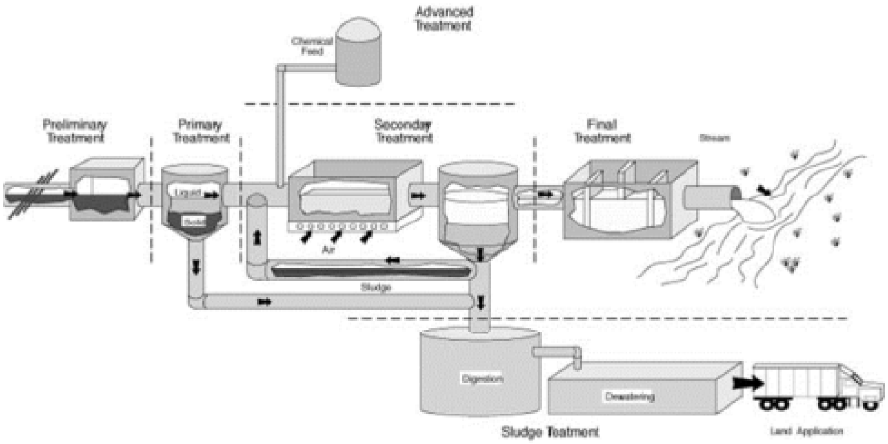
Introduction to Wastewater Week 1



Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

Introduction to Wastewater Treatment

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Introduction to Wastewater Treatment

Section 1 Introduction to Wastewater Treatment

Fleming Training Center
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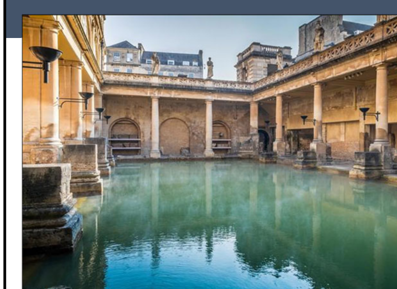
History of Wastewater– Romans



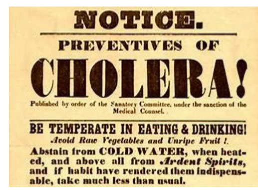
http://www.waterhistory.org/histories/rome/

- Water from the baths, toilets, fountains, etc. + urban runoff was discharged into collection system
- Few private connections to the sewers - Rich paid to use public toilets, poor used chamber pots
- No significant improvements in collection systems until the 1840's (17 centuries later)

History of Wastewater - 1800's

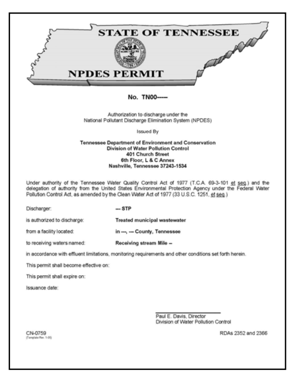
- 1817 - 1824: First Cholera Pandemic
  - South Asia + Southeast Asia + Middle East – little is known
- 1829 - 1849: Second Cholera Pandemic
  - India to Asia + Europe + United Kingdom + Americas
- 1854: London Cholera Pandemic
  - Dr. John Snow collected and mapped cholera data that led to the identification of epidemic's source – contaminated public drinking water

Distribution of cholera during the first cholera pandemic / Wikimedia Commons



Important Dates

- 1948: Federal Water Pollution Control Act
  - Basis of Clean Water Act - first major U.S. law to address water pollution
- 1972: Clean Water Act
  - 1948 Act amended - Establishes the basic structure for regulating discharges of pollutants to U.S. waters
  - Primary objective: restore and maintain the chemical, physical, and biological integrity of U.S. waters
    - National Pollutant Discharge Elimination System (NPDES) permits



National Pollutant Discharge Elimination System (NPDES) Permits

Know this acronym!!!

- Typically specify:
  - Discharge location
  - Allowable discharge flows
  - Allowable concentrations of pollutants in the discharge
    - "Mass loading" - typically expressed in mg/L or lbs/day
  - Limits of the mixing zone (if any)
    - Area where wastewater discharged from a permitted facility enters and mixes with a stream or water body
  - Sampling, monitoring, and reporting requirements

Before discharge, municipal wastewater must have received secondary treatment to meet water quality standards

Table 1.3 Secondary Treatment Standards

	30-Day Average, mg/L	7-Day Average, mg/L	Minimum Percentage Removal
BOD_5	30	45	85%
$CBOD_5$	25	40	85%
TSS	30	45	85%

Objectives of Wastewater Treatment

- Overloading a waterbody with wastewater can cause:
  - Low dissolved oxygen (DO) in the water
  - Fish Kills
  - Algae blooms*
  - Spread of waterborne diseases like cholera
  - Violations of safe drinking water standards

Nutrients discharged to rivers and lakes act like fertilizer and can cause ***algae blooms***, a sudden overgrowth of algae.

Objectives of Wastewater Treatment

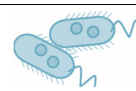
MOST IMPORTANT REASON!!!

Protect public health + Protect the environment

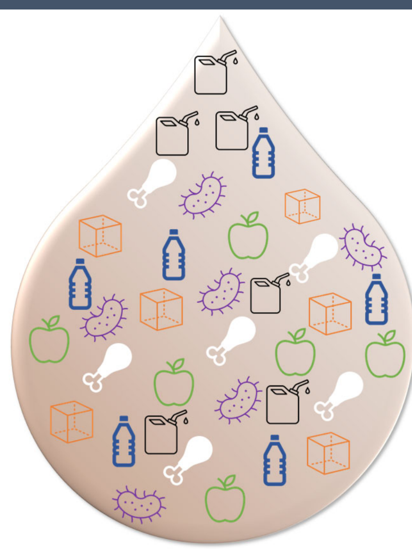
by reducing concentrations of:
solids
organic matter
nutrients
pathogenic organisms
other pollutants

An organism that can cause disease.
Ex. bacteria, viruses, parasites

National Geographic



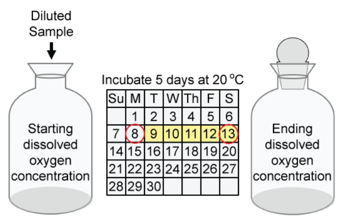
Components of Wastewater



Components of Wastewater

BOD is 5 day laboratory test conducted at 20°C

We think of **BOD** as a measure of organic material, but the test is to measure how much oxygen is needed to treat wastewater.



Components of Wastewater

1 kg of BOD consumes 1 kg of oxygen

Includes both carbonaceous biochemical oxygen demand (CBOD) and nitrogenous oxygen demand (NOD)

$$BOD_{total} = CBOD + NOD$$

Components of Wastewater

Dissolved Oxygen (DO)

- Molecular oxygen present in water or wastewater
  - Expressed as mg/L
- Saturation concentration: maximum amount of DO that can be dissolved in water
- Critical for biological treatment
- Key parameter to monitor

Components of Wastewater

Two important factors that can influence DO:

- Water Temperature
  - Greater temperature → Less DO
  - Lower temperature → More DO
- Organic waste
  - Organic material requires oxygen to decompose
  - More organic material → more DO used → DO depletion

Most living creatures, including aquatic life, need oxygen to survive

Most fish can survive with at least 5 mg/L DO

↑

TN General Water Quality Criteria!!!

Components of Wastewater

Organic waste
Chemical substances usually of animal or plant origin
- Can be consumed by bacteria + other small organisms
- Contains carbon

Inorganic waste
Chemical substances of mineral origin
- Only slightly affected by the action of organisms.
- Salts, metals, gravel, sand

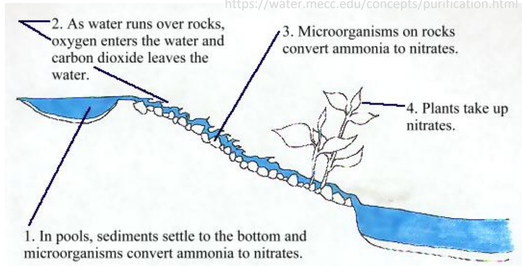
Both may come from domestic or industrial waste

Components of Wastewater

Organic waste

The treatment plant removes the organic matter the same way a stream would in nature

https://water.mecc.edu/concepts/purification.html



Objective: Prevent as much of this "oxygen-demanding" organic material as possible from entering the receiving water by using microorganisms to stabilize and remove organic matter in secondary treatment

Oxygen Utilization by Aerobic Microorganisms

Organic waste discharged to receiving stream

↓

Aerobic microorganisms use up oxygen to metabolize organic waste

↓

Biological activity creates oxygen deficiency in stream

→

Aquatic organisms requiring oxygen to survive die off or migrate

↓

In the absence of oxygen, anaerobic microorganisms dominate

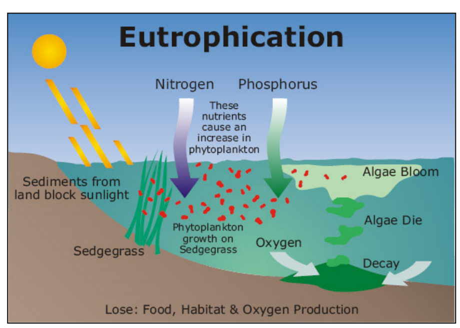
↓

Anaerobic activity causes putrefaction and odors

Components of Wastewater

Nutrients

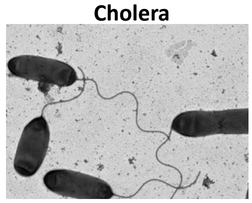
- Macronutrients:
  - Nitrogen
  - Phosphorus
  - Iron
- Problems associated with excess nutrients:
  - Act as fertilizer – algae blooms
    - Eutrophication
  - Odor problems
  - Extra vegetation near surface may inhibit light penetration

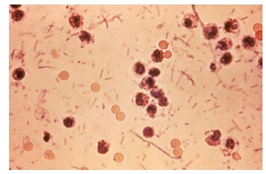


Components of Wastewater

- **Bacteria**
  - Cholera
  - Dysentery
  - Shigella
  - Salmonella
  - Typhoid
- **Viruses**
  - Polio
  - Hepatitis (Jaundice)
- **Protozoa**
  - *Giardia lamblia*
  - *Cryptosporidium parvum*
  - *Entamoeba hystolitica*

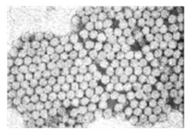
Cholera

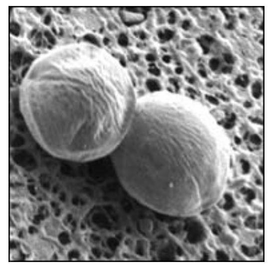




Dysentery

Hepatitis





Cryptosporidium

Components of Wastewater

Solids

Acronym	Term	Definition
TSS	Total Suspended Solids	Solids that cannot pass through a 1.2-µm filter
TVSS	Total Volatile Suspended Solids	Solids that cannot pass through a 1.2-µm filter AND are burned away when placed in a furnace at 550 ˚C
TDS	Total Dissolved Solids	Solids that are small enough to pass through a 1.2-µm filter. The sample must be dried completely before the dissolved solids can be seen with the naked eye.
TS	Total Solids	All of the solid material in a sample. This includes both organic and inorganic solids. TS = TSS + TDS
TVS	Total Volatile Solids	All of the solids in a sample that are burned away when placed in a furnace at 550 ˚C.

Components of Wastewater

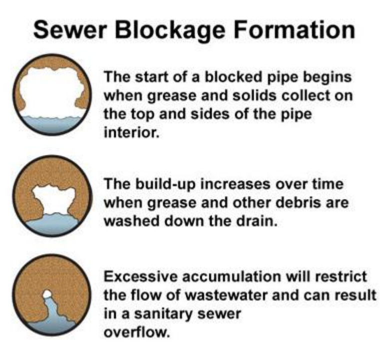
- Organic Solids + Inorganic Solids
  - Organic can be treated by biological processes, inorganic cannot
- Suspended Solids
  - Particles that settle
- Dissolved Solids
- "Soluble solids" – particles that do not settle
- Colloidal solids are measured in the total dissolved solids test even though they are not truly dissolved
- Total solids
- Suspended Solids + Dissolved Solids

Colloids: particles that act as if they are dissolved because they are so small that even random thermal currents in water keep them from settling.

Components of Wastewater

Fats, Oils, and Grease

- Generally listed under one heading called FOG as it is often not important to know the exact make-up of this group of components.



Components of Wastewater

Wastewater Characteristics

Fresh Wastewater
- Usually a grey/dishwater color
- Domestic wastewater has a musty/earthy odor

Septic Wastewater
- Typically a black color
- Can change to a rotten egg odor associated with the production of hydrogen sulfide gas

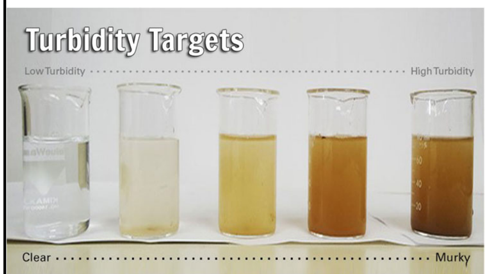
Components of Wastewater

Sludge and Scum

- If wastewater does not receive adequate treatment, solids may build up in the receiving stream as sludge (settled) or scum (floating)
- Unsightly
- May cause oxygen depletion
- Source of odors

Components of Wastewater

Turbidity



- measures the cloudiness of water
- A light is shined through the water and a detector, placed at a 90-deg angle to the light source, measures the amount of light scattered by suspended particles in the water.

Wastewater Collection and Conveyance

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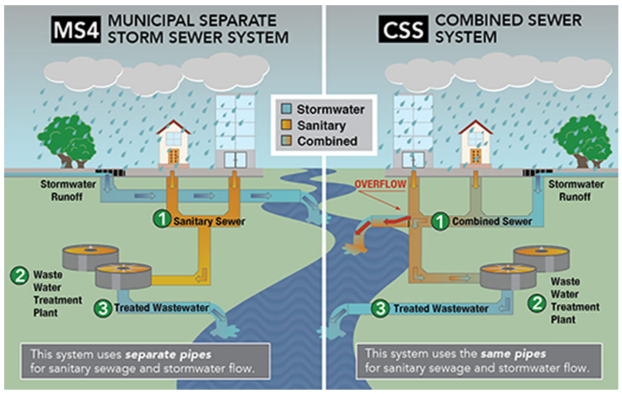
Wastewater Collection and Conveyance

Collection system

- Network of pipes, conduits, tunnels, equipment, and accessories used to collect, transport, and pump wastewater



Sanitary Sewer
- Domestic
- Industrial

Storm Sewer
- Stormwater

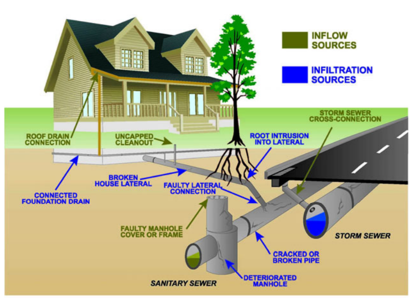
Combined Sewer
- Sanitary wastes
- Stormwater

http://www.chesapeakequarterly.net/V15N1/main1/

Wastewater Collection and Conveyance

Inflow & Infiltration

- Inflow: direct discharge into the sewer system from sources other than regular connections (yard drains, manhole covers, etc.)
- Infiltration: Seepage of groundwater into the sewer system through cracks, manholes, pipe connections, etc.



http://clogkingsllc.com/services/sewer-repair/

Image source: https://trekkllc.com

Wastewater Collection and Conveyance

Manholes are installed in lateral, main, trunk, and intercepting sewers for the purpose of placing persons, equipment, and materials into sewers for inspection, maintenance, and the removal of solids from cleaning operations

TN Design Criteria!!!

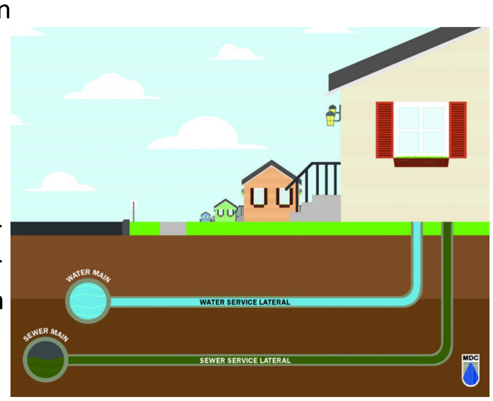
Manholes are required:

- At the end of each 8-inch diameter sewer or greater
- at all changes in grade, size, or alignment, and at all intersections
- at distances not greater than 400 feet for sewers 15 inches or less and
- at distances not greater than 500 feet for sewer 18 inches to 30 inches

Wastewater Collection and Conveyance

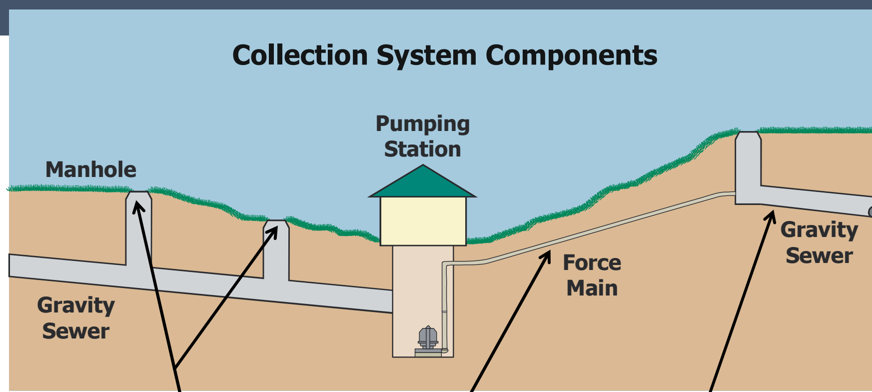
- Relation to Water Mains
  - Horizontal Separation: Maintain at least 10 feet of horizontal separation between the sewer and any existing or proposed water main measured edge to edge.
  - Vertical Separation : Whenever sewers must cross under water mains, install the sewer at such elevation that the top of the sewer is at least 18 inches below the bottom of the water main.

TN Design Criteria!!!



https://themdc.org/water-sewer-service-information-for-developers-and-owners/

Wastewater Collection and Conveyance

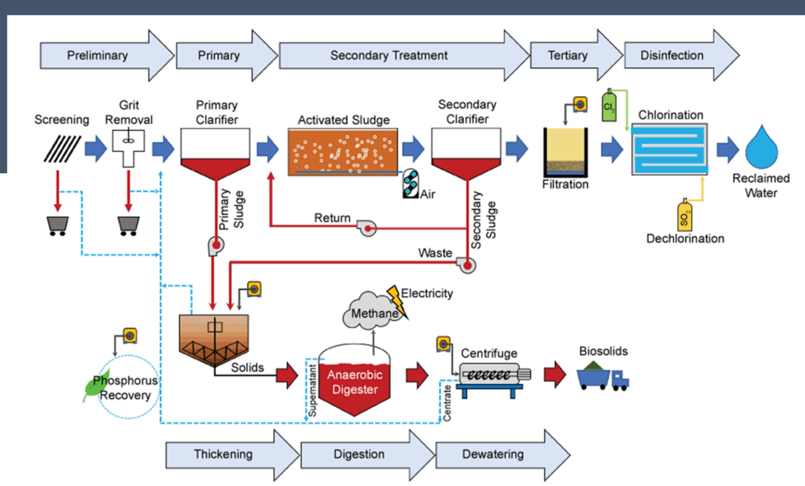


Manholes should be placed every 300-500 feet apart to provide access for inspections and cleaning

Minimum size is 4 inches

Constant minimum slope is required to provide a velocity of at least 2 fps to avoid solids depositing

Treatment Process



Wastewater Treatment Process

Preliminary Treatment → Primary Treatment → Secondary Treatment

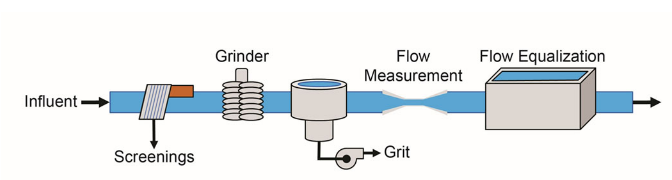
- Screening
- Grit Removal
- Flow Measurement and Sampling

→ Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

Preliminary Treatment

- Physical treatment process
- Takes place at WRRF headworks
- Removes large debris to protect downstream processes and equipment
- May include screening, grit removal, flow measurement, and/or flow equalization



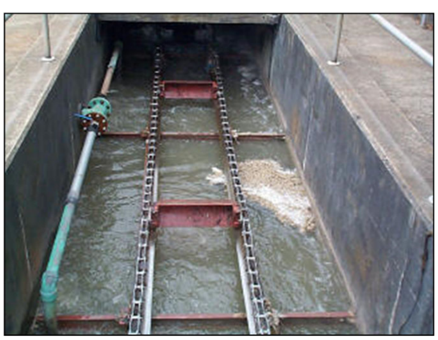
Preliminary Treatment
Headworks

Screening

- Protect equipment against damage such as clogging of pipes and pumps by removing larger debris (roots, rags, cans, etc.)
- Manual or Mechanical
- Openings can be from a few millimeters to 2 in.
- Coarse, bar, fine, & micro
- "Blinding off": excess material accumulates on screen & water can't move easily through openings

Preliminary Treatment
Headworks

Grit Removal



- Fine, discrete, non-biodegradable particles that have a settling velocity greater than organic solids
- Sand, eggshells, gravel, coffee grounds, etc.
- Protects equipment from abrasion and accompanying wear
- 1 ft/sec flow through grit chamber

Know this!!!

Preliminary Treatment
Headworks

Flow Measurement

Important to know for adjustments on pumping rates, chlorination rates, aeration rates, calculating loading, detention times, treatment efficiency, etc.

Primary Flow Metering (1°)

- Influent or effluent (or both!)
- Used for measuring and reporting flows for permit compliance

TN Rules and Regs!!!

Flow measuring devices must be calibrated and maintained to ensure +/-10% of true flow

Secondary Flow Metering (2°)

- Completed within the plant
- Used for internal flows that are required for accurate process control and compliance monitoring

Preliminary Treatment
Headworks

Sampling

Collected to obtain, develop, and use representative data for a variety of needs

Grab Sample

- Represents one moment in time and is not mixed with any other samples
- Defined by U.S. EPA as samples that are collected over a period of 15 minutes or less.

Composite Sample

- A single, larger sample that is prepared by combining a series of smaller grab samples over a known time or flow intervals
- Minimum of 8 samples, at least 100mL each, collected over a 24-hour period
- TN requirement: Flow proportioned

TN Rules and Regs!!!

Wastewater Treatment Process

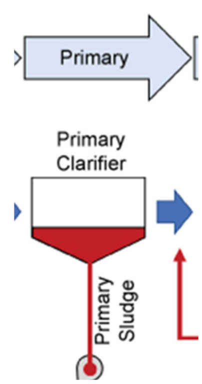
Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

- Sedimentation and Flotation

Primary Treatment

- Decreases velocity of wastewater to remove settleable and floatable material
- May use gravity or flotation
- Cannot remove **colloidal** material, soluble BOD, soluble phosphorus, or ammonia
- Removal rates depend on influent characteristics.
  - For domestic wastewater, primary treatment typically removes 20 to 35% of influent BOD_5 and 60 to 75% of influent TSS.

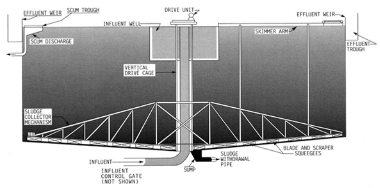


Colloidal solids are particles that are between 1 and 1000 µm in diameter. They are too small to settle to the bottom of the clarifier in the time allowed.

