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
^{o}C	Celsius
^{o}F	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^{o}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.

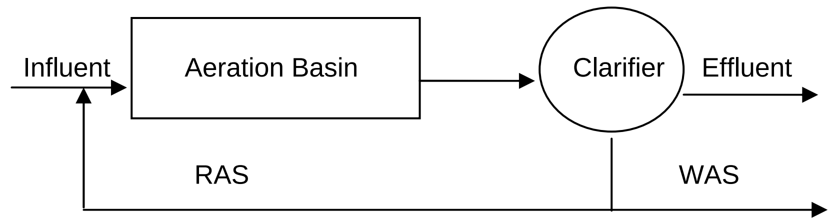
Types of Activated Sludge Processes

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

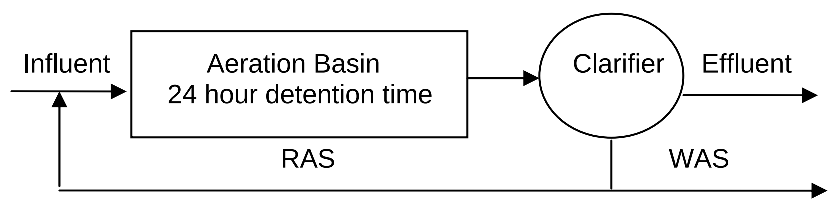
Common Activated Sludge Flow Schemes

Activated Sludge Modifications
Conventional Mode



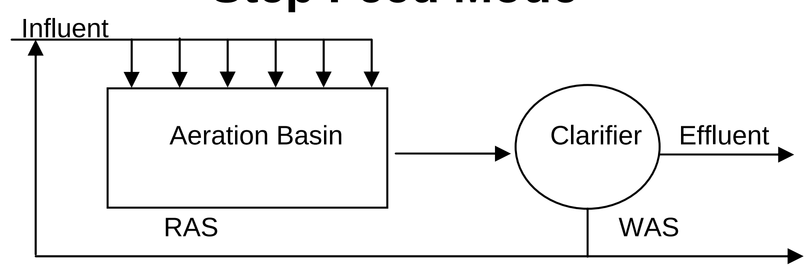
Plug flow design; 4-8 hour detention time;
F/M = 0.2-0.5 lbs BOD / lb MLVSS;
1000-3000 mg/L MLSS;
5-15 day SRT

Activated Sludge Modifications
Extended Aeration Mode



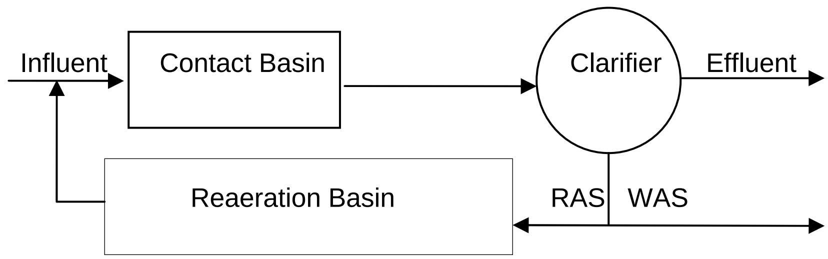
Complete mix; 18-30 hour detention time;
F/M = 0.05-0.15 lbs BOD / lb MLVSS;
2000-6000 mg/L MLSS;
20-30 day SRT

Activated Sludge Modifications
Step Feed Mode



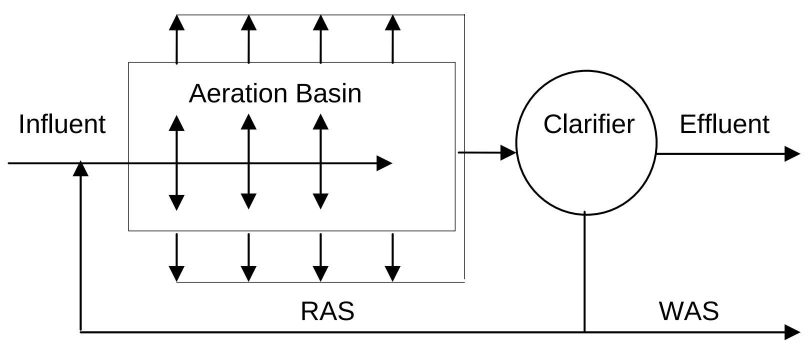
Plug flow design; 3-8 hour detention time;
F/M = 0.2-0.5 lbs BOD / lb MLVSS;
2000-3500 mg/L MLSS; 5-15 day SRT

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.

