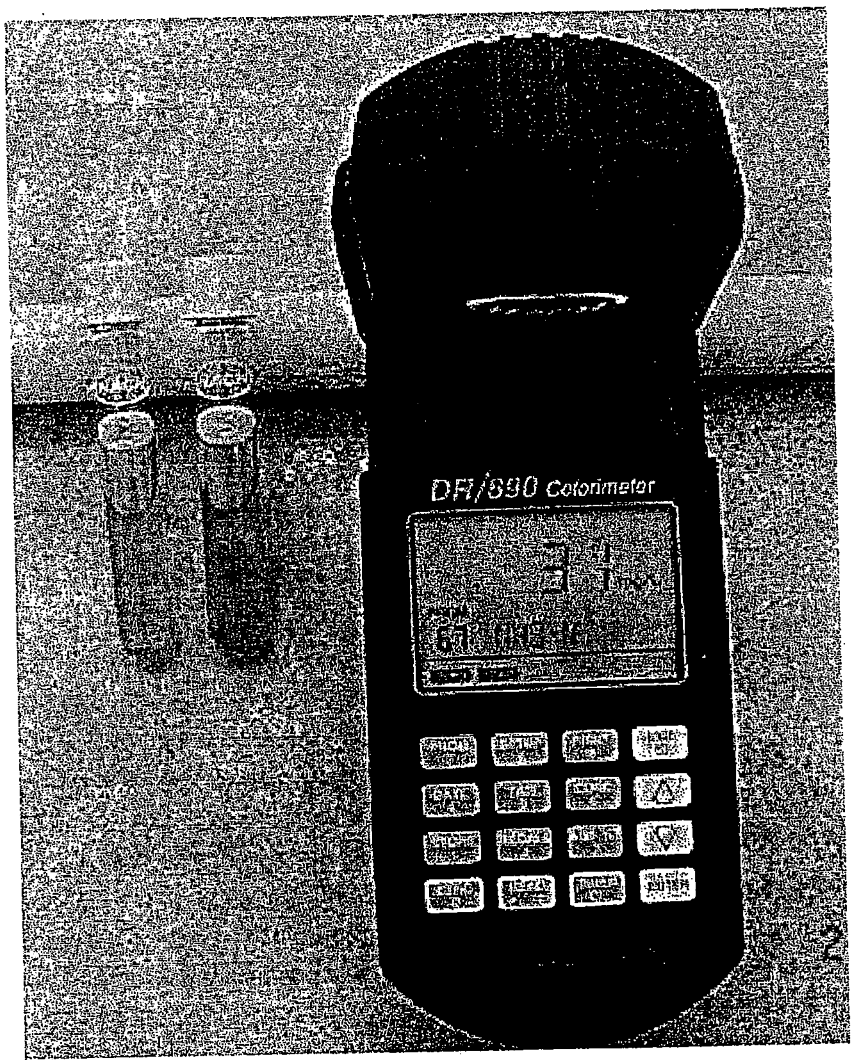


Figure 8 colorimeter

Dissolved oxygen

Monitoring dissolved oxygen (DO) is a vital part of controlling the conversion of nitrogen from ammonia to nitrate. As mentioned previously, it takes approximately 4.6 pounds of oxygen to convert one pound of ammonia to nitrate. About one and one half pounds of oxygen are required for the oxidation of carbonaceous biochemical oxygen demand (CBOD).

Keeping oxygen levels at optimum concentrations is necessary to maintain aerobic conditions. DO levels between 1.0 to 3.0 mg/L are acceptable, however DO concentrations over 3.0 mg/L provide no additional benefit. Keeping constant DO levels below 0.5 mg/L can contribute to the growth of filamentous organisms, which can cause slow settling in clarifiers (sludge bulking).

A DO meter hooked to a probe that is submerged into the mixed liquor is the best method for accurate dissolved oxygen measurement (Figure 9). If a test kit is used for DO measuring, it is crucial that the sample is not aerated additionally after the sample is pulled. Several companies manufacture DO meters that range in price from $250 to $1000.

Figure 9 Dissolved Oxygen meter

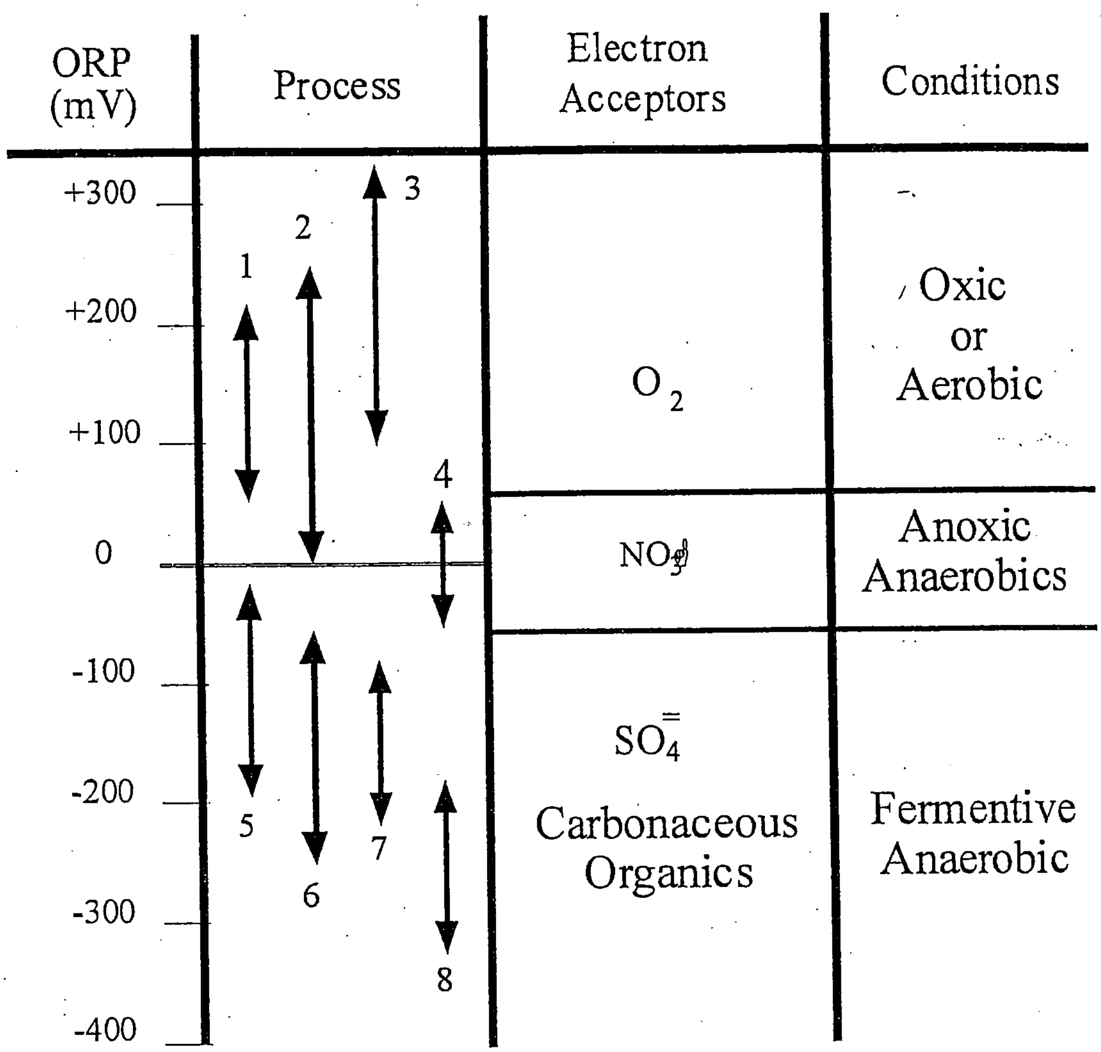
Oxidation Reduction Potential (ORP)

Oxidation Reduction Potential is an effective way of measuring the oxygen source is available to microorganisms. While a DO meter is a good way of measuring residual dissolved oxygen, it doesn't give an accurate representation of the oxygen source is available when DO gets to 0.2 mg/L and lower.

For purposes of this manual, we will look at the ORP ranges required for nitrification and denitrification. An ORP reading of +50 to about +225 mV indicate the presence of dissolved oxygen (O_2). An ORP reading of +225 to +400 mV indicates the presence of oxygen and nitrate (NO_3). ORP readings in the range of +50 to –50 mV indicate that no free available dissolved oxygen is present and nitrate is present as an electron acceptor (oxygen source). This is the range needed for anoxic tanks and timed anoxic cycles. There should be no free DO present in this zone, and a DO meter would read zero mg/L. ORP readings less than –50 mV indicate there is no free oxygen or nitrate present, and the microorganisms would be utilizing sulfate (SO_4) as an electron acceptor for their energy requirements. ORP meters vary in price, but for about $100 you can get a decent ORP meter and submersible probe with a ten-foot cable.

Figure 10 ORPmeter (at left) and DO meter

Figure 10 shows an ORP meter and a DO meter taking measurements from an aeration tank. The DO meter shows a residual DO of about 0.5 mg/L while the ORP meter shows 170 mV. These readings indicate that while dissolved oxygen levels are declining, there is still oxygen present since the ORP meter is registering a +170 mV. This particular aeration tank is not yet into an anoxic cycle. Figure 11 shows how ORP can be used to evaluate the treatment system or parts of a system for operating efficiency. The arrows that correspond to #3 and #4 show ranges for nitrification and denitrification, respectively.



1- Organic Carbon Oxidation
2- Polyphosphate Development
3- Nitrification
4- Denitrification
5- Polyphosphate Breakdown
6- Sulfide Formation
7- Acid Formation
8- Methane Formation

ORP & Metabolic Processes
(Gronsky, etal, 1992)

Figure 11

In the example given if Figure 12, the dissolved oxygen meter reads zero mg/L and the ORP meter reads +11. These readings indicate the basin is operating in an anoxic condition. This is the optimal condition for denitrification in an anoxic tank or in an aeration tank while the blower is in an off cycle.

Figure 12 ORP meter (left) and DO meter

Suggestions on Overall Plant Operation

When operating a wastewater treatment facility that has an aerobic digester for waste sludge stabilization and plant hydraulic capacity is not limited it can be beneficial to return digester supernatant during high daily flow periods. Since aerobic digester supernatant can be high in nitrate, this supernatant can be used as a source of oxygen in anoxic basins or during anoxic periods. This same supernatant can also be the cause of high nitrate results during regular effluent sampling required by the operating permit.

When operating a treatment facility with anaerobic digesters, it is beneficial to return digester supernatant during times of low flows. The strength of this type of supernatant can be high in BOD and ammonia, and returning this liquid during low flows provides food for bacteria during times when the food source is not readily available. Feeding this strong waste stream into the plant during peak flow can deplete dissolved oxygen levels in aeration tanks and adversely effect treatment efficiency.

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Cartoon: "Analytical Chemists as Book Reviewers" used with permission. Dr. Nick D. Kim Department of Chemistry, University of Waikato, Hamilton, New Zealand
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Wastewater C-Exam - August 29, 2003

*(Disclaimer: Questions & answers are representative of the types of questions that may be found on the actual exam. The structure of the questions and the choices offered may not be exactly as they appeared on the exam itself. This is intended to be used as a study guide and/or practice test. It is not recommended that you memorize the answers. The key to passing the exam is to **know the principles behind the questions**. Use your textbooks as a cross-reference and study!!!...Good Luck!)*

1) When operating a plant that treats 1 MGD, how often must flow measurements be taken?
   a) Hourly b) Daily c) 5 times a week d) Continuously

2) What should be done to a sample that has settled solids on the bottom of the sample jar prior to testing in the laboratory?
   a) Discard sample and ask operator to resample
   b) Filter the solids out of the sample
   c) Thoroughly mix the sample
   d) Remove the clear liquid from the top of the sample

3) According to DEP 62-601, at what intervals must a flow-proportioned sample be taken?
   a) Every ¼ hour b) Hourly c) Every 4 hours d) Daily

4) What are two ways to measure DO?
   a) Nephelometer & DO probe b) Nephelometer & Buchner Funnel c) Winkler & DO Probe d) Imhoff & Winkler

5) What problem can be expected when a high nitrogen content is present in the plant effluent that is being discharged to a stream?
   a) Abundance of algae growth b) Low DO c) High DO d) Cloudy water

6) Why should a soda-ash fire extinguisher never be used on an electric motor?
   a) An explosion can occur b) Soda-ash will actually support an electrical fire c) Harmful gases will be produced
   d) Use any kind of extinguisher when necessary

7). Water is collecting at the inlet of a clarifier. What is the most probable cause?
   a) Weirs adjusted too high b) Comminutor is clogged c) Weirs are adjusted too low d) Skimmer needs adjustment

8) What is the proper procedure when shutting down an aerated grit chamber for an extended period of time?
   a) Divert flow, shut down blowers, lock out & tag
   b) Shut down blowers, check shearing pins
   c) Clean excess debris, shut down blowers, check shearing pins
   d) Lock out & tag, divert flow, make necessary repairs

9) Before placing a new chlorinator on-line, what is the *first* thing an operator should do?
   a) Read the O&M manual b) Check for leaks around cylinders and tubing with ammonia
   c) Open cylinder valves before starting booster pump d) Check residual

10) What type of valve is best for use in a sludge line?
   a) Gate b) Check c) Plug d) Globe

11) What prevents water from flowing back into the inlet channel while cleaning screens?
   a) Outlet gate b) Inlet gate c) Weirs d) Backflow plate

12) What is the most accurate way to measure sludge age?
   a) MCRT b) MLSS c) SDI d) SVI

13) What process will occur when solids from the plant effluent fall to the bottom of a stabilization pond?
   a) Nitrification b) Methane fermentation c) Oxidation b) Aeration

14) Why is excess algae growth undesirable in a pond?
   a) Algae will cause a high DO b) H2S will form c) It is aesthetically unpleasing d) Fish will feed on the algae

15) At what temperature does a fusible plug in a chlorine cylinder melt?
   a) 110° - 135° b) 158°-162° c) 175°-190° d) 210°-225°

16) According to DEP rules, when are Discharge Monitoring Reports to be filed by?
   a) Last day of the following month b) 15^{th} of the following month c) 28^{th} of the following month
   d) Within 10 days of the end of the quarter

17) What do algae use to support metabolic functions?
   a) Hydrogen & nitrogen b) Oxygen & hydrogen c) Water & Oxygen d) Nitrogen & phosphorus

18) When analyzing data, a proportional increase or decrease in the values is called:
   a) Arithmetic mean b) Geometric mean c) Standard deviation d) Trend

19) Which manual is approved for use in determining proper lab procedures?
   a) Standard Methods b) Operation of Wastewater Treatment Plants II c) New York Laboratory Practices d) All of the above

20) If a pump will not start, what should an operator check *first*?
   a) Closed suction valve b) Closed discharge valve c) Tripped circuit breaker d) a & b

21) The primary clarifier is operating properly, and the trickling filter has black slime and odor. What is the most probable cause of this abnormal condition?
   a) Filter flies are consuming the slime growth
   b) Particles from the primary clarifier effluent are breaking rocks and causing voids to plug
   c) Plugged underdrain and/or recirculation lines
   d) Snails

22) What can happen when a centrifugal pump is operated against a closed discharge valve?
   a) This type of pump can be operated safely with discharge valve closed
   b) Pressure will build up and line will fail
   c) Packing will be blown out
   d) Water will heat up from cavitation and will damage pump

23) A piston pump with an 8" bore and 6" length pumps at 6 strokes per minute. How many gallons is the pump producing per stroke?
   a) 1.3 gal. b) 2.1 gal. c) 2.7 gal. d) 13 gal.

24) Plant effluent samples reveal a high coliform count. The chlorinator is operating properly and there is a good residual. What is the most probable cause?
   a) Short circuiting in contact chamber b) Sludge blanket too high c) Hydraulic overload d) Filters need backwashing

25) How often should a primary clarifier be shut down for cleaning?
   a) Every 6 months b) Yearly c) Every 3 years d) Only when absolutely necessary

26) Where should MLSS samples be taken in an aerator?
   a) At the inlet and 3" below surface b) Toward the middle of the tank c) Near the effluent and 1' below surface
   d) At the surface of the water in the tank

27) Why is wastewater disinfected?
   a) To "wipe out" harmful organisms b) To completely remove all coliform bacteria
   c) To reduce pathogenic bacteria to safe levels d) To sterilize prior to discharge

28) Why are aerobic digesters sometimes covered?
   a) To protect operators from weather b) To conserve heat in colder temperatures
   c) To keep sunlight off of digester d) To contain CO2 and methane gases

29) Nitrogen and phosphorus removal is achieved during:
   a) Advanced secondary treatment b) Primary treatment c) Secondary treatment d) b & c

30) Why should green sludge never be sent to a drying bed?
   a) Danger of water borne diseases to anyone near it b) Poor drainability and odors c) Dangerous gases may be produced
   d) Aesthetic reasons

31) What is the lowest concentration at which chlorine can be detected by smell?
   a) 8 ppm b) .08 ppm c) 5 ppm d) 10 ppm

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20) If a pump will not start, what should an operator check *first*?
a) Closed suction valve b) Closed discharge valve c) Tripped circuit breaker d) a & b

21) The primary clarifier is operating properly, and the trickling filter has black slime and odor. What is the most probable cause of this abnormal condition?
a) Filter flies are consuming the slime growth
b) Particles from the primary clarifier effluent are breaking rocks and causing voids to plug
c) Plugged underdrain and/or recirculation lines
d) Snails

22) What can happen when a centrifugal pump is operated against a closed discharge valve?
a) This type of pump can be operated safely with discharge valve closed
b) Pressure will build up and line will fail
c) Packing will be blown out
d) Water will heat up from cavitation and will damage pump

23) A piston pump with an 8" bore and 6" length pumps at 6 strokes per minute. How many gallons is the pump producing per stroke?
a) 1.3 gal. b) 2.1 gal. c) 2.7 gal. d) 13 gal.

24) Plant effluent samples reveal a high coliform count. The chlorinator is operating properly and there is a good residual. What is the most probable cause?
a) Short circuiting in contact chamber b) Sludge blanket too high c) Hydraulic overload d) Filters need backwashing

25) How often should a primary clarifier be shut down for cleaning?
a) Every 6 months b) Yearly c) Every 3 years d) Only when absolutely necessary

26) Where should MLSS samples be taken in an aerator?
a) At the inlet and 3" below surface b) Toward the middle of the tank c) Near the effluent and 1' below surface
d) At the surface of the water in the tank

27) Why is wastewater disinfected?
a) To "wipe out" harmful organisms b) To completely remove all coliform bacteria
c) To reduce pathogenic bacteria to safe levels d) To sterilize prior to discharge

28) Why are aerobic digesters sometimes covered?
a) To protect operators from weather b) To conserve heat in colder temperatures
c) To keep sunlight off of digester d) To contain CO2 and methane gases

29) Nitrogen and phosphorus removal is achieved during:
a) Advanced secondary treatment b) Primary treatment c) Secondary treatment d) b & c

30) Why should green sludge never be sent to a drying bed?
a) Danger of water borne diseases to anyone near it b) Poor drainability and odors c) Dangerous gases may be produced
d) Aesthetic reasons

31) What is the lowest concentration at which chlorine can be detected by smell?
a) 8 ppm b) .08 ppm c) 5 ppm d) 10 ppm

32) After removing sludge to a drying bed, an operator should:
   a) Close influent and effluent lines b) Flush lines and leave line open at effluent end of bed.
   c) Keep influent and effluent lines open d) Flush lines and leave influent line open

33) How often should tanks be drained for cleaning?
   a) Periodically to avoid disruption of process b) Never in water plants c) Never in wastewater plants d) Every 6 months

34) What is the simplest device for controlling water level?
   a) Bubbler tube b) Diaphragm c) Electrode d) Float

35) Which process involved in anaerobic digestion is most affected by pH and temperature?
   a) Acid formation b) Methane fermentation c) CO2 production d) H2S production

36) When pumping sludge to a digester, it is best to pump:
   a) Large amounts at frequent intervals b) Large amount 2 or 3 times a day
   c) Small amounts at frequent intervals d) It depends on the type of digester

37) What is the main reason for removing grit from raw sewage during preliminary treatment?
   a) To aid digestion b) To protect pumps c) To improve quality of sludge d) To prevent sludge lines from clogging

38) Domestic wastewater is composed primarily of:
   a) Settleable solids b) Floatable solids c) Grease & oil d) Suspended solids

39) What are the four types of pollution found in wastewater plant influent?
   a) Organic, inorganic, thermal, radioactive b) Organic, inorganic, bacterial, microbial
   c) Tuberculosis, malaria, hepatitis, cholera d) Coliform, hepatitis, cholera, tuberculosis

40) What is one disadvantage that anaerobic digesters have over aerobic digester?
   a) Methane production b) More sludge is produced c) Higher energy costs d) Algae formation

41) Anaerobic digester gas is leaking into the atmosphere. What is the *most probable* cause?
   a) Pilot flame went out b) Valve is open c) Gas mixture out of balance d) Air relief valve stuck

42) What is detritus?
   a) Suspended solids b) Settleable solids c) A mixture of grit and organic materials d) Gravel

43) What provides buffering capacity in an anaerobic digester?
   a) pH b) Alkalinity c) Acidity d) Hydraulic load

44) What is one advantage that aerobic digesters have over anaerobic digesters?
   a) Less odors b) Better gas production c) More sludge is produced d) Can handle higher loads

45) What should an operator *not* do prior to entering an anaerobic digester for cleaning purposes?
   a) Complete a confined space entry permit b) Completely drain the digester c) Open all doors to remove gas, then use a lighter to make sure that all dangerous gases have been removed d) None of the above

46) What process is used to remove chlorine from plant effluent prior to discharge into receiving waters?
   a) Sulfurization b) Aeration c) Dechlorination d) Disinfection

47) What is one reason for aerating wastewater?
   a) Separate oil & grease b) Removal of suspended solids c) Disinfection d) Removal of dissolved solids

48) On which part of a microscope is the slide placed?
   a) Lens b) Plate c) Stand d) Stage

49) What flow-through rate should be maintained in a wastewater collection system?
   a) 1 fps b) 1.5 fps c) 2 fps d) 3 fps

50) Clumps of sludge are floating on the surface of a digester. What is the most probable cause?
   a) DO too high b) Denitrification is occurring c) Aeration rates too high d) RAS rate too high

51) A dark, tan, shiny foam is present on the surface of an aeration basin, and pin floc is observed flowing over the weirs of the clarifier. What does this indicate?
   a) Young sludge b) Denitrification c) Nitrification d) Old sludge

52) What does a pH of 8.5 indicate?
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56) What could cause a false green sheen to appear on a membrane filter?
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57) What is indicated by the presence of a homogenous billowing sludge on the surface of an aerator?
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58) What is the minimum depth that should be maintained in a properly operated pond?
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   a) Lock out and tag b) Clean off excess slime growth c) Check chain drive d) Inspect unit

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   a) Solids build-up in chlorine contact chamber b) Filters need backwashing c) Chlorine residual too high
   d) Chlorine cylinder valves only open half way

63) Which of the following *is not* a part of a wastewater collection system?
   a) Clean outs b) Lateral lines c) Distribution lines d) Lift stations

64) What is zoogleal film?
   a) Organisms that break down organic matter b) A build up of scum on the walls of a clarifier
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65) The automatic screen rake has stopped moving. What should be done first?
   a) Check the shear pins b) Lock out and tag c) Check for break in chain d) Manually clean screen

66) An anaerobic digester is operating properly when the digester gas contains ____ methane.
   a) 50% b) 65% c) 70% d) 85%

67) What is head loss?
   a) The difference in height between two surfaces of water b) Loss of pressure in a collection system
   c) Low Rpm's in a motor d) A condition caused by the accumulation of excess gases

68) How many cubic yards of reuse water would be required to cover 5 acres at a depth of 2"? 3
   a) 100,560 cu. yds. b) 10,056 cu. yds. c) 25,450 cu. yds. d) 225,220 cu. yds. F) 1371.3

69) A chemical feed tank has a diameter of 4 feet, and is 5 feet deep. If the feed pump drops the level of the tank by 3'8" in 6 minutes, approximately how many gallons per minute are being pumped?
   a) 72 gpm b) 45 gpm c) 344 gpm d) 57 gpm

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70) What is the best indicator of a possible problem in an anaerobic digester?
a) pH b) Temperature c) VA/Alk ratio d) High CO2 levels

71) What is the proper sludge concentration from an aerobic digester?
a) 2% b) 4% c) 30% d) 40%

72) What is the first stage of anaerobic digestion?
a) Methane fermentation b) Acid formation c) Nitrification d) Decanting

73) When using two lift station pumps, what is the best way to operate them?
a) Run both pumps b) Alternated pumps every 24 hours c) Switch pumps during high flows d) Alternate pumps hourly

74) Floating solids in the primary clarifier may indicate:
a) Broken scum skimmer b) Denitrification c) Insufficient sludge removal d) b & c

75) A properly operating primary clarifier will remove what percentage of suspended solids?
a) 40% b) 50% c) 60% d) 75%

76) What DO level should be maintained in an aerobic digester?
a) 1 – 2 mg/L b) 2.5 – 3 mg/L c) 3.0 – 4.0 mg/L d) >4.0 mg/L

77) What condition may occur when a sludge pump draws too much water?
a) Coning b) Clogging c) Cavitation d) Denitrification

78) Which is an example of a proper log entry?
a) Employee absenteeism b) Made coffee and cleaned office c) Wasted 1,150 gallons from digester #6 to #1
d) Repaired coffee maker

79) A device that uses a spinning wheel to dry sludge is called a:
a) Filter press b) Centrifuge c) Belt press d) Dewaterer

80) Which dangerous gases may be found at a wastewater treatment plant?
a) H2S b) Cl2 c) Methane d) All of the above

81) What term describes the computer and all the components that are attached to it?
a) Software b) Programs c) Hardware d) Disk drives

82) What methods can be used to dispose of screenings?
a) Incineration & burial b) Burial & dewatering c) Disinfection & drying beds d) Incineration & drying beds
e) Approved Land Fill

83) A settleometer reveals that after 5 to 10 minutes solids won't concentrate above 700 to 900, and settling is slow. What does this indicate?
a) Young sludge b) Old sludge c) Hydraulic overload d) WAS rate too low

84) What device protects computers from power fluctuations?
a) Fuses b) Circuit breakers c) Rotameters d) Surge protectors

85) DEP regulations require that plant logs be:
a) Available for inspection 24 hours a day b) Protected c) Locked in a safe or cabinet at all times d) a & b

86) What is a disadvantage of effluent disposal on land?
a) Contamination of crops b) Vector control c) Possibility of odors d) b & c

87) What is an example of preventative maintenance on gate valves?
a) Painting the valve b) Utilizing the valve for flow control c) Exercising valve d) None of the above

88) Chlorine cylinder is half full
No leaks detected
Cylinder valve is open one complete turn
Chlorine will not feed

What is the most probable cause of the abnormal condition described above?

a) Inadequate injector vacuum b) Cylinder valve not opened all the way c) Gasket missing on cylinder valve d) Chemical feed pump not operating properly

89) Why should water never be put on a chlorine leak?

a) It will form a harmful gas b) It will become slippery c) It will cool the chlorine d) It will cause pipes and fittings to corrode

90) When ammonia is used to check for a chlorine leak, what color cloud will be produced if a leak is detected?

a) White b) Green c) Yellow d) Orange

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Wastewater C-Exam Answer Key

1) d
2) c
3) b
4) c
5) a
6) c
7) a
8) a
9) a
10) c
11) a
12) a
13) b
14) c
15) b
16) c
17) d
18) d
19) a
20) c
21) c
22) d
23) a
24) a
25) b
26) c
27) c
28) b
29) a
30) b
31) b
32) b
33) a
34) d
35) b
36) c
37) b
38) a
39) a
40) c
41) a
42) c
43) b
44) a
45) c
46) c
47) a
48) d
49) c
50) b
51) d
52) b
53) c
54) a
55) b
56) a
57) d
58) c
59) b
60) a
61) b
62) a
63) c
64) a
65) b
66) c
67) a
68) ~~b~~ E
69) d
70) c
71) b
72) b
73) b
74) d
75) c
76) a
77) a
78) c
79) b
80) d
81) c
82) ~~a~~ Approved Land Fill
83) a
84) d
85) d
86) d
87) c
88) a
89) d
90) a

Wastewater Treatment Plant Operations
Practice Test Level "B"

1. What typically happens to the ORP of final effluent when the ammonia concentration in the effluent increases?
   a. The ORP value increases
   b. The ORP value decreases
   c. The ORP value remains the same
   d. Ammonia concentration has nothing to do with ORP values

2. What is the best adjustment to make (from the list of possible answers) if solids are rising in the secondary clarifier, accompanied by small, pinpoint gas bubbles?
   a. Increase aeration D.O.
   b. Decrease the RAS rate
   c. Decrease WAS rate
   d. Decrease aeration D.O.