Primary Treatment
Primary Clarifier

Sedimentation

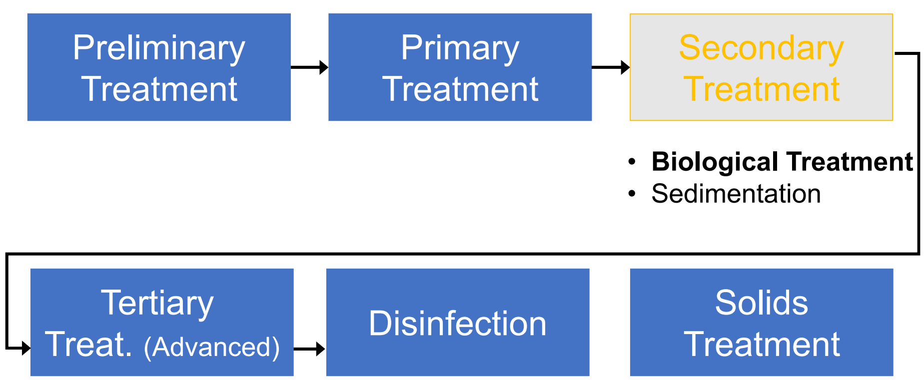
- Settleable solids sink to the bottom of the tank, where they are collected and removed
  - Dense, inorganic particles as well as dense organic solids
- Helps protect downstream equipment from wear and damage



Floatation

- Floatable material rise to the top of the tank where they are skimmed off and removed
  - Generally organic but includes grease, oils, plastics, and soaps
- Minimizes operational problems from the buildup of scum and improves overall appearance and smell

Wastewater Treatment Processes



Important Note!!!

Particles that remain after preliminary and primary treatment are very light and will not settle quickly on their own. For treatment to continue, the size of the remaining particles must be increased so that they can be efficiently removed.

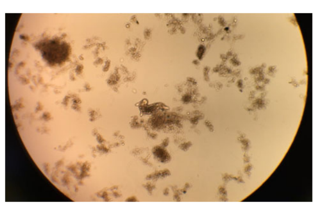
Secondary Treatment

Biological Reactor

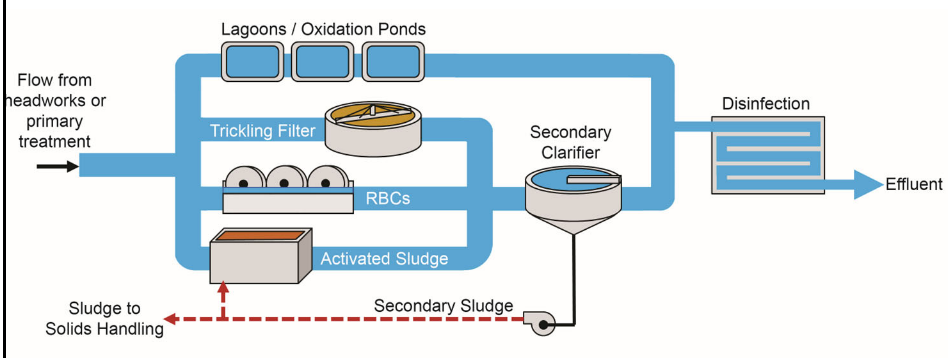
Biological Treatment

Excellent at converting smaller particles and soluble, biodegradable organic material in the raw wastewater into larger, heavier particles that can then be separated from the treated water by gravity (sedimentation)

- Rely on a mixed population of microorganisms, oxygen, and trace amounts of nutrients
- Microorganisms consume organic material to sustain themselves and reproduce



Secondary Treatment
Variations



Secondary Treatment

Suspended Growth

Microorganisms are drifting throughout the wastewater

- Ponds
- Activated Sludge

Attached Growth Systems

Microorganisms form a biofilm that is attached to supporting media

- Trickling filters
- Packed towers
- Rotating Biological Contactors (RBC)

Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment

- Biological Treatment
- **Sedimentation**

→ Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

Secondary Treatment

Secondary Clarifier

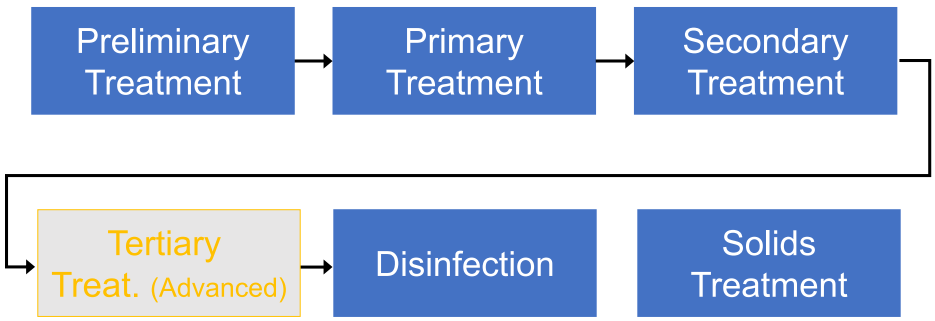
Sedimentation

Separation of the Mixed Liquor Suspended Solids (MLSS) from the liquid stream

- Interior baffles
- Equipment to control algae growth on weirs
- Hydraulic suction method of settled sludge removal
- Rider pipe mechanism for settled sludge removal
- Differences in depth and floor slope

Liquid/Solid Separation!!!

Wastewater Treatment Processes



- Chemical Phosphorous Removal
- Biological Nutrient Removal
- Multimedia Filtration

Tertiary Treatment

(Advanced)

May be physical, biological, or chemical treatment

Includes all treatment beyond the secondary treatment standards including removal of ammonia, nitrate, phosphorus, metals, and other constituents

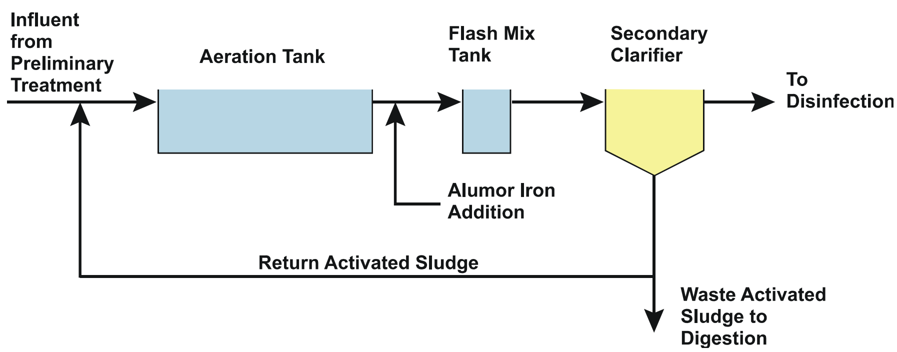
Includes technologies such as filtration and chemical precipitation

Important Note!!!

Secondary treatment processes may also remove ammonia, nitrate, and phosphorus even though, *technically*, any treatment that goes beyond the secondary treatment standards is considered tertiary treatment.

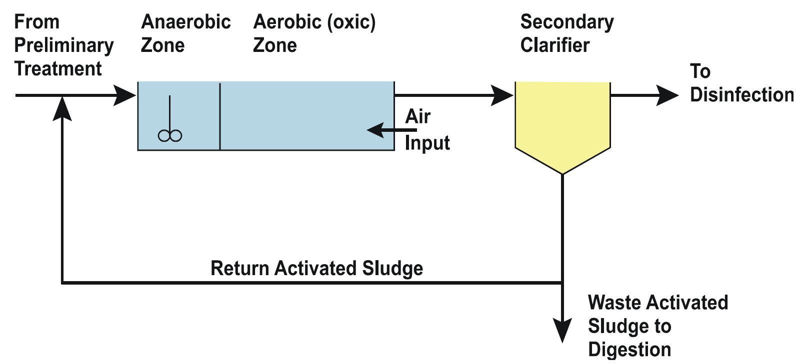
Tertiary Treatment

Chemical Phosphorus Removal



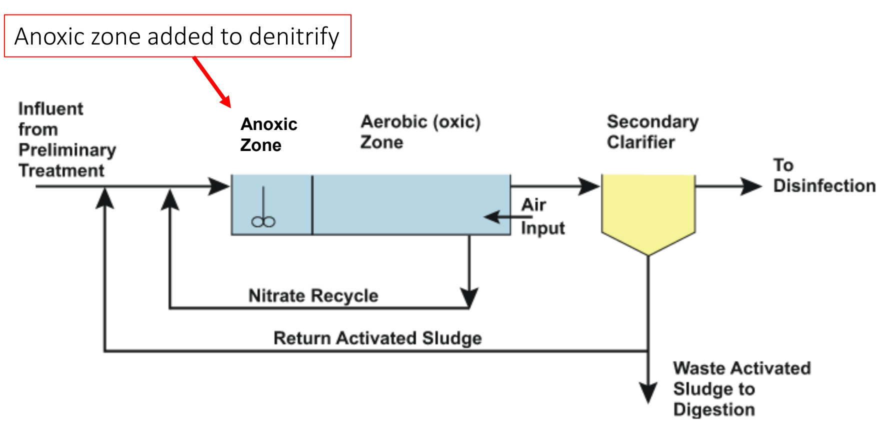
Tertiary Treatment

Biological Nutrient Removal - Phosphorus



Tertiary Treatment

Biological Nutrient Removal - Nitrogen



Tertiary Treatment

Multimedia Filtration

Deep bed sand filters at Murfreesboro Wastewater Plant

Wastewater Treatment Process

Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

- Ultraviolet Radiation
- Chlorine
- Ozone
- PAA

Disinfection

- Kills or damages potentially infectious microorganisms
  - Damaged microorganisms can't reproduce or cause disease
  - Not the same as sterilization!!
- Wastewater must contain less than 200 cfu/100mL for Fecal coliforms or 126 cfu/100mL for *E. coli* to be considered disinfected

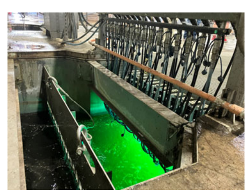
TN Rules and Regs!!!

cfu = colony forming unit

Disinfection

Ultraviolet Radiation

- Uses UV light to damage the DNA of microorganisms



Chlorine

- Chlorine Gas (Cl_2)
  - 100% pure chlorine
- Sodium Hypochlorite (NaOCl)
  - bleach
- Calcium Hypochlorite [$Ca(ClO)_2$]
  - Solid – powder, granular, disk, briquette, tablet form

Ozone

- Produced when oxygen (O_2) molecules are exposed to an energy source and converted to the unstable gas ozone (O_3)
- Generate on site because it is unstable

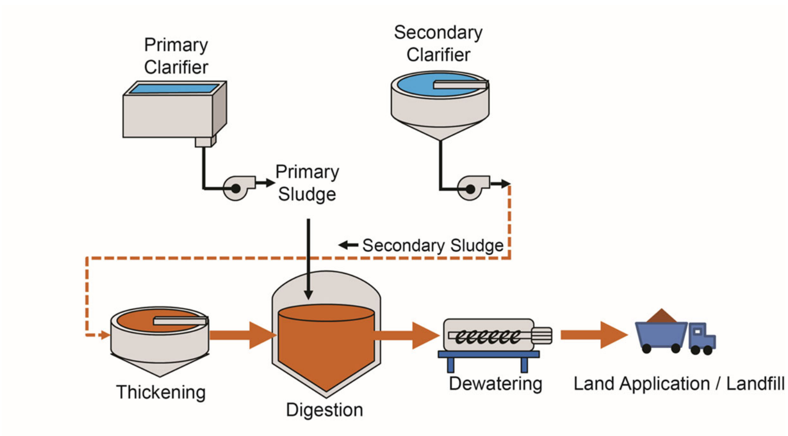
Wastewater Treatment Process

Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

- Thickening
- Digestion
- Dewatering
- Disposal

Solids Treatment



Solids Vocab

- ***Sludge***
  - encompasses any and all solid material—scum, settled solids, and floatables—that is removed from wastewater during treatment.
- ***Biosolids***
  - refers to stabilized solids that have been thoroughly treated and meet regulatory criteria. Biosolids may be beneficially reused as a soil amendment and fertilizer or can be sent to a landfill
- ***Residuals***
  - refers to the solid material left over after liquid treatment is completed

Solids Treatment

1. Thickening
- Increases solids concentration
- Low enough solids concentration (2%-10%) that they remain pourable

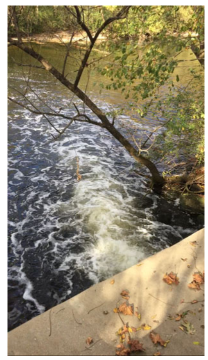
2. Digestion
- Reduce volatile solids
- Aerobic + Anaerobic
- Microorganisms use internally stored food + consume organic material from primary sludge (if available)
- Dead microorganisms become food for survivors

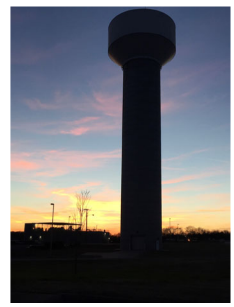
3. Dewatering
- Reduce volume (excess water) of sludge for further processing or disposal
- Higher solids concentration (10%-45%) and no longer pourable

4. Disposal
- 40 CFR Part 503: Class A or Class B

Effluent Discharge

- Most wastewater is discharged to a receiving stream, river, lake or ocean.
- Some is reclaimed or reused on golf courses, cemeteries, parks, etc.





Fleming Training Center Your Partner in Clean Water

TN Department of Environment & Conservation

Introduction Vocabulary

1. The impairment of water quality by agricultural, domestic, or industrial wastes to the point where the water is unusable, offensive, or poses a potential threat to human health or the environment is called ___________________________.

2. Water discharged directly into a sewer system from sources other than regular connections is called ______________________. This includes flow from yard drains, foundations, and around access and manhole covers.

3. A _____________________________ refers to any substance that is taken in by organisms and promotes growth. Nitrogen and phosphorus are examples that promote the growth of algae.

4. ____________________________ are a group of bacteria that are used as "indicator organisms," which means their presence may indicate that the water is polluted with pathogenic organisms.

5. Organic material undergoes ____________________________ by bacteria, in which the material is converted to gases and other relatively inert substances. Stabilized organic material generally will not give off obnoxious odors.

6. The __________________________________test , which lasts for 5 days, is the amount of oxygen used during the breakdown of organic material. It is considered an indirect measure of the organic content of a sample.

7. A wastewater treatment process that takes place in a rectangular or circular tank (ex. Primary clarifier) and allows those substances in wastewater that readily settle or float to be separated from the wastewater being treated is referred to as ____.

8. ____________________________ refers to the seepage of groundwater into a sewer system, including service connections. This seepage frequently occurs through defective or cracked pipes, pipe joints and connections, interceptor access risers and covers, or manhole walls.

9. _______________________ sewers carry waste (mostly domestic) from homes and commercial businesses. ________________________ sewers collect runoff from streets, land, and building roofs and is normally discharged to a waterway without treatment. A ___________________________ sewer system combines the two previously listed sewer systems into one, these types of sewers often become overloaded during heavy storms.

10. Waste material that comes from animal or plant sources is classified as _________________________ waste. These natural wastes generally can be consumed by bacteria and other small organisms.

11. The ___________________________ process is used to convert dissolved or suspended materials into a form more readily separated from the water, and usually follows primary treatment. It is

generally a type of biological treatment followed by secondary clarifiers that allow the solids to settle out.

12. A stream, river, lake, ocean, or other surface or groundwaters into which treated or untreated wastewater is discharged is called a _________________________________.
13. The water that has been treated and is discharged to a receiving stream, river, lake, or ocean is called ____________________________. NPDES permit limitations apply to this discharge.
14. Waste material such as sand, salt, iron, calcium, and other mineral materials that are only slightly affected by the action of organisms is classified as _______________________ waste.

<u>Word Bank</u>

Inflow

Effluent

Combined

Water pollution

Coliforms

Nutrients

Secondary treatment

Primary treatment

Sanitary

Organic

Biochemical oxygen demand (BOD)

Receiving water

Infiltration

Stormwater

Inorganic

Stabilization

Section 2
Preliminary Treatment

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Section 2
Preliminary Treatment

Preliminary Treatment

The removal of large debris that may hinder the operation of a treatment plant

Large debris can consist of:

- Cans/Bottles
- Sticks
- Scrap metal
- Rocks
- Egg shells
- Plastic products
- Rags/Trash
- Sand

- Large debris must be removed to prevent:
  - Blockages of pipes
  - Damage to pumps
  - Excessive wear on pumps and chains
  - Filling of digesters
  - Plant operating at reduced capacity

Preliminary Treatment

Located at the Headworks

How do we remove it?

Screening

Shredding

Grit removal

Additional preliminary treatment considerations:

Odor control

Septage Receiving

Flow Equalization

Screening

- Screens must be cleaned or raked by either manual or automatic control methods
- The type of screening selected will depend on which treatment processes are downstream and how much protection they require
- Debris collected on the screen depends on the opening space and the size, configuration, and amount of debris
- Screenings are typically sent to landfill for disposal

Categorized based on size opening:

- Coarse Screens
- Fine screens
- Microscreens

Screening

Coarse Screens

- Trash/Bar Rack
- Bar Screens
  - Chain/Cable-Driven
  - Single Rake
  - Multiple Rake
  - Catenary
  - Continuous Self-Cleaning

Fine Screens

- Perforated Plate
- Closely spaced bars
- Wedge-wire
  - Stair (Step) Screen
  - Drum
  - Continuous-Element
  - Inclined Cylindrical
  - Waterfall

Coarse Screens

Coarse Screens

Trash/Bar Rack

Spacing is 3-4 inches or more

Typically used for bypass channels or combined systems

Manually or mechanically cleaned

Bar Screens

Spacing is 3/8-inch to 2 inches

Manually or mechanically cleaned

Mechanically cleaned recommended for facilities greater than 1 MGD

Manually cleaned: 1-2 inches between openings

Mechanically cleaned: no less than 5/8-inch openings

TN Design Criteria!!!

Trash/Bar Rack

Manual

Mechanical

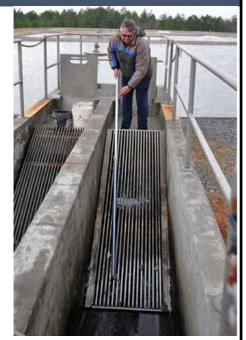
Bar Screens

Manual

Mechanical

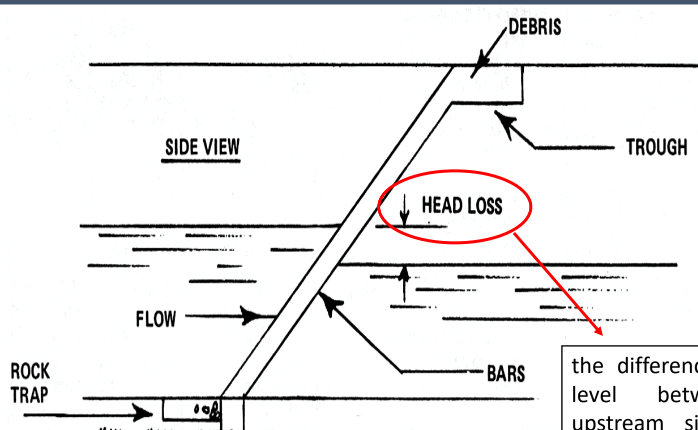
Manually Cleaned Bar Screens

- Clean using rake with tines that fit between bars, trash/debris goes in garbage
- Require frequent attention to prevent head loss
  - If allowable head loss is not specified in an Operation and Maintenance (O&M) manual, a max of 3 inches is a good starting point
- If flow backs up, organic wastes settle out, DO depletes and septic conditions are possible
  - Sudden rush of septic WW can create a shock to the system



the difference in water level between the upstream side of the screen and the downstream side of the screen

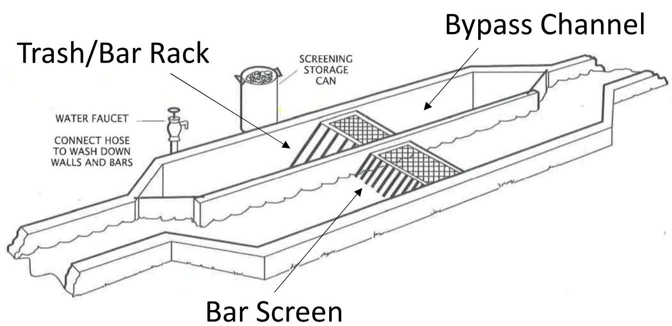
Manually Cleaned Bar Screens



Images from Sacramento Manual *Operation of Wastewater Treatment Plants* Vol I, p. 68

the difference in water level between the upstream side of the screen and the downstream side of the screen

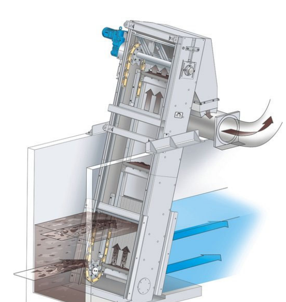
Manually Cleaned Bar Screens



Mechanically Cleaned Bar Screens

- Incorporates automatic controls that operate the cleaning device whenever the head loss reaches a preselected level or selected timeframe has elapsed
- Traveling mechanisms bring debris up out of the channel and into conveyors and/or hoppers
- Reduces labor cost, improves flow conditions and screening capture, and reduces nuisances

Chain/Cable-Driven
Single Rake
Multiple Rake
Catenary
Continuous Self-Cleaning



Chain/Cable-Driven Screen

How it Works:
- Two points of tension at the upper and lower sprockets that keep the chain taught
- Typical front-cleaning unit includes a toothed hopper (rake) that swings out from the bar screen as it travels down to the bottom of the channel
- When the channel reaches the bottom of the channel, cables, chains, or cogwheels draw the toothed hopper toward the bar screen
- The teeth of the hopper then slide between the bars and drag the screenings out of the wastewater

Single Rake Screen

How it Works:
- Simulates the movement of a person raking the screen
- Consists of stationary components (frame, bar rack, dead plate, and pin rack) along which the rake assembly travels
- A rake arm engages the screening materials and lifts it up and out of the channel
- Typically goes through a single operation cycle when initiated by timer or differential water-level signal

Multiple Rake Screen

How it Works:

- Similar to a single rake screen but with multiple rakes
- Stationary components (frame, bar rack, dead plate, and pin rack) along which the rake assembly travels
- Rake arms engage the screening materials and lift it up and out of the channel

Catenary Screen

How it Works:

- Similar to chain-driven and multiple rake screen
- Instead of having a flexible chain, catenary screens use rigid metal links or bars with joints that lock with one another
- Catenary screens only have one point of tension: the sprocket at the top

Continuous Self-Cleaning Screen

How it Works:

- Continuous belt of plastic or stainless-steel elements that are pulled through the wastewater to provide screening along the entire submerged length of the screen
- Solids are captured on the face of the screen and as the belt rotates, teeth protrude on the upward movement to collect screenings

Mechanically Cleaned Bar Screens

Maintenance

Preventative maintenance is key – routine inspection, lubrication, and repair (at recommendations of equipment supplier)

- Observe all moving mechanisms to determine if the components are free of obstructions, properly aligned, moving at constant speeds, and producing no unusual vibrations
- Lock out power to unit and divert flow through another channel before performing maintenance
- Chain drives require frequent replacement of chains, sprockets, and other parts