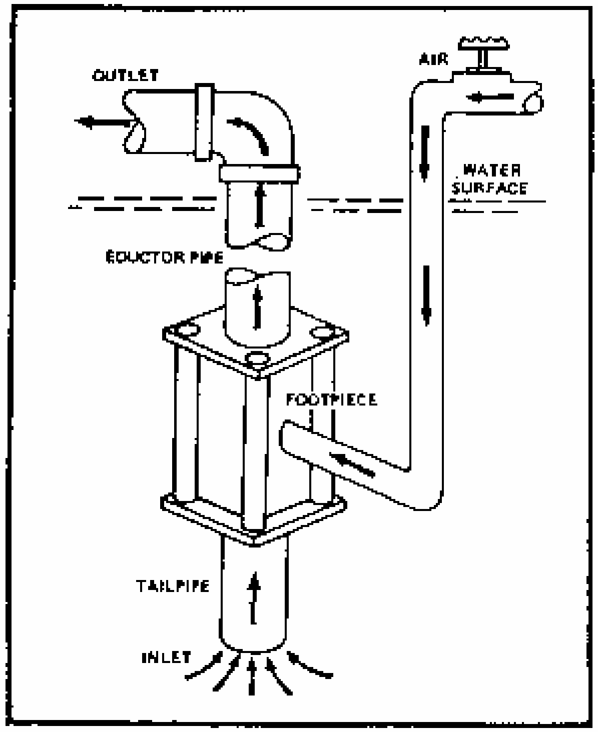
If the return activated sludge (RAS) rates are too low, there will not be enough microorganisms returned to the aeration basins to consume the influent waste or BOD. This can lead to sludge remaining in the clarifier too long and allowing the bugs to starve for oxygen resulting in denitrification.

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.

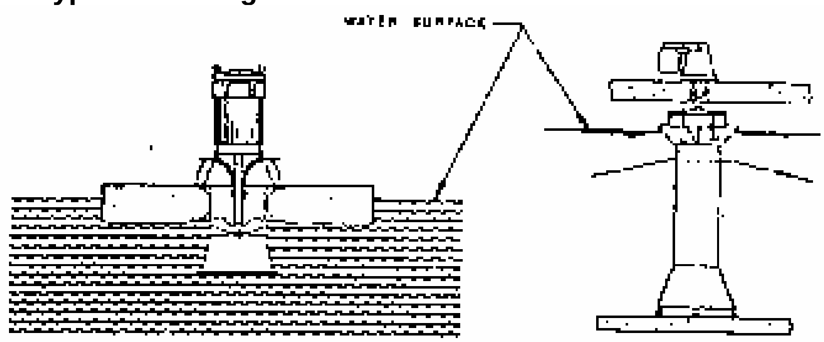
Increasing the RAS too much can lead to an increased hydraulic loading rate of the secondary clarifier. Since the RAS is pumped back into the aeration system, it increases the amount of flow received back at the clarifier. If this flow in combination with the influent flow to the WWTF exceeds the designed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