3. Is a high-rate aeration process typically overloaded or underloaded by design?
   a. Overloaded
   b. Underloaded
   c. Low MLSS
   d. High F/M

4. Which process adjustment will typically decrease the contact time in an aeration tank?
   a. Raising the weir
   b. Decreasing the air supply rate
   c. Increasing the RAS rate
   d. Increasing the WAS rate

5. Which condition may produce the poorest denitrification efficiency in an aeration tank?
   a. Low air supply
   b. High aeration D.O.
   c. Low aeration D.O.
   d. High RAS rate

6. What type of fire would a class 'C' fire extinguisher be used on?
   a. Energized electrical equipment
   b. Ordinary combustibles such as wood, paper, cloth, rubber, and many plastics
   c. Flammable and combustible liquids
   d. Combustible metals such as magnesium, sodium, zinc, and potassium

7. What is the function of wear rings in a centrifugal pump?
   a. Protect steel elements against corrosion
   b. Plug internal liquid leakage
   c. To keep air from being drawn in
   d. To make packing more air tight

8. Modified aeration is also known as ________.
   a. Complete mix
   b. Bardenpho
   c. High-rate
   d. Step-feed

9. Struvite can be controlled by the precipitation of phosphorus using which chemical?
   a. Caustic soda
   b. Iron salt
   c. Sodium bicarbonate
   d. Sodium hydroxide

10. What is the first step toward an effective contingency plan?
    a. Assess vulnerability
    b. Develop and implement a comprehensive plan of action
    c. Inventory emergency response equipment
    d. Prepare a list of emergency responders

11. What is the Sludge Volume Index (SVI)?
    a. A calculation which indicates the tendency of activated sludge solids to thicken or to become concentrated during the sedimentation/thickening process
    b. Measuring and comparing the turbidity of liquids by passing light through them
    c. The volume of sludge blanket divided by the daily volume of sludge
    d. Measurement of the volume of settleable solids in a specific volume of wastewater

12. What typically happens to the chlorine demand of reclaimed water when the nitrate concentration is elevated from 4 mg/L to 8 mg/L?
    a. The chlorine demand doubles
    b. The chlorine demand is cut in half
    c. The chlorine demand is fairly unaffected by nitrate concentrations
    d. The chlorine demand is tripled

13. What is the cause of foaming in an anaerobic digester?
    a. High pH
    b. Insufficient enzymes
    c. Low volatile acid/alkalinity relationship
    d. Overfeeding

14. Why should a "Y" strainer be installed at the inlet end of a water spray system?
    a. To filter out large material
    b. To increase future maintenance time
    c. To prevent short-circuiting in the water spray system
    d. To strain out any foam in the water

15. You should try not to change your sludge wasting rate by more than ________ from one day to the next.
    a. 1 to 5 percent
    b. 5 to 10 percent
    c. 10 to 15 percent
    d. 15 to 20 percent

16. The first action that should be taken when a plant becomes upset is?
    a. Check MLSS
    b. Check plant data
    c. Evaluate settleometer
    d. Ask for help

17. Which types of bacteria are responsible for converting NO_3 to N_2?
    a. Heterotrophic
    b. Nitrosomonas
    c. Nitrobacter
    d. Anaerobic

18. What may be the FIRST corrective action taken to resolve floating sludge conditions in a secondary clarifier, given these observations: SVI is 132, Microscopic exam reveals abundance of filamentous organisms.
    a. Decrease D.O.
    b. Increase D.O.
    c. Increase the WAS rate
    d. Reduce RAS rate

19. What may be the PROBABLE CAUSE for low chlorine gas pressure at a chlorinator?
    a. Chlorine cylinders are full
    b. Low injector vacuum
    c. Insufficient number of cylinders connected to the system
    d. Plugged diffusers

20. What is the standard design range for the R:Q ratio of a conventional activated sludge process?
    a. 10 to 15%
    b. 20 to 50%
    c. 75 to 100%
    d. 100 to 150%

21. What typically happens to the pH of mixed liquor when alum is used for phosphorus removal in the activated sludge process?
    a. The pH increases
    b. The pH decreases
    c. Alum does not affect MLSS pH
    d. The MLSS decreases

22. Which may be the most appropriate chemical to use in a wet scrubber treating high levels of hydrogen sulfide?
    a. Sodium hydroxide
    b. Sulfuric acid
    c. Unchlorinated water
    d. Polymer

23. Which condition is typically the least likely to be in the air space of a sewer collection system?
    a. Explosive gases
    b. Hydrogen sulfide
    c. Methane
    d. Oxygen

24. If the velocity in a sanitary sewer pipeline is about 1 fps, what may happen to the debris in the pipeline?
    a. The debris will dissolve
    b. The debris will be carried forward
    c. The debris will settle
    d. Velocity has nothing to do with debris in a pipeline

25. What happens to the alkalinity in wastewater during the denitrification process?
    a. It increases
    b. It decreases
    c. It does not change
    d. It stabilizes at 200 mg/L

26. What is most likely to happen in an aerobic digester when the air is turned off for certain periods each day?
    a. Nitrates are increased, the pH decreases, and the volatile solids reduction worsens
    b. Nitrates are decreased, the pH increases, and volatile solids reduction improves
    c. Air rates do not have an effect on nitrates, pH, or volatile solids reduction in an aerobic digester
    d. Nitrates are increased and alkalinity is decreased

27. What action should be performed if streaks of sludge appear on the belt of a gravity belt thickener?
    a. Increase the chemical feed rate
    b. Increase the sludge feed rate
    c. Reduce the belt speed
    d. Clean the washbox nozzles

28. In an anaerobic digester, foam is observed in supernatant from single stage or primary tanks. What is the PROBABLE CAUSE?
    a. Organic overload
    b. Plugging of external heat exchanger
    c. Short-circuiting
    d. Low temperature

29. What is the PROBABLE CAUSE if you are unable to meet coliform requirements?
    a. Solids in effluent
    b. Detention time too long
    c. Diffuser properly discharging chlorine
    d. Adequate mixing

30. Every sample bottle must be identified and should have attached to it a label or tag indicating what information?
    a. Date, time, and collector
    b. Where the sample was collected, date, hour, air an water temperature, and name of collector
    c. Where the sample was collected, hour, and name of collector
    d. Date, hour, air temperature, and collector

31. Which FDEP rule governs the disposal of treated wastewater effluent for wetlands application in Florida?
    a. 62-612
    b. 62-601
    c. 62-610
    d. 62-611

32. Given the following data, what is the annual budget for chlorination of reclaimed water at this plant? Plant flow is 4.5 mgd, chlorine residual is 2.9 mg/L, chlorine demand is 5.4 mg/L, and the cost of chlorine is $0.14 per pound.
    a. $4,794 per year
    b. $55,170 per year
    c. $15,918 per year
    d. $23,561 per year

33. What term is typically used to identify toxicity for wastewater effluent discharged to open bodies of water in Florida?
    a. $CBOD_5$
    b. TOC
    c. TTHM
    d. WET

34. In which form are nutrients better utilized by microorganisms in a biological treatment process?
    a. Particulate
    b. Solid
    c. Gaseous
    d. Soluble

35. Which repair kit is designed for use with 150-pound chlorine cylinders?
    a. 'A' kit
    b. 'B' kit
    c. 'C' kit
    d. None of the above

36. Which type of solid is typically the highest percentage in the total solids profile of raw wastewater?
    a. Suspended
    b. Dissolved
    c. Colloidal
    d. Soluble

37. What is the term when ammonia-N and organic-N are added together?
   a. TKN
   b. SON
   c. TN
   d. NOx

38. What is the term when ammonia-N, nitrate-N, and nitrite-N are added together?
   a. TKN
   b. SON
   c. TN
   d. TIN

39. Which FDEP rule governs water reuse in Florida?
   a. 62-602
   b. 62-699
   c. 62-503
   d. 62-610

40. Why should the pumps in a lift station not start and stop frequently?
   a. Not enough time for the pumps to be primed
   b. Because of the power surge problems
   c. Ultimately will result in premature failure of the check valve assembly
   d. Ultimately will result in premature failure of the motor winding insulation

41. What is the pipeline called that is installed on the discharge side of a sewage pump?
   a. Suction
   b. Sump
   c. Gravity
   d. Force main

42. Which F.A.C. rule provides standards for domestic wastewater residuals in Florida?
   a. 62-640
   b. 62-63
   c. 62-620
   d. 62-610

43. What are the two major zones of a belt filter press?
   a. Drainage and evaporation
   b. Gravity drainage and pressure filtration
   c. Pressure shearing and transpiration
   d. Liquefaction and expansion

44. What is generally required when the sludge blanket is too high on the floor of a gravity thickener?
    a. Increase the withdrawal rate of sludge from the gravity thickener
    b. Pump more sludge into the gravity thickener
    c. Decrease the speed of the drive unit
    d. Decrease the withdrawal rate of the sludge from the gravity thickener

45. Which adjustment will typically improve denitrification in an aeration tank?
    a. Increase the air supply
    b. Increase the D.O.
    c. Decrease the D.O.
    d. Shut off the RAS

46. Given the following data, what is the solids loading rate on the secondary clarifiers? Plant influent flow is 23.75 mgd, the RAS rate is 70% of Q, there are six 100-foot diameter secondary clarifiers, and the aeration MLSS is 2,250 mg/L.
    a. 21.5 lbs/day/ft^2
    b. 16.1 lbs/day/ft^2
    c. 2.8 lbs/day/ft^2
    d. 96.5 lbs/day/ft^2

47. Given the following Ortho P data for inlet and outlet of a BNR fermentation tank, does this appear to be a problem? Fermentation inlet Ortho P is 7.0 mg/L, fermentation outlet Ortho P is 4.0 mg/L.
    a. Yes, the Ortho P is too low in the fermentation tank outlet
    b. Yes, the fermentation outlet Ortho P should be 2 to 3 times the concentration of the outlet
    c. No, the fermentation tank is designed to remove phosphorus directly
    d. Both a & b

48. What is the best adjustment (from the list of possible answers) to make if solids are rising in the secondary clarifier accompanied by large gas bubbles and strong odors?
    a. Increase aeration D.O.
    b. Decrease the RAS rate
    c. Decrease the WAS rate
    d. Decrease aeration D.O.

49. Which repair kit is designed for use with one-ton chlorine cylinders?
    a. 'A' kit
    b. 'B' kit
    c. 'C' kit
    d. 'D' kit

50. What percent of suspended solids is typically removed in a primary clarifier?
   a. 20 to 25%
   b. 100%
   c. 50 to 60%
   d. 75 to 85%

51. Which factors generally affect the amount of sludge that can be applied to a land application site?
   a. Nitrogen and heavy metals
   b. Carbon and chlorides
   c. Phosphorus and alkalinity
   d. pH and $CBOD_5$

52. Which statement is most accurate associated with the nitrogen cycle in an activated sludge BNR process?
   a. Heterotrophic bacteria convert ammonia to nitrite
   b. Autotrophic bacteria consume CBOD during denitrification
   c. Alkalinity is recovered during nitrification
   d. Denitrification reduces the nitrate level

53. Which on-line instrumentation may provide a closer correlation to an ammonia value in final effluent?
   a. pH
   b. D.O.
   c. ORP
   d. Alkalinity

54. In a typical activated sludge process, what adjustments should be made to the air rate if the effluent ammonia value is higher than desired?
   a. Increase the air rate
   b. Decrease the air rate
   c. The air rate has nothing to do with effluent ammonia levels
   d. Cut the air rate in half

55. Which statement is most accurate associated with the biological phosphorus cycle in an activated sludge BNR process?
   a. Phosphorus is precipitated in the fermentation zone
   b. Phosphorus removal is enhanced by chlorinating the aerobic zone
   c. Phosphorus is released (remains soluble in the MLSS) in the fermentation zone
   d. Phosphorus is released (turns to gas) in the aerobic zone

56. What action(s) should never be performed around a UV system?
   a. Eating and drinking
   b. Looking into the lamps without eye protection
   c. Plugging a UV unit into an ungrounded electrical outlet
   d. Both b & c

57. Which chemical is typically used for dechlorination of final effluent?
   a. Sodium hypochlorite
   b. Bleach
   c. Sulfur dioxide
   d. Ferric chloride

58. In a well operated anoxic zone, what is the desired electron acceptor present in the MLSS?
   a. NO_2
   b. NH_3
   c. NH_4
   d. NO_3

59. What is the main purpose for a comprehensive maintenance program?
   a. To give the mechanics something to do
   b. To operate all of the plant equipment
   c. To allow the plant to operate at its peak performance
   d. To repair equipment after breakage

60. What is the correct time and temperature for the $CBOD_5$ test?
   a. 5 days at 20° F
   b. 5° F at 20 days
   c. 5° C at 20 days
   d. 5 days at 20° C

61. If your plant has a flow rate of 2.75 mgd, a chlorine demand in pretreatment of 2.5 mg/L, prefiltration of 1.5 mg/L and final effluent of 6.5 mg/L, and you maintain a chlorine residual of 2.5 mg/L, how many lbs/day of chlorine will be used?
   a. 241 lbs/day
   b. 1,398 lbs/day
   c. 298 lbs/day
   d. 57 lbs/day

62. What action should never be performed when working with liquid chlorine?
   a. Wear a respirator
   b. Trap liquid between two closed valves
   c. Feed liquid to an evaporator
   d. Use ammonia to test for leaks

Use operational data given below for a conventional activated sludge plant

Influent flow: 0.500 mgd	RAS SS: 12,600 mg/L
Influent CBOD: 199 mg/L	RAS VSS: 9450 mg/L
Influent TSS: 221 mg/L	RAS flow: 160%
Aeration tank volume: 350,000 gal	WAS flow: 6433 gpd
MLSS: 4200 mg/L	Effluent TSS: 45 mg/L
MLVSS: 3150 mg/L	Effluent VSS: 36 mg/L
Settleability results 30 min. = 360 ml/L	Effluent CBOD: 20 mg/L
Settleability results 60 min. = 330 ml/L	

63. Calculate the MCRT
   a. 10 days
   b. 11 days
   c. 14 days
   d. 16 days

64. Calculate the F/M ratio
   a. 0.09 lbs/lb MLVSS
   b. 0.10 lbs/lb MLVSS
   c. 0.12 lbs/lb MLVSS
   d. 0.15 lbs/lb MLVSS

65. Calculate the aeration tank detention time
   a. 0.3 hours
   b. 0.6 hours
   c. 13.0 hours
   d. 16.8 hours

66. Calculate the SVI
   a. 58
   b. 86
   c. 116
   d. 150

67. The key to operating all biological phosphorus removal processes is?
    a. Maintaining a pH of 5.0
    b. Adding sufficient lime to remove the phosphorus
    c. Adding the proper amount of alum to remove phosphorus
    d. Oxygen control (chemical and dissolved oxygen)

68. Throughout the fall a plant has been able to reduce influent ammonia levels by 75%. However, as winter progressed its removal efficiency dropped to only 25%. What is the probable cause?
    a. Biological solids are too high
    b. Biological solids are too low
    c. pH is 7.5
    d. MCRT is greater than 10 days

69. The majority of biological treatment in a SBR plant takes place during which process stages?
    a. The empty stage
    b. Fill and react stages
    c. Decant stages
    d. Settle stages

70. In a conventional activated sludge plant, the SVI is low, and a settleometer test shows high compaction with a turbid supernatant. The F/M is low and there is pin floc observed in the clarifier effluent. What microorganisms would be predominant under microscopic examination of the MLSS?
    a. Filamentous bacteria
    b. Nematode and rotifers
    c. Amoeboids and flagellates
    d. Free swimming stalks

71. What is the IDLH (Immediately Dangerous to Life or Health) for sulfur dioxide?
    a. 200 ppm
    b. 100 ppm
    c. 50-100 ppm
    d. 400-500 ppm

72. Sludge gasification causes large clumps of sludge to float on the water surface. The sludge is very odorous and acidic. This would meant that the pH is :
    a. high
    b. neutral
    c. extremely high
    d. low

73. According to Chapter 62-600 FAC, when chlorine is used for basic level disinfection, a minimum chlorine residual of 0.5 mg/L must be maintained for how long and at what flow?
    a. 30 minutes at average daily flow
    b. 30 minutes at peak flow
    c. 15 minutes at average daily flow
    d. 15 minutes at peak flow

74. In a conventional activated sludge plant, the settleometer indicates a poorly settling sludge with an extremely clear supernatant. Microscopic examination of the mixed liquor indicates excessive amounts of long filaments. The SVI in this plant would be what?
    a. Extremely low, below 30
    b. About 100
    c. The same as the pH
    d. Very high

75. The most important controlling factor in safety is?
    a. First aid
    b. Emergency planning
    c. Education
    d. Accident reports

76. What should be checked first if a pump will not start?
    a. Blown fuses or tripped circuit breakers
    b. The amperage using an amp meter
    c. To see if the equipment has been properly installed
    d. Improper electrical circuits

77. When a conventional activated sludge plant is operating above design loads switching to what mode of operation would produce the best quality effluent?
    a. Step-feed
    b. Kraus
    c. Bardenpho
    d. Conventional

78. In the Bardenpho process denitrification takes place in what basin?
    a. Aerator
    b. Clarifier
    c. Anoxic
    d. None of the above

79. What is the purpose of stop-nuts on aerator control gate stems?
   a. Limit length of travel
   b. Prevent short-circuiting
   c. Protect against corrosion
   d. Prevent ice formation

80. If a plant becomes upset by high flows from storm water infiltration, reduce wasting solids at this point to prevent what?
   a. Laboratory errors
   b. Organism losses
   c. Maintain D.O.
   d. Possible damage to equipment

81. A sprayfield has a total of 164 acres and is divided into six equal zones. Only one zone may be operated at a time and the permit states that no more than 4 inches of water can be applied to the zone. How long can a zone be operated at a rate of 0.500 MGD before it must be rotated to another zone?
   a. 5.9 days
   b. 6.5 days
   c. 6.9 days
   d. 7.5 days

82. What would be the probable cause of wide variations in chlorine residuals produced in effluents?
   a. Adequate feed rate adjustment of post chlorinators
   b. Flow proportioning chlorine control devices working properly
   c. Variation of chlorine demand
   d. Electrodes fouled

83. When operating a rotating biological contactor what would be the probable cause of decreased treatment efficiency?
   a. Stable pH
   b. Organic under load
   c. Hydraulic under load
   d. Low wastewater temperatures

84. What would be a possible solution to a black and odorous septic wastewater leaving a primary clarifier?
   a. If sludge blanket is thick, decrease sludge removal rate
   b. Dechlorinate clarifier effluent
   c. Maintain sludge blanket at plants optimum level
   d. Use only the bulking clarifier if multiple clarifiers are available

85. At what pH level does sulfide exist as 100 percent hydrogen sulfide gas?
    a. Below pH of 5
    b. Neutral pH of 7
    c. pH of 9 to 11
    d. pH of 14

86. What has been the most serious type of problem with ozonation units used to oxidize odor-causing compounds?
    a. Chemical
    b. Electrical
    c. Mechanical
    d. Physical

87. Why are polymers usually limited to 1.0 percent maximum solution strength?
    a. So the cost of polymer will not be to expensive
    b. So the solution can be pumped (metered) accurately
    c. So the solution will not be too corrosive
    d. So the solution will not be too heavy for the day tank

88. What is the "luxury uptake" process?
    a. Microorganisms breathing oxygen in a resting situation
    b. Microorganisms living in an environment with excess oxygen
    c. Microorganisms releasing phosphorus as they almost begin to die
    d. Microorganisms taking excess phosphorus into their bodies

89. What could be occurring in the BOD test when the effluent BOD is reported as higher than the effluent suspended solids?
    a. Aerobic selectors
    b. Carbonaceous BOD
    c. Denitrification
    d. Nitrification

90. In an ammonia stripping tower what is the probable cause if there is a loss of ammonia removal efficiency?
    a. No scale buildup
    b. pH of tower influent too high
    c. Insufficient hydraulic loading
    d. Insufficient air flow through tower

91. How do cold temperatures influence ammonia stripping?
    a. Cause sloughing of scale
    b. Increase the conversion rate by microorganisms
    c. Reduce conversion of ammonia ion to ammonia gas
    d. Reduce requirements for additional calcium oxide

92. What is a possible fallback position when controlling bulking activated sludge?
   a. Polymers to precipitate bulking solids
   b. Return activated sludge chlorination
   c. Screens to capture bulking solids in effluent
   d. Surface sprays to keep bulking down

93. Why should enhanced nitrogen oxidation systems have provisions for continuous sludge wasting?
   a. For ease of operation
   b. To allow pumping of thicker sludge
   c. To minimize solids in effluent
   d. To reduce capacity of sludge wasting facilities

94. Where should methanol application points be placed?
   a. Aerobic reaction is planned
   b. Anaerobic reaction is planned
   c. Anoxic reaction is planned
   d. Facultative reaction is planned

95. What is the rate of mass flow of permeate called that passes through a membrane filter?
   a. Concentrate
   b. Flow stream
   c. Flux
   d. Mass loading

96. What do large numbers of ciliates and rotifers in the mixed liquor indicate?
   a. High-quality effluent
   b. Need to increase MCRT
   c. Pin floc
   d. Poorly settling sludge

97. What is the most frequent problem encountered with belt filter presses?
   a. Belt blinding
   b. Belt tearing
   c. Cake solids too wet
   d. Washing out

98. In the luxury uptake of phosphorus process, under what conditions do microorganisms release phosphorus from their cells?
   a. Activated sludge
   b. Aerobic
   c. Anaerobic
   d. Clarification

99. Why does the ammonia stripping process require the pH of the wastewater to be increased up to the 10.5 to 11.5 range?
   a. To convert ammonia to gaseous ammonia
   b. To form an ammonia precipitate
   c. To prevent the corrosion of the stripping tower
   d. To shift the temperature to an optimum range

100. Which item(s) is (are) often an operators first indication that problems are developing in an activated sludge plant?
   a. Influent dissolved oxygen
   b. Power consumption
   c. Records
   d. Sight, smell, and touch

THE END

WASTEWATER MIDTERM REVIEW 8/27/2010

1. When Chlorine is combined with water what type of pipe should be used?
   - A. Ductile iron
   - B. Asbestos concrete
   - C. PVC
   - D. Carbon steel

2. A good settling sludge would consist of what type of protozoa?
   - A. Rotifers and nematodes
   - B .Amoebas and Flagellates
   - C. Stalked ciliates and mastagoria
   - D. Free swimmers and stalk ciliates

3. What is Phenolphthylein used for in titration?
   - A. Oxidizer
   - B. Indicator
   - C. Acid reducer to lower pH
   - D. Applicator

4. Your plant has an influent of 220 BOD and 163 TSS, and an effluent of 10 BOD and 6 TSS. What is the BOD removal efficiency in your plant?
   - A. 92%
   - B. 94%
   - C. 95%
   - D. 96%

5. You suspect your anaerobic digester is going sour. What is the best way to verify its condition?
   - A. PH
   - B. Foam type
   - C. VA/ALK ratio
   - D. DO

6. Before operating any piece of equipment what should be done?
   - A. Lock out Tag out (remember, safety first!)
   - B. Read O & M manual
   - C. Read Manufacturers manual
   - D. Notify supervisor

7. Detritus is noticed in your grit channel. What is the problem?
   A. Velocity too fast with short D/T
   B. Velocity too low with long D/T
   C. Short circuiting
   D. Density currents

8. What is considered normal operation of an aerobic digester?
   A. Fill react
   B. Skim off foam when needed
   C. Settle and Decant as needed
   D. Feed only during low flow or constant when the sun is out

9. A plant with a flow of 1 MGD should be monitored.
   A. Continuously
   B. Intermittently
   C. Daily
   D. Every four hours depending on surface load

10. What do total solids consist of?
   A. Dissolved and settleable
   B. Floatable and settlable
   C. Suspended and dissolved
   D. Setltable and non settleable

11. What would cause excessive wear on bearings?
   A. Misalignment
   B. Reduced oil due to low viscosity
   C. Blow seal
   D. Over tubercation

12. Amperometric titration is used to measure?
   A. Dissolved solids
   B. Chlorine residual
   C. Colloids
   D. Emulsions

13. What growth phase is an aerobic digester operated in.
   A. Log
   B. Lag
   C. Endogenous respiration
   D. Declining phase

14. If excessive pressure builds up in a chlorine tank due to excessive heat. What will prevent explosions?
   A. Valve seat adjustments
   B. Heat reducing valve
   C. Fusible plug
   D. Check valve

15. You notice that your bearings are excessively hot on a pump, why?
   A. Ambient temperature too high
   B. Over lubrication
   C. Oil seal blown
   D. Discharge rate too low

16. Where can you gain access for collection system maintenance?
   A. Lift station
   B. Force main
   C. Man hole
   D. Gravity main

17. Low DO and nutrient deficiency will promote the growth of what?
   A. Rotifers
   B. Filamentous bacteria
   C. Spirillium
   D. Amoebas

18. When charging a lead-acid type battery for a composite sampler, what dangerous gas could be produced?
   A. Hydrogen
   B. Oxygen
   C. Hydrogen sulfide
   D. Cyanide

19. What is the best method in dealing with a chemical spill?
   A. Contain and clean up
   B. Saw dust and kitty litter
   C. Foam congaing supertrimethalbromine
   D. Flood with water

20. There is septic wastewater entering your primary clarifier. What is the problem?
   A. Aerobic conditions in the collections system
   B. Lift station pumps operating on short cycles
   C. Anaerobic conditions in the collection systems
   D. High flows due to a low MCRT

21. Which of the following substances is highly viscous and very slippery?
   A. Calcium hypochlorite
   B. Calcium oxide
   C. Potassium permanganate
   D. Polymer

22. If you pump green sludge to a drying bed what chemical should be applied?
   A. Polymer
   B. Lime
   C. Cl2
   D. Alum

23. Chlorine leaks can be detected by?
   A. ISCBA
   B. Ammonia solution with Q-tip
   C. Alcohol vapor
   D. Spray with mist of water

24. What takes place in the stabilization tank in a contact stabilization plant?
   A. Adsorption
   B. Clarification
   C. BNR
   D. Absorption

25. Why is an aerobic digester covered?
   A. Hold in gas
   B. Protect for contaminants
   C. Reduce radiation
   D. Protect from cold weather

26. Which of the following would you not use a grab sample on?
   A. BOD
   B. DO
   C. PH
   D. Temp

27. Staffing is based on what?
   A. Budget
   B. Flow and type of treatment
   C. City hall
   D. Chief operator

28. What condition does an operator have the least amount of control over?
   A. Flow
   B. Wasting rate
   C. F/M ratio
   D. Temp

29. Why would you chlorinate the RAS line?
   A. Remove struvite
   B. Lower the pH of incoming
   C. Control filamentous bacteria
   D. Meet chlorine demand

30. What is the most common type of pond?
   A. Anaerobic
   B. Aerobic
   C. Facultative
   D. Polishing

31. The ash content in lab procedures is the same as?
   A. Organic solids
   B. Volatile solids
   C. Inorganic solids
   D. Total solids

32. Denitrification will cause what?
   A. Straggler floc
   B. Rising sludge
   C. Methane production
   D. Low MLSS

33. If a 220 volt, 3 phase motor is running backwards what should you do?
   A. Switch the two leads
   B. Return pump for a refund
   C. Check the polarity of magnets
   D. Check static pressure

34. Coliform count fails to meet standards your chlorine supply is not the problem. What is?
   A. Short circuiting and low contact time
   B. Chlorine has become stale
   C. High temps
   D. Lack of disinfectant bacteria

35. What type of material should be used for transporting samples?
   A. Glass
   B. Polyethylene
   C. Graduated cylinders
   D. Burette

36. How does temperature effect disinfection?
   A. Lower the temp the better the disinfection
   B. Has no effect
   C. Higher the temp the better the disinfection
   D. Depends on the constant altitude

37. The advantage of an anaerobic digester over an aerobic digester is?
   A. Less solids
   B. Increased power consumption
   C. Decrease power consumption
   D. Easier to operate

38. How long should you wait after you make a process change before making another change?
   A. 7 hours
   B. 10 days
   C. When the operator thinks its necessary
   D. 1 week

39. Determine the MCRT using the following:

Known

Aerator volume = 323,000 gal
Final clarifier vol.= 150,000 gal
Flow = 2 MGD
Waste flow = 20,000 gal
MLSS = 2,400 mg/L
Waste sludge SS = 6400 mg/L
Final eff. SS = 16 mg/L

A. 3.3 days
B. 4.8 days
C. 2.7 days
D. 4.1 days

40. What is needed to calculate the F/M ratio?

A. BOD mg/L and MLSS mg/L
B. BOD in lbs and MLVSS in lbs
C. BOD mg/L and MLVSS in lbs
D. BOD in lbs and MLSS mg/L

41. What type of ponds are used after a trickling filter, activated sludge, or RBC plant?

A. Facultative pond
B. Aeration pond
C. Anaerobic pond
D. Polishing pond

42. Convert 27* C to Fahrenheit

A. 81.6
B. 80.6
C. 106.2
D. 86.1

43. Determine the sludge age for an activated sludge plant with the following:

Known

Aerator tank vol.= 500,000 gal
Flow =5.25 MGD
PE SS= 72 mg/L
MLSS =2350 mg/L

A. 6.5 days
B. 4.2 days
C. 3.1 days
D. 5.2 days

44. You have excessive billowing white sudsy foam on the surface of your aerator. What is the cause?

A. MLSS too high
B. F/M too high
C. F/M too low
D. MLVSS too high

45. The settleometer settles fairly slowly. You have shiny dark foam on the surface of the aerator. What is the problem?

A. MCRT too high
B. MCRT too low
C. Sludge age too low
C. WAS too high

46. The removal of nitrogen and phosphorus are?

A. Useful in the growth of algae
B. Advanced secondary treatment
C. General practice in extended aeration
D. Prevents anaerobic conditions

47. What would cause a pump to fail to discharge?

A. Excessive gravity
B. Tubercation
C. Suction lift too high
D. Proper lubrication

48. Chlorine is not coming out. Another cylinder is hooked up with the same problem occurring. What is the problem?

A. Educator submerged
B. Icing
C. Manifold line is clogged
D. POA too far

49. How would you measure the amount of load being applied from the digester to the head works?

A. Total solids test
B. BOD
C. COD
D. DPD

50. Why is a vacuum/pressure relief valve used on an anaerobic digester?

A. Prevent methane gas from reaching the heat exchanger
B. Prevent CO2 from being released to the atmosphere
C. Prevent negative and positive pressure
D. Increase digester capacity

51. What would cause the most damage to a centrifugal pump?

A. Grit
B. Cavitation
C. Velocity too low
D. Intermediate operation

52. The rock in trickling filters is placed?

A. In a uniform manner
B. Small to large
C. With large voids
D. On system tile under drains

53. If you have a sudden increase of BOD by 50% or a BOD>400. What is this termed?
   A. Under loaded aerator
   B. Overloaded clarifier
   C. Increased inorganic load
   D. Increased organic load

54. Coliform bacteria are used for what?
   A. Process control changes
   B. Indicators of possible presence pathogenic organisms
   C. Prevent disease
   D. Remove Co2 residual in sample bottle

55. Where does the effluent from the aerator go?
   A. Secondary clarifier
   B. Primary clarifier
   C. Solids handling
   D. Digester

56. A decrease in temperature will have what effect on disinfection?
   A. Require longer contact time
   B. Require shorter contact time
   C. Increase rate of disinfection
   D. Have no effect on disinfection

57. Cl2 combined with ammonia forms what?
   A. Hydrochloric acid
   B. Chloroammonia acid
   C. Chloramines
   D. Hypochlorous acid

58. At what PH would disinfection be at its greatest?
   A. 9
   B. 7
   C. 6.5
   D. 5

59. It can be said that:
   A. The higher the PH, the greater the disinfection
   B. The lower the PH, the greater the disinfection
   C. The lower the disinfection the lower the PH
   D. PH and disinfection are not related

60. What is the distance between manholes?
   A. 300-600 ft
   B. 450-700 ft
   C. 300-500 ft
   D. Depends on the population of the given area

61. You have an RBC unit with the following parameters, what is the organic loading in lbs per 1,000 cu/ft?

Known
Q=1.4 MGD
Sol. BOD=100 mg/L
Surface Area= 500,000 s/f

A. 2.5 lbs
B. 2.3 lbs
C. 2.8 lbs
D. 4.8 lbs

62. What is the disadvantage of a hypochlorinator?
A. Lowers the pH and increases the disinfection
B. Lowers the pH and decreases the disinfection
C. Increases the pH and decreases the disinfection
D. Increases the pH and Increases the disinfection

63. What chemical would be used on a sample to be used for TSS test?
A. Sodium Thiosulfate
B. DPD
C. Nitriver
D. Nothing

64. What TSS test is most critical for plant operation?
A. TSS in air-bay
B. TSS in aerobic digester
C. TSS in primary clarifier
D. TSS in anaerobic digester

65. What is a quick test to check sludge condition?
A. BOD
B. COD
C. Autoclave
D. Settleometer

66. What is the funnel called that is used along with the vacuum apparatus when doing solids testing?
A. Buchner funnel
B. Filter funnel
C. Micro funnel
D. Straining funnel

67. What would be most harmful to the population of microorganisms?
A. High toxicity, Strong acids, Strong bases
B. Warm temperatures, High DO
C. Cold temperatures, Low DO
D. Neutral PH

68. What is the best range of parameters for the Activated Sludge process?
   A. 2 ppm DO, PH 7.0, 80-95 deg. F
   B. 1 ppm DO, PH 6.5, 60-70 deg. F
   C. 4 ppm DO, PH 5.0, 80-90 deg. F
   D. 3 ppm DO, PH 7.5, 45-65 deg. F

69. What is the breakdown of nitrate to nitrogen gas called?
   A. Nitrification
   B. Denitrification
   C. Autotrphication
   D. Anaerobic decomposition

70. What 2 stages are in an anaerobic digester?
   A. Fill and Decant
   B. Acid formation and Gas formation
   C. VA/Alk. and Redox
   D. Over feed and Under feed

71. What is the benefit of step feed aeration?
   A. Re-aeration tank stability
   B. Treat higher flows in less space
   C. Absorption in contact tank
   D. Anoxic zones enhance Denitrification

72. What is classic sludge bulking caused from?
   A. Young sludge
   B. Old sludge
   C. High MLSS
   D. Long MCRT

73. What should be the maximum allowable level of TSS and BOD in the eff. of a domestic w/w facility in accordance with FAC?
   A. 20 TSS, 20 BOD or 80% removal
   B. 30 TSS, 30 BOD or 90% removal
   C. 20 TSS, 30 BOD or 90% removal
   D. 20 TSS, 20 BOD or 90% removal

74. What does CBOD mean?
   A. Chemical Biological Oxygen Demand
   B. Carbonaceous Biochemical Oxygen Demand
   C. Carbonic Biological Oxygen Demand
   D. Chlorinated Biochemical Oxygen Demand

75. What is the min. depth of a pond?
   A. 6 ft.
   B. 10 ft.
   C. 4 ft.
   D. 3 ft.

76. What can happen if more than 40 lbs. of chlorine is withdrawn from a 150 lb. tank in a 24 hr. period?
   A. Reliquification
   B. Increased pressure
   C. Freezing of the lines
   D. Budget increase

77. What are the two main gasses produced by an anaerobic digester?
   A. Methane & Carbon Monoxide
   B. Co2 & CH3
   C. Methane & Co2
   D. Hydrogen Sulfide & Oxygen

78. When working in a man hole, what would be the biggest danger?
   A. Falling debris
   B. Cave-ins
   C. Asphyxiation
   D. Carcinogens

79. In a pond, what will happen to the PH during the day-time?
   A. Decrease
   B. Remain constant
   C. Increase
   D. Fluctuate

80. Cathodic protection is used for what purpose?
   A. The prevention of corrosion to metals
   B. To avoid electrical shocks
   C. Increase safety
   D. Protect utilities from lawsuits due to unsafe environments

81. In an anaerobic digester, when the VA/ALK ratio starts to increase, what will be noticeable?
   A. An inc. in Co2 & dec. in PH
   B. A dec. in Co2 & inc. in PH
   C. Optimum operation
   D. An inc. in Co2 & inc. in PH

82. What should you do if you samples come to the lab and have settled to the bottom?
   A. Discard
   B. Mix them well
   C. Re-sample
   D. Run tests

83. What are some similarities between Methane and H2S?
   A. Flammable, explosive, colorless
   B. Flammable, explosive, odorless
   C. Rotten egg odor, yellowish color, combustible
   D. Blue flame, non toxic, lighter than air

84. What causes the most wear to an impeller?
  A. High velocities
  B. No water
  C. Grit
  D. Constant head

85. If a pump will not start and you have power at the breaker, what is the next logical step?
  A. Call the power company
  B. Check for blown fuses
  C. Install new wiring
  D. Inspect power relay

86. What affect does Cl2, Acid, and Co2 have on PH?
  A. Raise
  B. Neutralization
  C. No affect
  D. Lower

87. As an operator, how do you control the anaerobic digestion process?
  A. Microbial population and temperature
  B. H2S and methane concentration
  C. Temperature and rate of raw sludge feed
  D. Methane and Co2 production

88. What is a true statement about recording data?
  A. Bar and line graphs are the most accurate
  B. There are many techniques to record data
  C. Pie charts are most common
  D. Data recording is not important

89. According to FAC Ch. 62-600, Domestic Wastewater Facilities, your job as an operator during major process breakdowns is to?
  A. Maintain competent documentation and record keeping
  B. Report to the DEP within 24 hours after the problem is fixed
  C. Call the fire department
  D. Shut down the plant immediately

90. Short circuiting in a primary clarifier can be prevented by?
  A. Scum troughs
  B. Vertical mixers
  C. Baffles
  D. Chain flights

91. What do you do if you experience a plant upset due to a hydraulic overload?
  A. Decrease DO
  B. Increase RAS
  C. Increase WAS
  D. Decrease WAS to maintain microorganism population?