Screening

- **Coarse Screens**
  - Trash/Bar Rack
  - Bar Screens
    - Chain/Cable-Driven
    - Single Rake
    - Multiple Rake
    - Catenary
    - Continuous Self-Cleaning
- **Fine Screens**
  - Perforated Plate
  - Closely spaced bars
  - Wedge-wire
    - Stair (Step) Screen
    - Rotary Drum
    - Continuous-Element
    - Inclined Cylindrical
    - Waterfall

Fine Screens

Fine Screens
Made of 1 of 3 materials:
Wedge-Wire
Perforated Plate
Closely Spaced Bars

- Openings of 0.02- to 0.25-inch
- Mechanical cleaning of these screens is essential
- Screenings typically contain higher concentrations of organic matter
- Washer/compactors must be used with fine screens

Stair (Step) Fine Screens

- Long, thin parallel plates called lamellas made from stainless steel
- 0.12-0.24-inch openings between plates
- Stair-stepped edge, most designs have one moving set and one that rotates in and out of the screen to provide step motion
- "Matted Operation" to prevent stringy material passing through

Rotary Drum Fine Screens

Internally Fed

- Influent fed into center
- Wastewater enters open end of drum and flows outward through rotating drum filter
- Spray systems wash debris off the screen and into hopper
- Screenings removed by auger/conveyor for disposal

Rotary Drum Fine Screens

Externally Fed

- Influent evenly distributed along outside length of rotating screen
- Solids collect on outside, water flows inside (basically double screened)
- Screenings removed by scraper and spray wash system
- Screenings collected in hopper

Continuous-Element Fine Screens

- Screens with an endless cleaning grid that is attached to a main drive
- Screenings collected and conveyed to top of screen then discharged in hopper or conveying system
- Most popular are perforated plate
- Often used when minimizing screenings downstream is important

Inclined Cylindrical Fine Screens

- Cylindrical screening basket with an internal screenings removal mechanism that is typical a helical screw
- Typical installed at 30°- 45° incline
- Screenings drop into hopper
- Big advantage: supplied with internal washer/compactor
- Large footprint and shallower influent

Wedge-Wire Waterfall Fine Screens

- Simple screen with no moving parts
- Influent flows over the top of the concave face of screen
- Gravity and weight of new screenings push debris down
- Not recommended for wastewater that contains grease
- 0.010-0.100-inch opening

Comminutors

- Grinds or chops solids that could interfere with downstream processes
- Solids stay in water + decrease treatment capacity
- Cutting teeth mounted in rows on drum
- Shredded rags can adversely affect operation and maintenance of primary clarifiers, thickening units, and dewatering units
- Often used in pump stations, smaller plants, and ponds

Macerators

- Designed for in-line pipe installation + best suited for refined cutting after the headworks
- Perforated sheer plate and rotating headstock
- These units tend to do better with small solids like hair, wipes, rags, and plastics as compared to large heavy solids
- Heavy solids separation (built in “rock trap”)

Barminutors

- Variation of comminutor
- Bar screen made of U-shaped bars and a rotating drum with teeth and "shear bars"
- The rotating drum moves up and down the bar screen
- Shredded material continues with the waste stream

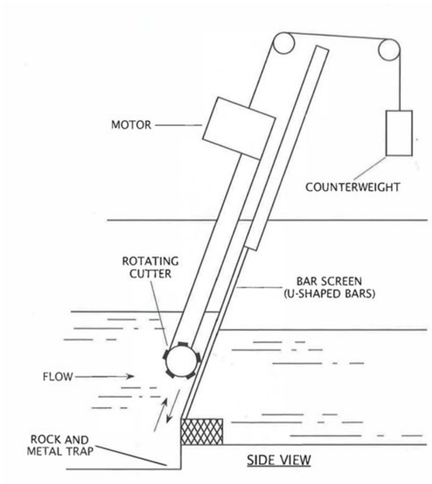


Fig. 4.11 Barminutor

Comminutors, Macerators, and Barminutors

Maintenance

Preventative maintenance is key – routine inspection, lubrication, and repair (at recommendations of equipment supplier)

- Observe all moving mechanisms to determine if the components are free of obstructions, properly aligned, moving at constant speeds, and producing no unusual vibrations
- Check for debris hung up in cutting drums and bars
- If stringing parts of rags are hanging from slotted drum or U-shaped bars of comminutor, it may indicate that the cutter is worn or out of adjustment - sharpen and adjust cutting blades

Screening Equipment Troubleshooting Chart (U.S. EPA, 1978)

Indicator/Observations	Probable Cause	Check or Monitor	Solutions
1. Obnoxious odors, flies, and other insects	1. Accumulation of rags and debris	1. Method and frequency of debris removal	1. Increase frequency of removal and disposal to an approved facility.
2. Excessive grit in bar screen chamber	2. Flow velocity too low	2. Depth of grit in chamber, irregular chamber bottom, flow velocity	2. Remove bottom irreqularity or reslope the bottom. Increase flow velocity in a chamber. Flush regularly with a hose.
3. Excessive screen clogging	3a. Unusual amount of debris in wastewater. Check industrial wastes. 3b. Inadequate cleaning frequency	3a. Upstream conditions 3b. Cleaning frequency	3a. Identify source of waste causing the problem so discharge can be stopped. 3b. Increase cleaning frequency.
4. Mechanical rake inoperable, circuit breaker will not reset	4. Jammed mechanism	4. Screen channel	4. Remove obstruction. Adjust spring tension if appropriate.
5. Rake inoperative, but motor runs	5a. Broken shear pin 5b. Broken chain or cable 5c. Broken limit switch	5a. Inspect shear pin. 5b. Inspect chain. 5c. Inspect switch.	5a. Identify cause of break and replace shear pin. 5b. Replace chain or cable. 5c. Replace limit switch.
6. Rake inoperative, no visible problem frequency.	6. Defective remote control circuit	6. Check switching circuits.	6. Verify correct operation of the PLC Replace circuit. Then replace circuit and motor.
7. Marks or metal against metal on screen binding	7. Screen needs adjustment	7. Operate screen through one cycle and listen for or observe metal-to-metal contact.	7. Manufacturer's adjustments recommended in equipment O&M manual.
8. Slow operation of grinders, screenings press, or belt conveyors. Screeching sounds during operation	8. Worn components	8. Operate through one cycle to identify components. Check maintenance logs.	8. Lubricate machine as indicated. Replace worn components.
9. Thumping sound during operation of screens, grinders, screenings press, or conveyors	9. Broken or loose components	9. Complete inspection of all components, nuts, and bolts.	9. Replace or tighten component.
10. Belt not tracking properly	10. Belt stretched; self-aligning idlers seized; tail pulley misaligned	10. Inspect belts, idlers, and tail pulley.	10. Adjust take-up; clean and lubricate self-aligning idlers; adjust tail pulley alignment.

Grit Removal

Grit Removal

- Fine, discrete, non-biodegradable particles that have a settling velocity greater than organic solids
- Sand, eggshells, gravel, coffee grounds, etc.
- Protects equipment from abrasion and accompanying wear
- 1 ft/sec flow through grit chamber

Know this!!!

Grit Removal

Grit Chambers

- Allow grit to settle out while keeping the lighter organic solids moving along to next treatment unit
  - Rely on differences in settling velocities
  - Slower settling particles require longer basins
- **Best velocity is 1 ft/sec***
  - Slowed to 0.7-1.4 ft/sec

*for rectangular and square grit chambers

Grit Removal

Velocity slowed by several means:

- In multiple channel installations, operator may vary number of channels (chambers) in service at any one time to maintain certain velocity
- Use of proportional weirs
- Shape of grit channel
- Using bricks or cinder blocks to change cross-sectional shape or area

Detritus Tanks

- Earliest grit chambers
- Constant level, short hydraulic retention time
- Flow is distributed across the tank inlet to minimize velocity across tank
- Require grit-washing step to remove organic material and return it to the wastewater stream
- Even flow distribution is maintained by proper adjustments of the deflector baffles

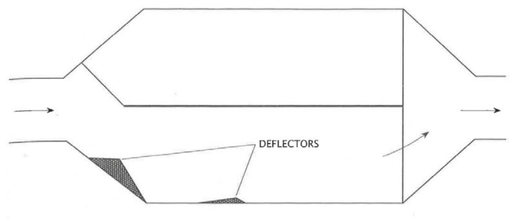


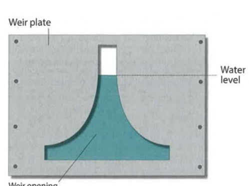
Fig. 4.16 Deflectors installed in a grit channel

Images from Operation of Wastewater Treatment Plants, Vol I

Velocity Control Tanks

Proportional Weir

- Will maintain the velocity in grit channels when flow increases
- Exit area will decrease, thus increasing the depth of water flow in the channel in direct proportion to the flow



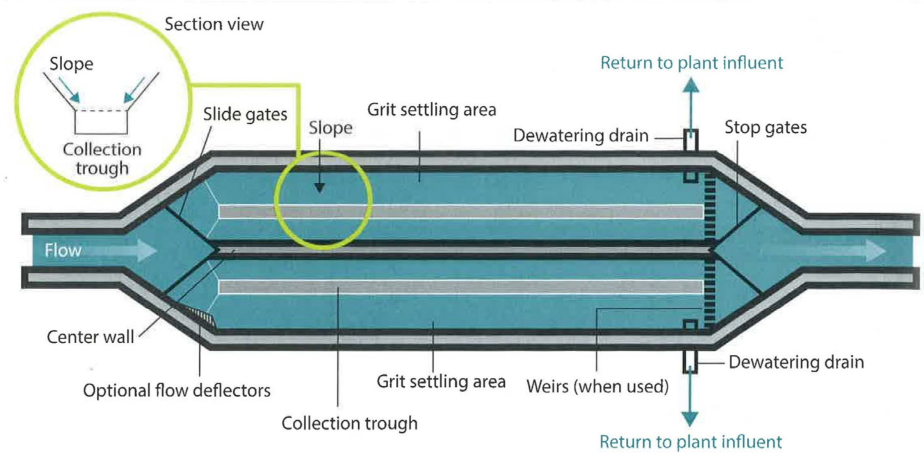
Images from Operation of Wastewater Treatment Plants, Vol I

Velocity is related to the cross-sectional area according to the formula:

$$Velocity = \frac{Flow}{Area}$$

- Horizontal flow grit chambers use proportional weirs to vary the depth of flow and keep the velocity of the flow stream at a constant 1 ft/sec
  - Debris must not be allowed to accumulate across opening
- Constant velocity can also be maintained by giving the grit channel a u-shaped cross-sectional area.

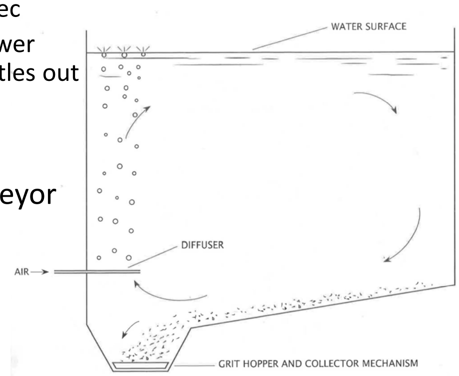
Grit Removal



Operations of Wastewater Treatment Plants, Vol I, 8th Ed., p. 166

Aerated Grit Chamber

- Air injected through diffusers located along one side of basin near bottom
  - Diffused air rolls wastewater at 1 ft/sec
  - The mixture of air and water has a lower specific gravity than water, so grit settles out better
- Particles travel in spiral direction
- Grit removed from hopper by conveyor or is pumped
- Aeration:
  - Adds DO and freshens wastewater
  - Improves sludge settleability
  - Removes floatables



Operation of Wastewater Treatment Plants, Vol I

Aerated Grit Chamber

- If the velocity of the roll is too great, grit will be carried out of chamber
- If the velocity is too low, organic matter will be removed with grit
- A good way to improve the effectiveness of all type of grit removal systems is to perform a volatile solids test on the collected grit
  - This should help you adjust your air flow and velocity

Vortex Grit Basin

- Gravity-type chambers that swirl the raw wastewater in the chamber
- Wastewater enters a vortex grit basin through a long, straight, inlet channel
- At the end of the inlet flume, a ramp causes grit that may already be on the flume bottom to slide downward along the ramp until reaching the chamber floor, where it is captured
- The inlet channel connects to the circular portion of the basin along one side, which creates a whirlpool or vortex effect
- The velocity of the vertical roll pattern allows denser particles to settle while keeping lighter organic material suspended
- Natural hydraulics or slow rotating mixer
- Ideal velocity: 1.5 to 3.5 ft/sec

Hand-Cleaned vs. Mechanically Cleaned

Hand cleaned channels

- Used in the smallest facilities with flows less than 1 MGD
- Flow drains to empty tanks for manual removal by shoveling
- Build up could interfere with flow-through velocity and cause wastewater to back up into sewer or cause an overflow

Mechanically Cleaned

- Gravity-type units – rectangular, circular, square
- Screw augers are most common
- Larger facilities with larger basins- Chain- and-flights (series of boards)

Flights are moved slowly along bottom and up an incline out of water to a hopper, or along the bottom to an underwater trough where a screw conveyor lifts the grit to a storage hopper or truck. Some designs use conveyor belts with buckets attached

Cyclone Grit Separators

Cyclones use centrifugal force in a cone-shaped unit to separate grit and organics from the wastewater

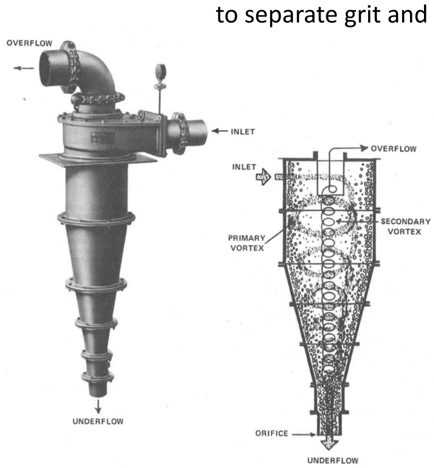


Fig. 4.20 How a grit cyclone separator works

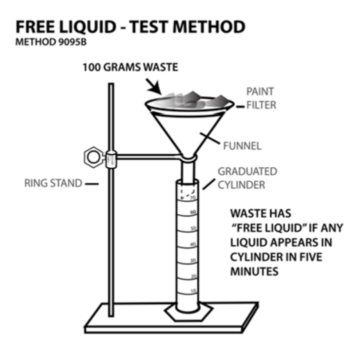
- A pump discharges a slurry of grit and organics into the cyclone at a controlled rate
- The velocity of the slurry as it enters along the wall of the cyclone causes slurry to spin or swirl around the outside of the cyclone ("primary vortex")
- The grit is forced outward to the primary vortex and spirals downward towards bottom
- A larger volume of slurry containing mostly volatile material is carried upward ("secondary vortex") and out the overflow discharge pipe

Grit Classifiers

- Removes organic matter from grit
- Inclined screw or rake moves grit up ramp
- Final grit disposal in landfill
- If grit used as fill material, it is necessary to wash it

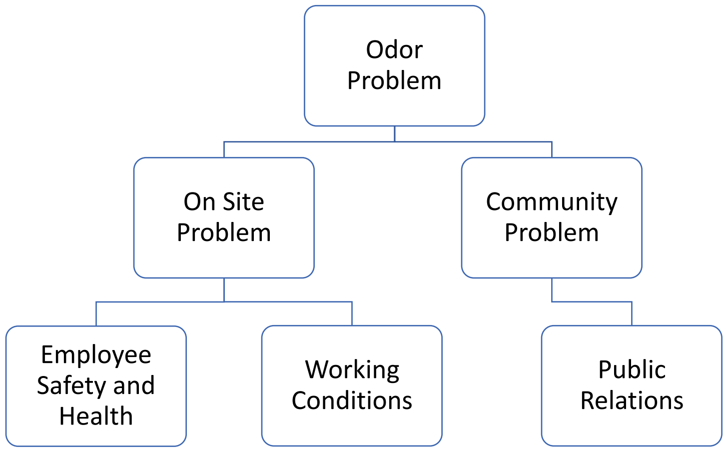
Disposal of Screenings and Grit

- Burial, incineration, or landfilling ← Most common
- Must pass paint-filter liquids test for landfilling
  - Measures the leaching effect of screenings
  - Filter of Mesh No. 60
  - If any liquid passes through the filter, the material is deemed to contain free liquid
    1. Pour in 100 mL of sample
    2. Wait **five** (5) minutes
    3. After five minutes if any liquid collects in cylinder see 40 CFR 264.314 and 265-314



Source: www.epa.gov

Odor Control



Odor Control

- Hydrogen Sulfide (H_2S)
  - Main cause of odors in wastewater systems
  - Poisonous to respiratory system
  - Rotten egg odor
  - Produced under anaerobic conditions
  - Explosive, flammable, corrosive
  - Dulls sense of smell on exposure
- Ammonia (NH_3)
- Methane (CH_4)

Table 13.4 Health effects of hydrogen sulfide exposure.

Concentration, ppm	Health effect
0.03	Can smell. Safe for 8-hour exposure.
4	May cause eye irritation. Mask must be used as exposure damages metabolism.
10	Maximum exposure for 8-hour period. Kills sense of smell in 3 to 15 minutes.
20	Exposure for more than 1 minute may cause eye injury.
30	Loss of smell, injury to blood brain barrier through olfactory nerves.
100	Respiratory paralysis in 30 to 45 minutes. Needs prompt artificial resuscitation. Will become unconscious quickly (15 minutes maximum).
200	Serious eye injury and permanent damage to eye nerves. Stings eyes and throat.
300	Loses sense of reasoning and balance. Respiratory paralysis in 30 to 45 minutes.
500	Asphyxia. Needs prompt artificial resuscitation. Will become unconscious in 3 to 5 minutes.
700	Breathing will stop and death will result if not rescued promptly, immediate unconsciousness. Permanent brain damage may result unless rescued promptly.

Operation of Municipal Wastewater Treatment Plants, Vol I, MOP No. 11, p. 13-9

Odor Control

Often requires a combination of treating/removing/and reducing potential causes

- Vapor-phase odor control methods
  - Atmospheric discharge and dilution
  - Masking agents and counteraction chemicals
  - Chemical wet scrubbing
  - Activated carbon adsorption
- Liquid-phase odor control methods
  - Chemical addition (chlorine)
- Operational odor control methods
  - Source control
  - Housekeeping improvements
  - Process or operational changes

- Bar screens/racks being maintained and not allowing solids to build up
- Efficient grit washing/burial/incineration/etc.
- Collection system improvements and maintenance – ensure 2 fps to avoid solids depositing

Activated Carbon Adsorption

Adsorption is the process in which the odorous components are removed from a gas through adherence to a solid surface. Activated Carbon (AC) is highly porous, and the adsorption takes place upon the wall of the pores within the AC.

- Odorous air is collected and directed through AC beds where the odor-causing organic and inorganic gases are removed from the air and adsorbed on the carbon.

Advantages include:
- Consistent reliability
- Simple operation
- Ability to increase adsorbent capability by the use of additive compounds
- Accommodation of high gas flow rates by use of multiple units

Disadvantages include:
- High regeneration costs
- Short use time due to high concentrations of odorous compounds
- Reactivity of caustic-impregnated material
- Fouling of the adsorbent by particulate matter
- Disposal of spent carbon if it is classified as a hazardous waste

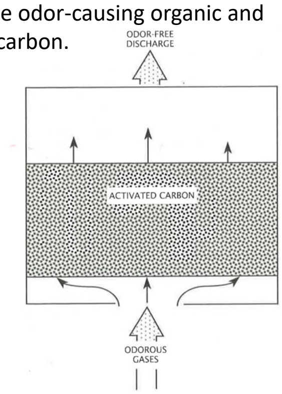


Fig. 1.10 Activated carbon adsorption process
Advanced Waste Treatment, p. 31

Chemical Scrubbers

- Packed bed is the most common type of wet scrubber system that uses chemical absorption to control odors.

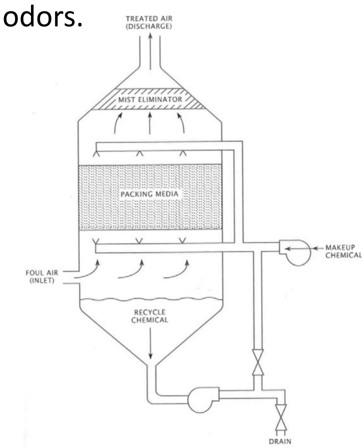
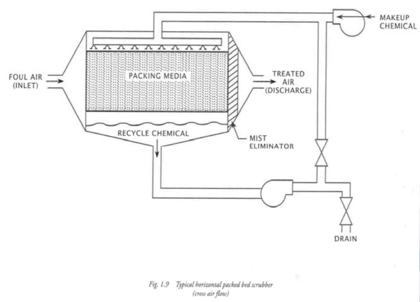


Fig. 1.8 Typical vertical packed bed scrubber odor control system (countercurrent air flow)

Chemical Scrubbers



Horizontal packed bed scrubber system

Figures from this and previous slide: Advanced Waste Treatment, Fifth edition, p. 30-31

Chemical Additions

- Chlorine and chlorine compounds — kill or inactivate anaerobic bacteria
- Hydrogen peroxide — oxidant that chemically oxidizes H_2S to elemental sulfur or sulfate (depending on the pH)
- Metal salts
  - Iron — react with sulfide to form insoluble precipitates
  - Zinc
  - Copper
- Ozone — extremely powerful oxidant that will oxidize H_2S into elemental sulfur
- Strong Alkalis — used to control pH
  - Sodium hydroxide
  - Lime
- Nitrates — Used as substitute oxygen source removal by biochemical process

Septage Management

- Septage = wastewater that is pumped out of septic tanks and other types of holding tanks
- Partially digested anaerobic wastewater
  - Higher strength (high BOD, COD, TSS, FOG)
- Can lead to toxic slug loads
  - Sampling can help identify toxic loads
  - If possible, maintain a way to hold septage and pump it slowly into your plant
- Maintain good records of who dumped, how much, and when
  - Water supply for washdown
  - Video monitoring

Flow Equalization

Reducing flow fluctuations

- Temporarily store influent wastewater during peak flows
- High flows can be managed by using:
  - Flow-equalization basins
  - Storage lagoons
  - Alternate process modes such as contact stabilization or step feed
- Locations can include:
  - Before preliminary treatment
  - Directly after preliminary treatment
  - Immediately after primary treatment

DO must be 1.0 mg/L

TN Design Criteria!!!

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Preliminary Treatment Vocabulary

1. A _______________ is a device used with a blower system that breaks the air stream into fine bubbles in an aeration tank or reactor.

2. _____________ is the heavy material present in wastewater such as sand, coffee grounds, eggshells, gravel, and cinders.

3. ___________________ is the gas with a rotten egg odor that is produced under anaerobic conditions. It is dangerous to human health and also very corrosive, capable of damaging concrete. This is the main cause of odors in a wastewater system.

4. Traveling rakes bring debris up of out the water channel in a ___________________ cleaned bar ____________________ unit.

5. ____________ screens generally have openings of 0.06 – 0.25 inches and are located downstream from coarse screens.

6. The simplest type of fine screen that contains no moving parts is called the ________________ screen. Influent flows over the top and gravity and the weight of new screenings push the debris down.

7. ______________________ screens fall into one of two types: internally fed or externally fed.

8. The ________________________ screen, also called a continuous conveyor, is made up of stainless steel plates with 0.125 – 0.250 inch openings which move up and around a top and bottom axis.

9. A ______________________ is a device that acts as both a cutter and a screen. Cutting teeth mounted in rows on the drum shred debris, which is left in the waste stream.