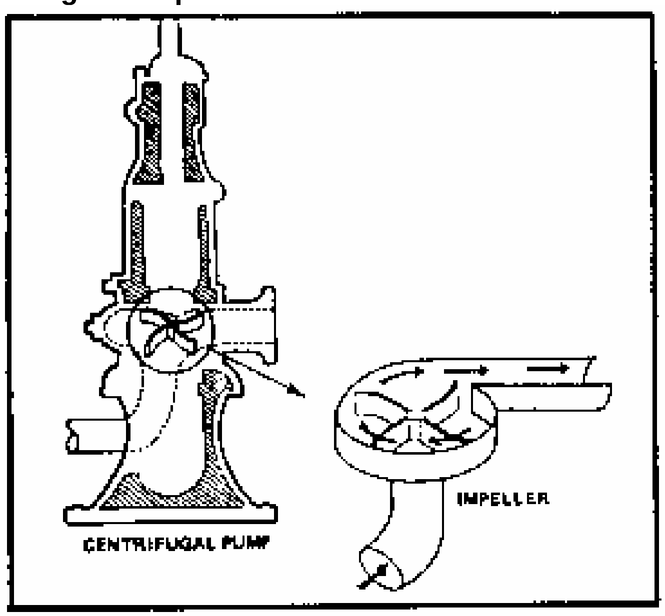


Activated Sludge Oxygen Requirements

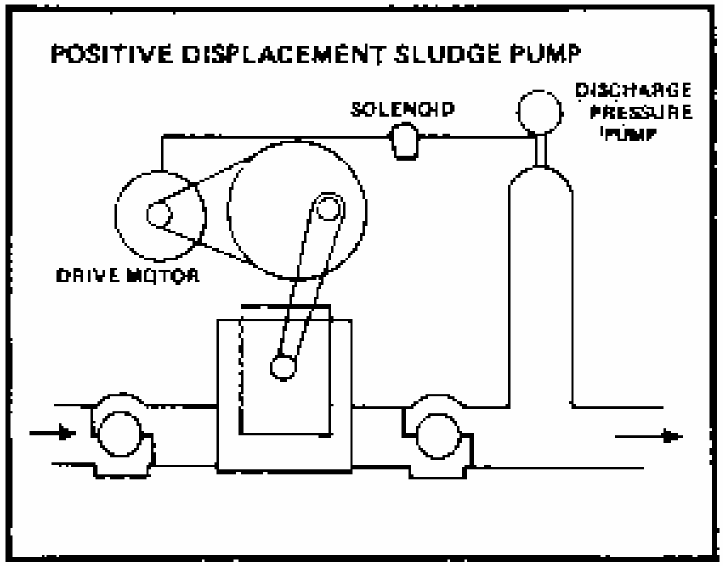
Aeration in the activated sludge basin mainly serves two purposes; to provide DO for the organisms and to mix or agitate the MLSS. DO levels can range from 0 to 3 mg/L depending on the kind of treatment plant, influent characteristics, oxygen uptake rate, aeration equipment condition and tank depth. 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

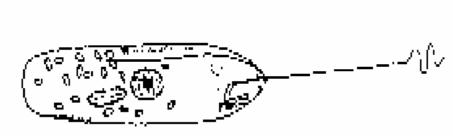
The activated sludge process has two important types of indicator microorganisms: Protozoa (ciliates) and Metazoa (Rotifers, Nematodes). The protozoa feed on the bacteria and help produce a clear effluent. Protozoans are simple, single-celled organisms that use different ways of locomotion. Rotifers, 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:

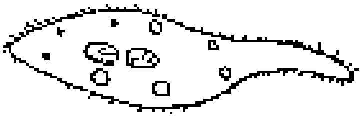
(1) Amoeba - Like in the movie 'The Blob'
(2) Flagellates - Use a whip-like tail called a Flagellum to propel themselves
(3) Ciliates - Have cilia or small hairs on their body to propel themselves or to feed

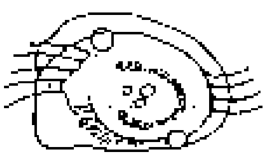
Activated Sludge Microorganisms

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^o F to 68^o F. Temperature is basically the ambient temperature, and not much biological activity occurs below 50^o 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^oF and 113^o F. Optimum range is between 85^o F and 100^o F, with the ideal temperature of around 95^o 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^o F, with 120^o 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.

APPLIED WASTEWATER "D" LEVEL
MATH FORMULA SHEET AND CONVERSION FACTORS

12 in.	= 1 ft.		8.34 lbs.	= 1 gal.		1000 mg.	= 1 gm.
3 ft.	= 1 yd.		62.4 lbs.	= 1 cu. ft.		1000 gm.	= 1 kg.
5280 ft.	= 1 mi.		454 gm.	= 1 lb.		1000 ml	= 1 liter
144 sq. in.	= 1 sq. ft.		60 sec.	= 1 min.		2.31 ft. water	= 1 psi
43,560 sq. ft.	= 1 acre		60 min.	= 1 hr.		0.433 psi	= 1 ft. water
27 cu. ft.	= 1 cu. yd.		1440 min.	= 1 day		Area	= 3.14 $(\text{radius})^2$
7.48 gal.	= 1 cu. ft.		10,000 mg/L	= 1%		1 grain / gal.	= 17.1 mg/L