92. You have dark foam, high MLSS, slow settling sludge with a clear effluent, you should?
   A. Increase WAS, decrease RAS
   B. Maintain 1-3 ft. sludge blanket, monitor MLSS, increase DO if necessary
   C. Decrease DO, decrease WAS, increase RAS
   D. Raise MCRT, sludge age, and SDI

93. If the blades on the comminutor become dull, this can cause?
   A. Pumps to become clogged with rags
   B. Excessive flows
   C. Increased efficiency
   D. Grit to settle out slower

94. After removing the roof of the chlorinator storage building during the summer, the Cl2 stops feeding, what is the cause?
   A. The CPRV became clogged
   B. The tank got hotter than the manifold
   C. The external pressure reducer failed
   D. The tank is empty

95. What do total suspended solids consist of?
   A. Settleable and dissolved
   B. Settleable, dissolved, and suspended
   C. Settleable and suspended
   D. Dissolved and suspended

96. The PH in your plant is decreasing, effluent turbidity is increasing, and sludge is rising in the clarifier. What is the problem?
   A. Hydraulic overload
   B. High F/M
   C. Over wasting
   D. Denitrification

97. The TSS of the digester supernatant should be calculated because?
   A. The DEP requires you to
   B. To measure the solids load on the plant
   C. To calculate the VA/Alkalinity ratio
   D. It's a good indication of methane concentration

98. How do you calculate the F/M ratio?
   A. Effluent BOD lbs., divided by the MLVSS lbs.
   B. Influent BOD mg/l, divided by the MLVSS lbs.
   C. Influent COD lbs., divided by the MLVSS lbs.
   D. Influent BOD lbs., divided by the MLVSS mg/l

99. If an activated sludge plant becomes upset, what is the most important and least time consuming operation an operator should do to discover the cause?
   A. Check the plant data for the previous 3 weeks
   B. Run BOD, DO, Suspended Solids, and PH tests on the system
   C. Check collection system
   D. Check effluent BOD and Cl2 residual

100. A colored dye solution is added into the raw wastewater entering a primary settling tank. The dye color was noticeable in the effluent in 15 min. and all of the color had passed through the tank in 40 min. What does this indicate?

A. Wastewater is passing through the tank too fast for effective settling
B. Optimal detention time is being achieved
C. This tank has a detention time of 40 min.
D. This tank design has a detention time of 55 min.

ANSWER SHEET FOR

Midterm review 8/27/2010

1. C
2. D
3. B
4. C
5. C
6. C
7. B
8. C
9. A
10. C
11. A
12. B
13. C
14. C
15. B
16. C
17. B
18. A
19. A
20. C
21. D
22. B
23. B
24. D
25. D
26. A
27. B
28. D
29. C
30. C
31. C
32. B
33. A
34. A
35. B
36. C
37. C
38. D
39. B
40. B
41. D
42. B
43. C
44. B
45. A

46. B
47. C
48. C
49. A
50. C
51. B
52. D
53. D
54. B
55. A
56. A
57. C
58. D
59. B
60. C
61. B
62. C
63. D
64. A
65. D
66. A
67. A
68. A
69. B
70. B
71. B
72. A
73. D
74. B
75. D
76. C
77. C
78. C
79. A
80. A
81. A
82. B
83. A
84. C
85. B
86. D
87. C
88. B
89. A
90. C
91. D
92. B
93. A

94. B
95. C
96. D
97. B
98. C
99. A
100. A

TRUE AND FALSE

1. FALSE
2. TRUE
3. FALSE
4. TRUE
5. TRUE
6. FALSE
7. TRUE
8. TRUE
9. TRUE
10. TRUE
11. FALSE
12. TRUE
13. TRUE
14. TRUE
15. TRUE
16. TRUE
17. TRUE
18. TRUE
19. TRUE
20. TRUE
21. FALSE
22. FALSE
23. TRUE
24. TRUE
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26. FALSE
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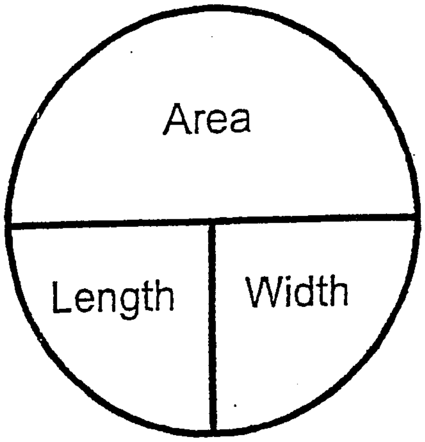
36. TRUE
37. FALSE
38. TRUE
39. TRUE
40. TRUE
41. TRUE
42. FALSE
43. TRUE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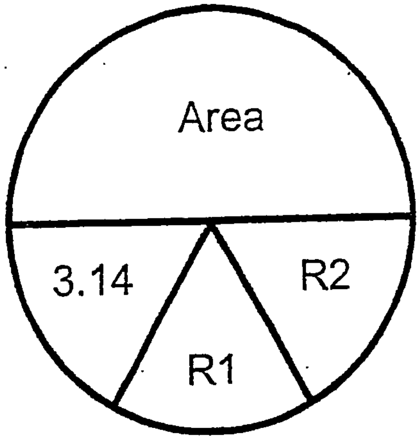
Length
Width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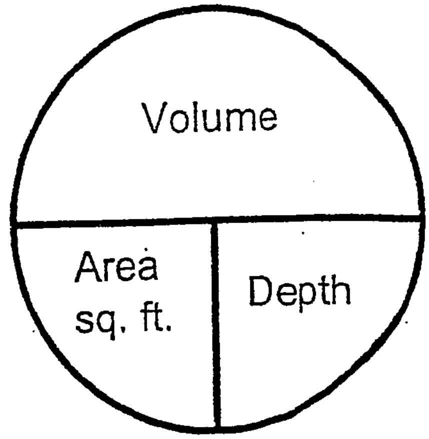
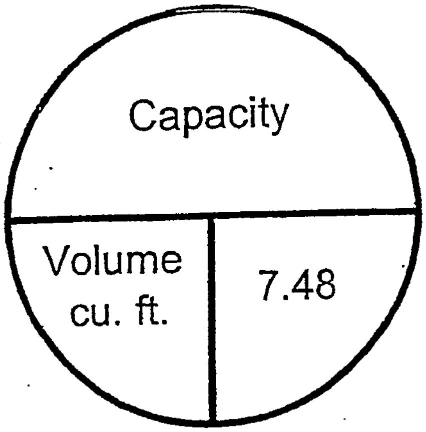
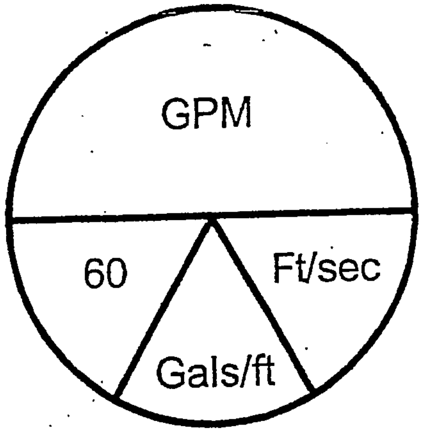
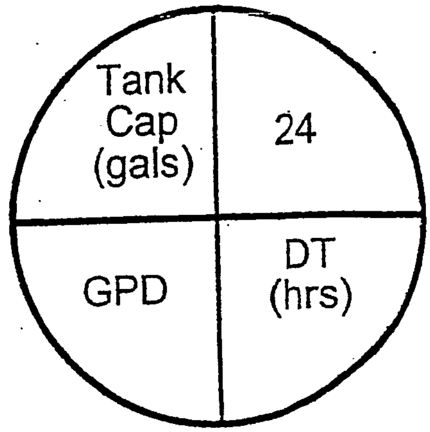
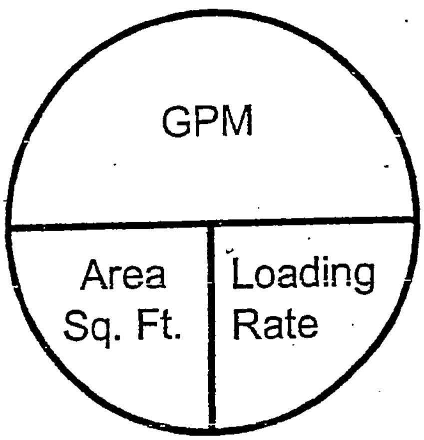
R1
R2

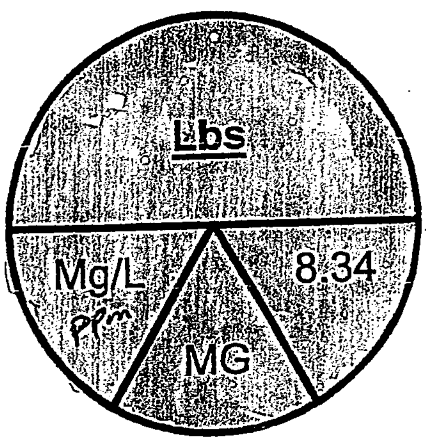

Volume
Area sq. ft.
Depth

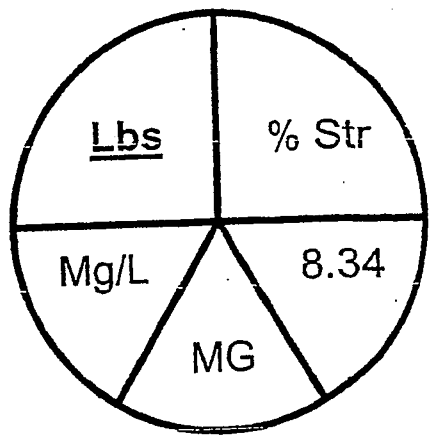

Capacity
Volume cu. ft.
7.48

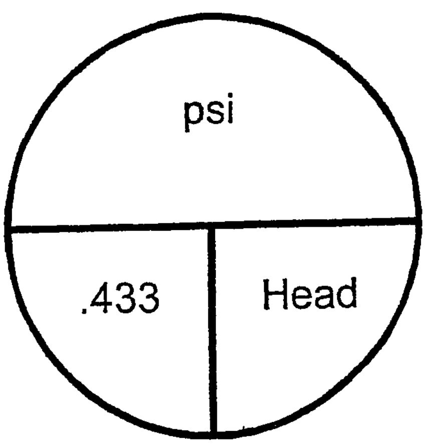

GPM
60
Gals/ft
Ft/sec


Tank Cap (gals)
24
GPD
DT (hrs)


GPM
Area Sq. Ft.
Loading Rate


Lbs
Mg/L
ppm
MG
8.34


Lbs
% Str
Mg/L
MG
8.34


psi
.433
Head

PARAMETER	YOUNG	OLD
Foam Characteristics	White, thick, billowy	Dark, leathery, scummy
Indicator Organisms	Amoebae, flagellates	Rotifers, worms
Floc Particle Size	Light, fluffy ***straggler floc***	Dense, round, granular ***pin-point floc***
Settleability	Slow	Fast, rapid
Oxygen Uptake Rate	High, bugs using lots of oxygen	Low, bugs using little oxygen
SVI	High (>300)	Low (<80)
F/M Ratio	High	Low
MLSS	Low, ***under oxidized***	High, ***over oxidized***
MCRT/Sludge Age	Low	High
Waste Sludge Change	Reduce	Increase

If the RAS Flow Rate:	Then: RAS/WAS Conc.	Then: WAS Pounds	Then: MLSS	Then: MCRT/Sludge Age	Then: F/M Ratio
↑	↓	↓	↑	↑	↓
↓	↑	↑	↓	↓	↑

Conc =
Consentration

PROCESS CONTROL MATH

for

WASTEWATER PLANT OPERATORS

Third Edition

1998

CONTENTS

INTRODUCTION

Welcome to Process Control Math for Wastewater Plant Operators. This workbook should be used after successful completion of the Water and Wastewater Technologies Core Program. In the Core Program, students were introduced to a process where problems were solved by organizing them into simple steps. Students were encouraged to follow each step, assign units to each value, and draw a diagram of the situation given.

The method of problem solving introduced in the Core Program will be used in solving more complex problems dealing with process control of drinking water facilities. These problems can sometimes involve multiple formulas, so it is extremely important that the steps introduced in the Core Workbook be adhered to.

As in the Core Workbook, examples will be given for each type of problem. The steps in the examples given are not labeled as in the Core Workbook, however, and many of the diagrams have been eliminated for simplicity. In the appendix, there are sample tests that represent each type of problem. The appendix also contains an answer key. Use the formula sheet and the table of equivalents provided in the appendix in completing the sample tests.

Remember that most students make errors in the actual setup of the problem. Take your time. Keep organized. Write down all information given that concerns the problem, draw a diagram if necessary, keep track of the units, and use the four steps:

1. Write the formula.
2. Substitute knowns for unknowns.
3. Simplify by canceling and calculating.
4. Write that answer in the units called for.

CHAPTER ONE

LOADING PROBLEMS

Weir Overflow Rates

Clarifiers or sedimentation tanks used to settle raw wastewater are known as *primary tanks*. *Final clarifiers* are settling tanks following secondary aerobic treatment. Sedimentation basins in wastewater treatment are designed with certain overflow, or loading rates. If the loading rates are exceeded, the efficiency of the sedimentation process diminishes greatly.

Weir overflow rates (sometimes called weir loading rates) are how many gallons of effluent flow over one foot of weir in a certain time period. They involve the total length of the weir and the total flow rate. Sometimes the weir length is given, and other times it must be calculated, such as in circular clarifiers where only the diameter of the clarifier is given. In all cases, the length of weir is in linear units (a single dimension resembling a straight line), usually feet. The flow rate can be given in any combination of gallons and time units and can be written as such in the formula.

The formula for calculating weir overflow rates in gallons per day per foot is:

- **Weir overflow rate, gal/day/ft =** $\frac{\text{total flow, gal/day}}{\text{length of weir, ft}}$

Example

Determine the weir overflow rate of a circular clarifier whose diameter is 60 feet and a flow of 1.5 MGD.

In this case, the length of the weir is not given. Knowing that the clarifier is circular, it is easy to calculate the weir length by using the circumference formula:

$C = \pi \times D$

$C = 3.14 \times 60$ ft

$C = 188.4$ feet, the length of the weir

Weir overflow rate, gal/day/ft= $\frac{\text{total flow rate, gal/day}}{\text{length of weir,ft}}$

Weir overflow rate, gal/day/ft= $\frac{1{,}500{,}000 \text{ gal/day}}{188.4 \text{ ft}}$

Weir overflow rate, gal/day/ft= 7, 962 gal/day/ft

Notice that none of the units cancel out. The new units for the weir overflow rate are in gallons per day per (linear) foot.

Surface Loading Rates

Surface loading is an important guideline used in the design of sedimentation tanks. In order to perform the calculations, the tank influent flow and the total surface area of the sedimentation tank or clarifier are needed. Sometimes the areas are given, and other times a calculation is required. Determine surface areas by the area formulas in the Core Workbook. Notice that the time units in the following formula are in days. The formula can be written with minutes or hours as the time unit. The calculations are performed in the same way.

The formula for surface loading rates in gallons per day per square foot is written:

- **SLR, gal/day/ft²=** $\frac{\text{influent flow (gal/day)}}{\text{surface area (ft}^2\text{)}}$

<u>Example</u>

What is the surface loading rate of a clarifier with a diameter of 55 ft and an influent flow of 1.152 MGD?

The clarifier is circular. Use the formula for the area of a circle.

$A = \pi \times R^2$

A= 3.14 x 27.5 ft x 27.5 ft

A= 2, 374.6 ft^2

After the surface area has been determined, substitute all the known values into the surface loading rate formula.

SLR, gal/day/ft^2 = $\frac{\text{influent flow (gal/day)}}{\text{surface area (ft}^2\text{)}}$

SLR, gal/day/ft^2 = $\frac{\text{1,152,000 gal/day}}{\text{2,374.6 ft}^2}$

SLR, gal/day/ft^2 = 485 gal/day/ft^2

The units are particular to surface loading rates. Notice that none of the units cancel out in the example, so all of the units must be kept.

Sometimes the answer must be in gallons per minute per square foot (gal/min/ft^2) as well as gallons per day per square foot (gal/day/ft^2). As stated previously, this can also apply to weir overflow rates. Just use the appropriate conversion factors as in the example given below.

$\frac{\text{485 gal/day/ft}^2}{\text{1,440 min/day}}$ = 0.34 gal/min/ft^2

Solids Loading

Another calculation that wastewater plant operators may be required to perform is solids loading of clarifiers or sedimentation tanks. Clarifiers are designed to remove a certain amount of solids per square foot of surface area. In order to perform this calculation, the amount of solids, in pounds, that are applied to the clarifier daily, the surface area of the clarifier, and the daily flow must be known.

Sometimes a laboratory result in mg/L for the solids concentration being applied to the clarifier is given. In this case, use the pounds formula introduced in the Core Workbook to calculate the pounds of solids applied to the clarifier daily.

The formula for solids loading, in pounds per day per square foot, is written:

- **Solids loading, lbs/day/ft^2** = $\frac{\text{solids applied, lbs/day}}{\text{surface area, ft}^2}$

Example

A primary clarifier has a diameter of 80 feet and treats a flow of 3.75 MGD. Laboratory results show that the total suspended solids concentration entering the clarifier is 265 mg/L. What is the solids loading in lbs/day/ft^2?

In solving this problem, the solids applied, in pounds per day, are needed. Use the pounds formula:

Solids, lbs/day = flow, MGD x mg/L x 8.34 lbs/gal

Solids, lbs/day = 3.75 MGD x 265 mg/L x 8.34 lbs/gal

Solids, lbs/day = 8,288 lbs/day

Now, the surface area of the clarifier must be calculated. It is circular, so use the appropriate area formula:

$A = \pi \times R^2$

A = 3.14 x 40 ft x 40 ft

A = 5,024 ft^2

Now, use the above information in the solids loading formula:

Solids loading, lbs/day/ft^2 = $\frac{\text{solids applied, lb/day}}{\text{surface area, ft}^2}$

Solids loading, lbs/day/ft^2 = $\frac{\text{8,288 lbs/day}}{\text{5,024 ft}^2}$

Solids loading, lbs/day/ft^2 = 1.65 lbs/day/ft^2

Efficiency Calculations

Efficiency calculations are dependent upon laboratory test results of the particular water quality indicator of interest. Efficiency compares what is entering a treatment unit with what is leaving that unit. The lab results are given in milligrams per liter (mg/L). The unit used in efficiency problems is percent (%).

The formula for any type of efficiency, in percent, is written as follows:

- **Efficiency, %** $= \frac{(\text{in, mg/L}) - (\text{out, mg/L})}{(\text{in, mg/L})}$ **x 100 %**

Example

A secondary clarifier in an activated sludge treatment plant receives a total suspended solids concentration of 3,550 mg/L. The effluent suspended solids concentration for this clarifier is 55 mg/L. What is the efficiency of this clarifier in percent?

$$\text{Efficiency, \%} = \frac{(\text{in, mg/L}) - (\text{out, mg/L})}{(\text{in, mg/L})} \times 100\%$$

$$\text{Efficiency, \%} = \frac{(3{,}550\ \text{mg/L}) - (55\ \text{mg/L})}{(3{,}550\ \text{mg/L})} \times 100\%$$

$$\text{Efficiency, \%} = \frac{3{,}495}{3{,}550} \times 100\%$$ *(notice that the mg/L units cancel out, leaving %)*

$$\text{Efficiency, \%} = 98\%$$

Organic Loading

Another type of loading problem that may be encountered in wastewater treatment, primarily in attached growth facilities, is the organic loading rate problem. BOD loading on a trickling filter is calculated using the BOD in the primary clarifier effluent which is then applied to the trickling filter, *without regard to the BOD in the recirculation flow.*

This calculation is important in that as the BOD load increases on a trickling filter, the amount of biological growth developed in the filter bed increases significantly, thus filling the voids in the bed and impeding the passage of liquid and air. BOD loadings are expressed in terms of pounds of BOD applied per day per unit of volume as 1,000 ft^3.

The formula for calculating the organic loading rate is written as follows:

- **Organic loading, lbs BOD/day/1000 ft^3** $= \frac{\text{BOD applied, lbs/day}}{\text{volume of media (in 1000 ft}^3)}$

Example

What is the organic loading rate in pounds of BOD per day per 1,000 ft^3 on a trickling filter that has a depth of 5 feet and a diameter of 60 feet if the influent to the filter has a BOD of 180 mg/L and the flow is 1,500,000 gallons per day?

In solving this problem, first determine how many pounds of BOD per day are applied to the filter. Use the pounds formula.

BOD, lbs/day = Flow, MGD x BOD, mg/L x 8.34 lbs/gal

BOD, lbs/day = 1.5 MGD x 180 mg/L x 8.34 lbs/gal

BOD, lbs/day = 2,252 lbs/day

Now, the next step is to calculate the volume of the trickling filter in 1,000 cubic foot units. Use the appropriate formula for the volume of a cylinder.

$V = \pi \times R^2 \times H$

V = 3.14 x 30 ft x 30 ft x 5 ft

V = 14,130 ft^3

$$\text{Volume, in } 1000\ ft^3 = \frac{14{,}130\ ft^3}{1000}$$

Volume, in 1000 ft^3 = 14.13/1000 ft^3

Now, use the organic loading formula, substituting with the values previously calculated:

$$\text{Organic loading, lbs BOD/day/1000 } ft^3 = \frac{\text{BOD applied, lbs/day)}}{\text{volume of media (in 1000 } ft^3)}$$

$$\text{Organic loading, lbs BOD/day/1000 } ft^3 = \frac{2{,}252 \text{ lbs/day}}{14.13/\ 1000\ ft^3}$$

Organic loading, lbs BOD/day/1000 ft^3 = 159 lbs BOD/day/1000 ft^3

RBC Loadings and Soluble BOD Calculations

There are two basic differences from trickling filters in calculating the organic loading for a rotating biological contactor. The formula is nearly the same, with the exception being that the media is expressed in square feet of media surface. This is usually given. The loadings on rotating biological contactors are based upon *soluble* BOD, which is sometimes given in a problem. Soluble BOD is the BOD of the filtrate from the standard suspended solids test. If calculating the soluble BOD is required, use the following formula:

- **Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)**

("K" is equal to 0.5 to 0.7 for most domestic wastewaters. This number is given in a test situation.)

Example

A rotating biological contactor has a media surface area of 834,000 sq ft, treats a domestic wastewater having a BOD of 330 mg/L, a total suspended solids of 310 mg/L, and receives an average daily flow of 2.0 MGD. What is the organic loading of this facility if the K factor is 0.65?

First, calculate the soluble BOD:

Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)

Soluble BOD, mg/L = 330 mg/L – (0.65 x 310 mg/L)

Soluble BOD, mg/L = 330 mg/L – 201.5 mg/L

Soluble BOD, mg/L = 128.5 mg/L

Now, calculate how many pounds of soluble BOD are applied per day using the pounds formula.

Soluble BOD, lbs/day = Flow, MGD x soluble BOD, mg/L x 8.34 lbs/gal

Soluble BOD, lbs/day = 2.0 MGD x 128.5 mg/L x 8.34 lbs/gal

Soluble BOD, lbs/day = 2,143 lbs soluble BOD/day

Now, use the organic loading formula. Remember to use square feet of media surface instead of cubic feet of media.

$\frac{834{,}000 \text{ ft}^2}{1000} = 834/1000 \text{ ft}^2$

ORL, lbs soluble BOD/day/1000 ft^2 = $\frac{\text{soluble BOD applied,lbs day}}{\text{surface area of media (in 1000 ft}^2)}$

ORL, lbs soluble BOD/day/1000 ft^2 = $\frac{2{,}143 \ lbs/day}{834/1000 \text{ ft}^2}$

ORL, lbs soluble BOD/day/1000 ft^2 = 2.6 lbs soluble BOD/day/1000 ft^2

Hydraulic Loading

Another type of loading problem that involves attached growth units is that of hydraulic loading. It is very similar to the surface loading rate problem that was demonstrated at the beginning of the section. When applied to the attached growth facilities, however, the recirculation flow must be considered. The total flow applied to the treatment plant is the average daily flow to the plant plus the recirculation flow.

The formula for hydraulic loading, in gal/day sq ft, is written:

- **Hydraulic loading, GPD/sq ft** = $\frac{\text{flow rate, gal/day}}{\text{surface area, sq ft}}$

Example

What is the hydraulic loading, in GPD/sq ft, for a tickling filter plant that has a diameter of 120 feet and a depth of 6 feet if the plant has a daily flow of 1.25 MGD and a 65% recirculation rate?

In figuring the new flow (the average daily flow plus the recirculation flow), if the recirculation flow is given as a percent of the average daily flow, simply multiply the average daily flow by 1 and the decimal equivalent of the percent. This automatically adds in the recirculation flow.

1.25 MGD x 1.65 = 2.0625 MGD (the daily flow plus recirculation flow)

Now, calculate the surface area of this filter using the appropriate area formula:

$A = \pi \times R^2$

A = 3.14 x 60 ft x 60 ft

A = 11,304 sq ft

Now, use the hydraulic loading formula and the information that has been calculated, above:

$$\text{Hydraulic loading, GPD/sq ft} = \frac{\text{flow rate, gal/day}}{\text{surface area,sq ft}}$$

$$\text{Hydraulic loading, GPD/sq ft} = \frac{\text{2,062,500 gal/day}}{\text{11,304 sq ft}}$$

Hydraulic loading, GPD/sq ft = 182 gal/day/sq ft

This concludes the LOADINGS portion of this workbook. In the appendix, there is a multiple-choice test which covers all of the information in this chapter. If you feel comfortable with the subject matter, it is suggested that you take this test now and compare your answers with those provided in the answer key. Use the formula sheet provided at the end of this workbook. Remember to write the problem out completely, as in the examples given in this section. Do each step carefully, and do not forget to keep track of your units.

CHAPTER TWO

ACTIVATED SLUDGE

Traditionally, operators have the most difficulty understanding the activated sludge process control calculations. One reason is because most of the problems require the use of several formulas and calculations. Most students do not take the time to set the problem up correctly and become confused while performing the calculations. Use the process introduced in the Core workbook – draw a diagram if necessary, set the problem up in steps, and be sure to label each number with the appropriate units.

Sludge Volume Index (SVI)

The sludge volume index is an operational parameter for the activated sludge process. It is a calculation of which the result is used to indicate the settling ability of activated sludge in secondary clarifiers. It compares the volume of the sludge to its weight. In order to make this calculation, laboratory results for the 30 minutes settleable solids test and the mixed liquor suspended solids test are needed.

The formula for the SVI is written as follows. The units for SVI are mL/mg.

- $\text{SVI} = \dfrac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$

Example

What is the SVI for a conventional activated sludge facility when the 30 minute settling is 420 mL/L and the MLSS is 3,300 mg/L?

$$\text{SVI} = \frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$$

$$\text{SVI} = \frac{420 \text{ mL/L}}{3{,}300 \text{ mg/L}} \times 1{,}000$$

SVI = 127 mL/mg *(in SVI calculations, the units mL/mg are usually left off)*

Sludge Density Index (SDI)

A calculation that is used similarly to SVI is the *sludge density index*, or SDI. SDI is the weight, in grams, of one mL of sludge after settling for 30 minutes.

The formula for sludge density index is written:

- $\text{SDI} = \dfrac{100}{\text{SVI}}$

Example

What is the SDI of the conventional activated sludge plant described in the previous example?

$$SDI = \frac{100}{SVI}$$

$$SDI = \frac{100}{127}$$

SDI = 0.79

Solids Inventory

The solids inventory is a basic calculation that is required for operational control in activated sludge treatment plants. The formula used in the pounds formula from the Core Workbook. However, since the pounds desired are located in the aeration tank, the capacity of the tank in MG is needed.

The tank volume and capacity may have to be calculated in solids inventory problems, and for this, use the appropriate volume formulas introduced in the Core Workbook. The mixed liquor suspended solids (MLSS), in mg/L, is a laboratory result, and is given in the problems.

The formula for solids inventory, or pounds of solids in the aeration tank, is written:

- **Solids, lbs = (tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)**

Example

What is the solids inventory of a treatment plant with an aeration tank capacity of 0.220 MG and an MLSS of 2,800 mg/L?

Since the tank capacity is given, just substitute the known values into the formula:

Solids, lbs = (tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

Solids, lbs = (0.220 MG) x (2,800 mg/L) x (8.34 lbs/gal)

Solids, lbs = 5,137 lbs

Another type of solids inventory operators should be familiar with is the volatile solids inventory. This is done in the exact same way as the solids inventory above, except that the volatile solids or MLVSS in mg/L, is used in place of the MLSS.

The volatile solids may be given as a percentage of the MLSS. In order to get MLVSS from this, just multiply the MLSS by the decimal equivalent of the percent given. This is demonstrated in the example below.

Example

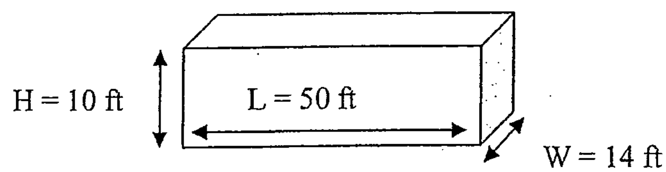
What is the volatile solids inventory of an activated sludge plant with an aeration tank that has a length of 50 feet, a width of 14 feet, and a depth of 10 feet if the average daily flow through the tank is 0.0650 MGD and the MLSS is 3,550 mg/L? Assume the volatiles to be 65 percent of MLSS.

In setting this problem up, notice that a flow is given. This is NOT needed in the calculation. However, the tank capacity in MG and the MLVSS are needed. Calculate those values as shown below:

V = L x W x H

V = 50 ft x 14 ft x 10 ft

$V = 7{,}000\ ft^3$



$7{,}000\ ft^3 \times 7.48\ \frac{gal}{ft^3}$

capacity, gal = 52,360 gal

capacity, MG = 0.05236 MG

Now, the given MLSS is 3,550 mg/L

3,550 mg/L x 0.65 = 2,308 mg/L *(the 0.65 is the decimal equivalent of the percent volatile solids)*

Volatile solids, mg/L = 2,308 mg/L

In substituting:

Volatile solids, lbs = (tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)

Volatile solids, lbs = (0.05236 MG) x (2,308 mg/L) x (8.34 lbs/gal)

Volatile solids, lbs = 1,008 lbs

Sludge Age

Another important process control calculation is the sludge age. It is a measure of the length of time (in days) that suspended solids remain in the activated sludge process. It is calculated by dividing the weight of suspended solids added per day to the aeration tank into the weight of suspended solids under aeration (the solids inventory).