10. Screenings are either buried or incinerated. For landfill disposal, screenings must be dewatered enough to pass the _____________________, which measures the leaching effect of the screenings.

11. Best described as partially digested anaerobic wastewater, ___________________________ has been pumped out of septic tanks and other types of holding tanks and is transported via truck to a wastewater treatment plant for treatment.

12. In order to allow grit to settle out while keeping the lighter organic solids moving along to the next treatment unit, a velocity of 1 ft/sec must be maintained in the ______________________.

13. Grit particles travel in a spiral direction due to diffused air that rolls the wastewater at 1 ft/sec inside the ____________________________.

14. The principle behind the ________________________ separator is that the primary vortex will force the grit outward, while the secondary vortex carries lighter particles and water upward and out the overflow discharge pipe.

15. _______________________ is the gathering of a gas, liquid, or dissolved substance on the outside surface or interface zone of another material. Activated carbon is utilized in this process when used for odor control.

16. Oxidants such as chlorine, sodium hypochlorite, and hydrogen peroxide are used as the packing media in chemical scrubbers. These systems use the process of chemical _______________ to control odors.

17. A device or tank designed to hold back or store a portion of peak flows for release during low-flow periods is part of the __________________________ system. According to the TN Design Criteria for Sewage Works, this may be required where peak flows are greater than 2 times the average design flow. Either in-line or side-line systems are acceptable.

<u>Word Bank:</u>

Flow equalization	Paint filter test
Absorption	Mechanically
Diffuser	Hydrogen Sulfide (H_2S)
Septage	Grit
Rotary drum	Screen
Comminutor	Aerated grit chamber
Grit channel	Fine
Adsorption	Wedgewire
Cyclonic grit	Escalating step screen

United States
Environmental Protection
Agency

Wastewater Technology Fact Sheet

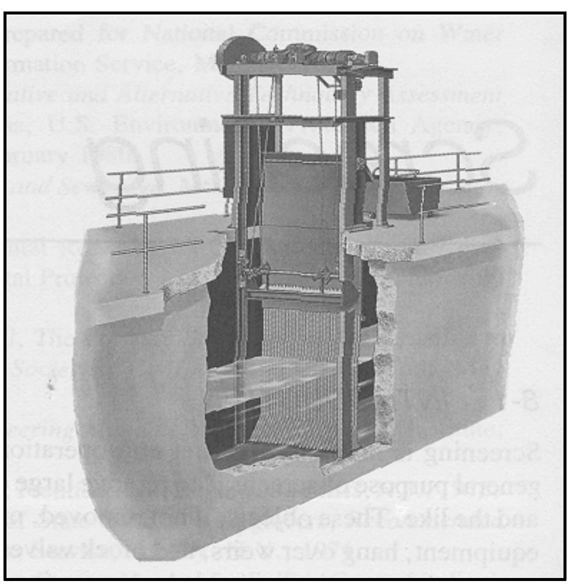
Screening and Grit Removal

DESCRIPTION

Wastewater contains large solids and grit that can interfere with treatment processes or cause undue mechanical wear and increased maintenance on wastewater treatment equipment. To minimize potential problems, these materials require separate handling. Preliminary treatment removes these constituents from the influent wastewater. Preliminary treatment consists of screening, grit removal, septage handling, odor control, and flow equalization. This fact sheet discusses screening and grit removal.

Screening

Screening is the first unit operation used at wastewater treatment plants (WWTPs). Screening removes objects such as rags, paper, plastics, and metals to prevent damage and clogging of downstream equipment, piping, and appurtenances. Some modern wastewater treatment plants use both coarse screens and fine screens. Figure 1 depicts a typical bar screen (a type of coarse screen).



Source: Qasim, 1994.

FIGURE 1 CABLE OPERATED BAR SCREEN

Coarse Screens

Coarse screens remove large solids, rags, and debris from wastewater, and typically have openings of 6 mm (0.25 in) or larger. Types of coarse screens include mechanically and manually cleaned bar screens, including trash racks. Table 1 describes the various types of coarse screens.

Fine Screens

Fine screens are typically used to remove material that may create operation and maintenance problems in downstream processes, particularly in systems that lack primary treatment. Typical opening sizes for fine screens are 1.5 to 6 mm (0.06 to 0.25 in). Very fine screens with openings of 0.2 to 1.5 mm (0.01 to 0.06 in) placed after coarse or fine screens can reduce suspended solids to levels near those achieved by primary clarification.

Comminutors and Grinders

Processing coarse solids reduces their size so they can be removed during downstream treatment operations, such as primary clarification, where both floating and settleable solids are removed. Comminuting and grinding devices are installed in the wastewater flow channel to grind and shred material up to 6 to 19 mm (0.25 to 0.75 in) in size.

Comminutors consist of a rotating slotted cylinder through which wastewater flow passes. Solids that are too large to pass through the slots are cut by blades as the cylinder rotates, reducing their size until they pass through the slot openings.

Grinders consist of two sets of counterrotating, intermeshing cutters that trap and shear wastewater solids into a consistent particle size, typically 6 mm (0.25 in). The cutters are mounted on two drive

TABLE 1 DESCRIPTION OF COARSE SCREENS

Screen Type	Description
Trash Rack	Designed to prevent logs, timbers, stumps, and other large debris from entering treatment processes. Opening size: 38 to 150 mm (1.5-6 in)
Manually Cleaned Bar Screen	Designed to remove large solids, rags, and debris. Opening size: 30 to 50 mm (1 to 2 in) Bars set at 30 to 45 degrees from vertical to facilitate cleaning. Primarily used in older or smaller treatment facilities, or in bypass channels.
Mechanically Cleaned Bar Screen	Designed to remove large solids, rags, and debris. Opening size: 6 to 38 mm (0.25 to 1.5 in). Bars set at 0 to 30 degrees from vertical. Almost always used in new installations because of large number of advantages relative to other screens.

Source: Design of Municipal Wastewater Treatment Plants, WEF MOP 8, Fourth Edition, 1998.

shafts with intermediate spacers. The shafts counterrotate at different speeds to clean the cutters. Figure 2 depicts a channel wastewater grinder.

The chopping action of the grinder reduces the formation of rag "balls" and rag "ropes" (an inherent problem with comminutors). Wastewaters that contain large quantities of rags and solids, such as prison wastewaters, utilize grinders downstream from coarse screens to help prevent frequent jamming and excessive wear.

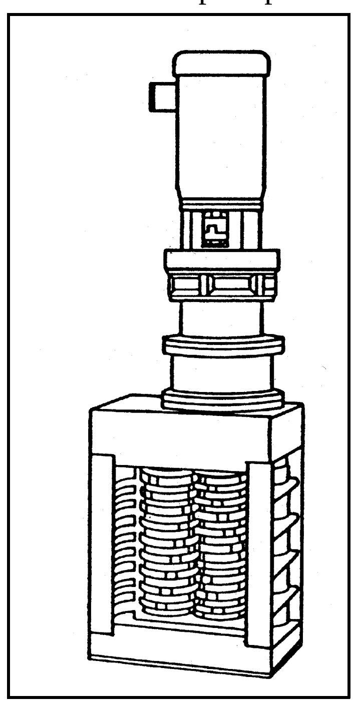
Grit Removal

Grit includes sand, gravel, cinder, or other heavy solid materials that are "heavier" (higher specific gravity) than the organic biodegradable solids in the wastewater. Grit also includes eggshells, bone chips, seeds, coffee grounds, and large organic particles, such as food waste. Removal of grit prevents unnecessary abrasion and wear of mechanical equipment, grit deposition in pipelines and channels, and accumulation of grit in anaerobic digesters and aeration basins. Grit removal facilities typically precede primary clarification, and follow screening and comminution. This prevents large solids from interfering with grit handling equipment. In secondary treatment plants without primary clarification, grit removal should precede aeration (Metcalf & Eddy, 1991).

Many types of grit removal systems exist, including aerated grit chambers, vortex-type (paddle or jet-induced vortex) grit removal systems, detritus tanks (short-term sedimentation basins), horizontal flow grit chambers (velocity-controlled channel), and hydrocyclones (cyclonic inertial separation). Various factors must be taken into consideration when selecting a grit removal process, including the quantity and characteristics of grit, potential adverse effects on downstream processes, head loss requirements, space requirements, removal efficiency, organic content, and cost. The type of grit removal system chosen for a specific facility should be the one that best balances these different considerations. Specifics on the different types of grit removal systems are provided below.

Aerated Grit Chamber

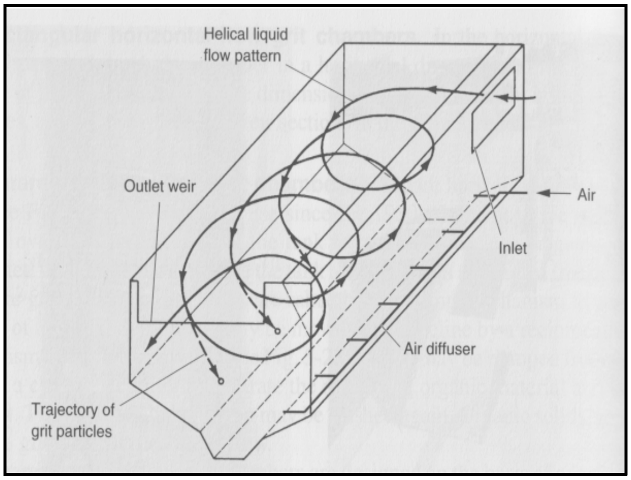
In aerated grit chambers, grit is removed by causing the wastewater to flow in a spiral pattern, as shown



Source: WEF, 1998.

FIGURE 2 WASTEWATER GRINDER: CHANNEL UNIT

in Figure 3. Air is introduced in the grit chamber along one side, causing a perpendicular spiral velocity pattern to flow through the tank. Heavier particles are accelerated and diverge from the streamlines, dropping to the bottom of the tank, while lighter organic particles are suspended and eventually carried out of the tank.



Source: Crites and Tchobanoglous, 1998.

FIGURE 3 AERATED GRIT CHAMBER

Vortex-Type Grit Chamber

The vortex-type grit chamber consists of a cylindrical tank in which the flow enters tangentially, creating a vortex flow pattern. Grit settles by gravity into the bottom of the tank (in a grit hopper) while effluent exits at the top of the tank. The grit that settles into the grit hopper may be removed by a grit pump or an air lift pump.

Detritus Tank

A detritus tank (or square tank degritter) is a constant-level, short-detention settling tank. These tanks require a grit-washing step to remove organic material. One design option includes a grit auger and a rake that removes and classifies grit from the grit sump.

Horizontal Flow Grit Chamber

The horizontal flow grit chamber is the oldest type of grit removal system. Grit is removed by maintaining a constant upstream velocity of 0.3 m/s (1 ft/s). Velocity is controlled by proportional weirs or rectangular control sections, such as Parshall flumes. In this system, heavier grit particles settle to the bottom of the channel, while lighter organic particles remain suspended or are resuspended and transported out of the channel. Grit is removed by a conveyor with scrapers, buckets, or plows. Screw conveyors or bucket elevators are used to elevate the grit for washing or disposal. In smaller plants, grit chambers are often cleaned manually.

Hydrocyclone

Hydrocyclone systems are typically used to separate grit from organics in grit slurries or to remove grit from primary sludge. Hydrocyclones are sometimes used to remove grit and suspended solids directly from wastewater flow by pumping at a head ranging from 3.7 to 9 m (12 to 30 ft). Heavier grit and suspended solids collect on the sides and bottom of the cyclone due to induced centrifugal forces, while scum and lighter solids are removed from the center through the top of the cyclone.

APPLICABILITY

Because various types of screening and grit removal devices are available, it is important that the proper design be selected for each situation. Though similarities exist between different types of equipment for a given process, an improperly applied design may result in an inefficient treatment process.

Screening

As discussed above, most large facilities use mechanically cleaned screening systems to remove larger materials because they reduce labor costs and they improve flow conditions and screening capture. Typically, only older or smaller treatment facilities use a manually cleaned screen as the primary or only screening device. A screening compactor is usually situated close to the mechanically cleaned screen and compacted screenings are conveyed to a dumpster or disposal area. However, plants utilizing mechanically cleaned screens should have a standby screen to put in operation when the primary screening device is out of service. This is standard design practice for most newly designed plants.

The use of fine screens in preliminary treatment has experienced a resurgence in the last 20 years. Such screens were a common feature before 1930 but their use diminished because of difficulty in cleaning oils and grease from the screens. In the early 1980s, fine screens regained popularity because of improved materials.

Communitors and Grinders

Comminutors and grinders are used primarily at smaller treatment facilities (less than 5 MGD) to process material between 6 and 19 mm (0.25 to 0.75 in) (WEF, 1998). This shredded material remains in the wastewater and is removed in downstream treatment processes.

Grit Removal

When selecting a grit removal process, the quantity and characteristics of grit and its potential to adversely affect downstream processes are important considerations. Other parameters to consider may include headloss requirements, space requirements, removal efficiency, organic content, and economics.

ADVANTAGES AND DISADVANTAGES

Advantages

Screening

Manually cleaned screens require little or no equipment maintenance and provide a good alternative for smaller plants with few screenings. Mechanically cleaned screens tend to have lower labor costs than manually cleaned screens and offer the advantages of improved flow conditions and screening capture over manually cleaned screens.

Communitors and Grinders

A major advantage of using communitors and grinders is that removal of grit reduces damage and maintenance to downstream processes. Comminutors and grinders also eliminate screenings handling and disposal, which may improve the aesthetics of the plant, reducing odors, flies, and the unsightliness associated with screenings. Some recently developed grinders can chop, remove, wash, and compact the screenings. The use of comminutors in cold weather eliminates the need to prevent collected screenings from freezing. Comminutors and grinders typically have a lower profile than screens, so cost savings can be significant when the units must be enclosed.

Grit Removal

Aerated Grit Chamber

Some advantages of aerated grit chambers include:

- Consistent removal efficiency over a wide flow range.
- A relatively low putrescible organic content may be removed with a well controlled rate of aeration.
- Performance of downstream units may be improved by using pre-aeration to reduce septic conditions in incoming wastewater.
- Aerated grit chambers are versatile, allowing for chemical addition, mixing, pre-aeration, and flocculation.

Vortex-Type Grit Chamber

- These systems remove a high percentage of fine grit, up to 73 percent of 140-mesh (0.11 mm/0.004 in diameter) size.
- Vortex grit removal systems have a consistent removal efficiency over a wide flow range.
- There are no submerged bearings or parts that require maintenance.
- The “footprint” (horizontal dimension) of a vortex grit removal system is small relative to other grit removal systems, making it advantageous when space is an issue.
- Headloss through a vortex system is minimal, typically 6 mm (0.25 in). These systems are also energy efficient.

Detritus Tank

Detritus tanks do not require flow control because all bearings and moving mechanical parts are above the water line. There is minimal headloss in this type of unit.

Horizontal Flow Grit Chamber

Horizontal flow grit chambers are flexible because they allow performance to be altered by adjusting the outlet flow control device. Construction is not complicated. Grit that does not require further classification may be removed with effective flow control.

Hydrocyclone

Hydrocyclones can remove both grit and suspended solids from wastewater. A hydrocyclone can potentially remove as many solids as a primary clarifier.

Disadvantages

Screening

Manually cleaned screens require frequent raking to avoid clogging and high backwater levels that cause buildup of a solids mat on the screen. The increased raking frequency increases labor costs. Removal of this mat during cleaning may also cause flow surges that can reduce the solids-capture efficiency of downstream units. Mechanically cleaned screens are not subject to this problem, but they have high equipment maintenance costs.

Communitors and Grinders

Comminutors and grinders can create problems for downstream processes, such as increasing plastics buildup in digestion tanks or rag accumulation on air diffusers. In addition, solids from comminutors and grinders will not decompose during the digestion process. If these synthetic solids are not removed, they may cause biosolids to be rejected for reuse as a soil amendment.

Grit Removal

Grit removal systems increase the headloss through a wastewater treatment plant, which could be problematic if headloss is an issue. This could require additional pumping to compensate for the headloss.

The following paragraphs describe the specific disadvantages of different types of grit removal systems.

Aerated Grit Chamber

Potentially harmful volatile organics and odors may be released from the aerated grit chamber. Aerated grit chambers also require more power than other grit removal processes, and maintenance and control of the aeration system requires additional labor.

Vortex-Type Grit Chamber

- Vortex grit removal systems are usually of a proprietary design, which makes modifications difficult.

- Paddles tend to collect rags.

- Vortex units usually require deep excavation due to their depth, increasing construction costs, especially if unrippable rock is present.

- The grit sump tends to clog and requires high-pressure agitation using water or air to loosen grit compacted in the sump.

Detritus Tank

- Detritus tanks have difficulty achieving uniform flow distribution over a wide range of flows because the inlet baffles cannot be adjusted.

- This type of removal system removes large quantities of organic material, especially at low flows, and thus requires grit washing and classifying.

- Grit may be lost in shallow installations (less than 0.9 m [3 ft]) due to the agitation created by the rake arm associated with this system.

Horizontal Flow Grit Chamber

- It is difficult to maintain a 0.3 m/s (1 ft/s) velocity over a wide range of flows.
- The submerged chain, flight equipment, and bearings undergo excessive wear.
- Channels without effective flow control will remove excessive amounts of organic material that require grit washing and classifying.
- Head loss is excessive (typically 30 to 40 percent of flow depth).
- High velocities may be generated at the channel bottom with the use of proportional weirs, leading to bottom scour.

Hydrocyclone

Hydrocyclones require energy because they use a pump to remove grit and suspended solids. Coarse screening is required before these units to remove sticks, rags, and plastics.

DESIGN CRITERIA

Screening

Screening devices are classified based on the size of the material they remove (the screenings). The "size" of screening material refers to its diameter. Table 2 lists the correlation between screening sizes and screening device classification.

In addition to screening size, other design considerations include the depth, width, and approach velocity of the channel; the discharge height, the screen angle; wind and aesthetic considerations; redundancy; and head loss.

Table 3 lists typical design criteria for mechanically cleaned bar rack type screens.

TABLE 2 SCREENING DEVICE CLASSIFICATION

Screening Device Classification	Size Classification/Size Range of Screen Opening
Bar screen	
Manually Cleaned	Coarse/25-50 mm (1-2 in)
Mechanically Cleaned	Coarse/15-75 mm (0.6-3.0 in)
Fine bar or perforated coarse screen (mechanically cleaned)	
Fine Bar	Fine Coarse/3-12.5 mm (0.1-0.5 in)
Perforated Plate	Fine Coarse/3-9.5 mm (0.1-0.4 in)
Rotary Drum	Fine Coarse/3-12.5 mm (0.1-0.5 in)
Fine screen (mechanically cleaned)	
Fixed Parabolic	Fine/0.25-3.2 mm (0.01-0.13 in)
Rotary Drum	Fine/0.25-3.2 mm (0.01-0.13 in)
Rotary Disk	Very fine (micro)/0.15-0.38 mm (0.01-0.02 in)

Source: Crites and Tchobanoglous, 1998.

The use of fine screens produces removal characteristics similar to primary sludge removal in primary sedimentation. Fine screens are capable of removing 20 to 35 percent suspended solids and BOD_5. Fine screens may be either fixed or movable, but are permanently set in a vertical, inclined, or horizontal position and must be cleaned by rakes, teeth, or brushes.

Communitors and Grinders

Figure 4 depicts a typical comminutor. When designing a comminutor, headloss should be considered. Headloss through a comminutor is usually in the range of a few centimeters to 0.9 m (3 ft). Therefore, the manufacturer's ratings should be decreased by 70 to 80 percent to account for clogging of the screen, since manufacturer's headloss characteristics are usually based on clean water flow (Crites and Tchobanoglous, 1998).

TABLE 3 DESIGN CRITERIA FOR MECHANICALLY CLEANED BAR SCREENS

Item	Design Criteria	
	Metric Units	English Units
Bar width	5-15 mm	0.2-0.6 in
Bar depth	25-40 mm	1.0-1.5 in
Clear spacing between bars	15-75 mm	0.6-3.0 in
Slope from vertical	0-30 degrees	0-30 degrees
Approach velocity	0.6-1.0 m/s	2.0-3.25 ft/s
Allowable Headloss	150 mm	6 in

Source: WEF, 1998.

When a comminution device is installed upstream of a grit removal device, the teeth of the comminutor are subject to high wear and tear. Rock traps are recommended to prolong the life of the comminutor. In addition, a bypass manual bar rack should be installed in the event that flow rates exceed the comminutor capacity or there is a mechanical failure.

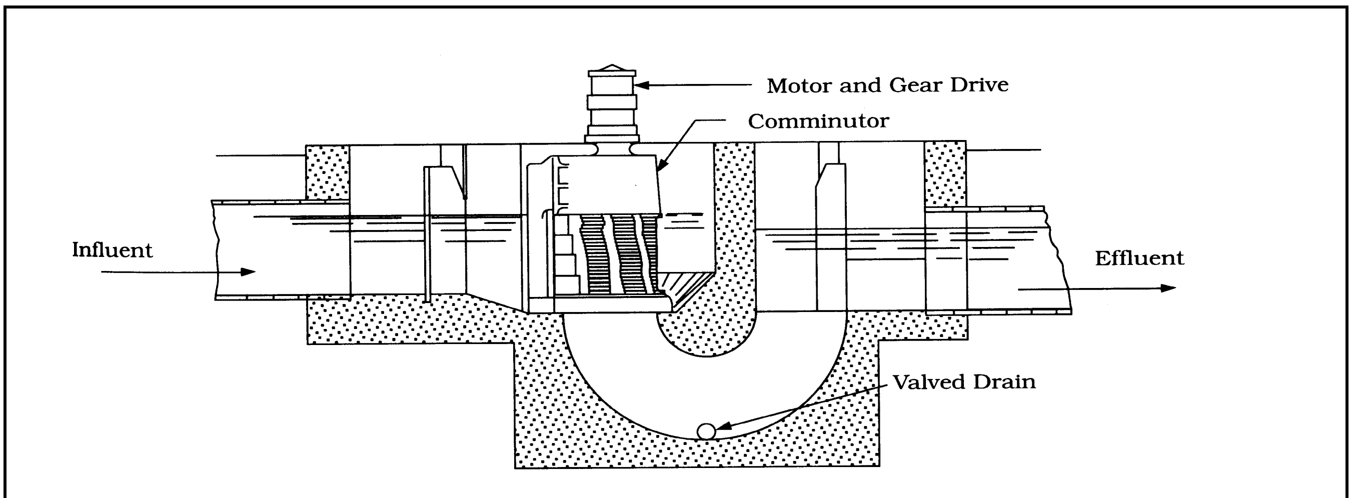
Grit Removal

With respect to grit removal systems, grit is traditionally defined as particles larger than 0.21 mm (0.008 in) (65 mesh) and with a specific gravity of greater than 2.65 (U.S. EPA, 1987). Equipment design was traditionally based on removal of 95 percent of these particles. However, with the recent recognition that smaller particles must be removed to avoid damaging downstream processes, many modern grit removal designs are capable of removing up to 75 percent of 0.15 mm (0.006 in) (100 mesh) material.

Aerated Grit Chamber

Aerated grit chambers are typically designed to remove particles of 70 mesh (0.21 mm/0.008 in) or larger, with a detention period of two to five minutes at peak hourly flow. When wastewater flows into the grit chamber, particles settle to the bottom according to their size, specific gravity, and the velocity of roll in the tank. A velocity that is too high will result in lower grit removal efficiencies, while a velocity that is too low will result in increased removal of organic materials. Proper adjustment of air velocity will result in nearly 100 percent removal of the desired particle size and a well-washed grit.