Chlorine Demand mg/L = dosage mg/L – residual mg/L

DETENTION TIME

1. Detention Time = $\dfrac{\text{(tank volume, cu. ft.)(7.48 gal. / cu. ft.)(24 hr. / day)}}{\text{Flow (gal / day)}}$

PARTS PER MILLION / POUNDS

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

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

SEDIMENTATION AND LOADINGS

1. Efficiency, % = $\dfrac{\text{(in) - (out)}}{\text{(in)}}$ x 100%

ACTIVATED SLUDGE

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

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

HORSEPOWER, FORCE, CHEMICAL PUMPS

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

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

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

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

APPLIED WASTEWATER "C" LEVEL
MATH FORMULA SHEET AND CONVERSION FACTORS

12 in.	= 1 ft.
3 ft.	= 1 yd.
5280 ft.	= 1 mi.
144 sq. in.	= 1 sq. ft.
43,560 sq. ft.	= 1 acre
27 cu. ft.	= 1 cu. yd.
7.48 gal.	= 1 cu. ft.

8.34 lbs.	= 1 gal.
62.4 lbs.	= 1 cu. ft.
454 gm.	= 1 lb.
60 sec.	= 1 min.
60 min.	= 1 hr.
1440 min.	= 1 day
10,000 mg/L	= 1%

1000 mg.	= 1 gm.
1000 gm.	= 1 kg.
1000 ml	= 1 liter
2.31 ft. water	= 1 psi
0.433 psi	= 1 ft. water
Area	= 3.14 $(\text{radius})^2$
1 grain / gal.	= 17.1 mg/L

Chlorine Demand mg/L = dosage mg/L – residual mg/L

VELOCITIES and FLOW RATES

1. Velocity, ft. / sec. $= \dfrac{\text{distance, feet}}{\text{time, sec.}}$

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

DETENTION TIME

1. Detention Time $= \dfrac{(\text{tank volume, cu. ft.})(7.48\text{ gal. / cu. ft.})(24\text{ hr. / day})}{\text{Flow (gal / day)}}$

PARTS PER MILLION / POUNDS

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

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

SEDIMENTATION AND LOADINGS

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

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

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

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

5. Organic loading, lbs. CBOD/day/1000 cu. ft. = $\frac{\text{CBOD applied, lbs. / day}}{\text{vol. of media (in 1000 cu. ft.)}}$

6. 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)

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

8. Centrifuge hydraulic loading

Hydraulic load, gal/hour = flow gal/min x $\frac{\text{Run Time, min.}}{\text{(run time, min. + skim time, min)}}$ x 60 min/hr

ACTIVATED SLUDGE

1. SVI = $\frac{\text{30 min settling, mL/L}}{\text{MLSS, mg/L}}$ x 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 = $\frac{(\text{raw sludge, gal.}) \times (\text{raw sludge, \% solids}) \times (8.34 \text{ lbs. / gal})}{100\ \%}$

2. VS pumped,lbs/d = (ret.sludge,gpd) x $\frac{(\text{ret.sludge solids,\%})}{(100\%)} \times \frac{(\text{ret.sludge vol,\%})}{(100\%)}$ x (8.34 lbs/gal)

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

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

6. Percent reduction = $\frac{(\text{in - out}) \times 100\%}{\text{in - (in} \times \text{out)}}$

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

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

HORSEPOWER, FORCE, CHEMICAL PUMPS

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

2. BHP = $\frac{(\text{flow, gal. / min.}) \times (\text{head, ft.})}{(3{,}960 \times \text{Ep})}$

3. Motor HP = $\frac{(\text{flow, gal. / min.}) \times (\text{head, ft.})}{(3{,}960) \times (\text{Ep}) \times (\text{Em})}$

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 $(\text{height, ft.})^2$ x (length, ft.)

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

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

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

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

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

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

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

13. $\frac{\text{Polymer solution \%}}{100\ \%} = \frac{\text{dry polymer, lb.}}{\text{vol. of sol. gal} \times 8.34}$

LAB PROCEDURES AND MEASUREMENTS

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

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

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

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

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

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

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

7. Temperature Conversion: $^{o}C = (5/9)(^{o}F - 32)$

$^{o}F = (9/5)(^{o}C) + 32$

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