The formula for sludge age is written:

- **Sludge age, days** $= \frac{\text{solids under aeration, lbs}}{\text{solids added, lbs/day}}$

This is the same as writing the formula as:

- **Sludge age, days** $= \frac{\text{(Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)}}{\text{(Flow, MGD) x (TSS influent, mg/L) x (8.34 lbs/gal)}}$

If either the solids inventory, in pounds, or the pounds of solids being added daily are given, or possibly both, it is easier to substitute those values into the first formula. If calculations are necessary to obtain the values needed to substitute into the formulas, it is less confusing to use the second formula given above. The tank capacity may have to be calculated, however, and this should be treated as a separate problem altogether, as will be shown in the example.

Example

What is the sludge age for the activated sludge plant described below?

Aeration tank:	80 ft = L, 20 ft = W, 15 ft = D
MLSS:	4,025 mg/L
TSS, influent:	235 mg/L
Daily flow:	525,000 gpd
Volatile solids:	68 % of MLSS

First, calculate the aeration tank capacity using the appropriate volume formula. The dimensions are all in feet, so no conversions are necessary.

V = L x W x H

V = 80 ft x 20 ft x 15 ft

V = 24,000 ft^3

Capacity, gallons = 24,000 ft^3 x 7.48 $\frac{gal}{ft^3}$ =

179,520 gallons or 0.180 MG

Notice that a percentage of volatiles is given. This is not necessary in calculating the sludge age, so just disregard it.

$$\text{Sludge age, days} = \frac{(\text{Tank cap, MG}) \times (\text{MLSS, mg/L}) \times (8.34\ \text{lbs/gal})}{(\text{Flow, MGD}) \times (\text{TSS influent, mg/L}) \times (8.34\ \text{lbs/gal})}$$

$$\text{Sludge age, days} = \frac{(0.18\ \text{MG}) \times (4{,}025\ \text{mg/L}) \times (8.34\ \text{lbs/gal})}{(0.525\ \text{MGD}) \times (235\ \text{mg/L}) \times (8.34\ \text{lbs/gal})}$$

$$\text{Sludge age, days} = \frac{724.5}{123.4\ \text{days}}$$

Sludge age, days = 5.9 days *(notice that all units except for days cancel)*

F/M Ratios

The F/M, or food to microorganism ratio, is an operational control parameter based upon the pounds of food available (pounds of BOD) and the pounds of microorganisms (volatile solids) present to consume this food. Metabolism of the microorganisms results in an increased mass of microorganisms in the system. The excess microorganisms are removed (wasted) from the system to maintain the proper balance between food supply and the mass of microorganisms in the aeration tank.

A high F/M ratio is characterized by excess food and poor settling characteristics. The settling tank is not as effective in separating microorganisms form the effluent, and there is excess unused organic matter in solution which will not be consumed by the microorganisms and consequently will pass out in the effluent, contributing to poor overall treatment.

At a low F/M ratio, overall metabolic activity in the aeration tank may be considered near the endogenous stage in that competition for the small amount of food available to the large mass of microorganisms results in near-starvation conditions in a very short time. Under these conditions, even though the rate of metabolism of the microorganisms is relatively low, settling characteristics in the sedimentation tank is quite good and the consumption of the food in nearly complete.

The formula for calculating F/M ratios is written as follows:

- **F/M, lbs/day/lb** = $\frac{\text{(inf. BOD, mg/L) x (flow, MGD) x (8.34 lbs/gal)}}{\text{(Aeration tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)}}$

Notice that the formula is just two pounds formulas, the top being the pounds of BOD added per day, and the bottom being the volatile solids inventory in pounds. Remember that the volatile solids are representative of the amount of microorganisms present. The units will be lbs/day/lb, but are usually left off.

Example

What is the F/M ratio for a treatment plant if the following information is given?

Aeration tank capacity:	0.220 MG
Influent BOD:	205 mg/L
Daily flow:	0.300 MGD
MLVSS:	1,700 mg/L

F/M, lbs/day/lb = $\frac{\text{(inf. BOD,mg/L) x (flow, MGD) x (8.34 lbs/gal)}}{\text{(Aeration tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)}}$

F/M, lbs/day/lb = $\frac{\text{(205 mg/L) x (0.30 MGD) x (8.34 lbs/gal)}}{\text{(0.220 mg/L) x (0.30 MGD) x (8.34 lbs/gal)}}$

F/M, lbs/day/lb = $\frac{\text{512.9 lbs/day}}{\text{3,119 lbs}}$

F/M = 0.16

(this means that for every hundred pounds of microorganisms, there are 16 pounds of food)

As stated previously, F/M ratios are usually expressed without any units.

Mean Cell Residence Time

MCRT, or mean cell residence time, is another way that the theoretical amount of time that microorganisms spend in the activated sludge process can be calculated. Solids retention in activated sludge systems is measured in days whereas liquid retention is measured in hours. Remember that the solids are recycled in the system from the final clarifier back to the aeration tank, while the liquid flows through the aeration tank, into the clarifier, and out of the process as effluent.

MCRT involves three pounds formulas – the first is the solids inventory, which measures the pounds of MLSS in the aeration tank. On the bottom of the formula, the effluent solids in pounds is a function of the daily flow and the total suspended solids (TSS), in mg/L, of the effluent. Also on the bottom, the WAS, or waste activated sludge in pounds is a function of the sludge intentionally wasted in MG and the concentration of this sludge in mg/L.

The MCRT formula is written as follows:

- **MCRT** = $\dfrac{\text{solids inventory, lbs}}{\text{(effluent solids, lbs)} + \text{(WAS solids, lbs)}}$

You may also see the formula written as follows. Both formulas are the same.

MCRT =

$$\frac{\text{(Aeration tank cap, MG) x (MLSS,mg/L) x (8.34 lbs/gal)}}{\text{[(Flow, MGD) x (TSS eff, mg/L) x (8.34 lbs/gal)] + [(WAS flow, MGD) x (WAS,mg/L) x (8.34 lbs/gal)]}}$$

In working MCRT problems, it is less confusing if the first formula is used. If calculations are necessary in order to substitute numbers in the formula, just treat each calculation as a separate pounds problem, then substitute the values into the MCRT formula as in the example shown below.

Example

What is the MCRT of the activated sludge plant described?

Aeration tank capacity:	150,000	gallons
MLSS:	2,250	mg/L
Daily flow:	820,000	gallons per day
TSS, effluent:	5.0	mg/L
WAS, mg/L:	10,500	mg/L
WAS flow, daily:	6,000	gallons per day

First, determine the amount of solids in the aeration tank, or solids inventory.

Solids, lbs = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

Solids, lbs = (0.150 MG) x (2,250 mg/L) x (8.34 lbs/gal)

Solids, aeration, lbs = 2,815 lbs

Now, determine the amount of solids lost in the effluent daily.

Solids, effluent lbs/day = (Flow, MGD) x (TSS effluent, mg/L) x (8.34 lbs/gal)

Solids, effluent lbs/day = (0.82 MGD) x (5 mg/L) x (8.34 lbs/gal)

Solids, effluent, lbs/day = 34 lbs

Finally, determine the pounds of solids wasted daily.

WAS, lbs = (WAS, MG) x (WAS, mg/L) x (8.34 lbs/gal)

WAS, lbs = (0.006 MG) x (10,500 mg/L) x (8.34 lbs/gal)

WAS, lbs = 525 lbs/day

Now that all of the information is available and ready to substitute, proceed with the formula.

$$\text{MCRT} = \frac{\text{solids inventory, lbs}}{(\text{effluent solids, lbs}) + (\text{WAS solids, lbs})}$$

$$\text{MCRT} = \frac{2{,}815\ \text{lbs}}{(34\ \text{lbs/day}) + (525\ \text{lbs/day})}$$

MCRT = 5 days

WAS Pumping Rates

If a plant runs well in a certain MCRT, and that MCRT is to be maintained, a certain amount of sludge must be wasted daily. If a new MCRT must be met, the following formulas can be used to calculate a wasting rate to achieve that desired MCRT.

- **WAS, lbs/day** $= \dfrac{\textbf{(solids inventory, lbs)}}{\textbf{desired MCRT, days}}$ **- (solids lost in effluent, lbs/day)**
- **WAS flow, MGD** $= \dfrac{\textbf{WAS, lbs/day}}{\textbf{(WAS, mg/L) x (8.34 lbs/gal)}}$

Example

An activated sludge plant was determined to have a MCRT of 5 days under present operating conditions. The desired MCRT for this facility is 8 days. The amount of solids lost in the effluent daily is 34 pounds. The solids inventory of the plant is kept at 2,815 pounds. The WAS concentration is 10,500 mg/L. What WAS pumping rate is necessary to achieve the desired MCRT?

$$\text{WAS, lbs/day} = \frac{\text{(solids inventory, lbs)}}{\text{desired MCRT, days}} - \text{(solids lost in effluent, lbs/day)}$$

$$\text{WAS, lbs/day} = \frac{\text{(2,815 lbs)}}{\text{8 days}} - \text{(34 lbs/day)}$$

WAS, lbs/day = 351.9 lbs/day - 34 lbs/day

WAS, lbs/day = 318 lbs/day

Now, use the second formula to get these units into a flow:

$$\text{WAS flow, MGD} = \frac{\text{WAS, lbs/day}}{\text{(WAS, mg/L) (8.34 lbs/gal)}}$$

$$\text{WAS flow, MGD} = \frac{\text{318 lbs/day}}{\text{(10,500 mg/L) (8.34 lbs/gal)}}$$

$$\text{WAS flow, MGD} = \frac{318}{(87{,}570)}$$

WAS flow, MGD = 0.0036 or 3,600 gallons per day

Changing Sludge Pumping Rates

The *constant MLSS* method technique of process control is simple to understand and requires a minimum amount of laboratory work. As long as the incoming wastewater characteristics remain fairly constant with minimal variations in flow rates, a good quality effluent can be produced using this method. When the MLSS begins to rise, it is time to change the sludge pumping rate. The present sludge pumping rate should already be known.

The control technique is implemented by choosing an MLSS concentration which has been found to produce a high quality effluent. Therefore, before an operator begins to use this method, the plant's past operation records and process control data must be researched.

This method has its drawbacks, however. It does not account for variations in flow, influent BOD, amount of solids remaining in the secondary clarifier, and microorganism growth rates.

This method can also be used with the MLVSS instead of MLSS. The results will be the same, but choose either MLSS or MLVSS. NEVER combine the two in the formula.

To change, or adjust the sludge pumping rate, use this formula:

- **Change, WAS rate, MGD** $= \frac{\text{(current SI)} - \text{(desired SI)}}{\text{WAS,}\frac{mg}{L} \times 8.34\frac{lbs}{gal}}$

Example

An extended aeration plant has been observed to produce an excellent effluent over a period of time with an MLSS concentration of 2,555 mg/L and a WAS pumping rate of 18 gallons per minute. Currently, the effluent quality has deteriorated and the MLSS under aeration has risen to 3,350 mg/L. The WAS has a value of 10,500 mg/L. If the aeration tank capacity is 440,000 gallons, what is the change in sludge pumping rate in order to achieve the desired MLSS and the NEW sludge pumping rate?

First, calculate the CURRENT solids inventory.

SI, current = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

SI, current = (0.440 MG) x (3,350 mg/L) x (8.34 lbs/gal)

SI, current = 12,293 lbs

Now, calculate the DESIRED solids inventory.

SI, desired = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

SI, desired = (0.440 MG) x (2,555 mg/L) x (8.34 lbs/gal)
SI, desired = 9,376 lbs

Now, use the change in WAS flow formula, substituting the values that have just been calculated:

$$\text{WAS change, MGD} = \frac{\text{(current SI)} - \text{(desired SI)}}{\text{WAS, mg/L x 8.34 lbs/gal}}$$

$$\text{WAS change, MGD} = \frac{\text{(12,293 lbs)} - \text{(9,376 lbs)}}{\text{10,500 mg/L x 8.34 lbs/gal}}$$

$$\text{WAS change, MGD} = \frac{\text{2917 lbs}}{\text{87,570 lbs/gal}}$$

WAS change, MGD = 0.033 MGD or 33,000 gal/day

Now the pumping rate can be changed to gallons per minute by using the following conversion:

$$\frac{\text{33,000 gal/day}}{\text{1,440 min/day}} = \text{22.9 or 23 gal/min}$$

The old WAS pumping rate was 18 gal/min, and the change, as calculated, is 23 gal/min. The new pumping rate is equal to the OLD plus the NEW.

23 gal/min + 18 gal/min = 41 gal/min

Return Sludge Rate

A simple way to estimate the proper return sludge pumping rate for an activated sludge facility is by using the results from the 30 minute settleable solids test.

The formula is written:

- **Return sludge rate, MGD =** $\frac{\text{(set. solids, mL) x (Flow, MGD)}}{\text{(1,000 mL) - (set. solids, mL)}}$

Example

What is the proper return sludge rate in gallons per minute for an activated sludge plant that has an average daily flow of 2.0 MGD and a settleable solids concentration of 350 mL?

Return sludge rate, MGD = $\frac{\text{(set. solids, mL) x (Flow, MGD)}}{\text{(1,000 mL) - (set. solids, mL)}}$

Return sludge rate, MGD = $\frac{\text{(350 mL) x (2.0 MGD)}}{\text{(1,000 mL) - (350 mL)}}$

Return sludge rate, MGD = $\frac{\text{700 MGD}}{\text{650}}$

Return sludge rate, MGD = 1.08 MGD

Now the MGD can be changed to gallons per minute:

$\frac{\text{1,080,000 gal/day}}{\text{1,440 min/day}}$ = 750 gal/min

This concludes the activated sludge process control portion of this program. In the appendix, there is a multiple-choice test which covers all of the information in this section. If you feel comfortable with the subject matter, it is suggested that you take this test now and compare your answers with those provided in the answer key.

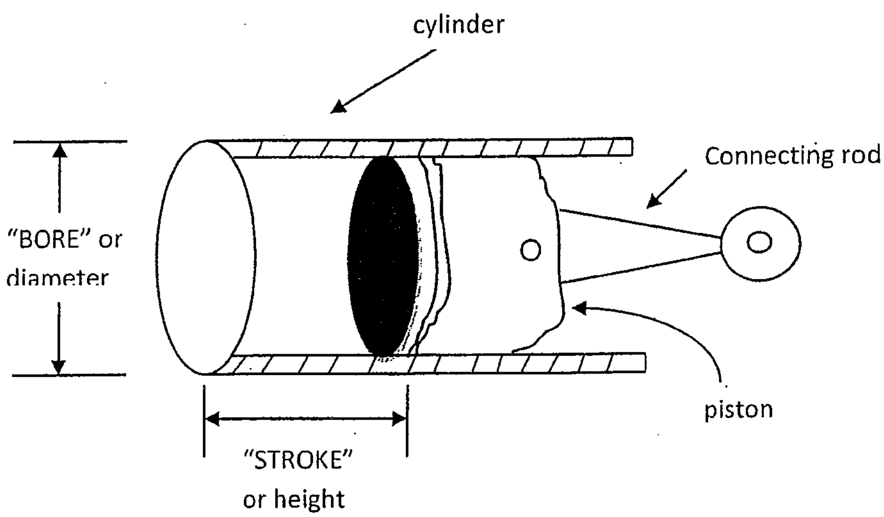
Remember to write the problem out completely, as in the examples given in this section. Do each step carefully, and do not forget to keep track of your units.

CHAPTER THREE

SLUDGE DIGESTION

Sludge Pumping

Positive displacement pumps are used in wastewater to handle sledges. One type of positive displacement pump is the piston pump. Sometimes operators must calculate the capacity of piston pumps and how many gallons of sludge will be pumped over a period of time. As shown in the diagram below, a piston moves back and forth over a distance called the *stroke.* The width of the piston, or its diameter, is called the *bore.* Every time the piston moves upward and downward in the cylinder (*called a revolution*) it pumps the volume of water contained in the cylinder.



Calculating the capacity of piston pumps is similar to calculating the volume of a cylinder.

<u>Example</u>

What is the capacity, in gallons per minute, of a piston pump that has a bore of 4 inches and a stroke of 8 inches if it pumps 30 revolutions (rev) per minute?

Calculate the volume of the cylinder in the pump using the volume of a cylinder formula:

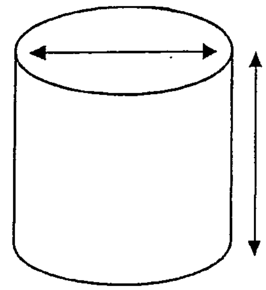
$V = \pi \times R^2 \times H$

$V = 3.14 \times 0.17 \text{ ft} \times 0.17 \text{ ft} \times 0.67 \text{ ft}$

$V = 0.061 \text{ ft}^3$

$0.061 \text{ cu ft} \times 7.48 \text{ gal/ft}^3 =$

Capacity = 0.46 gal



This means that for every revolution, the pump pumps 0.46 gallons of sludge.

0.46 gal/rev x 30 rev/min = 13.8 gal/min

The units "rev" cancel out and gal/min is left.

Dry Solids

If the percent total solids in sludge is known, the pounds of dry solids that are handled can be calculated.

The formula for dry solids, in pounds, is written:

- **Dry solids, lbs** $= \dfrac{\text{(raw sludge, gal) x (raw sludge, \% solids) x (8.34 lbs/gal)}}{100\ \%}$

Example

Each day, 6,500 gallons of raw sludge are pumped to a disposal area. This sludge contains 6.0% total solids. How many pounds of dry sludge are handled per day?

Dry solids, lbs $= \dfrac{\text{(6,500 gal) x (6.0 \%) x (8.34 lbs/gal)}}{100\ \%}$

Dry solids, lbs $= \dfrac{\text{325,260 lbs}}{100}$

Dry solids, lbs = 3,253 lbs

Sometimes the pounds of volatile solids (VS) contained in a known volume of sludge must be calculated. The percentage of volatile solids in the sludge will be given in this case. Multiply the pounds of total solids by the decimal equivalent of the percent volatile solids are shown below.

Example

Using the dry solids example above, if the lab has determined that the volatile solids content of the sludge being disposed of is 72%, how many pounds of volatile solids are being disposed of daily?

3,253 lbs x 0.72 =

Volatile solids, lbs = 2,342 lbs

Seed Sludge, Volatile and Suspended Solids Pumping

In startup of anaerobic digesters, seed sludge is sometimes required. The seed sludge can be added based upon the capacity of the digester tank, or by the amount of raw sludge which will be added to the digester.

If the sludge is added based upon the capacity of the digester, just multiply the capacity of the digester by the percentage of seed sludge that is necessary.

Example

A digester measures 14 feet in depth and has a diameter of 24 feet. In starting this digester, it is recommended that the digester be filled to 25% of the tank volume in seed sludge. How many gallons of seed sludge must be added?

First, calculate the digester capacity in gallons. It is a circular tank, so the volume of a cylinder formula is used:

$V = \pi \times R^2 \times H$

V = 3.14 x 12 ft x 12 ft x 14 ft

$V = 6{,}330 \text{ ft}^3$

$6{,}330 \text{ cu ft} \times \frac{7.48 \text{ gal}}{\text{ft}^3} =$

47,350 gallons *(digester capacity)*

47,350 gal x 0.25 = 11,838 gallons of seed required

(NOTE: the 0.25 is the decimal equivalent of the percent of tank volume required to be filled.)

Another method of calculating seed sludge (SS) depends upon the gallons of raw sludge (RS) that will be added initially, the solids content of the raw sludge (RSS), and the percent volatiles of the raw sludge (RSV). A loading factor will also be given, which will usually be between 0.03 and 0.10, and this means that there can be 0.03 to 0.10 pounds of raw volatile solids (RSV) added for every pound of volatile solids (VS) already under digestion.

The formulas necessary to accomplish this are written using the abbreviations above:

- **VS pumped, lbs/day** $= \frac{(\text{RS, gal/day})(\text{RSS, \%})(\text{RSV, \%})(8.34\text{ lbs/gal})}{(100\ \%)\quad(100\ \%)}$
- **Seed sludge, lbs VS** $= \frac{\text{VS pumped, lbs VS / day}}{\text{Loading factor, lbs VS/day/lb VS in digester}}$
- **Seed sludge, gallons** $= \frac{\text{Seed sludge, lbs VS}}{(\text{SS, lbsgal})\left(\frac{\text{Solids \%}}{100\ \%}\right)\left(\frac{\text{VS \%}}{100\ \%}\right)}$

Example

A new digester is going on line as part of a plant expansion. How many pounds of volatile solids will be pumped to the digester per day and how many gallons of seed sludge will be necessary to start this digester if the following information is given?

• Raw sludge, gal/day:	650
• Raw sludge solids, %	5.5 %
• Raw sludge volatiles, %	70 %
• Seed sludge solids, %	8.5 %
• Seed sludge volatiles, %	58 %
• Wt. of seed sludge, gal:	9.5 lbs/gal
• Loading factor:	0.05 lbs VS/day per lb VS under digestion

First, calculate the pounds of volatile solids that will be pumped to the digester daily.

$$\text{VS pumped, lbs/day} = \frac{(\text{RS, gal/day})(\text{RSS, \%})(\text{RSV, \%})(8.34\text{ lbs/gal})}{(100\ \%)\ (100\ \%)}$$

$$\text{VS pumped, lbs/day} = \frac{(650\text{ gal/day})(5.5\ \%)(70\ \%)(8.34\text{ lbs/gal})}{(100\ \%)(100\ \%)}$$

$$\text{VS pumped, lbs/day} = \frac{2{,}087{,}085\text{ lbs/day}}{10{,}000}$$

VS pumped, lbs/day = 209 lbs VS/day

Now, find the pounds of seed volatile solids needed:

$$\text{SS, lbs volatile solids} = \frac{\text{VS pumped, lbs VS / day}}{\text{loading factor, lbs VS/day/lb VS in digester}}$$

$$\text{SS, lbs volatile solids} = \frac{209\text{ lbs VS / day}}{0.05\text{ lbs VS/day/lb VS in digester}}$$

SS, lbs volatile solids = 4,180 lbs VS

In order to seed the digester with 4,180 pounds of volatile solids, it is necessary to convert the pounds of VS to gallons of seed sludge.

$$\text{SS, gal} = \frac{\text{SS, lbs VS}}{(\text{SS, lbs/gal})\left(\frac{\text{solids \%}}{100\ \%}\right)\left(\frac{\text{VS \%}}{100\ \%}\right)}$$

$$\text{SS, gal} = \frac{4{,}180\ \text{lbs VS}}{(9.5\ \text{lbs/gal})\left(\frac{8.5\ \%}{100\ \%}\right)\left(\frac{58\ \%}{100\ \%}\right)}$$

$$\text{SS, gal} = \frac{4{,}180\ \text{lbs VS}}{(9.5\ \text{lbs/gal})\ (0.085)\ (0.58)}$$

$$\text{SS, gal} = \frac{4{,}180}{0.47}$$

SS, gal = 8,894 gallons of seed sludge

Neutralizing Upset Digesters

If an anaerobic digester becomes upset, sometimes it is necessary to add lime to neutralize it. The lime required to neutralize an upset digester is estimated using the pounds formula.

The formula for neutralizing a sour or upset digester using lime is written:

- **Lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)**

Example

An anaerobic digester is upset and should be neutralized with lime. If the digester contains 45,000 gallons of sludge and the volatile acids content is 2,980 mg/L, how many pounds of lime are required?

lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)

lime req'd, lbs = (0.045 MG) x (2,980 mg/L) x (8.34 lbs/gal)

lime req'd, lbs = 1,118 lbs of lime

Percent Reduction of Volatile Solids

The percent reduction of volatile solids in a digester as the result of digestion is a calculation that operators need to perform.

The formula for percent reduction of volatile solids is written as follows:

- **% reduction** = $\frac{\text{(in-out) x (100\%)}}{\text{in - (in x out)}}$

Example

An anaerobic digest is operating properly. The raw sludge has a volatile solids content of 72% and the digested sludge has a volatile content of 47%. What is the percent reduction of volatile solids accomplished by this digester?

% reduction = $\frac{\text{(in-out) x (100 \%)}}{\text{in-(in x out)}}$

% reduction = $\frac{(0.72 - 0.47) \times (100\ \%)}{0.72 - (0.72 \times 0.47)}$ *(NOTE that the percentages are expressed as decimals)*

% reduction = $\frac{0.25\ (100\ \%)}{0.72 - 0.338}$

% reduction = $\frac{25\ \%}{0.382}$

% reduction = 65 %

Volatile Solids Destroyed

The information used in calculating volatile solids percent reduction can be used to calculate the pounds of volatile solids destroyed per day per cubic foot of digester space.

The formula for estimating pounds of volatile solids destroyed in written:

- **VS destroyed, lbs/day/cu ft** = $\frac{\text{(VS added, lbs/day) (VS reduction, \%)}}{\text{(digester volume, cu ft) (100 \%)}}$

Example

How many pounds of volatile solids are destroyed per day if a digester has a volume of 22,750 cubic feet and 8,800 pounds of volatiles are added per day with a percent reduction due to digestion of 65%?

VS destroyed, lbs/day/cu ft = $\frac{\text{(VS added, lbsday) (VS reduction, \%)}}{\text{(digester volume, cu ft) x (100 \%)}}$

VS destroyed, lbs/day/cu ft = $\frac{\text{(8,800 lbs/day) (65 \%)}}{\text{(22,750 cu ft) (100 \%)}}$

VS destroyed, lbs/day/cu ft = $\frac{\text{(572,000 lbs / day)}}{\text{(2,275,000 cu ft)}}$

VS destroyed, lbs/day/cu ft = 0.25 lbs/day/cu ft

A precaution that should be taken in this type of problem is that the volume of the digester may need to be calculated. *Remember that cubic feet are required, not the capacity in gallons*. Also, volatiles may be given in gallons added instead of pounds. In this case, the weight of one gallon of the volatiles will be given so a calculation *from gallons to pounds* can be made.

Digester Gas Production

Another digestion problem involving anaerobic digestion is the amount of gas production as related to the volatile solids destroyed. Gas production is dependent upon the amount of volatiles destroyed per day per cubic foot of digester space, as described in the example illustrated above.

The formula for calculating gas production is written as follows:

- **Gas production, cu ft/ lb VS =** $\frac{\text{(gas produced, cu ft/day)}}{\text{(VS destroyed, lbs/day)}}$

Example

An anaerobic digester destroys 988 pounds of volatile solids daily. The gas meter indicates that 12,750 cubic feet of gas are produced each day. How many cubic feet of gas are produced per pound of volatile solids destroyed?

Gas production, cu ft/lb VS = $\frac{\text{(gas produced, cu ft/day)}}{\text{(VS destroyed, lbs/day)}}$

Gas production, cu ft/lb VS = $\frac{\text{(12,750 cu ft/day)}}{\text{(988 lbs/day)}}$

Gas production, cu ft/lb VS = 13 cu ft gas / lb of VS destroyed

This concludes the sludge digestion portion of the program. A 10 question multiple choice test can be found in the appendix. Do your work on a separate sheet of paper, and feel free to refer to the formula sheet at the beginning of this workbook.

CHAPTER FOUR

HORSEPOWER, FORCE, FEED PUMPS

Horsepower

One horsepower is equal to 33,000 ft-lbs per minute. This means that one horsepower is the same as lifting one pound of a vertical distance of 33,000 feet in a period of one minute. If the discharge from a pump is converted into the weight of water and this weight is multiplied by the vertical distance it is lifted (head), and it is known that 1 horsepower is equal to 33,000 ft-lbs/min, a formula for water horsepower can be written. Water horsepower is the *horsepower required to lift water*.

The formula for water horsepower is written:

- **Water HP** $= \dfrac{(\text{flow, gal/min}) \times (\text{head, feet})}{(3{,}960\ \text{gal/min/ft}}$

The 3,960 at the bottom of the formula is derived from dividing 33,000 ft-lbs per minute, which is the equivalent of one horsepower, by 8.34 lbs/gal, which is the weight of one gallon of water. The units for the 3,960 are gal/min/ft, which cancel out with the units in the numerator of the formula.
(The units are usually left off the 3,960 in the formula to avoid confusion.)

Each pump has its own characteristics relative to power requirements and efficiency. No pump is 100 percent efficient, with the normal range of efficiency being between 50% and 85% for centrifugal pumps. Pump efficiency usually increases with the size and capacity of the pump.

The horsepower applied from the motor to the pump is called the Brake Horsepower, or BHP. The formula for brake horsepower takes into account the pump efficiency, or Ep. *The Ep is always expressed in the formula as a decimal.*

The BHP formula is written:

- **BHP** $= \dfrac{(\text{flow, gal/min}) \times (\text{head, ft})}{(3{,}960\ \text{gal/min/ft}) \times (\text{Ep})}$

The motors that drive pumps are also not 100 percent efficient. Motor efficiency is usually in the range of 80 to 90 percent, and this is expressed as Em. *In the formula, the motor efficiency percent is always expressed as a decimal.*

The formula for motor horsepower is written:

- **Motor HP** $= \dfrac{(\text{flow, gal/min}) \times (\text{head, ft})}{(3{,}960) \times (\text{Ep}) \times (\text{Em})}$

The above formulas work well when pumping water with a specific gravity of 1.0. If liquids with a greater specific gravity such as sludge are being pumped, more horsepower will be required. In this case, multiply the calculated horsepower by the specific gravity of the liquid being pumped. Sludges are heavier than water and have a specific gravity of greater than one. Therefore, multiplying the calculated horsepower by a number greater than one will cause the horsepower number to increase.

Example

An effluent pumping station is to be designed for a capacity of 1,200 gallons per minute at a total head of 80 feet. What is the pump horsepower and the motor horsepower that will be required if Ep is 65% and the Em is equal to 82%?

$$\text{BHP} = \frac{(\text{flow, gal/min}) \times (\text{head, ft})}{(3{,}960) \times (\text{Ep})}$$

$$\text{BHP} = \frac{(1{,}200 \text{ gal/min}) \times (80 \text{ ft})}{(3{,}960) \times (0.65)}$$

$$\text{BHP} = \frac{96{,}000 \text{ gal/min/ft}}{2{,}574}$$

BHP = 37

In solving for motor HP:

$$\text{Motor HP} = \frac{(\text{flow, gal/min}) \times (\text{head, ft})}{(3{,}960) \times (\text{Ep}) \times (\text{Em})}$$

$$\text{Motor HP} = \frac{(1{,}200 \text{ gal/min}) \times (80 \text{ ft})}{(3{,}960) \times (0.65) \times (0.82)}$$

$$\text{Motor HP} = \frac{96{,}000 \text{ gal/min/ft}}{2{,}111}$$

Motor HP = 45 HP

Force

In the Core Workbook, pressure and head were introduced. Pressure creates a force. Force calculations can become very important to wastewater plant operators when applied to tank bottoms and tank walls. If a tank is emptied during periods where the ground water table is very high, the pressure exerted on the tank bottom by the ground water can float the tank out of the ground.

The formula for calculating the upward force on a tank bottom is written:

- **Force, lbs = 62.4 lbs/cu ft x height, ft x area, sq ft**

NOTE: the 62.4 lbs/cu ft represents the weight of one cubic foot of water (8.34 lbs/gal x 7.48 gal/cu ft)

Example

What is the upward force, in pounds, on the bottom of an empty tank when the groundwater is 6 feet above the tank bottom and the tank is 40 feet long, 20 feet wide, and 16 feet in depth?

In the text of the problem, a depth is given. It is not necessary in solving this problem. Calculate the area of the tank bottom first.

A = L x W

A = 40 ft x 20 ft

A = 800 sq ft

Now, use the force formula:

Force, lbs = 62.4 lbs/cu ft x Height, ft x Area, sq ft

Force, lbs = 62.4 lbs/cu ft x 6 ft x 800 sq ft

Force, lbs = 299,520 lbs

(Notice how the units cancel, leaving pounds)

Another calculation concerning force and pressure is that of the force created by water on the side wall of a tank. The pressure at the bottom of the wall is different from the pressure at the water level, or top of the wall. The pressure at the surface is 0 psi, but the pressure at the bottom of the tank is equal to 0.433 times the height of the water in the tank.

The formula for calculating the force acting on the side wall of any tank is written:

- **Force, lbs = (31.2 lbs/cu ft) x (height. ft)^2 x (length, ft)**

Example

A tank is 40 feet long, 10 feet deep, and 16 feet in width. What is the force, in pounds, acting along the length of this tank wall when it is full?