Design considerations for aerated grit chambers include the following (WEF 1998):



Source: Reynolds/Richards, 1996.

FIGURE 4 TYPICAL COMMINUTOR INSTALLATION

- Air rates typically range from 0.3 to 0.7 $m^3/m \cdot min$ (3 to 8 $ft^3/ft \cdot min$) of tank length.

- A typical minimum hydraulic detention time at maximum instantaneous flow is two minutes.

- Typical length-to-width ratio is 2.5:1 to 5:1.

- Tank inlet and outlet are positioned so the flow is perpendicular to the spiral roll pattern.

- Baffles are used to dissipate energy and minimize short circuiting.

Vortex-Type Grit Chamber

Two designs of vortex grit units exist: chambers with flat bottoms and a small opening to collect grit; and chambers with a sloping bottom and a large opening into the grit hopper. Flow into a vortex-type grit system should be straight, smooth, and streamlined. The straight inlet channel length is typically seven times the width of the inlet channel, or 4.6 m (15 ft), whichever is greater. The ideal velocity range in the influent is typically 0.6 to 0.9 m/s (2 to 3 ft/s) at 40 to 80 percent of peak flow. A minimum velocity of 0.15 m/s (0.5 ft/s) should be maintained at all times, because lower velocities will not carry grit into the grit chamber (WEF, 1998).

Detritus Tank

Detritus tanks are designed to keep horizontal velocity and turbulence at a minimum while maintaining a detention time of less than one minute. Proper operation of a detritus tank depends on well-distributed flow into the settling basin. Allowances are made for inlet and outlet turbulence as well as short circuiting by applying a safety factor of 2.0 to the calculated overflow rate.

Horizontal Flow Grit Chamber

Horizontal flow grit chambers use proportional weirs or rectangular control sections to vary the depth of flow and keep the velocity of the flow stream at a constant 0.3 m/s (1 ft/s). The length of the grit chamber is governed by the settling velocity of the target grit particles and the flow control section-depth relationship. An allowance for inlet and outlet turbulence is added. The cross sectional area of the channel is determined by the rate of flow and the number of channels. Allowances are made for grit storage and grit removal equipment. Table 4 lists design criteria for horizontal flow grit chambers.

TABLE 4 HORIZONTAL FLOW GRIT CHAMBER DESIGN CRITERIA

Item	Design Criteria	
	Range Metric (English)	Typical Metric (English)
Detention time	45-90 s	60 s
Horizontal velocity	0.24-0.4 m/s (0.8-1.3 ft/s)	0.3 m/s (1.0 ft/s)
Settling velocity[1]:		
50-mesh	2.8-3.1 m/min (9.2-10.2 ft/min)	2.9 m/min (9.6 ft/min)
100-mesh	0.6-0.9 m/min (2.0-3.0 ft/min)	0.8 m/min (2.5 ft/min)
Headloss (% of channel depth)	30-40%	36%[2]
Inlet and outlet length allowance	25-50%	30%

[1]If the specific gravity of the grit is significantly less than 2.65, lower velocities should be used.
[2]For Parshall flume control.

Source: Crites and Tchobanoglous, 1998.

PERFORMANCE

The use of screening and grit removal systems is well documented. The performance of bar screens varies depending on the spacing of the bars. Table 5 lists typical screening quantities for various screen sizes.

The quantity of screenings depends on the length and slope of the collection system and the presence of pumping stations. When the collection system is long and steep or when pumping stations exist, fewer screenings are produced because of disintegration of solids. Other factors that affect screening quantities are related to flow, as quantities generally increase greatly during storm flows. Peak

TABLE 5 SCREENING REMOVAL QUANTITIES

Screen Size	Screenings Quantity	
	$m^3/10^6\ m^3$	ft^3/Mgal
13 mm (0.5 in)	60	8
38 mm (1.5 in)	11.2	1.5

Source: Reynolds and Richards, 1996.

daily removals may vary by a 20:1 ratio on an hourly basis from average flow conditions. Combined collection systems may produce several times the coarse screenings produced by separate collection systems.

Given the complexity of collection systems and types of materials that may be considered "grit," the quantity and characteristics of grit removed from wastewater will vary. Grit quantity is influenced by the type and condition of the collection system, the characteristics of the drainage area, garbage disposal methods, the slope of the collection system, and the efficiency of the grit removal system. The quantity of grit may vary from 0.004 to 0.21 $m^3/10^3m^3$ (0.5 to 30 ft^3/Mgal) (Crites and Tchobanoglous, 1998). The performance of a grit removal system may be enhanced if actual plant data is used when designing a new grit removal system.

Table 6 depicts quantities of screenings and grit from various wastewater treatment plants. There are no obvious trends associated with design flow through a plant and grit and screenings removal quantities. Differences in wastewater characteristics and equipment efficiencies make a correlation between flow and quantities of screenings and grit removed nearly impossible.

OPERATION AND MAINTENANCE

Screening

Manually cleaned screens require frequent raking to prevent clogging. Cleaning frequency depends on the characteristics of the wastewater entering a plant. Some plants have incorporated screening devices, such as basket-type trash racks, that are manually hoisted and cleaned. Mechanically cleaned screens usually require less labor for operation than manually cleaned screens because screenings are raked with a mechanical device rather than by facility personnel. However, the rake teeth on mechanically cleaned screens must be routinely inspected because of their susceptibility to breakage and bending. Drive mechanisms must also be frequently inspected to prevent fouling due to grit and rags. Grit removed from screens must be disposed of regularly.

TABLE 6 GRIT AND SCREENINGS REMOVAL QUANTITIES AT VARIOUS PLANTS

Plant Location	Flow, m^3/d (MGD)	Grit, $m^3/10^3m^3$ (ft^3/Mgal)	Screenings, $m^3/10^3m^3$ (ft^3/Mgal)[a]
Uniontown, Pennsylvania	11,400 (3.0)	0.074 (10.5)	0.006 (0.9)
East Hartford, Connecticut	15,100 (4.0)	0.017 (2.4)	0.009 (1.33)
Duluth, Minnesota	45,400 (12.0)	0.006 (0.8)	0.004 (0.56)
Lamberts Point Water Pollution Control Plant, Norfolk, Virginia	75,700 (20.0)	0.034 (4.85)	0.009 (1.20)
Village Creek Wastewater Treatment Plant, Ft. Worth, Texas	170,000 (45.0)	0.009 (1.29)	0.005 (0.72)
County of Milwaukee, Wisconsin, South Shore	454,000 (120.0)	0.003 (0.48)	0.004 (0.60)
Twin Cities Metro Wastewater Treatment Plant, Minnesota	825,000 (218.0)	0.034 (4.82)	0.008 (1.15)
Chicago, Illinois (Northside)	1,260,000 (333.0)	0.003 (0.41)	0.006 (0.83)

[a] ft^3/Mgal=cubic feet per million gallons

Source: WEF, 1998.

Communitors and Grinders

Comminutors can create operation and maintenance problems in downstream processes. While shredding solids eliminates the problem of handling screening materials at the head of the plant, problems inherent to the use of communitors, such as the decreased quality of digested biosolids and the accumulation of rags on air diffusers, have lessened the popularity of this technology. Comminutors are generally avoided in new designs and are being removed from many existing plants. Grinders are greatly affected by grit and other solids. As such, they require routine inspection every six months and replacement of bearings and cutter teeth every one to three years.

Grit Removal

Collected grit must be removed from the chamber, dewatered, washed, and conveyed to a disposal site. Some smaller plants use manual methods to remove grit, but grit removal is usually accomplished by an automatic method. The four methods of automatic grit removal include inclined screw or tubular conveyors, chain and bucket elevators, clamshell buckets, and pumping. A two-step grit removal method is sometimes used, where grit is conveyed horizontally in a trough or channel to a hopper, where it is then elevated from the hopper to another location.

Aerated grit chambers use a sloped tank bottom in which the air roll pattern sweeps grit along the bottom to the low side of the chamber. A horizontal screw conveyor is typically used to convey settled grit to a hopper at the head of the tank. Another method to remove grit from the chamber floor is a chain and flight mechanism.

Once removed from the chamber, grit is usually washed with a hydrocyclone or grit classifier to ease handling and remove organic material. The grit is then conveyed directly to a truck, dumpster, or storage hopper. From there, the grit is taken to a landfill or other disposal facility.

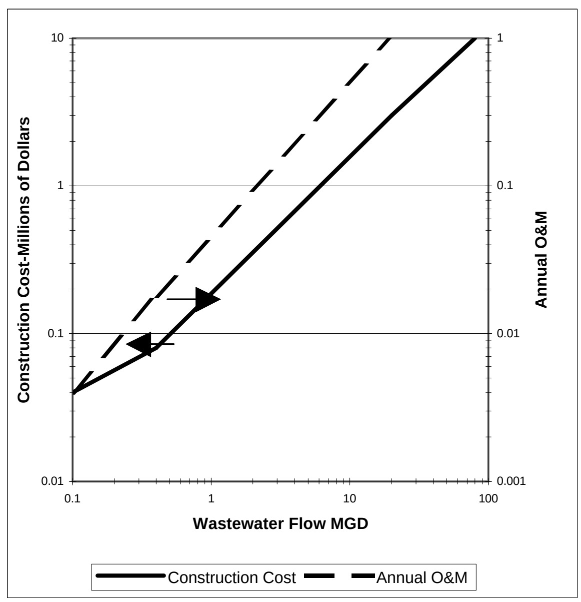
COSTS

The cost of screens and grit removal systems varies depending on the type of technology used, ancillary equipment, and applicability of various technologies to different situations.

Graphs can be used to relate average wastewater flow through a plant to a specific technology. Figure 5 shows a graph relating wastewater flow to the cost of a horizontal shaft rotary screen. Costs include construction, operation, and maintenance. Contractor bids on a recent wastewater project ranged from $150,000 to $400,000 for Rotary Drum Screenings Removal and from $150,000 to $208,800 for Vortex-type Grit Removals. Generally, equipment costs will be close for each bid. However, the overall costs vary for each treatment process/project because of differences in construction approaches by the contractors.

REFERENCES

Other Related Fact Sheets



Source: Martin, 1991.

FIGURE 5 COST CURVE FOR HORIZONTAL SHAFT ROTARY SCREEN

Sewer Lift Station
EPA 832-F-00-073
September 2000

Sewer Cleaning & Inspection
EPA 832-F-99-031
September 1999

Screens
EPA 832-F-99-040
September 1999

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owm/mtb/mtbfact.htm

1. Crites, R. and G. Tchobanoglous, 1998. *Small and Decentralized Wastewater Management Systems*. The McGraw-Hill Companies. Boston, Massachusetts.

2. Martin, E.J. and E.T. Martin, 1991. *Technologies for Small Water and Wastewater Systems*. Van Nostrand Reinhold. New York, New York.

3. Qasim, S., 1994. *Wastewater Treatment Plants: Planning, Design and Operation*. Technomic Publishing Co., Lancaster, Pennsylvania.

4. Reynolds, T. and P. Richards, 1996. *Unit Operations and Processes in Environmental Engineering*. PWS Publishing Company. Boston, Massachusetts.

5. Urquhart, L., 1962. *Civil Engineering.* Costs include construction, operation, and maintenance. Specific cost data from contractor bids.

6. Water Environment Federation, 1998. *Design of Municipal Wastewater Treatment Plants.* Water Environment Federation. Alexandria, Virginia.

ADDITIONAL INFORMATION

H.I.L. Technology, Inc.
94 Hutchins Drive
Portland, ME 04102

Lakeside Equipment Corporation
1022 E. Devon Ave.
Bartlett, IL 60103

National Small Flows Clearing House
at West Virginia University
P.O. Box 6064
Morgantown, WV 26506

Parkson Corporation
2727 NW 62nd Street
P.O. Box 408399
Fort Lauderdale, FL 33340-8399

U.S. Filter
Link-Belt Headworks Products
100 High Point Drive - Suite 101
Chalfont, PA 18914

Office of Water
EPA 832-F-03-011
June 2003

For more information contact:

Municipal Technology Branch
U.S. EPA
Mail Code 4204
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460

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CHAPTER 4

Preliminary and Pretreatment Facilities

PRELIMINARY AND PRETREATMENT FACILITIES

4.1 Screening and Grinding

4.1.1 General

Some type of screening and/or grinding device shall be provided at all mechanical wastewater plants. The effective removal of grit, rocks, debris, excessive oil or grease and the screening of solids shall be accomplished prior to any activated sludge process. Any grinding which does not dispose of the shredded material outside of the wastewater stream must be evaluated with regard to the influent characteristics (rags, combined sewers) of the waste prior to any activated sludge process.

4.1.2 Location

4.1.2.1 Indoors

Screening devices installed in a building where other equipment or offices are located shall be accessible only through an outside entrance. Adequate lighting, ventilation and access for maintenance or removal of equipment and screenings shall be provided.

4.1.2.2 Outdoors

The removal point for screenings should be as practical as possible for the plant personnel, preferably at ground level. Ladder access is not acceptable unless hoisting facilities for screenings are provided. Separate hoisting is not required for bar screens in manual bypass channels.

4.1.2.3 Deep Pit Installations

Stairway access, adequate lighting and ventilation with a convenient and adequate means for screenings removal shall be provided.

4.1.3 Bar Screens

4.1.3.1 Manually Cleaned

Clear openings between bars shall be from 1 to 2 inches. Slope of the bars shall be 30 to 60 degrees from the vertical. Bar size shall be from 1/4 to 5/8 inches with 1 to 3 inches of depth, depending on the length and material to maintain integrity. A perforated drain plate shall be installed at the top of the bar screen for temporary storage and drainage.

4.1.3.2 Mechanically Cleaned

Mechanically cleaned bar screens are recommended for all plants greater than 1 MGD. Both front cleaned or back cleaned models may be acceptable. Clear openings no less than 5/8 inch are acceptable. Protection from freezing conditions should be considered.

Other than the rakes, no moving parts shall be below the water line.

4.1.3.3 Velocities

Approach velocities no less than 1.25 fps nor a velocity greater than 3.0 fps through the bar screen is desired.

4.1.4 Fine Screens

4.1.4.1 General

Fine screens shall be preceeded by a trash rack or coarse bar screen. Comminution shall not be used ahead of fine screens. A minimum of two fine screens shall be provided, each capable of independent operation at peak design flow. The design engineer must fully evaluate a proposal where fine screens are to be used in lieu of primary sedimentation. Fine screens shall not be considered equivalent to primary sedimentation or grit removal, but will be reviewed on a case-by-case basis. Oil and grease removal must be considered.

4.1.4.2 Design

The operation should be designed to not splash operating personnel with wastewater or screenings. Fine screens will generally increase the dissolved oxygen content of the influent which may be beneficial in certain circumstances. The screens must be enclosed or otherwise protected from cold weather freezing conditions. Disposal of screenings must be addressed. To be landfilled, screenings must be dried to approximately 20% solids. Odors may be a problem in sensitive locations.

4.1.5 Comminution

4.1.5.1 General

In-line comminution may not be acceptable prior to an activated sludge process for facilities with a history of problems with rags. Out-of-stream comminution or disintegration is acceptable for activated sludge processes; however, screenings should not return to the wastewater stream.

4.1.5.2 Design

A coarse bar screen with an automatic bypass shall precede comminution for all mechanical plants. Gravel traps shall precede comminution which is not preceded by grit removal. Clear openings of 1/4 inch are prefered in the comminution device. An automatic unit bypass or other means of protection shall be provided to protect the comminutor motor from flooding. The design shall incorporate a method for removing the equipment from service and for repairs or sharpening of the teeth.

4.1.6 Operability

All screening devices shall have the capability of isolation from the wastewater stream. Sufficient wash water shall be available for cleanup of the area. All mechanical screening devices shall be provided with a manually cleaned bar screen bypass. Multiple bar screens should be considered for plants with rag problems instead of comminutors.

Adequate space must be provided for access to each screening or comminution device. This is critical in elevated, indoor or deep pit installations.

4.1.7 Disposal

All screenings shall be disposed of in an approved manner. Suitable containers shall be provided for holding the screenings. Run-off control must be provided around the containers, where applicable. If fine screens are proposed, consideration must be given to the wastewater overflow if the screens clog or blind. Overflows must be contained and bypassed around the screens by dikes or other means.

4.2 Grit Removal

4.2.1 General

Grit removal is recommended for all mechanical wastewater plants and is required in duplicate for plants receiving wastewater from combined sewers. Systems with a history of substantial grit accumulations may be required to provide for grit removal. Where a system is designed without grit removal facilities, the design shall allow for future installation by providing adequate head and area. Grit washing may be required.

4.2.2 Location

Wherever circumstances permit, grit removal shall be located prior to pumps and comminution when so equiped. Bar screens shall be prior to grit removal. Adequate lighting, ventilation and access for maintenance and removal of grit shall be provided. Stairway access is required if the chamber is above or below ground level. Adequate and convenient means of grit removal shall be provided.

4.2.3 Design

4.2.3.1 Channel Type

A controlled velocity of one foot per second is recommended. Control by either sutro or proportional weir should be used. If a Parshall flume is used for control, the grit chamber must be designed to approach a parabolic cross-section. The length of the channel depends on the size of grit to be removed. The design engineer shall provide this information. Inlet and outlet turbulence must be minimized.

4.2.3.2 Square Type

Square-type basins or similar arrangements should be sized for an overflow rate of 46,300 (WPCF) gallons per day per square foot at the peak flow based on 65-mesh grit at a specific gravity of 2.65. Other overflow rates may be used when the design incorporates particle travel distance and detention. Inlet and outlet turbulence must be minimized.

4.2.3.3 Aerated Type

Aerated grit chambers shall be designed on the basis of detention and/or particle travel distance. Detention time of 2-5 minutes at peak flow is acceptable. Control of the air shall be provided for flexibility. Skimming equipment must be provided in the aerated grit chamber if the outlet is below the water surface.

4.2.3.4 Other Types

Cyclone or swirl-type grit removal processes may be acceptable. The design engineer will be expected to provide a complete treatment analysis for approval.

4.2.4 Disposal

Temporary storage containers shall be provided to hold the grit. Run-off control shall be provided. Attention should be given to operations which may splash waste or grit on operating personnel. Grit washing is required before removal to drying beds. If not washed, the grit shall be disposed of in an approved landfill.

4.2.5 Operability

Adjustable control valves shall be included in each diffuser air line to control mixing and particle segregation. Variable speed arrangements should be provided in cyclone or mechanical type systems. Provisions shall be made for isolation and dewatering each unit or units.

4.3 Pre-Aeration

Pre-aeration is desirable in certain instances, such as to reduce septicity. Pre-aeration may be required where pressure or small diameter collection systems are used. Long detention times in pump stations or collection lines should also be considered. Units shall be designed so that removal from service will not interfere with normal plant operations.

4.4 Flow Equalization

4.4.1 General

Equalization may be used to minimize random or cyclic peaking of organic or hydraulic loadings when the total flow is ultimately processed through the plant. Either in-line or side-line equalization is acceptable. Equalization may be required where peak flows are greater than 2 times the average design flow.

4.4.2 Location

Tanks are generally located after screening and grit removal. Care should be taken in design to minimize solids deposition if located upstream of primary clarifiers. Equalization downstream of primary clarifiers should be investigated, as primary clarifier performance is less sensitive to flow peaking when compared to other processes. Other locations will be evaluated on a case-by-case basis.

4.4.3 Design and Operability

Generally, aeration will be required. Minimum requirements are to maintain 1.0 mg/l of dissolved oxygen. Odor consideration must be addressed when a plant is located in a sensitive area or large equalization basins are used. Large tanks must be divided into compartments to allow for operational flexibility, repair and cleaning. Each compartment shall be capable of dewatering and access. In plant upgrades, existing units which are otherwise to be abandoned may be used for equalization, where possible. Sizing the tankage and compartments will depend on the intended use; i.e., when equalization is for periodic high organic loadings, peak flow events, toxics, etc. A complete analysis shall accompany all engineering report (or plan) submission.

The tank must be capable of being drained and isolated. Controlling the flow rate from the equalization tank to the plant is desirable.

4.5 Swirls and Helical Bends

These units are not to be used in lieu of primary clarification unless special design considerations are used. They are primarily designed for 'coarse' floating and settleable solids removal and will be considered only on a case-by-case basis for in-plant processes. They will, however, be approved for replacing regulators in combined sewer systems, as an interim measure until separation of the sanitary and storm flows is completed. Treatability studies will be required as part of the design. A separate NPDES permit will be required for each of these units that will discharge to a surface water.

Section 3
Flow Measurement

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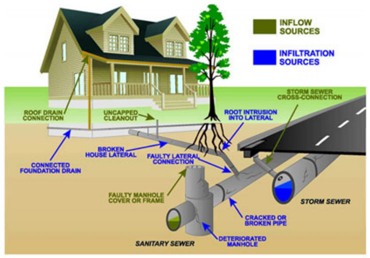
TN Department of Environment & Conservation

Section 3
Flow Measurement

Sources of Flow

- Sanitary Sewer
  - Domestic
  - Industrial waste
- Storm Sewer
  - Stormwater (snow melt, rain, etc.)
- Combined sewer
  - Sanitary + Storm
- **Inflow and Infiltration (I&I)**
  - groundwater into sewer system
  - direct discharge into sewer system

Note



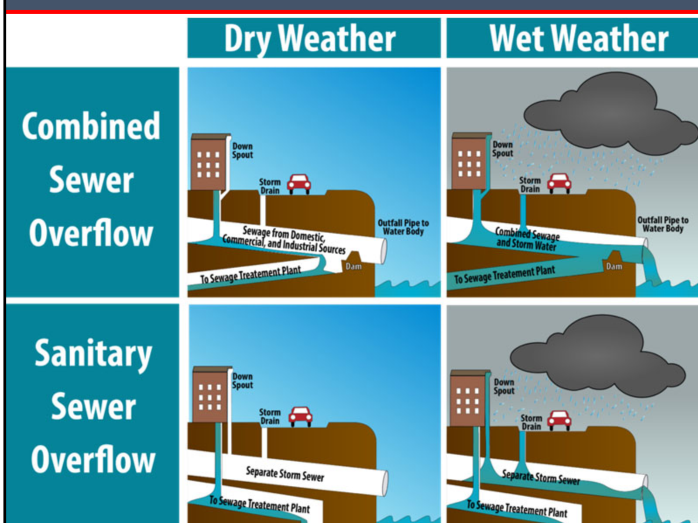
Infiltration

- The seepage of groundwater into a sewer system, including service connections.
- Seepage frequently occurs through defective or cracked pipes, pipe joints and connections, interceptor access risers and covers, or manhole walls

Inflow

- Water discharged into sewer system and service connections from sources other than regular connections.
- Inflow differs from infiltration in that it's a direct discharge into the sewer rather than a leak in the sewer itself.
- Ex: yard drains, foundations, manhole covers

Combined vs. Sanitary



Flow Measurement

Flow is the amount of water passing a reference point over a certain time

Q = AV

Q = Flow (volume through a system)

A = Area (cross-sectional)

V = Velocity of flow

Units include cfs (ft^3/sec), gpm, MGD, etc.

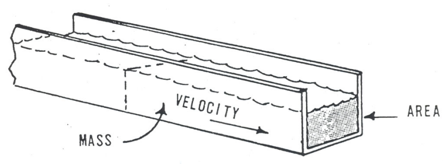


Fig. 15.57 Flow mass

Why Measure Flow?

TN Rules and Regs!!!

- NPDES permits
  - Flow-proportional composite sampling
- Process Control
  - adjust process equipment
  - chemical feed systems
  - pumping rates
  - aeration rates
  - determine when system is at capacity
  - calculation of loadings
  - identify, correct, and prevent operational problems

Flow Measurement

2 basic types of flow measurement:

Open Channel

Assume a constant **velocity** created by the geometry or shape of the device and measure the change in cross-sectional area that the flow occupies

Closed Pipe

Assume a constant **area** and measure velocity through a variety of different methods

Open Channel Flow Measurement

2 primary measuring devices

Weirs

Obstruction that stretches across the entire channel

Flumes

Specially shaped open channel flow section that restricts the channel area and/or changes the slope, resulting in an increased velocity and a change in the level of liquid flowing through the flume

Weirs

2 primary measuring devices

Open Channel Flow Measurement: Weirs

4 most common types:

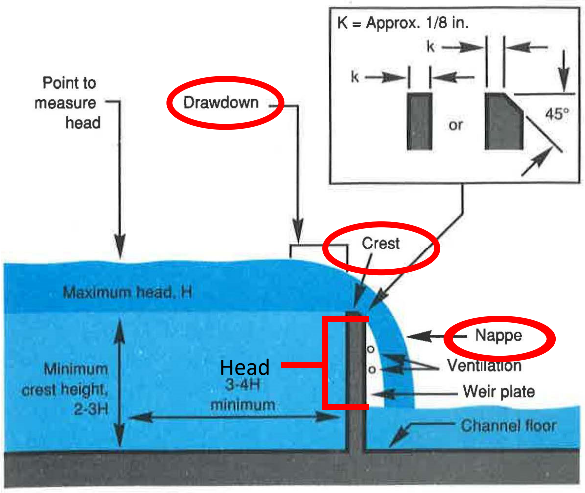
Triangular (V-notch) Weirs

Rectangular Weir with end constrictions

Rectangular Weir without end constrictions

Trapezoidal (Cipolletti) Weir

Open Channel Flow Measurement: Weirs



Weir terminology:

Head: the liquid depth from crest to liquid surface in pool upstream from the crest

Drawdown: slope from highest water depth to the weir opening

Crest: the edge or surface over which the water passes

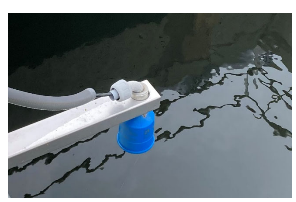
Nappe: the stream of water leaving the weir crest

Open Channel Flow Measurement: Weirs

Head is typically measured with staff gauge or ultrasonic level sensor

Staff Gauge

- Similar to a ruler or yard stick with markings for depth
- Permanently installed to the side of the channel

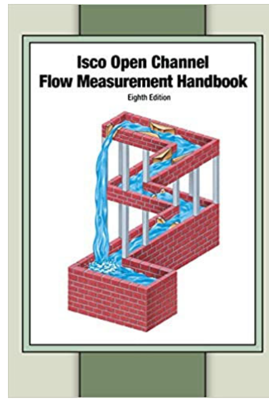


Ultrasonic Level Sensor

- Transmits a pulse of sound from sensor suspended above channel to surface of water and then measuring the time for the echo to return
- Changes in air temp, surface foams, mist, and fog can adversely affect level measurements
- A distance 3 to 4 times the maximum expected head back from weir edge is recommended

Open Channel Flow Measurement: Weirs

- Each weir type has a different calculation that is used to estimate the amount of flow passing over it
- Calculations based on water depth and head that builds up behind the weir
- Calculations specific to the length of the weir and its shape



Open Channel Flow Measurement: Weirs

- Inexpensive to install and low cost compared to other flow measurement
- Can trap foam and solids behind weir
- Must be cleaned periodically
- Unsuitable for channels carrying large quantities of debris – good for final effluent

Flumes

2 primary measuring devices

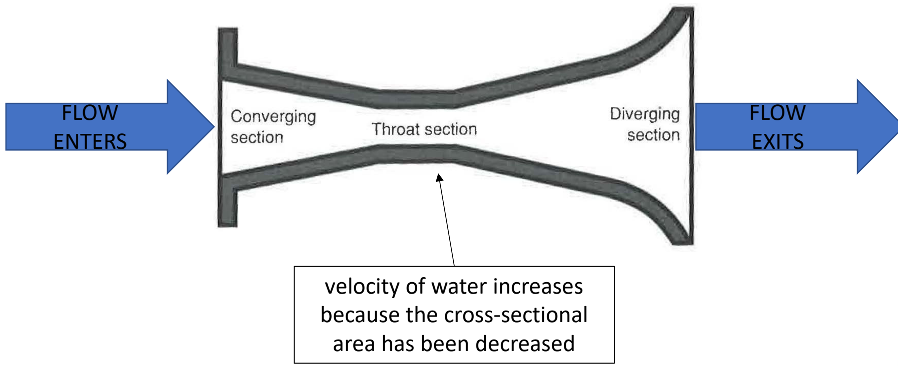
Open Channel Flow Measurement: Flumes

Specially shaped open channel flow section that restricts the channel area and/or changes the slope, resulting in an increased velocity and a change in the level of liquid flowing through the flume.

- Constriction causes a change in head which can be converted to flow rates

Open Channel Flow Measurement: Flumes

Flumes consist of 3 sections:



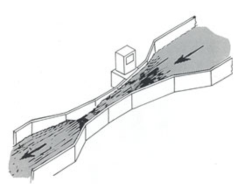
Open Channel Flow Measurement: Flumes

3 most common types:

Palmer-Bowlus Flume
- Originally designed for measuring flows in existing pipes and channels
- Widely used for measuring flows in manholes

https://tracomfrp.com/palmer-bowlus-flume-errors/

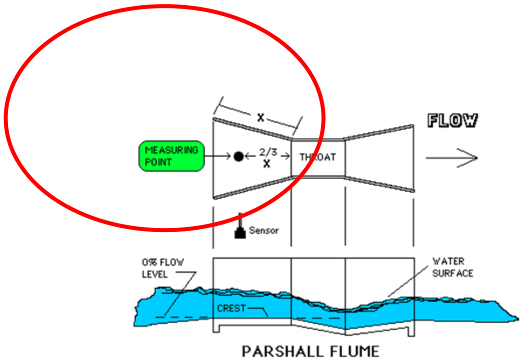
Parshall Flume
- Most widely used
- Available in a variety of sized to accommodate most flowrates



Trapezoidal Flume
- Work well for measuring flows over a wide range
- Well suited for extremely low flows

https://tracomfrp.com/benefits-of-trapezoidal-

Open Channel Flow Measurement: Flumes



Closed Pipe Flow Measurement

Remember..

Closed pipe flow measurement assumes a constant **area** and measures velocity through a variety of different methods

5 classes of closed pipe flow meters in wastewater

- Differential head
- Mechanical
- Magnetic
- Ultrasonic
- Mass flow ← Not discussed in references!

Common in:

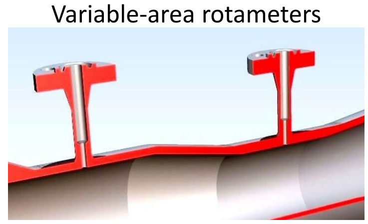
- Primary Sludge Flow
- Return Activated Sludge (RAS) Flow
- Waste Activated Sludge (WAS) Flow

Closed Pipe Flow Measurement: Differential Head

- Use in-pipe constriction that produces a temporary and measurable pressure drop across it
- Require clear pipe taps both upstream and downstream of constriction
- Routine maintenance: clearing the taps by blowing them out and removing accumulated moisture (gas applications)

Types

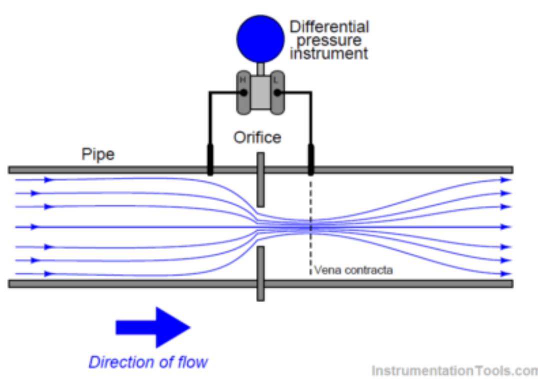
Orifice plates
Venturi tubes
Nozzles
Pitot tubes
Variable-area rotameters



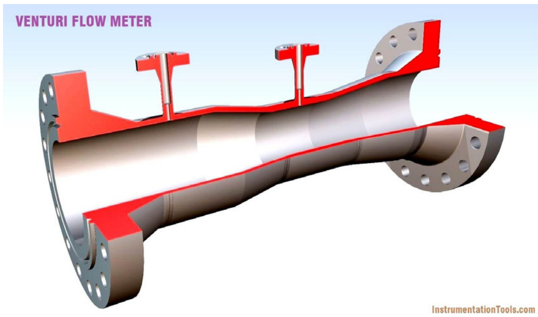
⚠ clean liquids and gases (biosolids)

Closed Pipe Flow Measurement: Differential Head: Orifice Plate

- Thin metal plate with a hole bored through the middle
- The upstream side has a sharp edge that creates a pressure drop as the flow moves through the hole
- Work well for large pipe diameters, have no moving parts, and are relatively low cost
- Can not be used for with dirty liquids because solids will erode the metal and change the pressure drop



Closed Pipe Flow Measurement: Differential Head: Venturi Tube



SAC Advanced Treatment: at least 5 pipe-diameters distance downstream from any pipe bends, elbows, or valves and at least 2 pipe-diameters distance upstream from any pipe bends, elbows, or valves

Pipe diameter gradually reduces at the throat and returns to original diameter

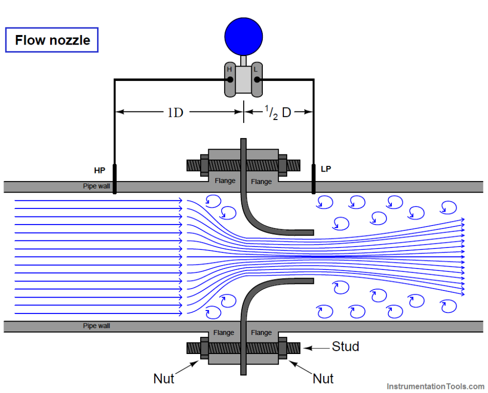
Low pressure is created in throat

Difference in pressure indicates amount of flow

Simple and inexpensive

Need straight runs of pipe before and after for accurate flow readings

Closed Pipe Flow Measurement: Differential Head: Nozzles



Same concept as orifice plate – pressure drop is created as flow moves through the throat

High pressure and temperature steam flows (biosolids)

Compact; requires less upstream piping than orifice plate

More difficult to install than orifice plate

Closed Pipe Flow Measurement: Differential Head: Pitot Tube

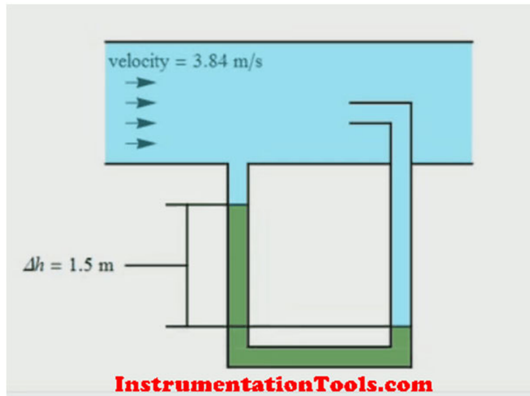
Insertion flowmeter

A pressure generated in a tube facing the flow by the velocity of the fluid

Velocity pressure is compared against reference (static) pressure in the pipe

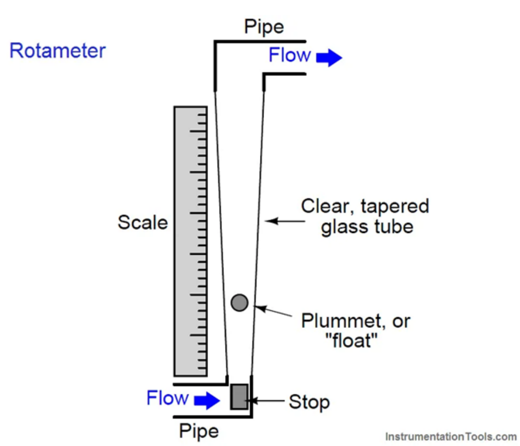
Mathematical equation is used to determine velocity

Right side measures total pressure, left side measures static pressure

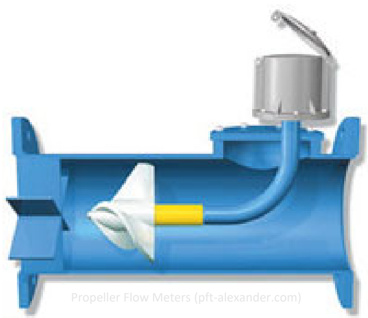


Closed Pipe Flow Measurement: Differential Head: Rotameter

- Float or ball in vertical tube
- Increased flow causes float to ride higher
- Simple, accurate, easy
- Must keep tube and float clean
- Used in chemical feed systems



Closed Pipe Flow Measurement: Mechanical



Propeller Flow Meters (pft-alexander.com)

Most common: Propeller Meter

- Liquid impacting a propeller causes rotation at a speed proportional to flowrate
- Propeller is linked mechanically to an indicator and often to a totalizer or transmitter
- Requires low suspended solids and debris
- Needs to be mounted sufficiently far downstream of any flow inputs to ensure laminar flow

Closed Pipe Flow Measurement: Electromagnetic

"Magnetic Flow Meter"

Application range from filtered effluent to thickened or digested solids

Creates magnetic field in water stream

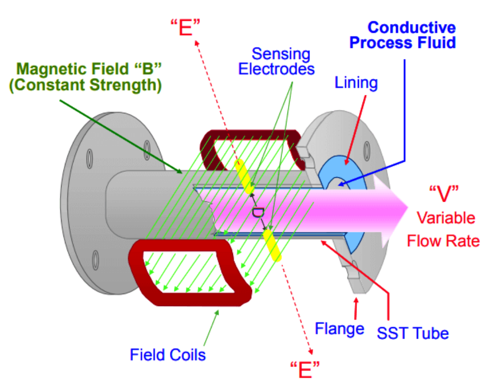
Conductor (water) moving through magnetic field produces electric current

Measure of electricity indicates amount of flow

Require full pipe

Very accurate, low maintenance

Expensive



Magnetic Flow Meter Corrosion Effects - InstrumentationTools

Closed Pipe Flow Measurement: Ultrasonic

Measurement of ultrasonic wave-transit time or frequency shift caused by the flowing fluid

Ultrasonic waves of known frequency and duration are beamed across the pipe at known angles

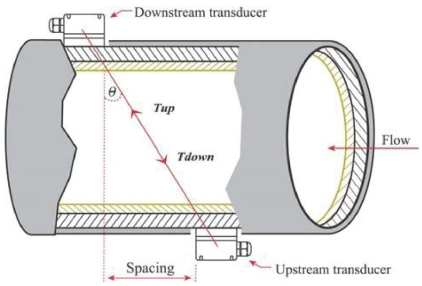
Waves are sensed either:

- directly by an opposing receiver
- indirectly as reflected waves

The changes in wave transit time or frequency are linearly proportional to the liquid velocity = math

Presence or absence of air bubbles and density of solids affect metering

"clamp on"



Type	Accuracy	Advantages	Disadvantages
Open-Channel Flume	5-7%	Low headloss, self-cleaning	Requires careful construction, susceptible to flooding
Open-Channel Weir	5-7%	Low cost, ease of installation	High headloss, requires a well-developed flow profile, cleaning required
Full-Pipe Electro-magnetic	1-3%	No headloss, bi-directional	Minimum conductivity required, expensive, well-developed velocity profile required
Full-Pipe Doppler	2-5%	No headloss, low cost, not affected by air bubbles	Not suitable for some pipe material, well-developed velocity profile required
Full-Pipe Venturi	1-3%	Low headloss, high accuracy	Expensive, well-developed velocity profile required

Source: MOP No. 11 – Operation of Municipal Wastewater Treatment Plants

Primary vs. Secondary Flow Measurement

Primary Flow Metering (1°)

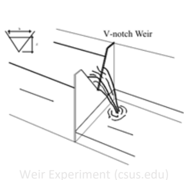
- Used for measuring and reporting flows for permit compliance
- Influent or effluent
- "Instantaneous flow" measurements can be obtained from primary flow device
- Ex: weirs, flume

All flow measurement devices should be calibrated and maintained to ensure the accuracy of the measurement is ± 10% of the true flow.

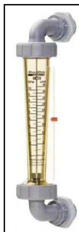
Secondary Flow Metering (2°)

- Required for process control but not NPDES Permit
- Completed within treatment plant
- Return Activated Sludge (RAS)
- Wasted Activated Sludge (WAS)
- Side stream flows (digesters, centrifuges, solid filter presses)
- Measures hydraulic responses of the primary flow measurement device
- Ex: float, ultrasonic meter, staff gauge

Types of Flow Instruments/Meters

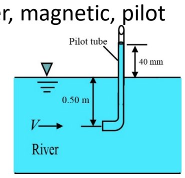


Head Area: a mechanical constriction or barrier is placed in the open flow line causing an upstream rise (head) in water level. The head is mathematically related to flow.



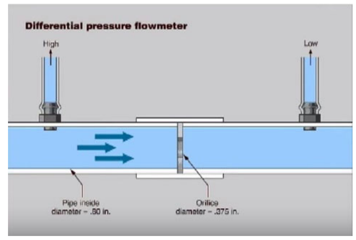
Constant differential: a float is placed in a tapered tube in the flow line. The difference in pressures above and below the float causes the flow to move with flow variations

Velocity Meter: the velocity of water flowing through a given area is directly related to flow rate (propeller, magnetic, pilot tube)



Types of Flow Instruments/Meters

Differential Producers: a mechanical constriction inside a pipe (reduction in pipe diameter) that causes the velocity of flow to increase, creating a pressure drop. The difference between line pressure at meter inlet and reduced pressure at throat determines flow rate



BiRotor Mechanical Positive Displacement Flow Meters - Models B13X & B23X (pft-alexander.com)

Displacement Units: water or gas enters and fills a tanks of known dimensions, activates a mechanical counter, and empties the tanks for another filling. Flow rate can be calculated using the size of the tanks and the time factor it takes to empty the tank

Type	Common Name	Application
Constant differential	Rotameters	Liquids and gases (Ex: Chlorination)
Head area	Weirs Flumes	Liquids – Partially filled channels, basins, clarifiers Liquids – Partially filled pipes and channels
Velocity meters	Propeller Magnetic	Liquids – channel flow, clean water piped flow Liquids and sludge in closed pipes
Differential producers	Venturi tube Flow nozzle Orifice	Gases and liquids in closed pipes
Displacement units	Piston Diaphragm	Gases and liquids in closed pipes

*See Table 15.10 in Operation of Wastewater Treatment Plants, Vol II for complete table

Level Measuring Devices

A **float**, in combination with either a cable and pulley or a pivoting arm, measures the water level in primary (1°) measuring devices (flume or weir)

- Recommended use in combination with a stilling well
- Simple, inexpensive
- Grease or debris may accumulate

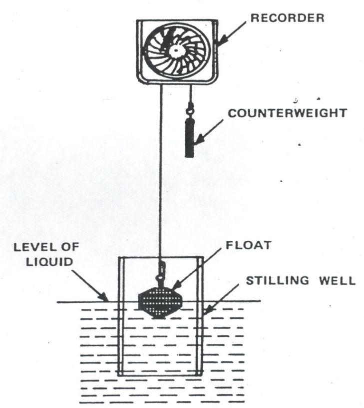


Fig. 6.12 A float is used to measure liquid level and convert the level reading to a flow measurement

Level Measuring Devices

A **stilling well** is a chamber connected to the main flow channel by a small inlet.

ISCO recommends the installation of a stilling well in primary (1°) measuring devices (those using Floats)

To aid in the zero adjustment of the flow meter, ISCO recommends that every primary measuring device include a **staff gauge**.

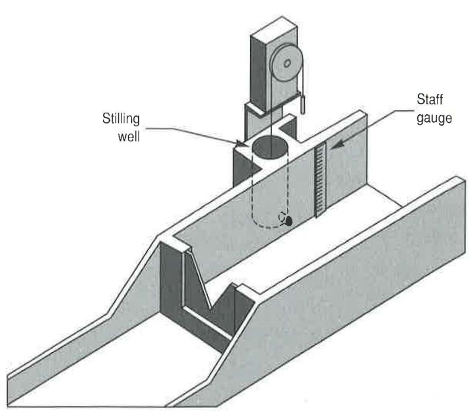


Figure 7-1: Flow measurement system with stilling well and staff gauge

Level Measuring Devices

Bubbler System

Depth measurement based on the amount of pressure required to force air through tube to create bubbles

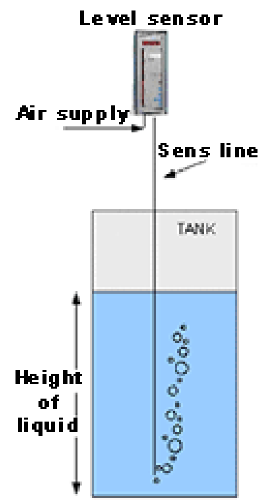
Constant flow of air

Suitable for small channels

Very accurate

Line can become clogged

Recommended for liquid with heavy foam



Flow Equalization

Reducing flow fluctuations
- Temporarily store influent wastewater during peak flows

- High flows can be managed by using:
  - Flow-equalization basins
  - Storage lagoons
  - Alternate process modes such as contact stabilization or step feed
- Locations can include:
  - Before preliminary treatment
  - Directly after preliminary treatment
  - Immediately after primary treatment

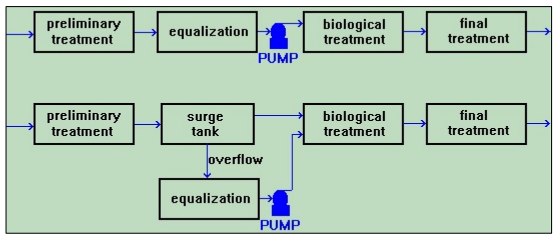
DO must be 1.0 mg/L

TN Design Criteria!!!

Flow Equalization

2 common methods:

In-line:
- All flow enters EQ basin before entering biological treatment
- Discharges at the average flow rate



Side-line:
- Only flow greater than daily average is diverted to EQ basin
- Wastewater released from basin when plant flows are below average

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Flow Vocabulary

1. The amount of water passing a reference point over a certain amount of time is _________________.

2. An ________________________________ is any channel in which the liquid flows with a free or uncovered surface.

3. An obstruction or dam built across an open channel over which the water flows, often through a specially shaped opening or notch is called a ______________________________.

4. A _________________________ is a specially shaped open channel flow section that restricts the channel area and/or changes the slope, resulting in an increased velocity and a change in the level of liquid flowing through it.

5. The _______________________________flume is most commonly used to retrofit manholes.

6. The ______________________________of a flume restricts flow. Velocity is increasing in this area.

7. The _______________ is the section of a flume that creates a hydraulic jump transition from higher velocity to slower velocity. It produces a head that is related to the discharge.

8. A ____________________________________ is any channel in which flow is in a completely filled pressure conduit (a.k.a. pipes). This includes sewer lines running full or force mains.

9. Weirs, flumes, and nozzles are all examples of ________________________________ measuring devices.

10. The _____________________________ section of the flume is where water returns to original shape of channel, it assures the downstream level is less than the level in the converging section.