Force, lbs = (31.2 lbs/cu ft) x (height. ft)^2 x (length, ft)

Force, lbs = (31.2 lbs/cu ft) x (10 ft)^2 x (40 ft)

Force, lbs = 31.2 lbs/cu ft x 10 ft x 10 ft x 40 ft

Force, lbs = 124,800 lbs

Chemical Solutions and Feed Pumps

Sometimes in wastewater treatment the setting in percent stroke of a chemical feeder must be determined. The chemical solutions come in various solution strengths and are fed in doses measured in milligrams per liter.

Usually, adjusting feeders is accomplished by turning a knob or hand crank on the feeder itself. The feeder has a rate scale with a pointer, calibrated over a range from 0 to 100 percent.

In order to calculate the setting of a solution chemical feeder, it may be necessary to convert a solution strength in percent into pounds of chemical per gallon of solution. The formula for this is written:

- **Chemical sol'n, lbs/gal** $= \dfrac{(\text{sol'n }\%) \times (8.34 \text{ lbs/gal})}{100\ \%}$

The desired flow, in gallons per day, may also have to be calculated.

The formula is written as shown:

- **Feed pump gal/day** $= \dfrac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$

The time unit gal/day could just as well be gal/hr or gal/min. Be sure that you keep track of the time units and do the unit conversions properly.

Now that the amount of solution needed (in gallons per time unit) has been established, it is easy to set the pump.

The formula for solution chemical feeders is written:

- **Scale setting, %** $= \dfrac{(\text{desired flow, gal/day})\ (100\ \%)}{\text{maximum feed rate, gal/day}}$

The chemical required, in pounds per day, pounds per hour, or whatever time unit is being used, may also have to be estimated. For this, the pounds formula is used. It is written below.

- **Chemical req'd, lbs/day = (Flow, MGD) x (dose, mg/L) x (8.34 lbs/gal)**

<u>**Example**</u>

A solution feeder has a scale that reads in percent. The maximum output of this feeder is 40 gallons per day. A polymer solution must be fed which will result in a chemical dose of 2.5 mg/L to a flow of 0.450 MGD. At what percent should the chemical feeder be set if the polymer being fed is in a 6 percent solution?

In solving this problem, notice that the pump output is in gallons per day and the flow is given in gallons per day. Therefore, it is best to set up the formulas using days as the time unit.

First, calculate how many pounds per gallon are contained in a 6% chemical solution.

Chemical sol'n, lbs/gal = $\frac{(\text{sol'n\%}) \times (8.34 \text{ lbs/gal})}{100\ \%}$

Chemical sol'n, lbs/gal = $\frac{(6\ \%) \times (8.34 \text{ lbs/gal})}{100\ \%}$

Chemical sol'n, lbs/gal = $\frac{50 \text{ lbs/gal}}{100}$ *(NOTE: The % units cancel out.)*

Chemical sol'n, lbs/gal = 0.5 lbs/gal

Now, figure the chemical requirement in milligrams per liter.

Chem. req'd, lbs/day = Flow, MGD x dose, mg/L x 8.34 lbs/gal

Chem. req'd, lbs/day = 0.450 MGD x 2.5 mg/L x 8.34 lbs/gal

Chem. req'd, lbs/day = 9.4 lbs/day

Now, calculate the output required of the feed pump.

Feed pump, gal/day = $\frac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$

Feed pump, gal/day = $\frac{9.4 \text{ lbs/day}}{0.5 \text{ lbs/gal}}$

Feed pump, gal/day = 18.8 gal/day

Now, use the *scale setting* formula.

Scale setting, % = $\frac{(\text{desired flow, gal/day})\ (100\ \%)}{\text{maximum feed rate, gal/day}}$

Scale setting, % = $\frac{(18.8 \text{ gal/day})\ (100\ \%)}{40 \text{ gal/day}}$

Scale setting, % = $\frac{1{,}800\ \%}{40}$ *(NOTE: the units 'gal/day' cancel)*

Scale setting, % = 47 %

This concludes this section of the workbook. A ten question test in is in the appendix, covering all subjects contained in this section, and some possible review questions from previous sections. Some of the problems in the test will require several calculations. Be sure to set these problems up using the steps as outlined in the examples. Draw a simple diagram where necessary.

CHAPTER FIVE

LAB PROCEDURES AND MEASUREMENTS

Suspended Solids Calculations

In order to calculate suspended solids concentrations from laboratory results, the follow information must be known:

- Sample volume, mL
- Wt. of crucible, grams
- Wt. of crucible and dry residue, grams
- Wt. of crucible and ash, grams

When the above information is given, the following parameters can be calculated:

- Total suspended solids, mg/L
- Volatile suspended solids, mg/L
- Volatile suspended solids, %
- Fixed suspended solids, mg/L
- Fixed suspended solids, %

To calculate the total suspended solids, the formula is written:

- **TSS, mg/L =** $\frac{(\text{RDD} - \text{DD}) \times 1\text{ M}}{\text{sample volume, mL}}$

RDD = dried residue + dish + disc (filter), grams
DD = dish + disc, grams
1 M = 1 million

The formula for calculating fixed suspended solids, a subtraction is necessary:

- **VSS, mg/L =** $\frac{(\text{RDD} - \text{FDD}) \times 1\text{ M}}{\text{sample volume, mL}}$

RDD = dried residue + dish + disc (filter), grams
FDD = fired residue + dish + disc, grams
1 M = 1 million

To calculate fixed suspended solids, a subtraction is necessary:

- **Fixed solids, mg/L = TSS, mg/L – VSS, mg/L**

TSS = total suspended solids
VSS = volatile suspended solids

In order to calculate the percent of volatile and fixed solids, use these formulas:

- **Volatile solids, % =** $\frac{\text{volatile solids, mg/L}}{\text{TSS, mg/L}}$ **x 100%**

- **Fixed solids, % =** $\frac{\text{fixed solids, mg/L}}{\text{TSS, mg/L}}$ **x 100%**

<u>**Example**</u>

A lab technician obtains the following results from a suspended solids test. What are the total suspended solids, volatile suspended solids, and percent of volatile suspended solids?

Sample volume:	10 mL
Wt. of dish + filter:	21.7319 grams
Wt. of dish + filter + dry residue:	21.7714 grams
Wt. of dish + filter + ash:	21.7387 grams

$$\text{TSS, mg/L} = \frac{(\text{RDD}-\text{DD}) \times 1\text{ M}}{\text{sample vol, mL}}$$

$$\text{TSS, mg/L} = \frac{(21.7714\text{ g} - 21.7319\text{ g})}{10\text{ mL}} \times 1{,}000{,}000$$

TSS, mg/L = 3,950 mg/L

$$\text{VSS, mg/L} = \frac{(\text{RDD}-\text{FDD})}{\text{sample volume, mL}} \times 1\text{ M}$$

$$\text{VSS, mg/L} = \frac{(21.7714\text{ g} - 21.7387\text{ g})}{10\text{ mL}} \times 1{,}000{,}000$$

VSS, mg/L = 3,270 mg/L

$$\text{Volatile solids, \%} = \frac{\text{volatile solids, mg/L}}{\text{TSS, mg/L}} \times 100\ \%$$

$$\text{Volatile solids, \%} = \frac{3{,}270\text{ mg/L}}{3{,}950\text{ mg/L}} \times 100\%$$

Volatile solids, % = 83 %

Biochemical Oxygen Demand

If a sample contains high levels of organic material, the BOD result will be high and small portions of the sample should be used in the dilution. If a sample has a low BOD, such as a final wastewater effluent or a lake, larger portions of sample will be necessary. When using the standard 300 mL BOD bottles, the amount of sample to add can be calculated if an estimate of the BOD can be made.

The formula for BOD sample size is written:

- **Size of sample, mL** $= \frac{1{,}200\ (mg/L)\ (mL)}{\text{estimated BOD, mg/L}}$

(The '1,200' comes from the most valid BOD oxygen depletion, 4 mg/L, times the standard BOD bottle volume, 300 mL)

<u>Example</u>

The BOD of an industrial waste treatment facility is estimated to be 470 mg/L. How many mL of actual sample should be added to the standard BOD bottle in preparation of the BOD test?

Size of sample, mL $= \frac{1{,}200}{\text{estimated BOD, mg/L}}$

Size of sample, mL $= \frac{1{,}200}{470\ mg/L}$

Size of sample, mL = 2.6 mL or 3 mL

When the BOD cannot be estimated, select more than one sample size. Use a range of samples such as 1 mL, 3 mL, 6 mL, and 12 mL.

When testing a BOD sample that has been chlorinated, such as in a wastewater final effluent, a seed must be added. The calculations for the BOD test with seed vary slightly from the BOD test without the use of seed. Both formulas and information necessary are below.

In order to calculate a 5-day BOD that is unseeded, the following information is necessary.

- Sample volume, mL
- Initial dissolved oxygen, mg/L
- Final dissolved oxygen, mg/L
- Bottle volume, mL

To calculate a 5-day BOD using seed, the information above *and* the additional information below is used.

- Seed added to sample, mL
- Seed added to blank, mL
- Initial seed dissolved oxygen, mg/L
- Final seed dissolved oxygen, mg/L
- Seed correction factor, mg/L

When using seed, a *seed correction factor* must be calculated first. The *seed correction factor* is determined by actually conducting a separate BOD test on the seed itself. A measured amount of seed material is placed in a blank of dilution water and incubated for 5 days.

The formula for finding the seed correction factor is written:

- **Seed correction for 1 mL of seed =** $\frac{\text{initial D.O.} - \text{final D.O.}}{\text{mL of seed added to blank}}$

If more than 1 mL of seed is to be used in any BOD bottle, multiply the calculated *seed correction factor* for that particular seed material by the mL of seed being used in that BOD bottle.

The formula for calculating BOD with a *seed* is written:

- **BOD, mg/L** $= \frac{[(\text{Initial D.O.} - \text{Final D.O.}) - \text{seed correction factor}] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

The formula for calculating BOD *without seed* being added is written:

- **BOD, mg/L** $= \frac{[(\text{Initial D.O.}) - (\text{Final D.O.})] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

Example

A BOD sample is run for a chlorinated effluent from a conventional activated sludge plant. What is the BOD if the following information is known?

Sample volume	225 mL
Initial D.O.	8.2 mg/L
Final D.O.	4.2 mg/L
Bottle volume	300 mL
Seed added to BOD sample	1 mL
Seed added to blank	3 mL
Initial seed D.O.	7.9 mg/L
Final seed D.O.	3.8 mg/L

Seed correction for 1 mL of seed = $\frac{\text{Initial D.O} - \text{Final D.O.}}{\text{mL of seed added to blank}}$

Seed correction for 1 mL of seed = $\frac{7.9 \text{ mg/L} - 3.8 \text{ mg/L}}{3 \text{ mL}}$

Seed correction for 1 mL of seed = 1.4 mg/L

Since only 1 mL of seed has been added to the BOD bottles, the correction factor will be 1.4 mg/L.

Now, use the BOD formula with seed correction:

BOD, mg/L = $\frac{[(\text{Initial D.O.} - \text{Final D.O.}) - \text{seed correction factor}] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

BOD, mg/L = $\frac{[(8.2 \text{ mg/L} - 4.2 \text{ mg/L}) - 1.4 \text{ mg/L}] \times (300 \text{ mL})}{225 \text{ mL}}$

$$\text{BOD, mg/L} = \frac{780 \text{ mg}}{225 \text{ mL}}$$

BOD, mg/L = 3.5 mg/L

Data Analysis

Sometimes operators may be required to analyze and calculate data from laboratory results, flows, or other groups of measurements. The *average, or arithmetic mean*, is adding all of the measurements and dividing by the total number of measurements. The formula for finding an average or mean is written:

- $$\textbf{Average} = \frac{\textbf{sum of all measurements}}{\textbf{number of measurements}}$$

In a wastewater facility that operates 7 days per week, *moving averages* may be used. They are calculated the same way that averages are, except that each day the oldest measurement is replaced with the newest measurement. Moving averages are used to better reveal trends in treatment plant operation.

A useful method of indicating a spread in a series of measurements is the *range*. The range is calculated by the smallest measurement from the largest measurement.

- **Range = largest value – smallest value**

<u>**Example**</u>

The laboratory submits the following influent TSS values for one week. What is the *mean and range* of these values?

DAY	*TSS, mg/L*
1	190
2	220
3	225
4	195
5	208
6	210
7	204

$$\text{Average} = \frac{\text{sum of all measurements}}{\text{number of measurements}}$$

$$\text{Average} = \frac{1{,}452}{7}$$

Average = 207 mg/L

Range = largest value – smallest value

Range = 225 - 190

Range = 35 mg/L for the 7-day period

In analyzing data, high values in a list of numbers may sometimes be encountered. In this case, the *median* value may be better to use than the mean, or average value.

To calculate the median, first rank all of the measurements in ascending to descending order, and then pick the middle measurement.

Example

What is the median value of the weekly data for flows shown below?

DAY	FLOW, MGD
1	2.7
2	1.9
3	3.4
4	5.6
5	1.9
6	1.8
7	2.0

First, rank the flows in ascending order.

FLOWS: 1.8 1.9 1.9 2.0 2.7 3.4 5.6

Now, pick the middle measurement:

Median = 2.0 MGD

The next measurement that operators should be familiar with is the *mode*. The mode is the measurement that occurs most frequently in a series of measurements. In the example given above, the mode would be 1.9 MGD, since it is the only measurement that occurs twice in the 7-day period.

This concludes the laboratory mathematics section of this program. A 10 question multiple-choice test can be found in the appendix. Try to adhere to the time limit, keep organized, and set up the problems according to the steps.

Do your work on a separate sheet of paper and feel free to consult the formula sheet and table of equivalents. Be sure to read the problem carefully, and check your answers with the answer key provided at the end of the workbook.

Test No. 1
SEDIMENTATION AND LOADING PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

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1. A clarifier has a depth of 14 feet, a diameter of 35 feet, and receives a flow of 350,000 gal/day. What is the surface loading rate and weir overflow rate of this facility, assuming the weir has the same diameter as the tank?

Surface loading rate	*weir overflow rate*
A: 364 gal/day/ft	6,369 gal/day/ft
B: 364 gal/day/ft	3,185 gal/day/ft
C: 26 gal/day/ft	6,369 gal/day/ft
D: 26 gal/day/ft	3,185 gal/day/ft

2. A primary clarifier has a diameter of 65 feet, a depth of 12 feet and receives a flow of 1.75 MGD. The influent suspended solids concentration is 312 mg/L. What is the solids loading in pounds per day per square foot?

   A: 0.23 lbs/day/ft
   B: 0.66 lbs/day/ft
   C: 1.1 lbs/day/ft
   D: 1.4 lbs/day/ft

3. The clarifier described in problem 2 above has an effluent suspended solids concentration of 55 mg/L. What is the efficiency, in percent, of this clarifier in solids removal?

   A: 121 %
   B: 82 %
   C: 50 %
   D: 25.7 %

4. A trickling filter receives an influent BOD of 285 mg/L. The filter has a diameter of 100 feet and an effective depth of 6 feet. What is the organic loading, in pounds of BOD per day per 1000 cubic feet when the flow is 1.75 MGD?

   A: 91.4 lbs/day/1000 cu ft
   B: 62.4 lbs/day/1000 cu ft
   C: 18.4 lbs/day/1000 cu ft
   D: 0.09 lbs/day/1000 cu ft

5. A domestic wastewater has a 'K' factor of 0.65 when the total suspended solids is 280 mg/L. If the BOD is 205 mg/L, what is the *soluble* BOD?

A: 318 mg/L
B: 210 mg/L
C: 183 mg/L
D: 23 mg/L

6. A trickling filter plant receives a flow of 1.65 MGD. The best recirculation rate is 70 percent of this flow. If the filter is 80 feet in diameter and 7 feet in depth, what is the hydraulic loading on this plant?

A: 558 gal/day/sq ft
B: 328 gal/day/sq ft
C: 230 gal/day/sq ft
D: 80 gal/day/sq ft

7. How many cubic yards of media must be ordered to replace the existing media in a trickling filter plant if the filter is 80 feet in diameter and 7 feet in depth?

A: 65 cu yds
B: 622 cu yds
C: 1,303 cu yds
D: 9,743 cu yds

8. A rotating biological contactor's disk area is 150,000 square feet. The plant's daily flow is 18,750 gal/hr. If the influent BOD is 180 mg/L, the influent TSS is 165 mg/L, and the 'K' factor for this wastewater is 0.6, what is the organic loading in lbs/day/1000 sq ft?

A: 0.002 lbs/day/1000 sq ft
B: 0.08 lbs/day/1000 sq ft
C: 1.28 lbs/day/1000 sq ft
D: 2 lbs/day/1000 sq ft

9. What is the organic load in pounds of BOD per day on a treatment facility that receives a raw wastewater with a BOD of 308 mg/L if the average daily flow is 440,000 gal/day?

A: 113,000 lbs/day
B: 11,300 lbs/day
C: 1,130 lbs/day
D: 1,014 lbs/day

10. A plant clarifier was designed to have a surface loading rate of 400 gal/day/sq ft. The diameter of the clarifier is 50 ft, the depth is 15 ft, and the plant is receiving an average daily flow of 0.980 MGD. How many gal/day/sq ft *over* or *under* the design capacity is this plant operating?

A: 499 gal/day/sq ft over
B: 499 gal/day/sq ft under
C: 99 gal/day/sq ft over
D: 99 gal/day/sq ft under

TEST NO. 2

ACTIVATED SLUDGE

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. A daily lab report shows the settlometer reading to be 330 mL/L after 30 minutes. The lab has also determined the MLSS to be 3,670 mg/L. What is the SVI and SDI at this facility?

	SVI	*SDI*
A:	111	0.89
B:	90	0.90
C:	102	1.11
D:	90	1.11

2. An aeration tank has a diameter of 50 feet and a depth of 12 feet. The lab determines the MLSS to be 4,200 mg/L. What is the solids inventory in this tank?

   A: 24,659 lbs
   B: 11,220 lbs
   C: 6,170 lbs
   D: 806 lbs

3. An operator is trying to keep the sludge age of a plant at 8 days. The solids inventory is 5,890 pounds and the average daily flow is 0.225 MGD. The TSS of the influent is 365 mg/L. How many days over or under the operator's target sludge age is the plant operating at presently?

   A: 8 days over
   B: 0.6 days over
   C: 4 days under
   D: 0.5 days under

4. What is the F/M ratio of a treatment facility with an influent BOD of 196 mg/L, a MLSS of 3,654 mg/L, an aeration tank capacity of 0.216 MG, and an average daily flow of 1,200,000 gallons per day is 79 percent of the solids are volatile?

   A: 0.04
   B: 0.14
   C: 0.24
   D: 0.38

5. Settlometer results indicate that 275 mL/L settled in 30 minutes. The average daily flow of this conventional activated sludge plant is 0.975 MGD. What is the estimated return sludge pumping rate based on the settlometer result?

A: 188 gpm
B: 257 gpm
C: 370 gpm
D: 725 gpm

6. An activated sludge plant produces a desirable effluent using 8 days as a target MCRT. What is the WAS rate of this plant when the following information is known?

solids inventory, lbs	5,960	lbs
SS lost in effluent, lbs/day	180	lbs
WAS suspended solids, mg/L	7,600	mg/L
Desired MCRT, days	8	days

A: 8,914 gal/day
B: 9,720 gal/day
C: 12,706 gal/day
D: 13,710 gal/day

7. What is the MCRT of and activated sludge plant when the following data is known?

aeration tank capacity	325,000	gal
MLSS	3,800	mg/L
daily flow	0.350	MGD
WAS flow	6,500	gal/day
WAS suspended solids	9,750	mg/L
TSS influent	215	mg/L
TSS effluent	4.0	mg/L
volatile solids	65	%

A: 19.1 days
B: 19.8 days
C: 22.0 days
D: 24.1 days

8. An extended aeration plant produces its best effluent when the MLSS is held at 3,200 mg/L and the sludge is pumped at a rate of 21,600 gallons per day. The MLSS has risen to 4,150 mg/L and the effluent has deteriorated considerably. If the WAS concentration is 9,500 mg/L, and the aeration tank capacity is 0.5 MG, what is the new sludge pumping rate that is required in order to achieve the desired MLSS?

A: 50,100 gal/day
B: 55,520 gal/day
C: 71,606 gal/day
D: 82,236 gal/day

9. The specifications and lab results for a water reclamation facility are shown below. What is the present sludge age?

TSS, raw	225	mg/L	
TSS, final	5	mg/L	
aeration tank	L = 130 ft,	W = 24 ft,	D = 15 ft
clarifier	Dia = 60 ft,	D = 15 ft	
MLSS	3,680	mg/L	
30 minute SS	420	mL/L	
daily flow	1.5	MGD	

A: 1.5 days
B: 2.8 days
C: 3.8 days
D: 5.8 days

10. Using the information given in question 9 above, what would be an estimated sludge return rate based on the present flow?

A: 120 gal/min
B: 256 gal/min
C: 754 gal/min
D: 920 gal/min

TEST NO. 3
DIGESTION PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. An anaerobic digester must be neutralized with lime. The digester contains 0.015 MG of sludge with a volatile acid level of 2,875 mg/L as acetic acid. How many pounds of lime are necessary for neutralization?

   A: 2,960 lbs
   B: 918 lbs
   C: 360 lbs
   D: 147 lbs

2. If 15,000 gallons of sludge with a solids content of 2.5 percent are pumped to a thickener, what is this expressed as pounds of dry sludge?

   A: 313 pounds
   B: 1,468 pounds
   C: 2,712 pounds
   D: 3,128 pounds

3. How many gallons per hour of sludge can be pumped with a piston pump that has a 6 inch diameter piston and a 4 inch stroke if the pump is operating at 30 revolutions per minute?

   A: 14 gal/hr
   B: 58 gal/hr
   C: 872 gal/hr
   D: 3,487 gal/hr

4. Raw sludge has a volatile solids count of 75 percent. The digester reduces the volatiles to 40 percent. What is the percent reduction accomplished by the digester?

   A: 41 %
   B: 52 %
   C: 78 %
   D: 35 %

5. An anaerobic digester must be started at a plant expansion project. If the digester is 20 feet in depth and has a diameter of 30 feet, how many gallons of seed sludge must be added, based on the recommendation that 20 percent of the digester volume be filled with seed?

   A: 11,300 gal
   B: 21,138 gal
   C: 44,260 gal
   D: 84,500 gal

6. A digester receives a raw sludge that has a volatile content of 80 percent. The digester reduces this to 37 percent. How many pounds of volatile solids are destroyed per day per cubic foot of digester space if the digester is 16 feet deep, has a diameter of 24 feet, and 2,250 lbs of volatiles are added daily?

   A: 0.12 lbs/day/cu ft
   B: 0.26 lbs/day/cu ft
   C: 0.33 lbs/day/cu ft
   D: 0.41 lbs/day/cu ft

7. A digester destroys 2,275 lbs of volatile solids per day. The digester has an effective volume of 65,250 cubic feet. The gas meter indicated that 27,500 cubic feet of gas are produced daily. How many cubic feet of gas are produced for every pound of VS destroyed?

   A: 2.4 cu ft / lb VS
   B: 8.9 cu ft / lb VS
   C: 12.1 cu ft / lb VS
   D: 28.7 cu ft / lb VS

8. An anaerobic digester has gone sour and must be neutralized. The digester is 24 feet in depth and has a diameter of 18 feet. It is presently 1/3 full of sludge containing a VA concentration of 4,225 mg/L. How many pounds of lime are required?

   A: 72 lbs
   B: 458 lbs
   C: 536 lbs
   D: 1,609 lbs

9. A new digester must be seeded. How many gallons of seed will be required based on the following information?

Raw sludge, gal/day	2,500
Raw sludge solids, %	2.5
Raw sludge volatiles, %	65
Seed sludge solids, %	5.0
Seed sludge volatiles, %	75
wt. of seed sludge, lbs/gal	9.8
Loading factor	0.05 lbs VS/day

A: 18,449 gal
B: 20,707 gal
C: 26,114 gal
D: 28,800 gal

10. How many pounds of dry sludge are handled if a 5,000 cubic foot capacity digester is pumped to a press and the sludge pumped contains 5 percent solids?

A: 1,625 lbs
B: 2,085 lbs
C: 10,450 lbs
D: 15,596 lbs

TEST NO. 4
HORSEPOWER, FORCE, & CHEMICAL PUMP PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. An in-ground sedimentation tank must be drained. The tank has a depth of 15 feet and a diameter of 75 feet. What is the upward force on this tank created by groundwater if the groundwater is 3.5 feet above the tank bottom?

   A: 36,003 lbs
   B: 126,011 lbs
   C: 688,212 lbs
   D: 964,373 lbs

2. A pump must be able to pump against a total head of 135 feet at the rate of 250 gallons per minute. If the pump is 56 percent efficient and the motor is 90 percent efficient, what should the minimum motor horsepower be?

   A: 10 hp
   B: 17 hp
   C: 20 hp
   D: 23 hp

3. How many pounds of chemical are in one gallon of a 10 percent hypochlorite solution?

   A: 0.0834 lbs/gal
   B: 0.834 lbs/gal
   C: 3.2 lbs/gal
   D: 1.8 lbs/gal

4. Hypochlorite is being fed at the rate of 66 gallons per day using a 7 percent solution. What is the dose being fed, in mg/L, if the flow is 2.4 MGD?

   A: 1.2 mg/L
   B: 1.5 mg/L
   C: 1.9 mg/L
   D: 3.0 mg/L

5. A chemical feed pump has a scale that reads from 0 to 100 in percent. The pump has an output of 25 gallons per day when set at 100 percent. A sludge conditioner with a 5.5 percent concentration must be fed to a flow of 1.25 MGD to achieve a dose of 0.5 mg/L. At what percent should the pump be set to achieve this dose?

   A: 24 %
   B: 35 %
   C: 45 %
   D: 62 %

6. What is the force in pounds acting on a side wall of a chlorine contact chamber that has a depth of 14 feet and a length of 25 feet?

   A: 10,920 lbs
   B: 19,500 lbs
   C: 152,880 lbs
   D: 273,000 lbs

7. An in-ground tank has a depth of 12 feet, a width of 24 feet and a length of 30 feet. What is the upward force on the bottom on this tank exerted by groundwater if the groundwater depth is 8.5 feet below the top of the tank?

   A: 157,248 lbs
   B: 196,560 lbs
   C: 210,200 lbs
   D: 381,888 lbs

8. A 6.5 percent solution of polymer must be fed to a flow of 0.440 MGD to result in a chemical dose of 10 mg/L. How many gallons of this chemical will be required for a 30-day period?

   A: 37 gal
   B: 68 gal
   C: 1,402 gal
   D: 2,031 gal

9. What is the brake horsepower of a pump that can pump 0.425 MGD at a total head of 110 ft if the pump efficiency if 62 percent?

   A: 10 BHP
   B: 13 BHP
   C: 15 BHP
   D: 22 BHP

10. A circular tank is filled to a depth of 20 ft. The diameter of this tank if 32 feet. What is the force, in pounds, acting on the wall of this tank?

A:	149,361	lbs
B:	516,232	lbs
C:	798,720	lbs
D:	1,253,990	lbs

TEST NO. 5

LAB PROCEDURES & MEASUREMENT PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. Results for fecal coliforms have been compiled for one week. What is the range *and* median of these results?

DAY	1	2	3	4	5	6	7
COLONIES/100 mL	22	40	16	4	16	31	28

range	*median*
A: 36	22
B: 36	16
C: 22	26
D: 26	22

2. The following information is from a wastewater lab bench sheet. What is the BOD of the sample?

sample volume	12 mL
initial DO	8.6 mg/L
final DO	3.1 mg/L
bottle volume	300 mL
seed added to sample	1 mL
seed added to blank	2 mL
initial seed DO	7.5 mg/L
final seed DO	4.0 mg/L

A: 88 mg/L
B: 94 mg/L
C: 120 mg/L
D: 128 mg/L

3. An industrial waste influent is estimated to have a BOD of 1,500 mg/L. How many mL of sample must be added to a 300 mL BOD bottle?

A: 2.0 mL
B: 1.3 mL
C: 0.8 mL
D: 0.5 mL

4. A bench sheet has the following data for solids testing. What is the volatile suspended solids in mg/L?

Sample volume	100	mL
Wt. of crucible + filter	23.3819	gr
Wt. of crucible + filter + dry residue	24.0090	gr
Wt. of crucible + filter + ash	23.7272	gr

A: 1,157 mg/L
B: 2,818 mg/L
C: 2,920 mg/L
D: 3,453 mg/L

5. Using the information in question 4 above, what is the percent volatile solids?

A: 45 %
B: 52 %
C: 75 %
D: 81 %

6. TSS results for one week are shown below. What is the median and mode measurements of these results?

DAY	1	2	3	4	5	6	7
TSS, mg/L	308	212	316	286	308	312	318

	median	*mode*
A:	312	308
B:	308	312
C:	318	212
D:	308	308

7. A lab bench sheet shows the following information. What is the TSS and VSS of the sample?

Sample volume	1,250 mL
Wt. of dish + filter	19.2752 g
Wt. of dish + filter + residue	19.2823 g
Wt. of dish + filter + ash	19.2799 g

TSS	*VSS*
A: 6.5 mg/L	2.3 mg/L
B: 5.6 mg/L	1.9 mg/L
C: 5.6 mg/L	1.0 mg/L
D: 6.5 mg/L	1.9 mg/L

8. A BOD test is conducted on a stream where wastewater effluent if discharged. What is the BOD if the bench sheet reads as follows?

Sample volume	275	mL
Initial D: O.	8.5	Mg/L
Final D: O.	7.0	Mg/L
Bottle vol.	300	mL

A: 1.0 mg/L
B: 1.6 mg/L
C: 2.7 mg/L
D: 5.0 mg/L

9. A BOD test is conducted on a final effluent where seed must be added. What is the BOD of the data is as follows?

sample volume	250	mL
initial D: O.	8.1	mg/L
final D: O.	4.0	mg/L
seed added to sample	2	mL
seed added to blank	4	mL
initial seed D: O.	7.8	mg/L
final seed D: O.	2.8	mg/L

A: 9.1 mg/L
B: 3.6 mg/L
C: 1.9 mg/L
D: 1.3 mg/L

10. The data for the effluent TSS test is below. How many pounds of solids are discharged in 30 days from this plant if the average daily flow is 1.65 MG?

sample volume	500	mL
wt. of dish + filter	22.7255	g
wt. of dish + filter + residue	22.7380	g
wt. of dish + filter + ash	22.7299	g

A: 345 lbs
B: 2,818 lbs
C: 9,516 lbs
D: 10,321 lbs

ANSWER KEYS

Allow 10 points for each correct answer. The minimum passing score for each test is 70%. If you missed a question, go back to your work and retrace your steps and your unit conversions.

TEST NO. 1

1.	B
2.	D
3.	B
4.	A
5.	D
6.	A
7.	C
8.	D
9.	C
10.	C

TEST NO. 2

1.	D
2.	C
3.	B
4.	D
5.	B
6.	A
7.	A
8.	C
9.	C
10.	C

TEST NO. 3

1.	C
2.	D
3.	C
4.	C
5.	B
6.	B
7.	C
8.	C
9.	A
10.	D

TEST NO. 4

1.	D
2.	B
3.	B
4.	C
5.	C
6.	C
7.	A
8.	D
9.	B
10.	D

TEST NO. 5

1.	A
2.	B
3.	C
4.	B
5.	A
6.	D
7.	B
8.	B
9.	C
10.	D

APPLIED WASTEWATER MATH FORMULA SHEET AND CONVERSION FACTORS

Below is a list of basic conversion factors and formulas that will be used with throughout this workbook. Feel free to refer to this page when doing the section test.