11. This type of flume is best for wastewater containing solids and debris. ________________________________

12. ____________________________________ is an indirect measure of loss of energy or pressure. Flowing water will lose some of its energy when it passes through a pipe, bar screen, Comminutor, filter or other obstruction. This is measured as the difference in elevation between the upstream water surface and the downstream water surface and may be expressed in feet or meters.

13. Open channel flow meters, such as floats, ultrasonic meters, and bubbler systems, are all examples of __________________________________ measuring devices.

14. Adequate aeration and mixing must be provided in the _____________________________basin to keep the basins aerobic and prevent solids deposition. A DO of 1.0 mg/L must be maintained throughout.

Word Bank

Flow

Diverging

Palmer-Bowlus

Flume

Headloss

Parshall

Primary (1°)

Weir

Throat

Flow equalization

Open channel

Closed channel

Converging section

Secondary (2°)

CHAPTER 13

Plant Flow Measurement and Sampling

PLANT FLOW MEASUREMENT AND SAMPLING

13.1 Purpose

Complete and accurate flow measuring and sampling are essential in the proper treatment of wastewater. Compliance with discharge limits requires proper flow measurement and sampling. They provide the operator with the information to optimize process control and operational costs, as well as providing an accurate data base of flows and process performance which can be used to analyze changes in operational strategy or assist future plant design.

13.2 Flow Measurement

13.2.1 General Considerations

13.2.1.1 Facilities for measuring the volume of sewage flows should be provided at all treatment works.

13.2.1.2 Plants with a capacity equal to or less than 100,000 gallons per day (gpd) shall be equipped, as a minimum, with a primary metering device such as: a Parshall flume having a separate float well and staff gauge, a weir box having plate and staff gauge, or other approved devices. Continuous recording devices may be required where circumstances warrant.

13.2.1.3 Plants having a capacity of greater than 100,000 gpd shall be provided with indicating, recording, and totalizing equipment using strip or circular charts and with flow charts for periods of 1 or 7 days. The chart size shall be sufficient to accurately record and depict the flow measured.

13.2.1.4 Flows passed through the plant and flows bypassed shall be measured in a manner which will allow them to be distinguished and separately reported.

13.2.1.5 Measuring equipment shall be provided which is accurate under all expected flow conditions (minimum initial flow and maximum design peak flow). The accuracy of the total flow monitoring system (primary device, transmitter, and indicator) must be acceptable. The effect of such factors as ambient temperature, power source voltage, electronic interference, and humidity should be considered. Surges must be eliminated to provide accurate measurement.
Two primary devices and flow charts may be required in some cases.

13.2.1.6 Metering devices within a sewage works shall be located so that recycle flow streams do not inadvertently affect the flow measurement. In some cases, measurement of the total flow (influent plus recycle) may be desirable.

13.2.1.7 All clarifiers must be provided with a means for accurate flow measurement of sludge wasting and sludge return lines so that solids handling can be controlled. Sludge digesters, thickeners, and holding tanks should be provided with some way to determine the volume of sludge added or removed. This can be accomplished by a sidewall depth scale or graduation in batch operations.

13.2.1.8 Flow meter and indicator selection should be justified considering factors such as probable flow range, acceptable headloss, required accuracy, and fouling ability of the water to be measured. For more detailed information the consultant is encouraged to read the EPA Design Information Report "Flow Measurement Instrumentation"; Journal WPCF, Volume 58, Number 10, pp. 1005-1009. This report offers many installation details and considerations for different types of flow monitoring equipment.

13.2.1.9 Flow splitter boxes shall be constructed so that they are reliable, easily controllable, and accessible for maintenance purposes.

13.2.1.10 Where influent and effluent flow-proportional composite sampling is required, separate influent and effluent flow measuring equipment is required.

13.2.1.11 Consideration should be given to providing some types of flow meters with bypass piping and valving for cleaning and maintenance purposes.

13.2.2 Parshall Flumes

Parshall Flumes are ideal for measuring flows of raw sewage and primary effluents because clogging problems are usually minimal.

The properly sized flume should be selected for the flow range to be encountered. All Parshall Flumes must be designed to the specified dimensions of an acceptable reference.

The following requirements must be met when designing a Parshall Flume.

13.2.2.1 Flow should be evenly distributed across the width of the channel.

13.2.2.2 The crest must have a smooth, definite edge. If a liner is used, all screws and bolts should be countersunk.

13.2.2.3 Longitudinal and lateral axes of the crest floor must be level.

13.2.2.4 The location of the head measuring points (stilling well) must be two-thirds the length of the converging sidewall upstream from the crest. Sonar-type devices are only acceptable when foaming or turbulance is not a problem.

13.2.2.5 The pressure tap to the stilling well must be at right angles to the wall of the converging section.

13.2.2.6 The invert (i.e., inside bottom) of the pressure tap must be at the same elevation as the crest.

13.2.2.7 The tap should be flush with the flume side wall and have square, sharp corners free from burrs or other projections.

13.2.2.8 The tap pipe should be 2 inches in size and be horizontal or slope downward to the stilling well.

13.2.2.9 Free-flow conditions shall be maintained under all flow rates to be encountered by providing low enough elevations downstream of the flume. No constrictions (i.e., sharp bends or decrease in pipe size) should be placed after the flume as this might cause submergence under high flow conditions.

13.2.2.10 The volume of the stilling well should be determined by the conditions of flow. For flows that vary rapidly, the volume should be small so that the instrument float can respond quickly to the changes in rate. For relatively steady flows, a large-volume stilling well is acceptable. Consideration should be given to protecting the stilling well from freezing.

13.2.2.11 Drain and shut-off valves shall be provided to empty and clean the stilling well.

13.2.2.12 Means shall be provided for accurately maintaining a level in the stilling well at the same elevation as the crest in the flume, to permit adjusting the instrument to zero flow conditions.

13.2.2.13 The flume must be located where a uniform channel width is maintained ahead of the flume for a distance equal to or greater than fifteen (15) channel widths.

The approach channel must be straight and the approaching flow must not be turbulent, surging, or unbalanced. Flow -lines should be essentially parallel to the centerline of the flume.

13.2.3 Sharp Crested Weirs

The following criteria are for V-notch weirs, rectangular weirs with and without end contractions, and Cipolletti weirs. The following details must be met when designing a sharp crested weir:

13.2.3.1 The weir must be installed so that it is perpendicular to the axis of flow. The upstream face of the bulkhead must be smooth.

13.2.3.2 The thickness of the weir crest should be less than 0.1 inch or the downstream edge of the crest must be relieved by chamfering at a 45° angle so that the horizontal (unchamfered) thickness of the weir is less than 0.1 inch.

13.2.3.3 The sides of rectangular contracted weirs must be truly vertical. Angles of V-notch weirs must be cut precisely. All corners must be machined or filed perpendicular to the upstream face so that the weir will be free of burrs or scratches.

13.2.3.4 The distance from the weir crest to the bottom of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot.

13.2.3.5 The distance from the sides of the weir to the side of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot (except for rectangular weirs without end contractions.

13.2.3.6 The nappe (overflow sheet) must touch only the upstream edges of the weir crest or notch. If properly designed, air should circulate freely under and on both sides of the nappe. For suppressed rectangular weirs (i.e., no contractions), the enclosed space under the nappe must be adequately ventilated to maintain accurate head and discharge relationships.

13.2.3.7 The measurement of head on the weir must be taken at a point at least four (4) times the maximum head on the crest upstream from the weir.

13.2.3.8 The cross - sectional area of the approach channel must be at least eight (8) times that of the nappe at the crest for a distance upstream of 15-20 times the maximum head on the crest in order to minimize the approach velocity.

The approach channel must be straight and uniform upstream of the weir for the same distance, with the exception of weirs with end contractions where a uniform cross section is not needed.

13.2.3.9 The head on the weir must have at least three (3) inches of free fall at the maximum downstream water surface to ensure free fall and aeration of the nappe.

13.2.3.10 All of the flow must pass over the weir and no leakage at the weir plate edges or bottom is permissable.

13.2.3.11 The weir plate is to be constructed of a material equal to or more resistant than 304 Stainless Steel.

13.2.4 Venturi and Modified Flow Tube Meters

The following requirements should be observed for application of venturi meters:

13.2.4.1 The range of flows, hydraulic gradient, and space available for installation must be suitable for a venturi meter and are very important in selecting the mode of transmission to the indicator, recorder, or totalizer.

13.2.4.2 Venturi meters shall not be used where the range of flows is too great or where the liquid may not be under a positive head at all times.

13.2.4.3 Cleanouts or handholes are desirable, particularly on units handling raw sewage or sludge.

13.2.4.4 Units used to measure air delivered by positive - displacement blowers should be located as far as possible from the blowers, or means should be provided to dampen blower pulsations.

13.2.4.5 The velocity and direction of the flow in the pipe ahead of the meter can have a detrimental effect on accuracy. There should be no bends or other fittings for 6 pipe diameters upstream of the venturi meter, unless treated effluent is being measured when straightening vanes are provided.

13.2.4.6 Other design guidelines as provided by manufacturers of venturi meters should also be considered.

13.2.5 Other Flow Metering Devices

Flow meters, such as propeller meters, magnetic flow meters, orifice meters, pitot tubes, and other devices, should only be used in applications in accordance with the manufacturer's recommendations and design guidelines.

13.2.6 Hydrograph Controlled Release (HCR) Systems

For plants utilizing HCR systems, accurate stream flow measurements are required. Detailed plans must be submitted outlining the construction of the primary stream flow measuring device and the associated instrumentation. The following factors should be emphasized in the design.

13.2.6.1 Accuracy over the flow range required for effluent discharge limiting purposes.

13.2.6.2 Operational factors such as cleaning and maintenance requirements.

13.2.6.3 Cost

The use of sharp crested weirs as described in Section 13.2.3 will not be allowed due to the installation requirements such as approach channel details and upstream pool depth and since entrapment and accumulation of silt and debris may cause the device to measure inaccurately. Parshall Flumes may be used due to their self-cleaning ability but field calibration will be required. Self-cleaning V-notch weirs are recommended due to their accuracy in low flow ranges. The weir can be made self-cleaning by sloping both sides of the weir away from the crest. The top portion of the crest shall be covered with angle-iron to prevent its breakdown. The angle of the V-notch should be determined by the stream characteristics; however, a smaller angle will increase accuracy in the low flow range. The primary device shall be built with sufficient depth into the stream bed to prevent undercutting and sufficient height to cover the required flow range.

It is recommended that the wastewater system director, engineer, or other city official contact the U.S. Geological Survey (USGS), Water Resources Division, in Nashville, Tennessee, for assistance with the design and installation of the flow measuring device. They offer a program which shares much of the costs for designing and maintaining the device. After visiting the site, they can assist with the design of a self-cleaning weir for the stream. They provide the consultant with a field design that shows the proper location and installation of the weir. From this field design, the consultant must provide detailed plans to the State.
The wastewater system is responsible for constructing the weir at their own cost. The flow measuring station is installed, maintained, and calibrated by USGS personnel so that accurate results are insured.

The primary device will record continuous flow of the stream and can be designed to send a feedback signal to the WWTP for other purposes such as controlling plant discharge rates.

This program benefits both the local wastewater system, the State of Tennessee, and the USGS, as it adds to stream flow data bases archived for public use. Cost sharing allows the flow measuring station to be built and operated at a lower cost for all parties concerned.

13.3 Sampling

13.3.1 Automatic Sampling Equipment

The following general guidelines should be adhered to in the use of automatic samplers:

13.3.1.1 Automatic samplers shall be used where composite sampling is necessary.

13.3.1.2 The sampling device shall be located near the source being sampled, to prevent sample degradation in the line.

13.3.1.3 Long sampling transmission lines should be avoided.

13.3.1.4 If sampling transmission lines are used, they shall be large enough to prevent plugging, yet have velocities sufficient to prevent sedimentation. Provisions shall be included to make sample lines cleanable. Minimum velocities in sample lines shall be 3 feet per second under all operating conditions.

13.3.1.5 Samples shall be refrigerated unless the samples will not be effected by biological degradation.

13.3.1.6 Sampler inlet lines shall be located where the flow stream is well mixed and representative of the total flow.

13.3.1.7 Influent automatic samplers should draw a sample downstream of bar screens or comminutors. They should be located before any return sludge lines or scum lines.

13.3.1.8 Effluent sampling should draw a sample immediately upstream of the chlorination point. This will eliminate the need to dechlorinate and then re-seed the sample.

13.3.2 Manual Sampling

Because grab samples are manually obtained, safe access to sampling sites should be considered in the design of treatment facilities.

13.3.3 Long Outfall Lines

Many wastewater systems are constructing long outfall lines to take advantage of secondary or equivalent permit limits.

Due to possible changes in effluent quality between the treatment facility and the outfall, a remote sampling station will be required at or near the confluence of the outfall line and the receiving stream on all outfall lines greater than one mile in length.

Dissolved oxygen, fecal coliform, and chlorine residual may have to be measured at the remote sampling station for permit compliance purposes.

13.3.4 Sampling Schedules

Samples must be taken and analyzed for two purposes: permit compliance and process control. Any time a new permit is issued, a sampling schedule for permit compliance will be determined by the Division of Water Pollution Control. An additional sampling program needs to be set up for process control purposes. This would include all testing required for completing the monthly operational report, as well as any other tests that might aid the operation of the plant. This schedule can be determined by the Division of Water Pollution Control, Wastewater Treatment Section or the appropriate field office once final plans are approved. The designer shall provide safe access points to collect representative influent and effluent samples of all treatment units and to collect samples of all sludge transmission lines. This makes it possible to determine the efficiency of each treatment process. Additional information about methods of analyses can be obtained from the Federal Register 40 CFR Part 136. Information about sampling locations and techniques can be obtained from the EPA Aerobic Biological Wastewater Treatment Facilities Process Control Manual and EPA's NPDES Compliance Inspection Manual.

Section 4
Activated Sludge Systems

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Section 4
Activated Sludge Systems

Secondary Treatment

- Biological Treatment Process
  - Natural occurring **soil & aquatic bacteria, protozoa, metazoa**
  - **Organic matter + air + water + microorganisms** = the natural composting or rotting process
  - Organic waste is **stabilized** through this process so that streams are not degraded.

Secondary Treatment

- Two Methods of Biological Treatment Processes
  1. Suspended Growth – ***Activated Sludge***
  2. Fixed Film (Trickling Filter, Roughing Filter, Biotower, RBC) the biological film (zoogleal film) is attached to the media

Note

Activated sludge is a suspended growth treatment process because the microorganisms are not attached to a surface.

Activated Sludge

- Wastewater is food for the ***mixed liquor suspended solids (MLSS)***, a mixture of bacteria and other microorganisms.
- Bacteria form ***flocs*** that are kept suspended in the basin by mixing and aeration.
- ***Bioflocculation*** increases the size and density of particles that don't settle quickly on their own, including:
  - Smaller particles
  - Soluble, biodegradable organic material
- Most widely used biological treatment process

Note

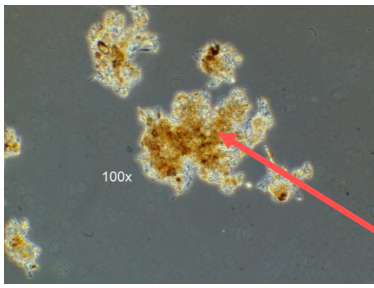
Mixed liquor suspended solids (MLSS) A mixture of raw or settled wastewater and microorganisms.

- In the biological reactor (big brown basin)

Flocculation means growing larger particles (***floc***) through collisions that help smaller particles stick together.

Bioflocculation uses a combination of flocculation and biological conversion and growth to combine smaller particles into larger ones.

Note



Flocculation means growing larger particles (***floc***) through collisions that help smaller particles stick together.

Floc-an agglomeration of entrapped organisms, solids, colloids & some inorganics

Activated Sludge

- Theory behind the operation:
    - Accelerates natural treatment processes by building up a large population of microorganisms
    - Combines influent wastewater with a mixture of microorganisms and oxygen
    - Microorganisms consume organic material (BOD), reproduce, and form flocs

Activated Sludge

- Function is to remove…
  1. Soluble (***dissolved***) pollutants

  2. ***Colloidal*** solids
- …To produce a clear effluent that meets regulatory limits
- Limits can be in pounds (lbs), concentration (mg/L), or percent removals.

Note

Dissolved solids

More readily *absorbed* into the surface of a bacteria to breakdown

Colloidal solids

Very small particles that are not truly dissolved; *adsorbed* to surface

Components of Activated Sludge

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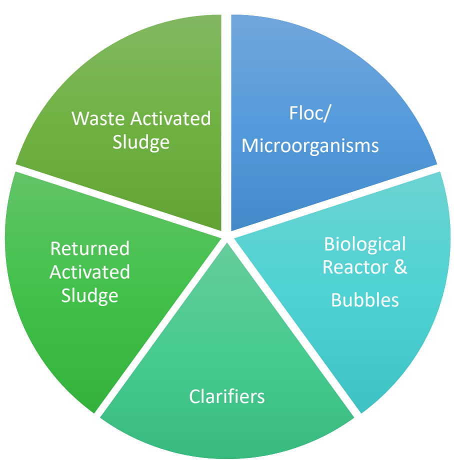
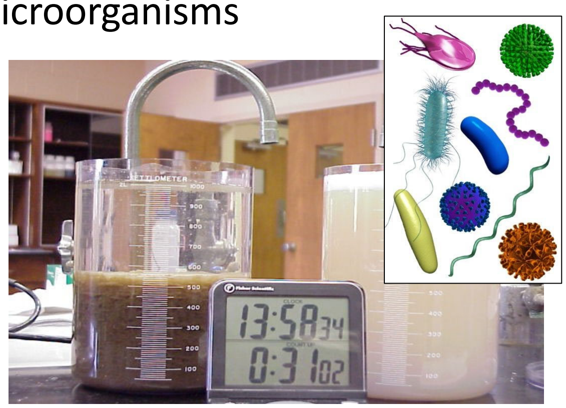
Components



Floc / Microorganisms

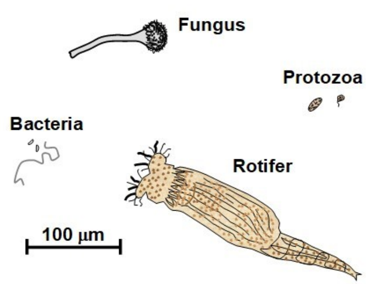
Flocculent slurry of sewage & wastewater and various naturally occurring soil & aquatic microorganisms

- Bacteria
- Protozoa
- Viruses
- Algae
- Metazoa
- Fungi



Microorganisms

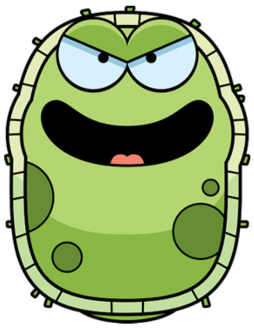
- Types of microorganisms present in activated sludge depend on:
  - Composition of the wastewater
  - Length of the system's ***MCRT***
  - pH
  - Temperature
  - DO concentration

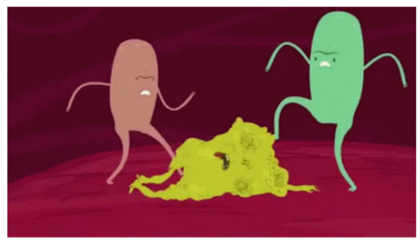


- Microorganism population type affects both activated sludge characteristics and treatment potential.

Note

Mean Cell Residence Time (MCRT) is the measure of the average time a microorganism will be in the system.

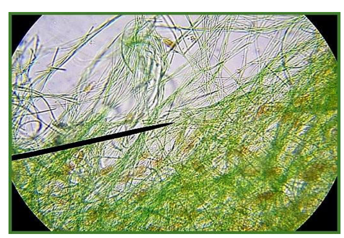




What are Microbes?

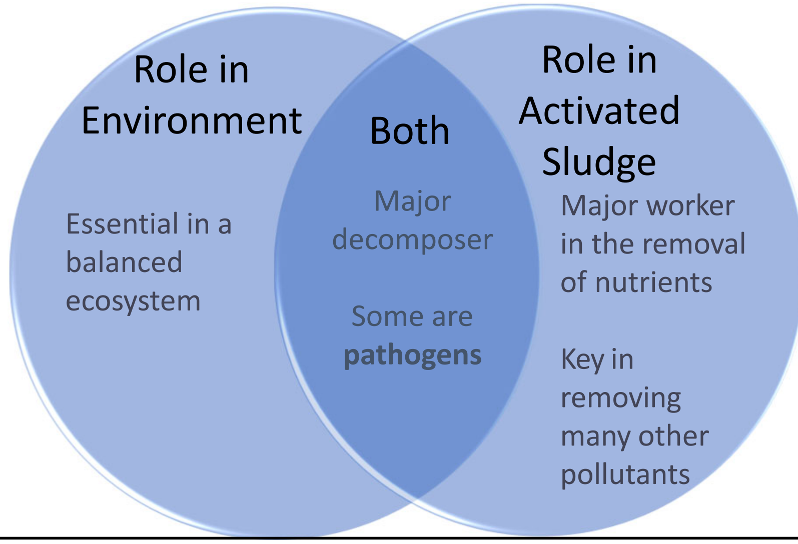
- Bacteria-main workers
- Protozoa-secondary
- Viruses- opportunistic
- Algae- plant
- Metazoa-more complex
- Fungi- rarely seen

Crawling ciliate on activated sludge floc



Cyanobateria

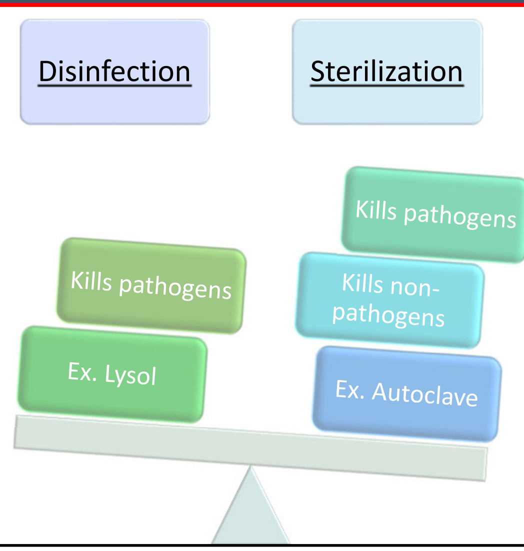
Why are they important?