---

12 in	= 1 ft	12 in/ft	1000 mg	= 1 gm	1000 mg/gm
3 ft	= 1 yd	3 ft/yd	1000 gm	= 1 kg	1000 gm/kg
144 sq in	= 1 sq ft	144 sq in/sq ft	1000 mL	= 1 liter	1000 ml/L
9 sq ft	= 1 sq yd	9 sq ft/sq yd	1 meter	= 39.37 in	39.37 in/meter
27 cu ft	= 1 cu yd	27 cu ft/cu yd	1 gram	= 0.035 oz	0.035 oz/gram
5,280 ft	= 1 mile	5,280 ft/mi	60 sec	= 1 min	60 sec/min
7.48 gal	= 1 cu ft	7.48 gal/cu ft	60 min	= 1 hour	60 min/hr
8.34 lb	= 1 gal	8.34 lb/gal	24 hr	= 1 day	24 hr/day
62.4 lb	= 1 cu ft	62.4 lb/cu ft	43,560 sq ft	= 1 acre	43,560 sq ft/ac

VELOCITIES and FLOW RATES

1. $V = \frac{\text{distance, feet}}{\text{time, min}}$
2. Q = V x A (Flow rate = velocity, ft/sec x area, sq. ft)

RETENTION TIME

1. $\text{Ret. Time} = \frac{\text{tank cap. (gal)}}{\text{flow, gal/time unit}}$

PARTS PER MILLION / POUNDS

1. $\text{mg/L} = \frac{\text{pounds of chemical}}{\text{(8.34 lb/gal) x (MG)}}$
2. lbs = 8.34 lbs/gal x mg/L x MG

SEDIMENTATION AND LOADINGS

1. $\text{Weir overflow, gal/day/ft} = \frac{\text{total flow, gal/day}}{\text{length of weir, ft}}$
2. $\text{Surface loading, gal/day/sq ft} = \frac{\text{influent flow, gal/day}}{\text{surface area, sq ft}}$
3. $\text{Solids loading, lbs/day/sq ft} = \frac{\text{solids applied, lbs/day}}{\text{surface area, sq ft}}$

4. Efficiency, $\% = \frac{(\text{in mg/L}) - (\text{out, mg/L})}{(\text{in, mg/L})} \times 100\%$

5. Organic loading, lbs BOD/day/1,000 cu ft $= \frac{\text{BOD applied, lbs/day}}{\text{vol of media (in 1,000 cu ft)}}$

6. Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)

   (where K = 0.5 to 0.7 for most domestic wastewaters)

7. Hydraulic loading, gal/day/sq ft $= \frac{\text{flow rate, gal/day}}{\text{surface area, sq ft}}$

ACTIVATED SLUDGE

1. SVI $= \frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$

2. SDI $= \frac{100}{\text{SVI}}$

3. Solids inventory, lbs = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

4. Sludge age, days $= \frac{\text{solids under aeration, lbs}}{\text{solids added, lbs/day}}$

5. F/M $= \frac{(\text{inf BOD, mg/L}) \times (\text{Flow, MGD}) \times (8.34 \text{ lbs/gal})}{(\text{Aer.tank cap, MG}) \times (\text{MLVSS, mg/L}) \times (8.34 \text{ lbs/gal})}$

6. MCRT $= \frac{\text{solids inventory, lbs}}{(\text{effluent solids, lbs}) + (\text{WAS solids, lbs})}$

7. WAS, lbs/day $= \frac{\text{solids inventory, lbs}}{\text{desired MCRT, days}}$ - (solids lost in effluent, lbs/day)

8. WAS flow, MGD $= \frac{\text{WAS, lbs/day}}{(\text{WAS, mg/L}) \times (8.34 \text{ lbs/gal})}$

9. Change, WAS rate, MGD $= \frac{(\text{current solids inventory, lbs}) - (\text{desired solids inventory, lbs})}{\text{WAS, mg/L} \times 8.34 \text{ lbs/gal}}$

10. Return sludge rate, MGD $= \frac{(\text{set. solids, mL}) \times (\text{flow, MGD})}{(1{,}000 \text{ mL}) - (\text{set. solids, mL})}$

SLUDGE DIGESTION

1. Dry solids, lbs $= \frac{\text{(raw sludge, gal) x (raw sludge, \% solids) x (8.34 lbs/gal)}}{100\%}$

2. VS pumped, lbs/d $= \frac{\text{(raw sludge, gal/day) (raw sludge solids,\%)(raw sludge vol, \%)(8.34 lbs/gal)}}{(100\%)\ (100\%)}$

3. Seed Sludge, lbs volatile solids $= \frac{\text{VS pumped, lbs VS/day}}{\text{loading factor, lbs VS/day/lb VS in digester}}$

4. Seed sludge, gal $= \frac{\text{seed sludge, lbs volatile solids}}{\text{(seed sludge, lbs/gal) x}\left(\frac{\text{solids \%}}{100\%}\right)\left(\frac{\text{VS \%}}{100\ \%}\right)}$

5. Lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)

6. Percent reduction $= \frac{\text{(in − out) x 100 \%}}{\text{in − (in x out)}}$

7. VS destroyed, lbs/day/cu ft $= \frac{\text{(VS added, lbs/day) (VS reduction, \%)}}{\text{(digester volume, cu ft) (100 \%)}}$

8. Gas production, cu ft/lb VS $= \frac{\text{gas production, cu ft/day}}{\text{VS destroyed, lbs/day}}$

HORSEPOWER, FORCE, CHEMICAL PUMPS

1. Water HP $= \frac{\text{(flow, gal/min) x (head, ft)}}{3{,}960}$

2. BHP $= \frac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960 x Ep)}}$

3. Motor HP $= \frac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960) x (Ep) x (Em)}}$

4. Upward force, lbs = 62.4 lbs/cu ft x height, ft x Area, sq ft

5. Side wall force, lbs = (31.2 lbs/cu ft) x (height, ft)^2 x (length, ft)

6. Chemical sol'n, lbs/gal $= \frac{\text{(sol'n \%) x (8.34 lbs/gal)}}{100\ \%}$

7. Feed pump flow, lbs/gal $= \frac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$

8. Scale setting, % = $\frac{\text{(desired flow, gal/day) (100 \%)}}{\text{maximum feed rate, gal/day}}$

LAB PROCEDURES AND MEASUREMENTS

1. TSS, mg/L = $\frac{\text{(RDD} - \text{DD)}}{\text{sample vol, mL}}$ x 1 M

2. VSS, mg/L = $\frac{\text{(RDD} - \text{FDD)}}{\text{sample vol, mL}}$ x 1 M

Where: RDD = dried residue + dish + disc (filter), grams
DD = dish + disc, grams
FDD = fired residue + dish + disc, grams
1 M = 1,000,000

3. VSS, % = $\frac{\text{volatile solids, mg/L}}{\text{total suspended solids, mg/L}}$ x 100%

4. BOD sample size, mL = $\frac{\text{1,200 (mg/L) (mL)}}{\text{estimated BOD, mg/L}}$

5. Seed correction, mg/L, for 1 mL seed = $\frac{\text{initial DO} - \text{Final DO}}{\text{mL seed added}}$

6. BOD, mg/L = $\frac{[\text{(initial DO} - \text{Final DO)} - \text{(seed correction factor)}] \times \text{(bottle volume, mL)}}{\text{sample volume, mL}}$

PROCESS CONTROL MATH

for

WASTEWATER PLANT OPERATORS

Third Edition

1998

CONTENTS

INTRODUCTION

Welcome to Process Control Math for Wastewater Plant Operators. This workbook should be used after successful completion of the Water and Wastewater Technologies Core Program. In the Core Program, students were introduced to a process where problems were solved by organizing them into simple steps. Students were encouraged to follow each step, assign units to each value, and draw a diagram of the situation given.

The method of problem solving introduced in the Core Program will be used in solving more complex problems dealing with process control of drinking water facilities. These problems can sometimes involve multiple formulas, so it is extremely important that the steps introduced in the Core Workbook be adhered to.

As in the Core Workbook, examples will be given for each type of problem. The steps in the examples given are not labeled as in the Core Workbook, however, and many of the diagrams have been eliminated for simplicity. In the appendix, there are sample tests that represent each type of problem. The appendix also contains an answer key. Use the formula sheet and the table of equivalents provided in the appendix in completing the sample tests.

Remember that most students make errors in the actual setup of the problem. Take your time. Keep organized. Write down all information given that concerns the problem, draw a diagram if necessary, keep track of the units, and use the four steps:

1. Write the formula.
2. Substitute knowns for unknowns.
3. Simplify by canceling and calculating.
4. Write that answer in the units called for.

CHAPTER ONE

LOADING PROBLEMS

Weir Overflow Rates

Clarifiers or sedimentation tanks used to settle raw wastewater are known as *primary tanks*. *Final clarifiers* are settling tanks following secondary aerobic treatment. Sedimentation basins in wastewater treatment are designed with certain overflow, or loading rates. If the loading rates are exceeded, the efficiency of the sedimentation process diminishes greatly.

Weir overflow rates (sometimes called weir loading rates) are how many gallons of effluent flow over one foot of weir in a certain time period. They involve the total length of the weir and the total flow rate. Sometimes the weir length is given, and other times it must be calculated, such as in circular clarifiers where only the diameter of the clarifier is given. In all cases, the length of weir is in linear units (a single dimension resembling a straight line), usually feet. The flow rate can be given in any combination of gallons and time units and can be written as such in the formula.

The formula for calculating weir overflow rates in gallons per day per foot is:

- **Weir overflow rate, gal/day/ft =** $\frac{\text{total flow, gal/day}}{\text{length of weir, ft}}$

<u>Example</u>

Determine the weir overflow rate of a circular clarifier whose diameter is 60 feet and a flow of 1.5 MGD.

In this case, the length of the weir is not given. Knowing that the clarifier is circular, it is easy to calculate the weir length by using the circumference formula:

$C = \pi \times D$

$C = 3.14 \times 60$ ft

$C = 188.4$ feet, the length of the weir

Weir overflow rate, gal/day/ft= $\frac{\text{total flow rate, gal/day}}{\text{length of weir,ft}}$

Weir overflow rate, gal/day/ft= $\frac{\text{1,500,000 gal/day}}{\text{188.4 ft}}$

Weir overflow rate, gal/day/ft= 7, 962 gal/day/ft

Notice that none of the units cancel out. The new units for the weir overflow rate are in gallons per day per (linear) foot.

Surface Loading Rates

Surface loading is an important guideline used in the design of sedimentation tanks. In order to perform the calculations, the tank influent flow and the total surface area of the sedimentation tank or clarifier are needed. Sometimes the areas are given, and other times a calculation is required. Determine surface areas by the area formulas in the Core Workbook. Notice that the time units in the following formula are in days. The formula can be written with minutes or hours as the time unit. The calculations are performed in the same way.

The formula for surface loading rates in gallons per day per square foot is written:

- **SLR, gal/day/ft^2=** $\frac{\text{influent flow (gal/day)}}{\text{surface area (ft}^2\text{)}}$

Example

What is the surface loading rate of a clarifier with a diameter of 55 ft and an influent flow of 1.152 MGD?

The clarifier is circular. Use the formula for the area of a circle.

$A = \pi \; x \; R^2$

A= 3.14 x 27.5 ft x 27.5 ft

A= 2, 374.6 ft^2

After the surface area has been determined, substitute all the known values into the surface loading rate formula.

$$\text{SLR, gal/day/ft}^2 = \frac{\text{influent flow (gal/day)}}{\text{surface area (ft}^2\text{)}}$$

$$\text{SLR, gal/day/ft}^2 = \frac{\text{1,152,000 gal/day}}{\text{2,374.6 ft}^2}$$

$$\text{SLR, gal/day/ft}^2 = \text{485 gal/day/ft}^2$$

The units are particular to surface loading rates. Notice that none of the units cancel out in the example, so all of the units must be kept.

Sometimes the answer must be in gallons per minute per square foot (gal/min/ft^2) as well as gallons per day per square foot (gal/day/ft^2). As stated previously, this can also apply to weir overflow rates. Just use the appropriate conversion factors as in the example given below.

$$\frac{\text{485 gal/day/ft}^2}{\text{1,440 min/day}} = \text{0.34 gal/min/ft}^2$$

Solids Loading

Another calculation that wastewater plant operators may be required to perform is solids loading of clarifiers or sedimentation tanks. Clarifiers are designed to remove a certain amount of solids per square foot of surface area. In order to perform this calculation, the amount of solids, in pounds, that are applied to the clarifier daily, the surface area of the clarifier, and the daily flow must be known.

Sometimes a laboratory result in mg/L for the solids concentration being applied to the clarifier is given. In this case, use the pounds formula introduced in the Core Workbook to calculate the pounds of solids applied to the clarifier daily.

The formula for solids loading, in pounds per day per square foot, is written:

- **Solids loading, lbs/day/ft^2** = $\frac{\text{solids applied, lbs/day}}{\text{surface area, ft}^2}$

Example

A primary clarifier has a diameter of 80 feet and treats a flow of 3.75 MGD. Laboratory results show that the total suspended solids concentration entering the clarifier is 265 mg/L. What is the solids loading in lbs/day/ft^2?

In solving this problem, the solids applied, in pounds per day, are needed. Use the pounds formula:

Solids, lbs/day = flow, MGD x mg/L x 8.34 lbs/gal

Solids, lbs/day = 3.75 MGD x 265 mg/L x 8.34 lbs/gal

Solids, lbs/day = 8,288 lbs/day

Now, the surface area of the clarifier must be calculated. It is circular, so use the appropriate area formula:

$A = \pi \times R^2$

$A = 3.14 \times 40 \text{ ft} \times 40 \text{ ft}$

$A = 5{,}024 \text{ ft}^2$

Now, use the above information in the solids loading formula:

Solids loading, lbs/day/ft^2 = $\frac{\text{solids applied, lb/day}}{\text{surface area, ft}^2}$

Solids loading, lbs/day/ft^2 = $\frac{8{,}288 \text{ lbs/day}}{5{,}024 \text{ ft}^2}$

Solids loading, lbs/day/ft^2 = 1.65 lbs/day/ft^2

Efficiency Calculations

Efficiency calculations are dependent upon laboratory test results of the particular water quality indicator of interest. Efficiency compares what is entering a treatment unit with what is leaving that unit. The lab results are given in milligrams per liter (mg/L). The unit used in efficiency problems is percent (%).

The formula for any type of efficiency, in percent, is written as follows:

- **Efficiency, % = $\frac{(\text{in, mg/L}) - (\text{out, mg/L})}{(\text{in, mg/L})}$ x 100 %**

Example

A secondary clarifier in an activated sludge treatment plant receives a total suspended solids concentration of 3,550 mg/L. The effluent suspended solids concentration for this clarifier is 55 mg/L. What is the efficiency of this clarifier in percent?

$$\text{Efficiency, \%} = \frac{(\text{in, mg/L}) - (\text{out, mg/L})}{(\text{in, mg/L})} \times 100\%$$

$$\text{Efficiency, \%} = \frac{(3{,}550\ \text{mg/L}) - (55\ \text{mg/L})}{(3{,}550\ \text{mg/L})} \times 100\%$$

$$\text{Efficiency, \%} = \frac{3{,}495}{3{,}550} \times 100\%$$ *(notice that the mg/L units cancel out, leaving %)*

Efficiency, % = 98%

Organic Loading

Another type of loading problem that may be encountered in wastewater treatment, primarily in attached growth facilities, is the organic loading rate problem. BOD loading on a trickling filter is calculated using the BOD in the primary clarifier effluent which is then applied to the trickling filter, *without regard to the BOD in the recirculation flow*.

This calculation is important in that as the BOD load increases on a trickling filter, the amount of biological growth developed in the filter bed increases significantly, thus filling the voids in the bed and impeding the passage of liquid and air. BOD loadings are expressed in terms of pounds of BOD applied per day per unit of volume as 1,000 ft^3.

The formula for calculating the organic loading rate is written as follows:

- **Organic loading, lbs BOD/day/1000 ft^3 = $\frac{\text{BOD applied, lbs/day}}{\text{volume of media (in 1000 ft}^3)}$**

Example

What is the organic loading rate in pounds of BOD per day per 1,000 ft^3 on a trickling filter that has a depth of 5 feet and a diameter of 60 feet if the influent to the filter has a BOD of 180 mg/L and the flow is 1,500,000 gallons per day?

In solving this problem, first determine how many pounds of BOD per day are applied to the filter. Use the pounds formula.

BOD, lbs/day = Flow, MGD x BOD, mg/L x 8.34 lbs/gal

BOD, lbs/day = 1.5 MGD x 180 mg/L x 8.34 lbs/gal

BOD, lbs/day = 2,252 lbs/day

Now, the next step is to calculate the volume of the trickling filter in 1,000 cubic foot units. Use the appropriate formula for the volume of a cylinder.

$V = \pi \times R^2 \times H$

$V = 3.14 \times 30\ ft \times 30\ ft \times 5\ ft$

$V = 14{,}130\ ft^3$

Volume, in 1000 ft^3 = $\frac{14{,}130\ ft^3}{1000}$

Volume, in 1000 ft^3 = 14.13/1000 ft^3

Now, use the organic loading formula, substituting with the values previously calculated:

Organic loading, lbs BOD/day/1000 ft^3 = $\frac{\text{BOD applied, lbs/day)}}{\text{volume of media (in 1000 ft}^3\text{)}}$

Organic loading, lbs BOD/day/1000 ft^3 = $\frac{2{,}252\ lbs/day}{14.13/\ 1000\ ft^3}$

Organic loading, lbs BOD/day/1000 ft^3 = 159 lbs BOD/day/1000 ft^3

RBC Loadings and Soluble BOD Calculations

There are two basic differences from trickling filters in calculating the organic loading for a rotating biological contactor. The formula is nearly the same, with the exception being that the media is expressed in square feet of media surface. This is usually given. The loadings on rotating biological contactors are based upon *soluble* BOD, which is sometimes given in a problem. Soluble BOD is the BOD of the filtrate from the standard suspended solids test. If calculating the soluble BOD is required, use the following formula:

- **Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)**

("K" is equal to 0.5 to 0.7 for most domestic wastewaters. This number is given in a test situation.)

Example

A rotating biological contactor has a media surface area of 834,000 sq ft, treats a domestic wastewater having a BOD of 330 mg/L, a total suspended solids of 310 mg/L, and receives an average daily flow of 2.0 MGD. What is the organic loading of this facility if the K factor is 0.65?

First, calculate the soluble BOD:

Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)

Soluble BOD, mg/L = 330 mg/L – (0.65 x 310 mg/L)

Soluble BOD, mg/L = 330 mg/L – 201.5 mg/L

Soluble BOD, mg/L = 128.5 mg/L

Now, calculate how many pounds of soluble BOD are applied per day using the pounds formula.

Soluble BOD, lbs/day = Flow, MGD x soluble BOD, mg/L x 8.34 lbs/gal

Soluble BOD, lbs/day = 2.0 MGD x 128.5 mg/L x 8.34 lbs/gal

Soluble BOD, lbs/day = 2,143 lbs soluble BOD/day

Now, use the organic loading formula. Remember to use square feet of media surface instead of cubic feet of media.

$$\frac{834{,}000\ ft^2}{1000} = 834/1000\ ft^2$$

$$\text{ORL, lbs soluble BOD/day/1000 ft}^2 = \frac{\text{soluble BOD applied,lbs day}}{\text{surface area of media (in 1000 ft}^2)}$$

$$\text{ORL, lbs soluble BOD/day/1000 ft}^2 = \frac{2{,}143\ lbs/day}{834/1000\ ft^2}$$

$$\text{ORL, lbs soluble BOD/day/1000 ft}^2 = 2.6\ \text{lbs soluble BOD/day/1000 ft}^2$$

Hydraulic Loading

Another type of loading problem that involves attached growth units is that of hydraulic loading. It is very similar to the surface loading rate problem that was demonstrated at the beginning of the section. When applied to the attached growth facilities, however, the recirculation flow must be considered. The total flow applied to the treatment plant is the average daily flow to the plant plus the recirculation flow.

The formula for hydraulic loading, in gal/day sq ft, is written:

- **Hydraulic loading, GPD/sq ft** = $\frac{\text{flow rate, gal/day}}{\text{surface area, sq ft}}$

Example

What is the hydraulic loading, in GPD/sq ft, for a tickling filter plant that has a diameter of 120 feet and a depth of 6 feet if the plant has a daily flow of 1.25 MGD and a 65% recirculation rate?

In figuring the new flow (the average daily flow plus the recirculation flow), if the recirculation flow is given as a percent of the average daily flow, simply multiply the average daily flow by 1 and the decimal equivalent of the percent. This automatically adds in the recirculation flow.

1.25 MGD x 1.65 = 2.0625 MGD (the daily flow plus recirculation flow)

Now, calculate the surface area of this filter using the appropriate area formula:

$A = \pi \times R^2$

A = 3.14 x 60 ft x 60 ft

A = 11,304 sq ft

Now, use the hydraulic loading formula and the information that has been calculated, above:

$$\text{Hydraulic loading, GPD/sq ft} = \frac{\text{flow rate, gal/day}}{\text{surface area,sq ft}}$$

$$\text{Hydraulic loading, GPD/sq ft} = \frac{2{,}062{,}500 \text{ gal/day}}{11{,}304 \text{ sq ft}}$$

Hydraulic loading, GPD/sq ft = 182 gal/day/sq ft

This concludes the LOADINGS portion of this workbook. In the appendix, there is a multiple-choice test which covers all of the information in this chapter. If you feel comfortable with the subject matter, it is suggested that you take this test now and compare your answers with those provided in the answer key. Use the formula sheet provided at the end of this workbook. Remember to write the problem out completely, as in the examples given in this section. Do each step carefully, and do not forget to keep track of your units.

CHAPTER TWO

ACTIVATED SLUDGE

Traditionally, operators have the most difficulty understanding the activated sludge process control calculations. One reason is because most of the problems require the use of several formulas and calculations. Most students do not take the time to set the problem up correctly and become confused while performing the calculations. Use the process introduced in the Core workbook – draw a diagram if necessary, set the problem up in steps, and be sure to label each number with the appropriate units.

Sludge Volume Index (SVI)

The sludge volume index is an operational parameter for the activated sludge process. It is a calculation of which the result is used to indicate the settling ability of activated sludge in secondary clarifiers. It compares the volume of the sludge to its weight. In order to make this calculation, laboratory results for the 30 minutes settleable solids test and the mixed liquor suspended solids test are needed.

The formula for the SVI is written as follows. The units for SVI are mL/mg.

- $\mathbf{SVI} = \frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$

Example

What is the SVI for a conventional activated sludge facility when the 30 minute settling is 420 mL/L and the MLSS is 3,300 mg/L?

$$SVI = \frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$$

$$SVI = \frac{\text{420 mL/L}}{\text{3,300 mg/L}} \times 1{,}000$$

SVI = 127 mL/mg *(in SVI calculations, the units mL/mg are usually left off)*

Sludge Density Index (SDI)

A calculation that is used similarly to SVI is the *sludge density index*, or SDI. SDI is the weight, in grams, of one mL of sludge after settling for 30 minutes.

The formula for sludge density index is written:

- $\mathbf{SDI} = \frac{100}{SVI}$

Example

What is the SDI of the conventional activated sludge plant described in the previous example?

$$SDI = \frac{100}{SVI}$$

$$SDI = \frac{100}{127}$$

SDI = 0.79

Solids Inventory

The solids inventory is a basic calculation that is required for operational control in activated sludge treatment plants. The formula used in the pounds formula from the Core Workbook. However, since the pounds desired are located in the aeration tank, the capacity of the tank in MG is needed.

The tank volume and capacity may have to be calculated in solids inventory problems, and for this, use the appropriate volume formulas introduced in the Core Workbook. The mixed liquor suspended solids (MLSS), in mg/L, is a laboratory result, and is given in the problems.

The formula for solids inventory, or pounds of solids in the aeration tank, is written:

- **Solids, lbs = (tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)**

Example

What is the solids inventory of a treatment plant with an aeration tank capacity of 0.220 MG and an MLSS of 2,800 mg/L?

Since the tank capacity is given, just substitute the known values into the formula:

Solids, lbs = (tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

Solids, lbs = (0.220 MG) x (2,800 mg/L) x (8.34 lbs/gal)

Solids, lbs = 5,137 lbs

Another type of solids inventory operators should be familiar with is the volatile solids inventory. This is done in the exact same way as the solids inventory above, except that the volatile solids or MLVSS in mg/L, is used in place of the MLSS.

The volatile solids may be given as a percentage of the MLSS. In order to get MLVSS from this, just multiply the MLSS by the decimal equivalent of the percent given. This is demonstrated in the example below.

Example

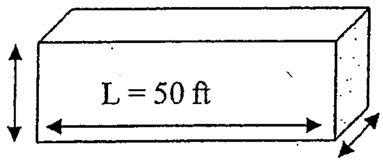
What is the volatile solids inventory of an activated sludge plant with an aeration tank that has a length of 50 feet, a width of 14 feet, and a depth of 10 feet if the average daily flow through the tank is 0.0650 MGD and the MLSS is 3,550 mg/L? Assume the volatiles to be 65 percent of MLSS.

In setting this problem up, notice that a flow is given. This is NOT needed in the calculation. However, the tank capacity in MG and the MLVSS are needed. Calculate those values as shown below:

V = L x W x H

V = 50 ft x 14 ft x 10 ft

V = 7,000 ft^3



7,000 ft^3 x 7.48 $\frac{gal}{ft^3}$

capacity, gal = 52,360 gal

capacity, MG = 0.05236 MG

Now, the given MLSS is 3,550 mg/L

3,550 mg/L x 0.65 = 2,308 mg/L *(the 0.65 is the decimal equivalent of the percent volatile solids)*

Volatile solids, mg/L = 2,308 mg/L

In substituting:

Volatile solids, lbs = (tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)

Volatile solids, lbs = (0.05236 MG) x (2,308 mg/L) x (8.34 lbs/gal)

Volatile solids, lbs = 1,008 lbs

Sludge Age

Another important process control calculation is the sludge age. It is a measure of the length of time (in days) that suspended solids remain in the activated sludge process. It is calculated by dividing the weight of suspended solids added per day to the aeration tank into the weight of suspended solids under aeration (the solids inventory).

The formula for sludge age is written:

- **Sludge age, days** = $\frac{\text{solids under aeration, lbs}}{\text{solids added, lbs/day}}$

This is the same as writing the formula as:

- **Sludge age, days** = $\frac{\text{(Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)}}{\text{(Flow, MGD) x (TSS influent, mg/L) x (8.34 lbs/gal)}}$

If either the solids inventory, in pounds, or the pounds of solids being added daily are given, or possibly both, it is easier to substitute those values into the first formula. If calculations are necessary to obtain the values needed to substitute into the formulas, it is less confusing to use the second formula given above. The tank capacity may have to be calculated, however, and this should be treated as a separate problem altogether, as will be shown in the example.

Example

What is the sludge age for the activated sludge plant described below?

Aeration tank:	80 ft = L, 20 ft = W, 15 ft = D
MLSS:	4,025 mg/L
TSS, influent:	235 mg/L
Daily flow:	525,000 gpd
Volatile solids:	68 % of MLSS

First, calculate the aeration tank capacity using the appropriate volume formula. The dimensions are all in feet, so no conversions are necessary.

V = L x W x H

V = 80 ft x 20 ft x 15 ft

$V = 24{,}000 \text{ ft}^3$

Capacity, gallons = $24{,}000 \text{ ft}^3 \times 7.48 \frac{\text{gal}}{\text{ft}^3}$ =

179,520 gallons or 0.180 MG

Notice that a percentage of volatiles is given. This is not necessary in calculating the sludge age, so just disregard it.

$$\text{Sludge age, days} = \frac{(\text{Tank cap, MG}) \times (\text{MLSS, mg/L}) \times (8.34 \text{ lbs/gal})}{(\text{Flow, MGD}) \times (\text{TSS influent, mg/L}) \times (8.34 \text{ lbs/gal})}$$

$$\text{Sludge age, days} = \frac{(0.18 \text{ MG}) \times (4{,}025 \text{ mg/L}) \times (8.34 \text{ lbs/gal})}{(0.525 \text{ MGD}) \times (235 \text{ mg/L}) \times (8.34 \text{ lbs/gal})}$$

$$\text{Sludge age, days} = \frac{724.5}{123.4 \text{ days}}$$

Sludge age, days = 5.9 days *(notice that all units except for days cancel)*

F/M Ratios

The F/M, or food to microorganism ratio, is an operational control parameter based upon the pounds of food available (pounds of BOD) and the pounds of microorganisms (volatile solids) present to consume this food. Metabolism of the microorganisms results in an increased mass of microorganisms in the system. The excess microorganisms are removed (wasted) from the system to maintain the proper balance between food supply and the mass of microorganisms in the aeration tank.

A high F/M ratio is characterized by excess food and poor settling characteristics. The settling tank is not as effective in separating microorganisms form the effluent, and there is excess unused organic matter in solution which will not be consumed by the microorganisms and consequently will pass out in the effluent, contributing to poor overall treatment.

At a low F/M ratio, overall metabolic activity in the aeration tank may be considered near the endogenous stage in that competition for the small amount of food available to the large mass of microorganisms results in near-starvation conditions in a very short time. Under these conditions, even though the rate of metabolism of the microorganisms is relatively low, settling characteristics in the sedimentation tank is quite good and the consumption of the food in nearly complete.

The formula for calculating F/M ratios is written as follows:

- **F/M, lbs/day/lb =** $\frac{\text{(inf. BOD, mg/L) x (flow, MGD) x (8.34 lbs/gal)}}{\text{(Aeration tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)}}$

Notice that the formula is just two pounds formulas, the top being the pounds of BOD added per day, and the bottom being the volatile solids inventory in pounds. Remember that the volatile solids are representative of the amount of microorganisms present. The units will be lbs/day/lb, but are usually left off.

Example

What is the F/M ratio for a treatment plant if the following information is given?

Aeration tank capacity:	0.220 MG
Influent BOD:	205 mg/L
Daily flow:	0.300 MGD
MLVSS:	1,700 mg/L

F/M, lbs/day/lb = $\frac{\text{(inf. BOD,mg/L) x (flow, MGD) x (8.34 lbs/gal)}}{\text{(Aeration tank cap, MG) x (MLVSS, mg/L) x (8.34 lbs/gal)}}$

F/M, lbs/day/lb = $\frac{\text{(205 mg/L) x (0.30 MGD) x (8.34 lbs/gal)}}{\text{(0.220 mg/L) x (0.30 MGD) x (8.34 lbs/gal)}}$

F/M, lbs/day/lb = $\frac{\text{512.9 lbs/day}}{\text{3,119 lbs}}$

F/M = 0.16

(this means that for every hundred pounds of microorganisms, there are 16 pounds of food)

As stated previously, F/M ratios are usually expressed without any units.

Mean Cell Residence Time

MCRT, or mean cell residence time, is another way that the theoretical amount of time that microorganisms spend in the activated sludge process can be calculated. Solids retention in activated sludge systems is measured in days whereas liquid retention is measured in hours. Remember that the solids are recycled in the system from the final clarifier back to the aeration tank, while the liquid flows through the aeration tank, into the clarifier, and out of the process as effluent.

MCRT involves three pounds formulas – the first is the solids inventory, which measures the pounds of MLSS in the aeration tank. On the bottom of the formula, the effluent solids in pounds is a function of the daily flow and the total suspended solids (TSS), in mg/L, of the effluent. Also on the bottom, the WAS, or waste activated sludge in pounds is a function of the sludge intentionally wasted in MG and the concentration of this sludge in mg/L.

The MCRT formula is written as follows:

- **MCRT** = $\dfrac{\textbf{solids inventory, lbs}}{\textbf{(effluent solids, lbs)+ (WAS solids, lbs)}}$

You may also see the formula written as follows. Both formulas are the same.

MCRT =

$$\frac{\text{(Aeration tank cap, MG) x (MLSS,mg/L) x (8.34 lbs/gal)}}{\text{[(Flow, MGD) x (TSS eff, mg/L) x (8.34 lbs/gal)] + [(WAS flow, MGD) x (WAS,mg/L) x (8.34 lbs/gal)]}}$$

In working MCRT problems, it is less confusing if the first formula is used. If calculations are necessary in order to substitute numbers in the formula, just treat each calculation as a separate pounds problem, then substitute the values into the MCRT formula as in the example shown below.

<u>Example</u>

What is the MCRT of the activated sludge plant described?

Aeration tank capacity:	150,000	gallons
MLSS:	2,250	mg/L
Daily flow:	820,000	gallons per day
TSS, effluent:	5.0	mg/L
WAS, mg/L:	10,500	mg/L
WAS flow, daily:	6,000	gallons per day

First, determine the amount of solids in the aeration tank, or solids inventory.

Solids, lbs = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

Solids, lbs = (0.150 MG) x (2,250 mg/L) x (8.34 lbs/gal)

Solids, aeration, lbs = 2,815 lbs

Now, determine the amount of solids lost in the effluent daily.

Solids, effluent lbs/day = (Flow, MGD) x (TSS effluent, mg/L) x (8.34 lbs/gal)

Solids, effluent lbs/day = (0.82 MGD) x (5 mg/L) x (8.34 lbs/gal)

Solids, effluent, lbs/day = 34 lbs

Finally, determine the pounds of solids wasted daily.

WAS, lbs = (WAS, MG) x (WAS, mg/L) x (8.34 lbs/gal)

WAS, lbs = (0.006 MG) x (10,500 mg/L) x (8.34 lbs/gal)

WAS, lbs = 525 lbs/day

Now that all of the information is available and ready to substitute, proceed with the formula.

$$\text{MCRT} = \frac{\text{solids inventory, lbs}}{\text{(effluent solids, lbs)} + \text{(WAS solids, lbs)}}$$

$$\text{MCRT} = \frac{\text{2,815 lbs}}{\text{(34 lbs/day)} + \text{(525 lbs/day)}}$$

MCRT = 5 days

WAS Pumping Rates

If a plant runs well in a certain MCRT, and that MCRT is to be maintained, a certain amount of sludge must be wasted daily. If a new MCRT must be met, the following formulas can be used to calculate a wasting rate to achieve that desired MCRT.

- **WAS, lbs/day** $= \dfrac{\textbf{(solids inventory, lbs)}}{\textbf{desired MCRT, days}}$ **- (solids lost in effluent, lbs/day)**
- **WAS flow, MGD** $= \dfrac{\textbf{WAS, lbs/day}}{\textbf{(WAS, mg/L) x (8.34 lbs/gal)}}$

<u>Example</u>

An activated sludge plant was determined to have a MCRT of 5 days under present operating conditions. The desired MCRT for this facility is 8 days. The amount of solids lost in the effluent daily is 34 pounds. The solids inventory of the plant is kept at 2,815 pounds. The WAS concentration is 10,500 mg/L. What WAS pumping rate is necessary to achieve the desired MCRT?

$$\text{WAS, lbs/day} = \frac{\text{(solids inventory, lbs)}}{\text{desired MCRT, days}} - \text{(solids lost in effluent, lbs/day)}$$

$$\text{WAS, lbs/day} = \frac{\text{(2,815 lbs)}}{\text{8 days}} - \text{(34 lbs/day)}$$

WAS, lbs/day = 351.9 lbs/day - 34 lbs/day

WAS, lbs/day = 318 lbs/day

Now, use the second formula to get these units into a flow:

$$\text{WAS flow, MGD} = \frac{\text{WAS, lbs/day}}{\text{(WAS, mg/L) (8.34 lbs/gal)}}$$

$$\text{WAS flow, MGD} = \frac{\text{318 lbs/day}}{\text{(10,500 mg/L) (8.34 lbs/gal)}}$$

$$\text{WAS flow, MGD} = \frac{318}{(87{,}570)}$$

WAS flow, MGD = 0.0036 or 3,600 gallons per day

Changing Sludge Pumping Rates

The *constant MLSS* method technique of process control is simple to understand and requires a minimum amount of laboratory work. As long as the incoming wastewater characteristics remain fairly constant with minimal variations in flow rates, a good quality effluent can be produced using this method. When the MLSS begins to rise, it is time to change the sludge pumping rate. The present sludge pumping rate should already be known.

The control technique is implemented by choosing an MLSS concentration which has been found to produce a high quality effluent. Therefore, before an operator begins to use this method, the plant's past operation records and process control data must be researched.

This method has its drawbacks, however. It does not account for variations in flow, influent BOD, amount of solids remaining in the secondary clarifier, and microorganism growth rates.

This method can also be used with the MLVSS instead of MLSS. The results will be the same, but choose either MLSS or MLVSS. NEVER combine the two in the formula.

To change, or adjust the sludge pumping rate, use this formula:

- **Change, WAS rate, MGD** $= \dfrac{\text{(current SI)} - \text{(desired SI)}}{\text{WAS}, \frac{mg}{L} \times 8.34 \frac{lbs}{gal}}$

Example

An extended aeration plant has been observed to produce an excellent effluent over a period of time with an MLSS concentration of 2,555 mg/L and a WAS pumping rate of 18 gallons per minute. Currently, the effluent quality has deteriorated and the MLSS under aeration has risen to 3,350 mg/L. The WAS has a value of 10,500 mg/L. If the aeration tank capacity is 440,000 gallons, what is the change in sludge pumping rate in order to achieve the desired MLSS and the NEW sludge pumping rate?

First, calculate the CURRENT solids inventory.

SI, current = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

SI, current = (0.440 MG) x (3,350 mg/L) x (8.34 lbs/gal)

SI, current = 12,293 lbs

Now, calculate the DESIRED solids inventory.

SI, desired = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

SI, desired = (0.440 MG) x (2,555 mg/L) x (8.34 lbs/gal)
SI, desired = 9,376 lbs

Now, use the change in WAS flow formula, substituting the values that have just been calculated:

$$\text{WAS change, MGD} = \frac{\text{(current SI)} - \text{(desired SI)}}{\text{WAS, mg/L x 8.34 lbs/gal}}$$

$$\text{WAS change, MGD} = \frac{\text{(12,293 lbs)} - \text{(9,376 lbs)}}{\text{10,500 mg/L x 8.34 lbs/gal}}$$

$$\text{WAS change, MGD} = \frac{\text{2917 lbs}}{\text{87,570 lbs/gal}}$$

WAS change, MGD = 0.033 MGD or 33,000 gal/day

Now the pumping rate can be changed to gallons per minute by using the following conversion:

$$\frac{\text{33,000 gal/day}}{\text{1,440 min/day}} = \text{22.9 or 23 gal/min}$$

The old WAS pumping rate was 18 gal/min, and the change, as calculated, is 23 gal/min. The new pumping rate is equal to the OLD plus the NEW.

23 gal/min + 18 gal/min = 41 gal/min

Return Sludge Rate

A simple way to estimate the proper return sludge pumping rate for an activated sludge facility is by using the results from the 30 minute settleable solids test.

The formula is written:

- **Return sludge rate, MGD =** $\frac{\text{(set. solids, mL) x (Flow, MGD)}}{\text{(1,000 mL) − (set. solids, mL)}}$

Example

What is the proper return sludge rate in gallons per minute for an activated sludge plant that has an average daily flow of 2.0 MGD and a settleable solids concentration of 350 mL?

Return sludge rate, MGD = $\frac{\text{(set. solids, mL) x (Flow, MGD)}}{\text{(1,000 mL) − (set. solids, mL)}}$

Return sludge rate, MGD = $\frac{\text{(350 mL) x (2.0 MGD)}}{\text{(1,000 mL) − (350 mL)}}$

Return sludge rate, MGD = $\frac{\text{700 MGD}}{650}$

Return sludge rate, MGD = 1.08 MGD

Now the MGD can be changed to gallons per minute:

$\frac{\text{1,080,000 gal/day}}{\text{1,440 min/day}}$ = 750 gal/min

This concludes the activated sludge process control portion of this program. In the appendix, there is a multiple-choice test which covers all of the information in this section. If you feel comfortable with the subject matter, it is suggested that you take this test now and compare your answers with those provided in the answer key.

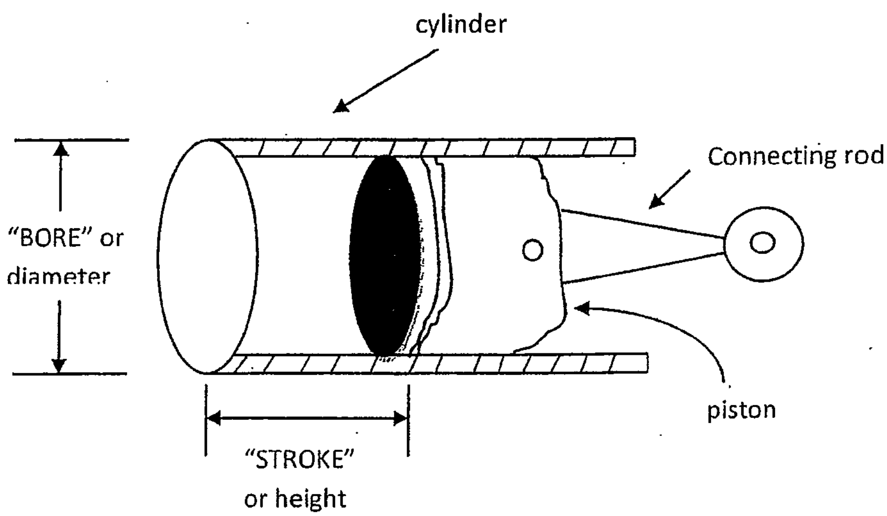
Remember to write the problem out completely, as in the examples given in this section. Do each step carefully, and do not forget to keep track of your units.

CHAPTER THREE

SLUDGE DIGESTION

Sludge Pumping

Positive displacement pumps are used in wastewater to handle sledges. One type of positive displacement pump is the piston pump. Sometimes operators must calculate the capacity of piston pumps and how many gallons of sludge will be pumped over a period of time. As shown in the diagram below, a piston moves back and forth over a distance called the *stroke*. The width of the piston, or its diameter, is called the *bore*. Every time the piston moves upward and downward in the cylinder (*called a revolution*) it pumps the volume of water contained in the cylinder.



Calculating the capacity of piston pumps is similar to calculating the volume of a cylinder.

<u>Example</u>

What is the capacity, in gallons per minute, of a piston pump that has a bore of 4 inches and a stroke of 8 inches if it pumps 30 revolutions (rev) per minute?

Calculate the volume of the cylinder in the pump using the volume of a cylinder formula:

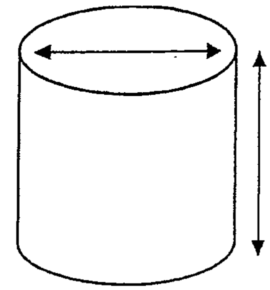
$V = \pi \times R^2 \times H$

$V = 3.14 \times 0.17 \text{ ft} \times 0.17 \text{ ft} \times 0.67 \text{ ft}$

$V = 0.061 \text{ ft}^3$

$0.061 \text{ cu ft} \times 7.48 \text{ gal/ft}^3 =$

Capacity = 0.46 gal



This means that for every revolution, the pump pumps 0.46 gallons of sludge.

0.46 gal/rev x 30 rev/min = 13.8 gal/min

The units "rev" cancel out and gal/min is left.

Dry Solids

If the percent total solids in sludge is known, the pounds of dry solids that are handled can be calculated.

The formula for dry solids, in pounds, is written:

- **Dry solids, lbs** $= \frac{(\text{raw sludge, gal}) \times (\text{raw sludge, \% solids}) \times (8.34 \text{ lbs/gal})}{100\ \%}$

Example

Each day, 6,500 gallons of raw sludge are pumped to a disposal area. This sludge contains 6.0% total solids. How many pounds of dry sludge are handled per day?

Dry solids, lbs $= \frac{(6{,}500 \text{ gal}) \times (6.0\ \%) \times (8.34 \text{ lbs/gal})}{100\ \%}$

Dry solids, lbs $= \frac{325{,}260 \text{ lbs}}{100}$

Dry solids, lbs = 3,253 lbs

Sometimes the pounds of volatile solids (VS) contained in a known volume of sludge must be calculated. The percentage of volatile solids in the sludge will be given in this case. Multiply the pounds of total solids by the decimal equivalent of the percent volatile solids are shown below.

Example

Using the dry solids example above, if the lab has determined that the volatile solids content of the sludge being disposed of is 72%, how many pounds of volatile solids are being disposed of daily?

3,253 lbs x 0.72 =

Volatile solids, lbs = 2,342 lbs

Seed Sludge, Volatile and Suspended Solids Pumping

In startup of anaerobic digesters, seed sludge is sometimes required. The seed sludge can be added based upon the capacity of the digester tank, or by the amount of raw sludge which will be added to the digester.

If the sludge is added based upon the capacity of the digester, just multiply the capacity of the digester by the percentage of seed sludge that is necessary.

Example

A digester measures 14 feet in depth and has a diameter of 24 feet. In starting this digester, it is recommended that the digester be filled to 25% of the tank volume in seed sludge. How many gallons of seed sludge must be added?

First, calculate the digester capacity in gallons. It is a circular tank, so the volume of a cylinder formula is used:

$V = \pi \times R^2 \times H$

V = 3.14 x 12 ft x 12 ft x 14 ft

$V = 6{,}330 \text{ ft}^3$

$6{,}330 \text{ cu ft} \times \frac{7.48 \text{ gal}}{\text{ft}^3} =$

47,350 gallons *(digester capacity)*

47,350 gal x 0.25 = 11,838 gallons of seed required

(NOTE: the 0.25 is the decimal equivalent of the percent of tank volume required to be filled.)

Another method of calculating seed sludge (SS) depends upon the gallons of raw sludge (RS) that will be added initially, the solids content of the raw sludge (RSS), and the percent volatiles of the raw sludge (RSV). A loading factor will also be given, which will usually be between 0.03 and 0.10, and this means that there can be 0.03 to 0.10 pounds of raw volatile solids (RSV) added for every pound of volatile solids (VS) already under digestion.

The formulas necessary to accomplish this are written using the abbreviations above:

- **VS pumped, lbs/day** $= \frac{(\text{RS, gal/day})(\text{RSS, \%})(\text{RSV, \%})(8.34\text{ lbs/gal})}{(100\%)\quad(100\%)}$

- **Seed sludge, lbs VS** $= \frac{\text{VS pumped, lbs VS / day}}{\text{Loading factor, lbs VS/day/lb VS in digester}}$

- **Seed sludge, gallons** $= \frac{\text{Seed sludge, lbs VS}}{(\text{SS, lbsgal})\left(\frac{\text{Solids \%}}{100\%}\right)\left(\frac{\text{VS \%}}{100\%}\right)}$

Example

A new digester is going on line as part of a plant expansion. How many pounds of volatile solids will be pumped to the digester per day and how many gallons of seed sludge will be necessary to start this digester if the following information is given?

- Raw sludge, gal/day: 650
- Raw sludge solids, % 5.5 %
- Raw sludge volatiles, % 70 %
- Seed sludge solids, % 8.5 %
- Seed sludge volatiles, % 58 %
- Wt. of seed sludge, gal: 9.5 lbs/gal
- Loading factor: 0.05 lbs VS/day per lb VS under digestion

First, calculate the pounds of volatile solids that will be pumped to the digester daily.

$$\text{VS pumped, lbs/day} = \frac{(\text{RS, gal/day})(\text{RSS, \%})(\text{RSV, \%})(8.34\text{ lbs/gal})}{(100\%)\ (100\%)}$$

$$\text{VS pumped, lbs/day} = \frac{(650\text{ gal/day})(5.5\%)(70\%)(8.34\text{ lbs/gal})}{(100\%)(100\%)}$$

$$\text{VS pumped, lbs/day} = \frac{2{,}087{,}085\text{ lbs/day}}{10{,}000}$$

$$\text{VS pumped, lbs/day} = 209\text{ lbs VS/day}$$

Now, find the pounds of seed volatile solids needed:

$$\text{SS, lbs volatile solids} = \frac{\text{VS pumped, lbs VS / day}}{\text{loading factor, lbs VS/day/lb VS in digester}}$$

$$\text{SS, lbs volatile solids} = \frac{209\text{ lbs VS / day}}{0.05\text{ lbs VS/day/lb VS in digester}}$$

$$\text{SS, lbs volatile solids} = 4{,}180\text{ lbs VS}$$

In order to seed the digester with 4,180 pounds of volatile solids, it is necessary to convert the pounds of VS to gallons of seed sludge.

$$\text{SS, gal} = \frac{\text{SS, lbs VS}}{(\text{SS, lbs/gal})\left(\frac{\text{solids \%}}{100\ \%}\right)\left(\frac{\text{VS \%}}{100\ \%}\right)}$$

$$\text{SS, gal} = \frac{4{,}180\ \text{lbs VS}}{(9.5\ \text{lbs/gal})\left(\frac{8.5\ \%}{100\ \%}\right)\left(\frac{58\ \%}{100\ \%}\right)}$$

$$\text{SS, gal} = \frac{4{,}180\ \text{lbs VS}}{(9.5\ \text{lbs/gal})\ (0.085)\ (0.58)}$$

$$\text{SS, gal} = \frac{4{,}180}{0.47}$$

SS, gal = 8,894 gallons of seed sludge

Neutralizing Upset Digesters

If an anaerobic digester becomes upset, sometimes it is necessary to add lime to neutralize it. The lime required to neutralize an upset digester is estimated using the pounds formula.

The formula for neutralizing a sour or upset digester using lime is written:

- **Lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)**

Example

An anaerobic digester is upset and should be neutralized with lime. If the digester contains 45,000 gallons of sludge and the volatile acids content is 2,980 mg/L, how many pounds of lime are required?

lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)

lime req'd, lbs = (0.045 MG) x (2,980 mg/L) x (8.34 lbs/gal)

lime req'd, lbs = 1,118 lbs of lime

Percent Reduction of Volatile Solids

The percent reduction of volatile solids in a digester as the result of digestion is a calculation that operators need to perform.

The formula for percent reduction of volatile solids is written as follows:

- **% reduction** = $\frac{\text{(in−out) x (100\%)}}{\text{in − (in x out)}}$

Example

An anaerobic digest is operating properly. The raw sludge has a volatile solids content of 72% and the digested sludge has a volatile content of 47%. What is the percent reduction of volatile solids accomplished by this digester?

% reduction = $\frac{\text{(in−out) x (100 \%)}}{\text{in−(in x out)}}$

% reduction = $\frac{(0.72 - 0.47) \text{ x } (100\ \%)}{0.72 - (0.72 \text{ x } 0.47)}$ *(NOTE that the percentages are expressed as decimals)*

% reduction = $\frac{0.25\ (100\ \%)}{0.72 - 0.338}$

% reduction = $\frac{25\ \%}{0.382}$

% reduction = 65 %

Volatile Solids Destroyed

The information used in calculating volatile solids percent reduction can be used to calculate the pounds of volatile solids destroyed per day per cubic foot of digester space.

The formula for estimating pounds of volatile solids destroyed in written:

- **VS destroyed, lbs/day/cu ft** = $\frac{\text{(VS added, lbs/day) (VS reduction, \%)}}{\text{(digester volume, cu ft) (100 \%)}}$

Example

How many pounds of volatile solids are destroyed per day if a digester has a volume of 22,750 cubic feet and 8,800 pounds of volatiles are added per day with a percent reduction due to digestion of 65%?

VS destroyed, lbs/day/cu ft = $\frac{\text{(VS added, lbsday) (VS reduction, \%)}}{\text{(digester volume, cu ft) x (100 \%)}}$

VS destroyed, lbs/day/cu ft = $\frac{\text{(8,800 lbs/day) (65 \%)}}{\text{(22,750 cu ft) (100 \%)}}$

VS destroyed, lbs/day/cu ft = $\frac{\text{(572,000 lbs / day)}}{\text{(2,275,000 cu ft)}}$

VS destroyed, lbs/day/cu ft = 0.25 lbs/day/cu ft

A precaution that should be taken in this type of problem is that the volume of the digester may need to be calculated. *Remember that cubic feet are required, not the capacity in gallons.* Also, volatiles may be given in gallons added instead of pounds. In this case, the weight of one gallon of the volatiles will be given so a calculation *from gallons to pounds* can be made.

Digester Gas Production

Another digestion problem involving anaerobic digestion is the amount of gas production as related to the volatile solids destroyed. Gas production is dependent upon the amount of volatiles destroyed per day per cubic foot of digester space, as described in the example illustrated above.

The formula for calculating gas production is written as follows:

- **Gas production, cu ft/ lb VS =** $\frac{\text{(gas produced, cu ft/day)}}{\text{(VS destroyed, lbs/day)}}$

Example

An anaerobic digester destroys 988 pounds of volatile solids daily. The gas meter indicates that 12,750 cubic feet of gas are produced each day. How many cubic feet of gas are produced per pound of volatile solids destroyed?

Gas production, cu ft/lb VS = $\frac{\text{(gas produced, cu ft/day)}}{\text{(VS destroyed, lbs/day)}}$

Gas production, cu ft/lb VS = $\frac{\text{(12,750 cu ft/day)}}{\text{(988 lbs/day)}}$

Gas production, cu ft/lb VS = 13 cu ft gas / lb of VS destroyed

This concludes the sludge digestion portion of the program. A 10 question multiple choice test can be found in the appendix. Do your work on a separate sheet of paper, and feel free to refer to the formula sheet at the beginning of this workbook.

CHAPTER FOUR

HORSEPOWER, FORCE, FEED PUMPS

Horsepower

One horsepower is equal to 33,000 ft-lbs per minute. This means that one horsepower is the same as lifting one pound of a vertical distance of 33,000 feet in a period of one minute. If the discharge from a pump is converted into the weight of water and this weight is multiplied by the vertical distance it is lifted (head), and it is known that 1 horsepower is equal to 33,000 ft-lbs/min, a formula for water horsepower can be written. Water horsepower is the *horsepower required to lift water*.

The formula for water horsepower is written:

- **Water HP** = $\frac{\text{(flow, gal/min) x (head, feet)}}{\text{(3,960 gal/min/ft}}$

The 3,960 at the bottom of the formula is derived from dividing 33,000 ft-lbs per minute, which is the equivalent of one horsepower, by 8.34 lbs/gal, which is the weight of one gallon of water. The units for the 3,960 are gal/min/ft, which cancel out with the units in the numerator of the formula.
(The units are usually left off the 3,960 in the formula to avoid confusion.)

Each pump has its own characteristics relative to power requirements and efficiency. No pump is 100 percent efficient, with the normal range of efficiency being between 50% and 85% for centrifugal pumps. Pump efficiency usually increases with the size and capacity of the pump.

The horsepower applied from the motor to the pump is called the Brake Horsepower, or BHP. The formula for brake horsepower takes into account the pump efficiency, or Ep. *The Ep is always expressed in the formula as a decimal.*

The BHP formula is written:

- **BHP** = $\frac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960 gal/min/ft) x (Ep)}}$

The motors that drive pumps are also not 100 percent efficient. Motor efficiency is usually in the range of 80 to 90 percent, and this is expressed as Em. *In the formula, the motor efficiency percent is always expressed as a decimal.*

The formula for motor horsepower is written:

- **Motor HP** = $\frac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960) x (Ep) x (Em)}}$

The above formulas work well when pumping water with a specific gravity of 1.0. If liquids with a greater specific gravity such as sludge are being pumped, more horsepower will be required. In this case, multiply the calculated horsepower by the specific gravity of the liquid being pumped. Sludges are heavier than water and have a specific gravity of greater than one. Therefore, multiplying the calculated horsepower by a number greater than one will cause the horsepower number to increase.

Example

An effluent pumping station is to be designed for a capacity of 1,200 gallons per minute at a total head of 80 feet. What is the pump horsepower and the motor horsepower that will be required if Ep is 65% and the Em is equal to 82%?

$$\text{BHP} = \frac{(\text{flow, gal/min}) \times (\text{head, ft})}{(3{,}960) \times (\text{Ep})}$$

$$\text{BHP} = \frac{(1{,}200 \text{ gal/min}) \times (80 \text{ ft})}{(3{,}960) \times (0.65)}$$

$$\text{BHP} = \frac{96{,}000 \text{ gal/min/ft}}{2{,}574}$$

BHP = 37

In solving for motor HP:

$$\text{Motor HP} = \frac{(\text{flow, gal/min}) \times (\text{head, ft})}{(3{,}960) \times (\text{Ep}) \times (\text{Em})}$$

$$\text{Motor HP} = \frac{(1{,}200 \text{ gal/min}) \times (80 \text{ ft})}{(3{,}960) \times (0.65) \times (0.82)}$$

$$\text{Motor HP} = \frac{96{,}000 \text{ gal/min/ft}}{2{,}111}$$

Motor HP = 45 HP

Force

In the Core Workbook, pressure and head were introduced. Pressure creates a force. Force calculations can become very important to wastewater plant operators when applied to tank bottoms and tank walls. If a tank is emptied during periods where the ground water table is very high, the pressure exerted on the tank bottom by the ground water can float the tank out of the ground.

The formula for calculating the upward force on a tank bottom is written:

- **Force, lbs = 62.4 lbs/cu ft x height, ft x area, sq ft**

NOTE: the 62.4 lbs/cu ft represents the weight of one cubic foot of water (8.34 lbs/gal x 7.48 gal/cu ft)

Example

What is the upward force, in pounds, on the bottom of an empty tank when the groundwater is 6 feet above the tank bottom and the tank is 40 feet long, 20 feet wide, and 16 feet in depth?

In the text of the problem, a depth is given. It is not necessary in solving this problem. Calculate the area of the tank bottom first.

A = L x W

A = 40 ft x 20 ft

A = 800 sq ft

Now, use the force formula:

Force, lbs = 62.4 lbs/cu ft x Height, ft x Area, sq ft

Force, lbs = 62.4 lbs/cu ft x 6 ft x 800 sq ft

Force, lbs = 299,520 lbs

(Notice how the units cancel, leaving pounds)

Another calculation concerning force and pressure is that of the force created by water on the side wall of a tank. The pressure at the bottom of the wall is different from the pressure at the water level, or top of the wall. The pressure at the surface is 0 psi, but the pressure at the bottom of the tank is equal to 0.433 times the height of the water in the tank.

The formula for calculating the force acting on the side wall of any tank is written:

- **Force, lbs = (31.2 lbs/cu ft) x (height. ft)^2 x (length, ft)**

Example

A tank is 40 feet long, 10 feet deep, and 16 feet in width. What is the force, in pounds, acting along the length of this tank wall when it is full?

Force, lbs = (31.2 lbs/cu ft) x (height. ft)^2 x (length, ft)

Force, lbs = (31.2 lbs/cu ft) x (10 ft)^2 x (40 ft)

Force, lbs = 31.2 lbs/cu ft x 10 ft x 10 ft x 40 ft

Force, lbs = 124,800 lbs

Chemical Solutions and Feed Pumps

Sometimes in wastewater treatment the setting in percent stroke of a chemical feeder must be determined. The chemical solutions come in various solution strengths and are fed in doses measured in milligrams per liter.

Usually, adjusting feeders is accomplished by turning a knob or hand crank on the feeder itself. The feeder has a rate scale with a pointer, calibrated over a range from 0 to 100 percent.

In order to calculate the setting of a solution chemical feeder, it may be necessary to convert a solution strength in percent into pounds of chemical per gallon of solution. The formula for this is written:

- **Chemical sol'n, lbs/gal** $= \frac{(\text{sol'n }\%) \times (8.34\text{ lbs/gal})}{100\ \%}$

The desired flow, in gallons per day, may also have to be calculated.

The formula is written as shown:

- **Feed pump gal/day** $= \frac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$

The time unit gal/day could just as well be gal/hr or gal/min. Be sure that you keep track of the time units and do the unit conversions properly.

Now that the amount of solution needed (in gallons per time unit) has been established, it is easy to set the pump.

The formula for solution chemical feeders is written:

- **Scale setting, %** $= \frac{(\text{desired flow, gal/day})\ (100\ \%)}{\text{maximum feed rate, gal/day}}$

The chemical required, in pounds per day, pounds per hour, or whatever time unit is being used, may also have to be estimated. For this, the pounds formula is used. It is written below.

- **Chemical req'd, lbs/day = (Flow, MGD) x (dose, mg/L) x (8.34 lbs/gal)**

<u>Example</u>

A solution feeder has a scale that reads in percent. The maximum output of this feeder is 40 gallons per day. A polymer solution must be fed which will result in a chemical dose of 2.5 mg/L to a flow of 0.450 MGD. At what percent should the chemical feeder be set if the polymer being fed is in a 6 percent solution?

In solving this problem, notice that the pump output is in gallons per day and the flow is given in gallons per day. Therefore, it is best to set up the formulas using days as the time unit.

First, calculate how many pounds per gallon are contained in a 6% chemical solution.

Chemical sol'n, lbs/gal = $\frac{(\text{sol'n\%}) \times (8.34 \text{ lbs/gal})}{100\ \%}$

Chemical sol'n, lbs/gal = $\frac{(6\ \%) \times (8.34 \text{ lbs/gal})}{100\ \%}$

Chemical sol'n, lbs/gal = $\frac{50 \text{ lbs/gal}}{100}$ *(NOTE: The % units cancel out.)*

Chemical sol'n, lbs/gal = 0.5 lbs/gal

Now, figure the chemical requirement in milligrams per liter.

Chem. req'd, lbs/day = Flow, MGD x dose, mg/L x 8.34 lbs/gal

Chem. req'd, lbs/day = 0.450 MGD x 2.5 mg/L x 8.34 lbs/gal

Chem. req'd, lbs/day = 9.4 lbs/day

Now, calculate the output required of the feed pump.

Feed pump, gal/day = $\frac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$

Feed pump, gal/day = $\frac{9.4 \text{ lbs/day}}{0.5 \text{ lbs/gal}}$

Feed pump, gal/day = 18.8 gal/day

Now, use the *scale setting* formula.

Scale setting, % = $\frac{(\text{desired flow, gal/day})\ (100\ \%)}{\text{maximum feed rate, gal/day}}$

Scale setting, % = $\frac{(18.8 \text{ gal/day})\ (100\ \%)}{40 \text{ gal/day}}$

Scale setting, % = $\frac{1{,}800\ \%}{40}$ *(NOTE: the units 'gal/day' cancel)*

Scale setting, % = 47 %

This concludes this section of the workbook. A ten question test in is in the appendix, covering all subjects contained in this section, and some possible review questions from previous sections. Some of the problems in the test will require several calculations. Be sure to set these problems up using the steps as outlined in the examples. Draw a simple diagram where necessary.

CHAPTER FIVE

LAB PROCEDURES AND MEASUREMENTS

Suspended Solids Calculations

In order to calculate suspended solids concentrations from laboratory results, the follow information must be known:

- Sample volume, mL
- Wt. of crucible, grams
- Wt. of crucible and dry residue, grams
- Wt. of crucible and ash, grams

When the above information is given, the following parameters can be calculated:

- Total suspended solids, mg/L
- Volatile suspended solids, mg/L
- Volatile suspended solids, %
- Fixed suspended solids, mg/L
- Fixed suspended solids, %

To calculate the total suspended solids, the formula is written:

- **TSS, mg/L =** $\frac{(\text{RDD} - \text{DD}) \times 1\text{ M}}{\text{sample volume, mL}}$

RDD = dried residue + dish + disc (filter), grams
DD = dish + disc, grams
1 M = 1 million

The formula for calculating fixed suspended solids, a subtraction is necessary:

- **VSS, mg/L =** $\frac{(\text{RDD} - \text{FDD}) \times 1\text{ M}}{\text{sample volume, mL}}$

RDD = dried residue + dish + disc (filter), grams
FDD = fired residue + dish + disc, grams
1 M = 1 million

To calculate fixed suspended solids, a subtraction is necessary:

- **Fixed solids, mg/L = TSS, mg/L – VSS, mg/L**

TSS = total suspended solids
VSS = volatile suspended solids

In order to calculate the percent of volatile and fixed solids, use these formulas:

- **Volatile solids, %** $= \frac{\text{volatile solids, mg/L}}{\text{TSS, mg/L}}$ **x 100%**

- **Fixed solids, %** $= \frac{\text{fixed solids, mg/L}}{\text{TSS, mg/L}}$ **x 100%**

Example

A lab technician obtains the following results from a suspended solids test. What are the total suspended solids, volatile suspended solids, and percent of volatile suspended solids?

Sample volume:	10 mL
Wt. of dish + filter:	21.7319 grams
Wt. of dish + filter + dry residue:	21.7714 grams
Wt. of dish + filter + ash:	21.7387 grams

$$\text{TSS, mg/L} = \frac{(\text{RDD} - \text{DD}) \times 1\text{ M}}{\text{sample vol, mL}}$$

$$\text{TSS, mg/L} = \frac{(21.7714\text{ g} - 21.7319\text{ g})}{10\text{ mL}} \times 1{,}000{,}000$$

TSS, mg/L = 3,950 mg/L

$$\text{VSS, mg/L} = \frac{(\text{RDD} - \text{FDD})}{\text{sample volume, mL}} \times 1\text{ M}$$

$$\text{VSS, mg/L} = \frac{(21.7714\text{ g} - 21.7387\text{ g})}{10\text{ mL}} \times 1{,}000{,}000$$

VSS, mg/L = 3,270 mg/L

$$\text{Volatile solids, \%} = \frac{\text{volatile solids, mg/L}}{\text{TSS, mg/L}} \times 100\ \%$$

$$\text{Volatile solids, \%} = \frac{3{,}270\text{ mg/L}}{3{,}950\text{ mg/L}} \times 100\%$$

Volatile solids, % = 83 %

Biochemical Oxygen Demand

If a sample contains high levels of organic material, the BOD result will be high and small portions of the sample should be used in the dilution. If a sample has a low BOD, such as a final wastewater effluent or a lake, larger portions of sample will be necessary. When using the standard 300 mL BOD bottles, the amount of sample to add can be calculated if an estimate of the BOD can be made.

The formula for BOD sample size is written:

- **Size of sample, mL** $= \frac{1{,}200\ (mg/L)\ (mL)}{\text{estimated BOD, } mg/L}$

(The '1,200' comes from the most valid BOD oxygen depletion, 4 mg/L, times the standard BOD bottle volume, 300 mL)

Example

The BOD of an industrial waste treatment facility is estimated to be 470 mg/L. How many mL of actual sample should be added to the standard BOD bottle in preparation of the BOD test?

Size of sample, mL $= \frac{1{,}200}{\text{estimated BOD, } mg/L}$

Size of sample, mL $= \frac{1{,}200}{470\ mg/L}$

Size of sample, mL = 2.6 mL or 3 mL

When the BOD cannot be estimated, select more than one sample size. Use a range of samples such as 1 mL, 3 mL, 6 mL, and 12 mL.

When testing a BOD sample that has been chlorinated, such as in a wastewater final effluent, a seed must be added. The calculations for the BOD test with seed vary slightly from the BOD test without the use of seed. Both formulas and information necessary are below.

In order to calculate a 5-day BOD that is unseeded, the following information is necessary.

- Sample volume, mL
- Initial dissolved oxygen, mg/L
- Final dissolved oxygen, mg/L
- Bottle volume, mL

To calculate a 5-day BOD using seed, the information above *and* the additional information below is used.

- Seed added to sample, mL
- Seed added to blank, mL
- Initial seed dissolved oxygen, mg/L
- Final seed dissolved oxygen, mg/L
- Seed correction factor, mg/L

When using seed, a *seed correction factor* must be calculated first. The *seed correction factor* is determined by actually conducting a separate BOD test on the seed itself. A measured amount of seed material is placed in a blank of dilution water and incubated for 5 days.

The formula for finding the seed correction factor is written:

- **Seed correction for 1 mL of seed =** $\frac{\text{initial D.O.} - \text{final D.O.}}{\text{mL of seed added to blank}}$

If more than 1 mL of seed is to be used in any BOD bottle, multiply the calculated *seed correction factor* for that particular seed material by the mL of seed being used in that BOD bottle.

The formula for calculating BOD with a *seed* is written:

- **BOD, mg/L =** $\frac{[(\text{Initial D.O.} - \text{Final D.O.}) - \text{seed correction factor}] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

The formula for calculating BOD *without seed* being added is written:

- **BOD, mg/L =** $\frac{[(\text{Initial D.O.}) - (\text{Final D.O.})] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

<u>Example</u>

A BOD sample is run for a chlorinated effluent from a conventional activated sludge plant. What is the BOD if the following information is known?

Sample volume	225	mL
Initial D.O.	8.2	mg/L
Final D.O.	4.2	mg/L
Bottle volume	300	mL
Seed added to BOD sample	1	mL
Seed added to blank	3	mL
Initial seed D.O.	7.9	mg/L
Final seed D.O.	3.8	mg/L

Seed correction for 1 mL of seed = $\frac{\text{Initial D.O} - \text{Final D.O.}}{\text{mL of seed added to blank}}$

Seed correction for 1 mL of seed = $\frac{7.9 \text{ mg/L} - 3.8 \text{ mg/L}}{3 \text{ mL}}$

Seed correction for 1 mL of seed = 1.4 mg/L

Since only 1 mL of seed has been added to the BOD bottles, the correction factor will be 1.4 mg/L.

Now, use the BOD formula with seed correction:

BOD, mg/L = $\frac{[(\text{Initial D.O.} - \text{Final D.O.}) - \text{seed correction factor}] \times (\text{Bottle volume, mL})}{\text{sample volume, mL}}$

BOD, mg/L = $\frac{[(8.2 \text{ mg/L} - 4.2 \text{ mg/L}) - 1.4 \text{ mg/L}] \times (300 \text{ mL})}{225 \text{ mL}}$

$$\text{BOD, mg/L} = \frac{780 \text{ mg}}{225 \text{ mL}}$$

BOD, mg/L = 3.5 mg/L

Data Analysis

Sometimes operators may be required to analyze and calculate data from laboratory results, flows, or other groups of measurements. The *average, or arithmetic mean*, is adding all of the measurements and dividing by the total number of measurements. The formula for finding an average or mean is written:

- $$\textbf{Average} = \frac{\textbf{sum of all measurements}}{\textbf{number of measurements}}$$

In a wastewater facility that operates 7 days per week, *moving averages* may be used. They are calculated the same way that averages are, except that each day the oldest measurement is replaced with the newest measurement. Moving averages are used to better reveal trends in treatment plant operation.

A useful method of indicating a spread in a series of measurements is the *range*. The range is calculated by the smallest measurement from the largest measurement.

- **Range = largest value – smallest value**

<u>**Example**</u>

The laboratory submits the following influent TSS values for one week. What is the *mean and range* of these values?

DAY	*TSS, mg/L*
1	190
2	220
3	225
4	195
5	208
6	210
7	204

$$\text{Average} = \frac{\text{sum of all measurements}}{\text{number of measurements}}$$

$$\text{Average} = \frac{1{,}452}{7}$$

Average = 207 mg/L

Range = largest value – smallest value

Range = 225 - 190

Range = 35 mg/L for the 7-day period

In analyzing data, high values in a list of numbers may sometimes be encountered. In this case, the *median* value may be better to use than the mean, or average value.

To calculate the median, first rank all of the measurements in ascending to descending order, and then pick the middle measurement.

Example

What is the median value of the weekly data for flows shown below?

DAY	FLOW, MGD
1	2.7
2	1.9
3	3.4
4	5.6
5	1.9
6	1.8
7	2.0

First, rank the flows in ascending order.

FLOWS: 1.8 1.9 1.9 2.0 2.7 3.4 5.6

Now, pick the middle measurement:

Median = 2.0 MGD

The next measurement that operators should be familiar with is the *mode*. The mode is the measurement that occurs most frequently in a series of measurements. In the example given above, the mode would be 1.9 MGD, since it is the only measurement that occurs twice in the 7-day period.

This concludes the laboratory mathematics section of this program. A 10 question multiple-choice test can be found in the appendix. Try to adhere to the time limit, keep organized, and set up the problems according to the steps.

Do your work on a separate sheet of paper and feel free to consult the formula sheet and table of equivalents. Be sure to read the problem carefully, and check your answers with the answer key provided at the end of the workbook.

Test No. 1
SEDIMENTATION AND LOADING PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. A clarifier has a depth of 14 feet, a diameter of 35 feet, and receives a flow of 350,000 gal/day. What is the surface loading rate and weir overflow rate of this facility, assuming the weir has the same diameter as the tank?

Surface loading rate	*weir overflow rate*
A: 364 gal/day/ft	6,369 gal/day/ft
B: 364 gal/day/ft	3,185 gal/day/ft
C: 26 gal/day/ft	6,369 gal/day/ft
D: 26 gal/day/ft	3,185 gal/day/ft

2. A primary clarifier has a diameter of 65 feet, a depth of 12 feet and receives a flow of 1.75 MGD. The influent suspended solids concentration is 312 mg/L. What is the solids loading in pounds per day per square foot?

    A: 0.23 lbs/day/ft
    B: 0.66 lbs/day/ft
    C: 1.1 lbs/day/ft
    D: 1.4 lbs/day/ft

3. The clarifier described in problem 2 above has an effluent suspended solids concentration of 55 mg/L. What is the efficiency, in percent, of this clarifier in solids removal?

    A: 121 %
    B: 82 %
    C: 50 %
    D: 25.7 %

4. A trickling filter receives an influent BOD of 285 mg/L. The filter has a diameter of 100 feet and an effective depth of 6 feet. What is the organic loading, in pounds of BOD per day per 1000 cubic feet when the flow is 1.75 MGD?

    A: 91.4 lbs/day/1000 cu ft
    B: 62.4 lbs/day/1000 cu ft
    C: 18.4 lbs/day/1000 cu ft
    D: 0.09 lbs/day/1000 cu ft

5. A domestic wastewater has a 'K' factor of 0.65 when the total suspended solids is 280 mg/L. If the BOD is 205 mg/L, what is the *soluble* BOD?

A: 318 mg/L
B: 210 mg/L
C: 183 mg/L
D: 23 mg/L

6. A trickling filter plant receives a flow of 1.65 MGD. The best recirculation rate is 70 percent of this flow. If the filter is 80 feet in diameter and 7 feet in depth, what is the hydraulic loading on this plant?

A: 558 gal/day/sq ft
B: 328 gal/day/sq ft
C: 230 gal/day/sq ft
D: 80 gal/day/sq ft

7. How many cubic yards of media must be ordered to replace the existing media in a trickling filter plant if the filter is 80 feet in diameter and 7 feet in depth?

A: 65 cu yds
B: 622 cu yds
C: 1,303 cu yds
D: 9,743 cu yds

8. A rotating biological contactor's disk area is 150,000 square feet. The plant's daily flow is 18,750 gal/hr. If the influent BOD is 180 mg/L, the influent TSS is 165 mg/L, and the 'K' factor for this wastewater is 0.6, what is the organic loading in lbs/day/1000 sq ft?

A: 0.002 lbs/day/1000 sq ft
B: 0.08 lbs/day/1000 sq ft
C: 1.28 lbs/day/1000 sq ft
D: 2 lbs/day/1000 sq ft

9. What is the organic load in pounds of BOD per day on a treatment facility that receives a raw wastewater with a BOD of 308 mg/L if the average daily flow is 440,000 gal/day?

A: 113,000 lbs/day
B: 11,300 lbs/day
C: 1,130 lbs/day
D: 1,014 lbs/day

10. A plant clarifier was designed to have a surface loading rate of 400 gal/day/sq ft. The diameter of the clarifier is 50 ft, the depth is 15 ft, and the plant is receiving an average daily flow of 0.980 MGD. How many gal/day/sq ft *over* or *under* the design capacity is this plant operating?

A: 499 gal/day/sq ft over
B: 499 gal/day/sq ft under
C: 99 gal/day/sq ft over
D: 99 gal/day/sq ft under

TEST NO. 2

ACTIVATED SLUDGE

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. A daily lab report shows the settlometer reading to be 330 mL/L after 30 minutes. The lab has also determined the MLSS to be 3,670 mg/L. What is the SVI and SDI at this facility?

	SVI	*SDI*
A:	111	0.89
B:	90	0.90
C:	102	1.11
D:	90	1.11

2. An aeration tank has a diameter of 50 feet and a depth of 12 feet. The lab determines the MLSS to be 4,200 mg/L. What is the solids inventory in this tank?

A: 24,659 lbs
B: 11,220 lbs
C: 6,170 lbs
D: 806 lbs

3. An operator is trying to keep the sludge age of a plant at 8 days. The solids inventory is 5,890 pounds and the average daily flow is 0.225 MGD. The TSS of the influent is 365 mg/L. How many days over or under the operator's target sludge age is the plant operating at presently?

A: 8 days over
B: 0.6 days over
C: 4 days under
D: 0.5 days under

4. What is the F/M ratio of a treatment facility with an influent BOD of 196 mg/L, a MLSS of 3,654 mg/L, an aeration tank capacity of 0.216 MG, and an average daily flow of 1,200,000 gallons per day is 79 percent of the solids are volatile?

A: 0.04
B: 0.14
C: 0.24
D: 0.38

5. Settlometer results indicate that 275 mL/L settled in 30 minutes. The average daily flow of this conventional activated sludge plant is 0.975 MGD. What is the estimated return sludge pumping rate based on the settlometer result?

   A: 188 gpm
   B: 257 gpm
   C: 370 gpm
   D: 725 gpm

6. An activated sludge plant produces a desirable effluent using 8 days as a target MCRT. What is the WAS rate of this plant when the following information is known?

solids inventory, lbs	5,960	lbs
SS lost in effluent, lbs/day	180	lbs
WAS suspended solids, mg/L	7,600	mg/L
Desired MCRT, days	8	days

   A: 8,914 gal/day
   B: 9,720 gal/day
   C: 12,706 gal/day
   D: 13,710 gal/day

7. What is the MCRT of and activated sludge plant when the following data is known?

aeration tank capacity	325,000	gal
MLSS	3,800	mg/L
daily flow	0.350	MGD
WAS flow	6,500	gal/day
WAS suspended solids	9,750	mg/L
TSS influent	215	mg/L
TSS effluent	4.0	mg/L
volatile solids	65	%

   A: 19.1 days
   B: 19.8 days
   C: 22.0 days
   D: 24.1 days

8. An extended aeration plant produces its best effluent when the MLSS is held at 3,200 mg/L and the sludge is pumped at a rate of 21,600 gallons per day. The MLSS has risen to 4,150 mg/L and the effluent has deteriorated considerably. If the WAS concentration is 9,500 mg/L, and the aeration tank capacity is 0.5 MG, what is the new sludge pumping rate that is required in order to achieve the desired MLSS?

A: 50,100 gal/day
B: 55,520 gal/day
C: 71,606 gal/day
D: 82,236 gal/day

9. The specifications and lab results for a water reclamation facility are shown below. What is the present sludge age?

TSS, raw	225	mg/L	
TSS, final	5	mg/L	
aeration tank	L = 130 ft,	W = 24 ft,	D = 15 ft
clarifier	Dia = 60 ft,	D = 15 ft	
MLSS	3,680	mg/L	
30 minute SS	420	mL/L	
daily flow	1.5	MGD	

A: 1.5 days
B: 2.8 days
C: 3.8 days
D: 5.8 days

10. Using the information given in question 9 above, what would be an estimated sludge return rate based on the present flow?

A: 120 gal/min
B: 256 gal/min
C: 754 gal/min
D: 920 gal/min

TEST NO. 3
DIGESTION PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. An anaerobic digester must be neutralized with lime. The digester contains 0.015 MG of sludge with a volatile acid level of 2,875 mg/L as acetic acid. How many pounds of lime are necessary for neutralization?

   A: 2,960 lbs
   B: 918 lbs
   C: 360 lbs
   D: 147 lbs

2. If 15,000 gallons of sludge with a solids content of 2.5 percent are pumped to a thickener, what is this expressed as pounds of dry sludge?

   A: 313 pounds
   B: 1,468 pounds
   C: 2,712 pounds
   D: 3,128 pounds

3. How many gallons per hour of sludge can be pumped with a piston pump that has a 6 inch diameter piston and a 4 inch stroke if the pump is operating at 30 revolutions per minute?

   A: 14 gal/hr
   B: 58 gal/hr
   C: 872 gal/hr
   D: 3,487 gal/hr

4. Raw sludge has a volatile solids count of 75 percent. The digester reduces the volatiles to 40 percent. What is the percent reduction accomplished by the digester?

   A: 41 %
   B: 52 %
   C: 78 %
   D: 35 %

5. An anaerobic digester must be started at a plant expansion project. If the digester is 20 feet in depth and has a diameter of 30 feet, how many gallons of seed sludge must be added, based on the recommendation that 20 percent of the digester volume be filled with seed?

A: 11,300 gal
B: 21,138 gal
C: 44,260 gal
D: 84,500 gal

6. A digester receives a raw sludge that has a volatile content of 80 percent. The digester reduces this to 37 percent. How many pounds of volatile solids are destroyed per day per cubic foot of digester space if the digester is 16 feet deep, has a diameter of 24 feet, and 2,250 lbs of volatiles are added daily?

A: 0.12 lbs/day/cu ft
B: 0.26 lbs/day/cu ft
C: 0.33 lbs/day/cu ft
D: 0.41 lbs/day/cu ft

7. A digester destroys 2,275 lbs of volatile solids per day. The digester has an effective volume of 65,250 cubic feet. The gas meter indicated that 27,500 cubic feet of gas are produced daily. How many cubic feet of gas are produced for every pound of VS destroyed?

A: 2.4 cu ft / lb VS
B: 8.9 cu ft / lb VS
C: 12.1 cu ft / lb VS
D: 28.7 cu ft / lb VS

8. An anaerobic digester has gone sour and must be neutralized. The digester is 24 feet in depth and has a diameter of 18 feet. It is presently 1/3 full of sludge containing a VA concentration of 4,225 mg/L. How many pounds of lime are required?

A: 72 lbs
B: 458 lbs
C: 536 lbs
D: 1,609 lbs

9. A new digester must be seeded. How many gallons of seed will be required based on the following information?

Raw sludge, gal/day	2,500
Raw sludge solids, %	2.5
Raw sludge volatiles, %	65
Seed sludge solids, %	5.0
Seed sludge volatiles, %	75
wt. of seed sludge, lbs/gal	9.8
Loading factor	0.05 lbs VS/day

A: 18,449 gal
B: 20,707 gal
C: 26,114 gal
D: 28,800 gal

10. How many pounds of dry sludge are handled if a 5,000 cubic foot capacity digester is pumped to a press and the sludge pumped contains 5 percent solids?

A: 1,625 lbs
B: 2,085 lbs
C: 10,450 lbs
D: 15,596 lbs

TEST NO. 4
HORSEPOWER, FORCE, & CHEMICAL PUMP PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. An in-ground sedimentation tank must be drained. The tank has a depth of 15 feet and a diameter of 75 feet. What is the upward force on this tank created by groundwater if the groundwater is 3.5 feet above the tank bottom?

   A: 36,003 lbs
   B: 126,011 lbs
   C: 688,212 lbs
   D: 964,373 lbs

2. A pump must be able to pump against a total head of 135 feet at the rate of 250 gallons per minute. If the pump is 56 percent efficient and the motor is 90 percent efficient, what should the minimum motor horsepower be?

   A: 10 hp
   B: 17 hp
   C: 20 hp
   D: 23 hp

3. How many pounds of chemical are in one gallon of a 10 percent hypochlorite solution?

   A: 0.0834 lbs/gal
   B: 0.834 lbs/gal
   C: 3.2 lbs/gal
   D: 1.8 lbs/gal

4. Hypochlorite is being fed at the rate of 66 gallons per day using a 7 percent solution. What is the dose being fed, in mg/L, if the flow is 2.4 MGD?

   A: 1.2 mg/L
   B: 1.5 mg/L
   C: 1.9 mg/L
   D: 3.0 mg/L

5. A chemical feed pump has a scale that reads from 0 to 100 in percent. The pump has an output of 25 gallons per day when set at 100 percent. A sludge conditioner with a 5.5 percent concentration must be fed to a flow of 1.25 MGD to achieve a dose of 0.5 mg/L. At what percent should the pump be set to achieve this dose?

A: 24 %
B: 35 %
C: 45 %
D: 62 %

6. What is the force in pounds acting on a side wall of a chlorine contact chamber that has a depth of 14 feet and a length of 25 feet?

A: 10,920 lbs
B: 19,500 lbs
C: 152,880 lbs
D: 273,000 lbs

7. An in-ground tank has a depth of 12 feet, a width of 24 feet and a length of 30 feet. What is the upward force on the bottom on this tank exerted by groundwater if the groundwater depth is 8.5 feet below the top of the tank?

A: 157,248 lbs
B: 196,560 lbs
C: 210,200 lbs
D: 381,888 lbs

8. A 6.5 percent solution of polymer must be fed to a flow of 0.440 MGD to result in a chemical dose of 10 mg/L. How many gallons of this chemical will be required for a 30-day period?

A: 37 gal
B: 68 gal
C: 1,402 gal
D: 2,031 gal

9. What is the brake horsepower of a pump that can pump 0.425 MGD at a total head of 110 ft if the pump efficiency if 62 percent?

A: 10 BHP
B: 13 BHP
C: 15 BHP
D: 22 BHP

10. A circular tank is filled to a depth of 20 ft. The diameter of this tank if 32 feet. What is the force, in pounds, acting on the wall of this tank?

A: 149,361 lbs
B: 516,232 lbs
C: 798,720 lbs
D: 1,253,990 lbs

TEST NO. 5

LAB PROCEDURES & MEASUREMENT PROBLEMS

The following test is of the multiple choice variety. There is only one correct answer per question, so circle the letter representing the answer that is most nearly correct. You have 1 hour for the completion of this test.

---

1. Results for fecal coliforms have been compiled for one week. What is the range *and* median of these results?

DAY	1	2	3	4	5	6	7
COLONIES/100 mL	22	40	16	4	16	31	28

range	*median*
A: 36	22
B: 36	16
C: 22	26
D: 26	22

2. The following information is from a wastewater lab bench sheet. What is the BOD of the sample?

sample volume	12 mL
initial DO	8.6 mg/L
final DO	3.1 mg/L
bottle volume	300 mL
seed added to sample	1 mL
seed added to blank	2 mL
initial seed DO	7.5 mg/L
final seed DO	4.0 mg/L

A: 88 mg/L
B: 94 mg/L
C: 120 mg/L
D: 128 mg/L

3. An industrial waste influent is estimated to have a BOD of 1,500 mg/L. How many mL of sample must be added to a 300 mL BOD bottle?

A: 2.0 mL
B: 1.3 mL
C: 0.8 mL
D: 0.5 mL

4. A bench sheet has the following data for solids testing. What is the volatile suspended solids in mg/L?

Sample volume	100	mL
Wt. of crucible + filter	23.3819	gr
Wt. of crucible + filter + dry residue	24.0090	gr
Wt. of crucible + filter + ash	23.7272	gr

A: 1,157 mg/L
B: 2,818 mg/L
C: 2,920 mg/L
D: 3,453 mg/L

5. Using the information in question 4 above, what is the percent volatile solids?

A: 45 %
B: 52 %
C: 75 %
D: 81 %

6. TSS results for one week are shown below. What is the median and mode measurements of these results?

DAY	1	2	3	4	5	6	7
TSS, mg/L	308	212	316	286	308	312	318

	median	*mode*
A:	312	308
B:	308	312
C:	318	212
D:	308	308

7. A lab bench sheet shows the following information. What is the TSS and VSS of the sample?

Sample volume	1,250 mL
Wt. of dish + filter	19.2752 g
Wt. of dish + filter + residue	19.2823 g
Wt. of dish + filter + ash	19.2799 g

TSS	*VSS*
A: 6.5 mg/L	2.3 mg/L
B: 5.6 mg/L	1.9 mg/L
C: 5.6 mg/L	1.0 mg/L
D: 6.5 mg/L	1.9 mg/L

8. A BOD test is conducted on a stream where wastewater effluent if discharged. What is the BOD if the bench sheet reads as follows?

Sample volume	275	mL
Initial D: O.	8.5	Mg/L
Final D: O.	7.0	Mg/L
Bottle vol.	300	mL

A: 1.0 mg/L
B: 1.6 mg/L
C: 2.7 mg/L
D: 5.0 mg/L

9. A BOD test is conducted on a final effluent where seed must be added. What is the BOD of the data is as follows?

sample volume	250	mL
initial D: O.	8.1	mg/L
final D: O.	4.0	mg/L
seed added to sample	2	mL
seed added to blank	4	mL
initial seed D: O.	7.8	mg/L
final seed D: O.	2.8	mg/L

A: 9.1 mg/L
B: 3.6 mg/L
C: 1.9 mg/L
D: 1.3 mg/L

10. The data for the effluent TSS test is below. How many pounds of solids are discharged in 30 days from this plant if the average daily flow is 1.65 MG?

sample volume	500	mL
wt. of dish + filter	22.7255	g
wt. of dish + filter + residue	22.7380	g
wt. of dish + filter + ash	22.7299	g

A: 345 lbs
B: 2,818 lbs
C: 9,516 lbs
D: 10,321 lbs

ANSWER KEYS

Allow 10 points for each correct answer. The minimum passing score for each test is 70%. If you missed a question, go back to your work and retrace your steps and your unit conversions.

TEST NO. 1

1.	B
2.	D
3.	B
4.	A
5.	D
6.	A
7.	C
8.	D
9.	C
10.	C

TEST NO. 2

1.	D
2.	C
3.	B
4.	D
5.	B
6.	A
7.	A
8.	C
9.	C
10.	C

TEST NO. 3

1.	C
2.	D
3.	C
4.	C
5.	B
6.	B
7.	C
8.	C
9.	A
10.	D

TEST NO. 4

1.	D
2.	B
3.	B
4.	C
5.	C
6.	C
7.	A
8.	D
9.	B
10.	D

TEST NO. 5

1.	A
2.	B
3.	C
4.	B
5.	A
6.	D
7.	B
8.	B
9.	C
10.	D

APPLIED WASTEWATER MATH FORMULA SHEET AND CONVERSION FACTORS

Below is a list of basic conversion factors and formulas that will be used with throughout this workbook. Feel free to refer to this page when doing the section test.

12 in	= 1 ft	12 in/ft	1000 mg	= 1 gm	1000 mg/gm
3 ft	= 1 yd	3 ft/yd	1000 gm	= 1 kg	1000 gm/kg
144 sq in	= 1 sq ft	144 sq in/sq ft	1000 mL	= 1 liter	1000 ml/L
9 sq ft	= 1 sq yd	9 sq ft/sq yd	1 meter	= 39.37 in	39.37 in/meter
27 cu ft	= 1 cu yd	27 cu ft/cu yd	1 gram	= 0.035 oz	0.035 oz/gram
5,280 ft	= 1 mile	5,280 ft/mi	60 sec	= 1 min	60 sec/min
7.48 gal	= 1 cu ft	7.48 gal/cu ft	60 min	= 1 hour	60 min/hr
8.34 lb	= 1 gal	8.34 lb/gal	24 hr	= 1 day	24 hr/day
62.4 lb	= 1 cu ft	62.4 lb/cu ft	43,560 sq ft	= 1 acre	43,560 sq ft/ac

VELOCITIES and FLOW RATES

1. $V = \frac{\text{distance, feet}}{\text{time, min}}$
2. Q = V x A (Flow rate = velocity, ft/sec x area, sq. ft)

RETENTION TIME

1. $\text{Ret. Time} = \frac{\text{tank cap. (gal)}}{\text{flow, gal/time unit}}$

PARTS PER MILLION / POUNDS

1. $\text{mg/L} = \frac{\text{pounds of chemical}}{(8.34\ \text{lb/gal})\ \text{x}\ (\text{MG})}$

2. lbs = 8.34 lbs/gal x mg/L x MG

SEDIMENTATION AND LOADINGS

1. $\text{Weir overflow, gal/day/ft} = \frac{\text{total flow, gal/day}}{\text{length of weir, ft}}$

2. $\text{Surface loading, gal/day/sq ft} = \frac{\text{influent flow, gal/day}}{\text{surface area, sq ft}}$

3. $\text{Solids loading, lbs/day/sq ft} = \frac{\text{solids applied, lbs/day}}{\text{surface area, sq ft}}$

4. Efficiency, $\% = \frac{(\text{in mg/L}) - (\text{out, mg/L})}{(\text{in, mg/L})} \times 100\%$

5. Organic loading, lbs BOD/day/1,000 cu ft $= \frac{\text{BOD applied, lbs/day}}{\text{vol of media (in 1,000 cu ft)}}$

6. Soluble BOD, mg/L = total BOD, mg/L – (K x suspended solids, mg/L)

(where K = 0.5 to 0.7 for most domestic wastewaters)

7. Hydraulic loading, gal/day/sq ft $= \frac{\text{flow rate, gal/day}}{\text{surface area, sq ft}}$

ACTIVATED SLUDGE

1. SVI $= \frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}} \times 1{,}000$

2. SDI $= \frac{100}{\text{SVI}}$

3. Solids inventory, lbs = (Tank cap, MG) x (MLSS, mg/L) x (8.34 lbs/gal)

4. Sludge age, days $= \frac{\text{solids under aeration, lbs}}{\text{solids added, lbs/day}}$

5. F/M $= \frac{(\text{inf BOD, mg/L}) \times (\text{Flow, MGD}) \times (8.34\text{ lbs/gal})}{(\text{Aer.tank cap, MG}) \times (\text{MLVSS, mg/L}) \times (8.34\text{ lbs/gal})}$

6. MCRT $= \frac{\text{solids inventory, lbs}}{(\text{effluent solids, lbs}) + (\text{WAS solids, lbs})}$

7. WAS, lbs/day $= \frac{\text{solids inventory, lbs}}{\text{desired MCRT, days}}$ - (solids lost in effluent, lbs/day)

8. WAS flow, MGD $= \frac{\text{WAS, lbs/day}}{(\text{WAS, mg/L}) \times (8.34\text{ lbs/gal})}$

9. Change, WAS rate, MGD $= \frac{(\text{current solids inventory, lbs}) - (\text{desired solids inventory, lbs})}{\text{WAS, mg/L} \times 8.34\text{ lbs/gal}}$

10. Return sludge rate, MGD $= \frac{(\text{set. solids, mL}) \times (\text{flow, MGD})}{(1{,}000\text{ mL}) - (\text{set. solids, mL})}$

SLUDGE DIGESTION

1. Dry solids, lbs = $\frac{\text{(raw sludge, gal) x (raw sludge, \% solids) x (8.34 lbs/gal)}}{100\%}$

2. VS pumped, lbs/d = $\frac{\text{(raw sludge, gal/day) (raw sludge solids,\%)(raw sludge vol, \%)(8.34 lbs/gal)}}{\text{(100\%) (100\%)}}$

3. Seed Sludge, lbs volatile solids = $\frac{\text{VS pumped, lbs VS/day}}{\text{loading factor, lbs VS/day/lb VS in digester}}$

4. Seed sludge, gal = $\frac{\text{seed sludge, lbs volatile solids}}{\text{(seed sludge, lbs/gal) x}\left(\frac{\text{solids \%}}{100\%}\right)\left(\frac{\text{VS \%}}{100\ \%}\right)}$

5. Lime req'd, lbs = (sludge, MG) x (volatile acids, mg/L) x (8.34 lbs/gal)

6. Percent reduction = $\frac{\text{(in - out) x 100 \%}}{\text{in - (in x out)}}$

7. VS destroyed, lbs/day/cu ft = $\frac{\text{(VS added, lbs/day) (VS reduction, \%)}}{\text{(digester volume, cu ft) (100 \%)}}$

8. Gas production, cu ft/lb VS = $\frac{\text{gas production, cu ft/day}}{\text{VS destroyed, lbs/day}}$

HORSEPOWER, FORCE, CHEMICAL PUMPS

1. Water HP = $\frac{\text{(flow, gal/min) x (head, ft)}}{3{,}960}$

2. BHP = $\frac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960 x Ep)}}$

3. Motor HP = $\frac{\text{(flow, gal/min) x (head, ft)}}{\text{(3,960) x (Ep) x (Em)}}$

4. Upward force, lbs = 62.4 lbs/cu ft x height, ft x Area, sq ft

5. Side wall force, lbs = (31.2 lbs/cu ft) x (height, ft)^2 x (length, ft)

6. Chemical sol'n, lbs/gal = $\frac{\text{(sol'n \%) x (8.34 lbs/gal)}}{100\ \%}$

7. Feed pump flow, lbs/gal = $\frac{\text{chemical feed, lbs/day}}{\text{chemical solution, lbs/gal}}$

8. Scale setting, % = $\frac{\text{(desired flow, gal/day) (100 \%)}}{\text{maximum feed rate, gal/day}}$

LAB PROCEDURES AND MEASUREMENTS

1. TSS, mg/L = $\frac{\text{(RDD − DD)}}{\text{sample vol, mL}}$ x 1 M

2. VSS, mg/L = $\frac{\text{(RDD −FDD)}}{\text{sample vol, mL}}$ x 1 M

Where: RDD = dried residue + dish + disc (filter), grams
DD = dish + disc, grams
FDD = fired residue + dish + disc, grams
1 M = 1,000,000

3. VSS, % = $\frac{\text{volatile solids, mg/L}}{\text{total suspended solids, mg/L}}$ x 100%

4. BOD sample size, mL = $\frac{\text{1,200 (mg/L) (mL)}}{\text{estimated BOD, mg/L}}$

5. Seed correction, mg/L, for 1 mL seed = $\frac{\text{initial DO − Final DO}}{\text{mL seed added}}$

6. BOD, mg/L = $\frac{\text{[(initial DO − Final DO)− (seed correction factor)] x (bottle volume, mL)}}{\text{sample volume, mL}}$