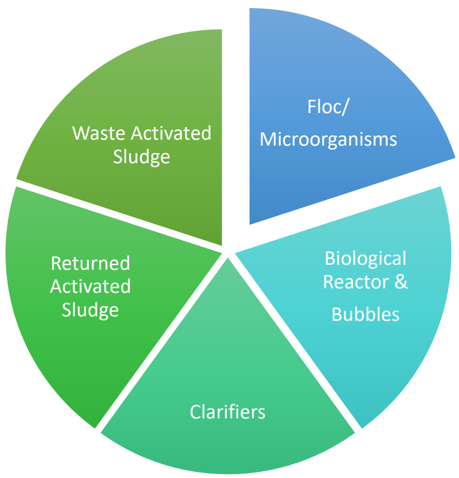
Note

Pathogens are microorganisms that cause disease

To kill ***pathogens*** you must <u>disinfect</u> or <u>sterilize</u>



Components



Flocculent slurry of sewage & wastewater and various naturally occurring soil & aquatic microorganisms

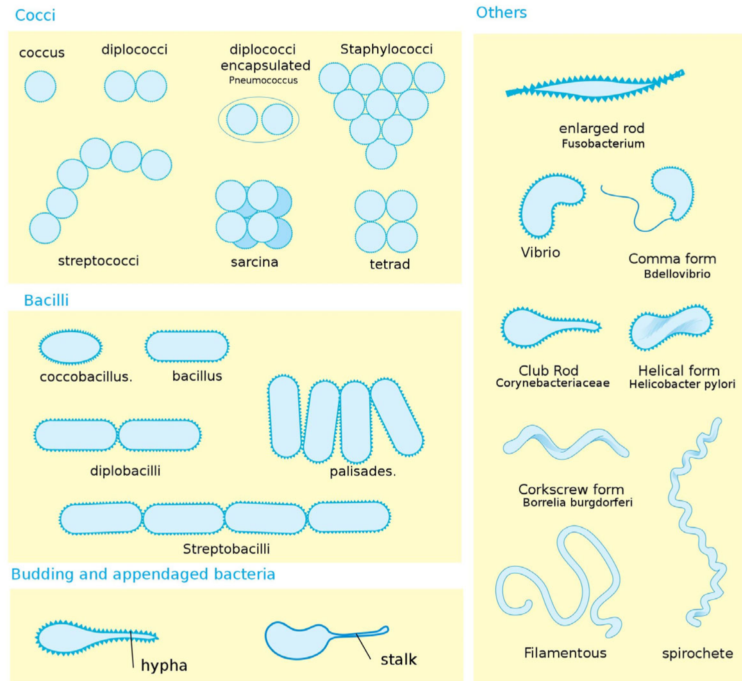
- **Bacteria (main workhorses)**
- Protozoa
- Viruses
- Algae
- Metazoa
- Fungi

Bacteria Classification

1. By Food Source
   - Heterotrophy, organic food, BOD
   - Autotrophy, inorganic food, ammonia
2. By Oxygen usage
   - Aerobic, Facultative, Anaerobic
3. By Shape
   - Round, Rods, Filaments (threadlike)

Bacteria Found in WW

- For WW Treatment, bacteria are the most important microorganisms in the process
- Most are soil bacteria
- About 95% of microorganisms in mixed liquor for activated sludge systems are the bacteria.



Bacteria

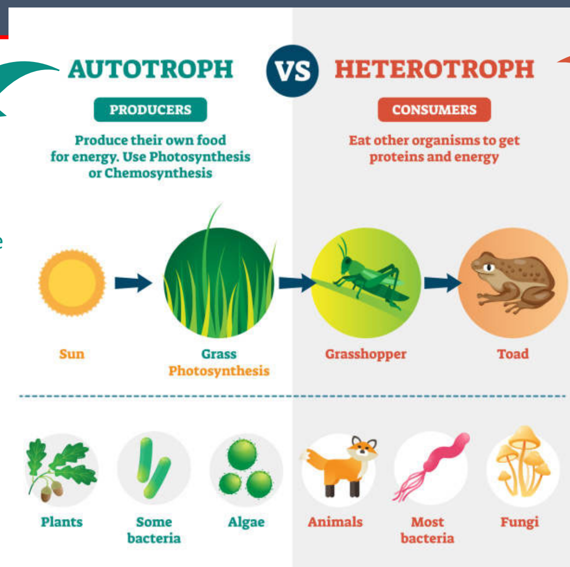
- Binary fission is the process by which one mature cell divides into two new cells.
- Generation Time: replication in PURE culture:
  - Bacillus sp. (BOD eating bacteria) 20-30 minutes
  - Nitrifiers 22-48 hours
  - Methanogens 10-30 days

Types of Bacteria

Types in WW:

Nitrifiers-remove ammonia

Algae



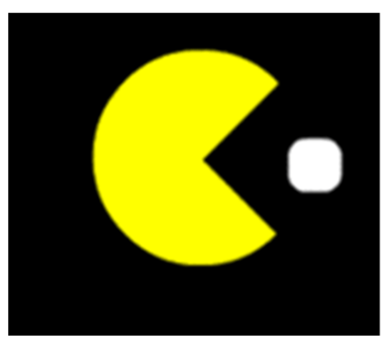
Types in WW:

CBOD removers

Denitrifiers

Heterotrophs

- **C**onsume organic **C**arbon as a food source
  - EX. Most wastewater bacteria,
  - Protozoa
  - Humans
- Organic food source
  - Carbohydrates- sugar, starch, cellulose
  - Protein
  - Fat
  - Other organisms
- All animals are heterotrophs, as are most microorganisms (the major exceptions being microscopic algae and blue - green bacteria)



Heterotrophs

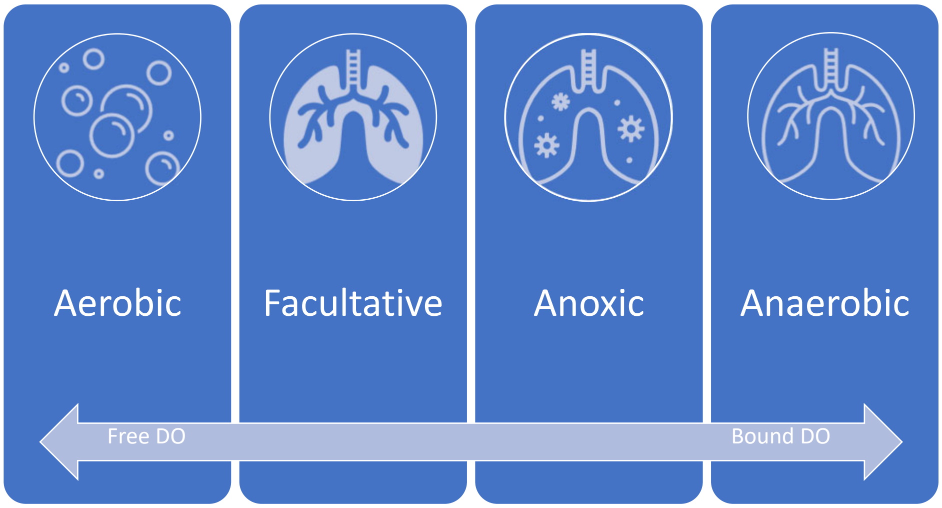
- Require Nutrients
  - Ex. Nitrogen, Phosphorus, micronutrients
  - Source is the Sewage and wastewater
  - Ideal Balance:
    - BOD (mg/L):**TKN** (mg/L) :P (mg/L)
    - 100:5:1
    - Sometimes 100:5:1:0.5 (Fe-Iron)
  - Domestic waste generally provides a good balance for the microorganisms, industrial waste may not, which could lead to filament growth.

NOTE

TKN is Total Kjeldahl Nitrogen

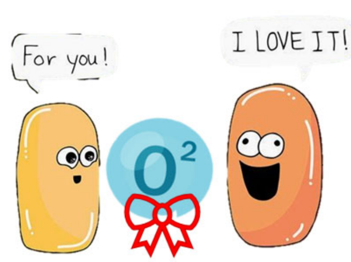
$$\boldsymbol{TKN} = Organic\ Nitrogen + \ Ammonia\ Nitrogen$$

Oxygen Requirements of Heterotrophs



Oxygen Requirements of Heterotrophs

Require free DO to function

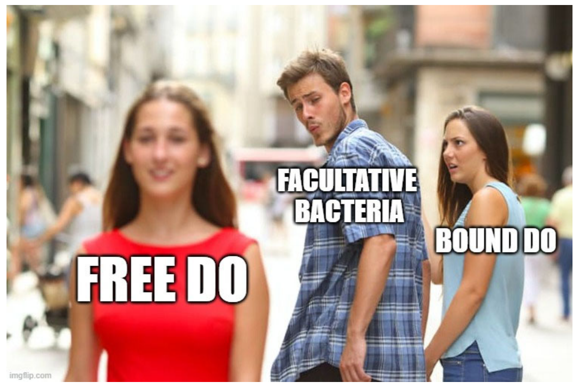


Oxygen Requirements of Heterotrophs

Facultative

Free DO/Bound DO

Prefer free DO but can function in the absence and used a combine oxygen



Oxygen Requirements of Heterotrophs

Anoxic

Bound DO

Use nitrate (NO_3^-) and nitrite (NO_2^-), bound oxygen

Oxygen Requirements of Heterotrophs

Anaerobic

Bound DO

Thrive in the absence of free DO, use sulfate (SO_4^-) or carbon dioxide (CO_2)

How do they work?

Decomposition:

$$C_6H_{12}O_6 + \text{Bugs} + O_2 \longrightarrow \text{More Bugs} + CO_2 + H_2O$$

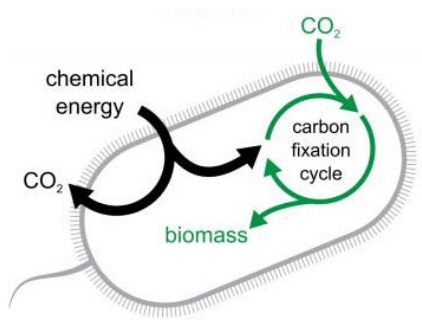
Glucose, Organic Matter

Energy and Nutrients

- Decomposition is the process of rotting or breaking down into simpler forms

Autotrophic

- Autotrophic organisms use inorganic substances like ammonia for energy and inorganic carbon (carbon dioxide) to grow
- The inorganic carbon is from the various alkalinity sources in the sewage (Ex. carbon dioxide, carbonate, or bicarbonate)
- Some drinking water in Tennessee has low alkalinity which eventually can cause operational issue at the wastewater plant if nitrification occurs



How do they work?

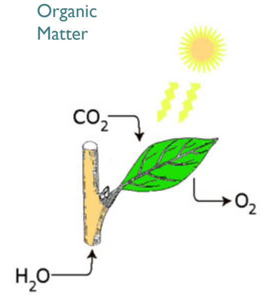
- What is the formula backwards?

$$CO_2 + H_2O + \text{energy} \longleftarrow C_6H_{12}O_6 + O_2$$

Energy and Nutrients

Glucose, Organic Matter

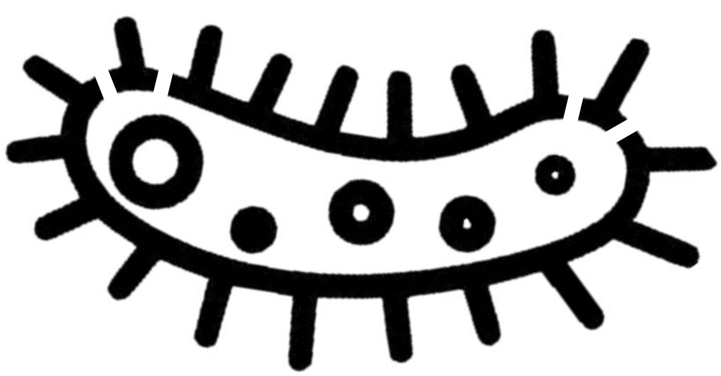
Photosynthesis!



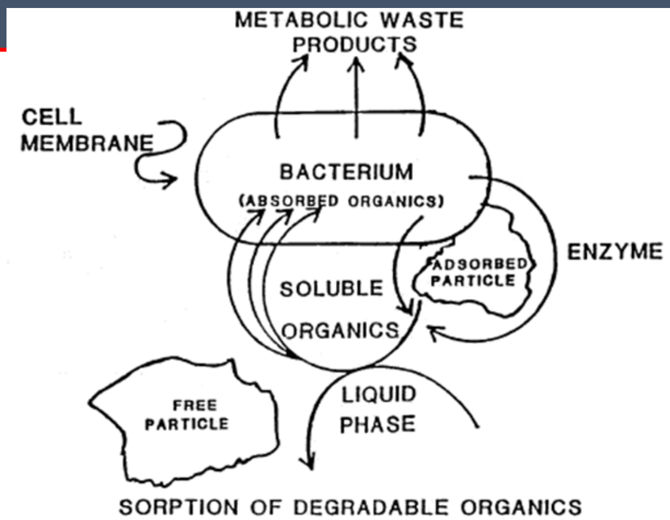
Food

- Two types of "food"
  - Dissolved
  - Example: sugar in oatmeal
  - "Chunky"
  - Example: oats in oatmeal
- Our body uses both "foods"
- We eat and our stomach and gut breaks the "chunky food" down into smaller dissolved food that our cells in our bodies can use
- If you had to stay in the hospital and could not eat, they would "feed" you dissolved food in the form of sucrose, a sugar water

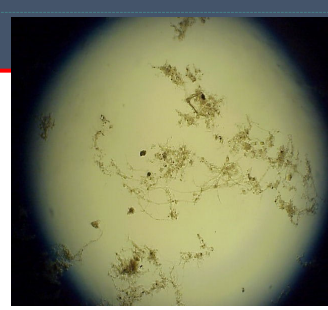
Note

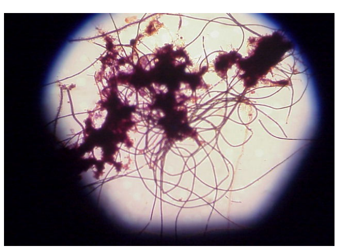


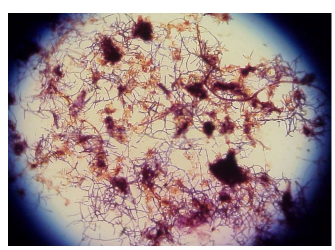
Microorganisms "Eating"



Various Filaments

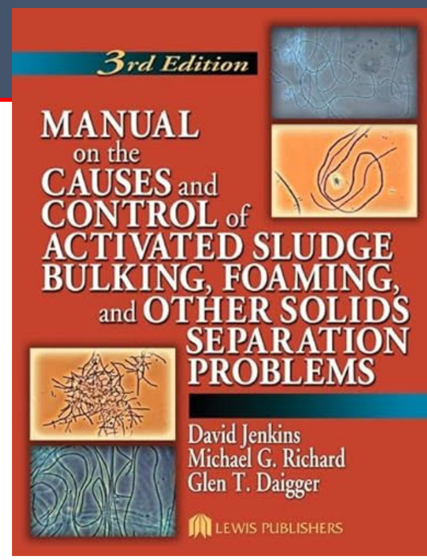






Filamentous Bacteria

Filaments prefer:
1) Low Dissolved Oxygen
2) Low F:M
3) Septicity
4) Grease and Oil
5) Nutrient Deficiency
6) Low pH



- Identify using Phase Contrast Microscope
  - Brett, Michael Richard, David Jenkins company, others

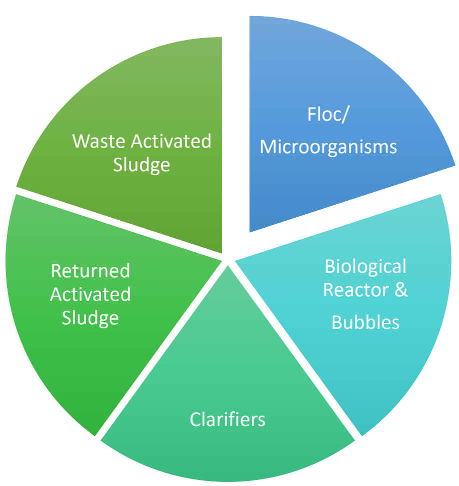
Nocardia

- Nocardia can be controlled by:
  1. Maintaining an MCRT <1 day in warm weather
     - Works with pure oxygen systems
     - Can be very difficult in nitrifying plants
  2. Physical removal and disposal by skimming and disposal
  3. Spray with chlorine – on the surface or inject into RAS
  4. Also Cationic polymers- forces the nocardia into the MLSS where is does not prefer to live

Filament Control

- Identify the filament and change the plant environment
  - Filament have specific growth preferences, take those away and the filament goes away
- Chlorination of the RAS is a old standby and often works
- Polymers and other chemicals fit in certain situations
- Foam can be skimmed and trapped
- Change Mode of operation: step feed or contact stabilization lowers the solids load to the clarifier. Contact stabilization can incubate filaments.
- Selector units can be added
  - Anaerobic, Anoxic, Aerobic
  - These change the F:M, DO, and growth environment

Components

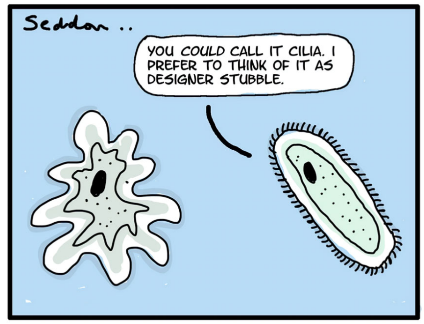


Flocculent slurry of sewage & wastewater and various naturally occurring soil & aquatic microorganisms

- Bacteria
- **Protozoa**
- Viruses
- Algae
- Metazoa
- Fungi

Protozoa- First Amimals

- Single-celled animals that also reproduce by binary fission
- Have complex digestive systems that ingest organic matter, which they use as an energy and carbon source
- Protozoans are much larger than bacteria, their size ranges from 10-500 microns



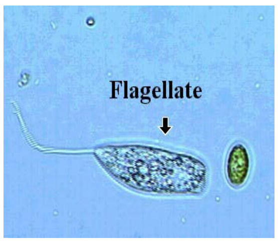
When protozoans show signs of a mid-life crisis.

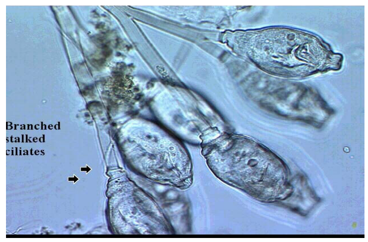
Protozoa- First Amimals

- They are an important link in the activated sludge food chain because they consume bacteria to fill a large part of their nutritional needs.
  - This seems not only to remove excess bacteria from WW, but appears to stimulate the growth of healthy bacteria, which produce floc more quickly and aid in the clarification of the effluent
- Form cysts
- Beneficial in wastewater treatment
- Indicators of health and secondary indicator of MCRT or age of system

Protozoa Found in the Activated Sludge Process

- Much less abundant than bacteria, but very important
- **Require DO**
- Flagellate has a whip-like tail and competes with bacteria
- Stalked ciliates – as adults, attach to something; as a "baby", has little hairs (cilia) to move around and move water and food into "mouth"
- Euglena – has green algae in it that makes oxygen when the sun shines.





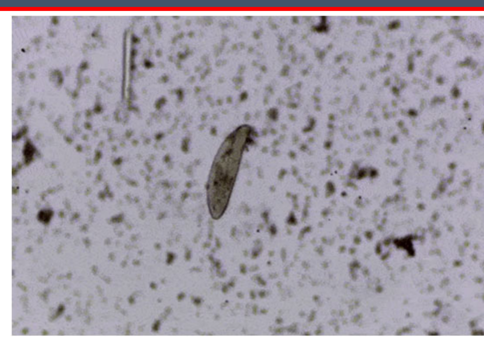
Protozoa - Amoeba

- Young sludge indicators
- They can encyst themselves to make it through the system (unfavorable conditions)
- Look like donuts
- Can be found during plant start up or after a plant is recovering from an upset.

Protozoa - Flagellates

- Can be found during plant start up or after a plant is recovering from an upset with a low population of microorganisms and a high organic (BOD) load

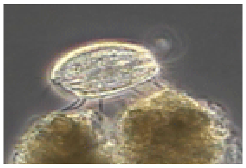
Protozoa – Free Swimming Ciliate (Paramecium)

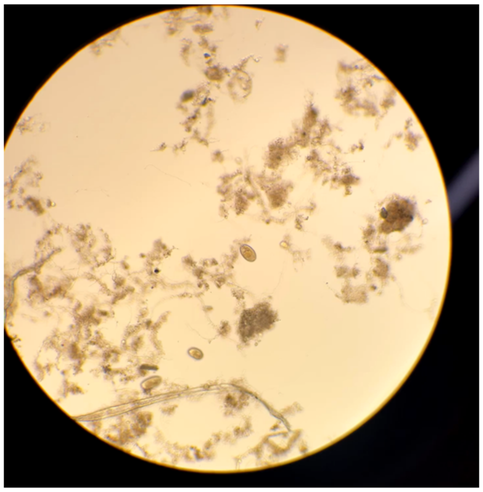


- Free swimming ciliates generally are younger biomass organisms but are common in many plants
- Cilia covers entire shape
- Paramecium - 4.7 hours growth rate

Protozoa – Crawling Ciliates

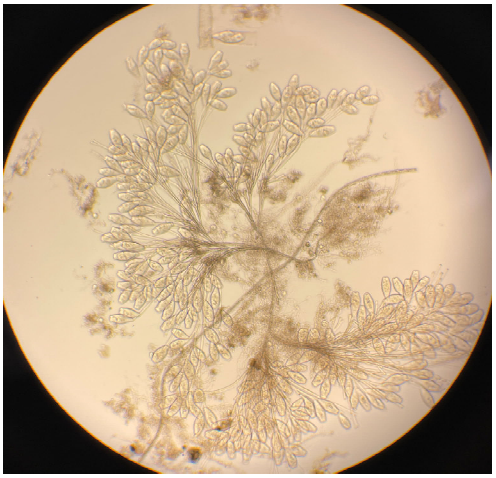
- Resemble crabs or ladybugs
- May have some cilia but majority of body does not contain any
- Croppers of biomass
- Cirri (A bundle or tuft of cilia serving as foot or tentacle in certain ciliate protozoa) are 4-5 cilia fused together
- Very efficient feeders



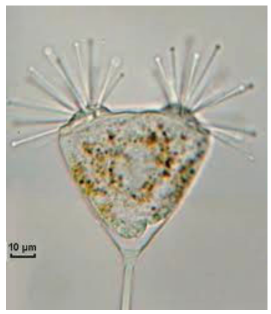


Protozoa – Stalked Ciliates

- They feed by drawing cells into their "mouth" with small cilia that create a visible twirling motion in the sample.
- Can be individual or colonial
- Length of stalk indicates age
- Some will have a myenome (contractile muscle fiber with in stalk)
- Size of oral opening may indicate health of system/more bacteria smaller opening and less bacteria larger opening
- Single (vorticella) vs colonial (epystylis) does not mean one is better than other, they are all individual species and grow based on the environment

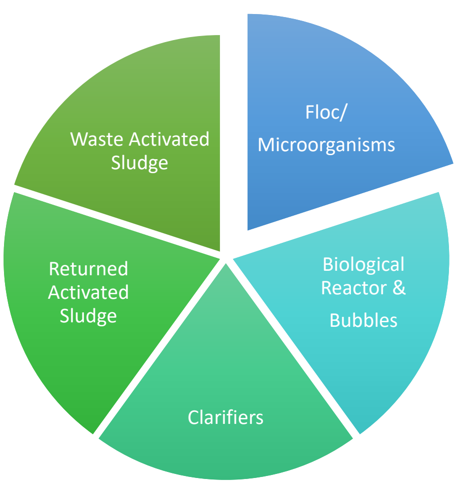


Protozoa – Suctoria



- These are the true vampires of the wastewater world
- Tentacles may recoil in presence of increased ammonia
- Some will have a stalk and others may not

Components



Flocculent slurry of sewage & wastewater and various naturally occurring soil & aquatic microorganisms

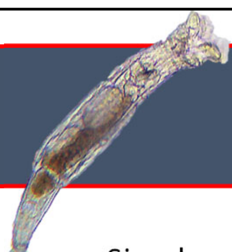
- Bacteria
- Protozoa
- Viruses
- Algae
- **Metazoa**
- Fungi

Metazoa

- Examples:
  - Rotifer
  - Water Mite
  - Water Bear
  - Nematodes
  - Ostracods

- Multi-cellular animals
- Slower growing
- Typically larger than protozoa
- Sexual and asexual reproduction
- Heterotrophic
- All are motile
  - Unless there has been an upset to the plant

Metazoa - Rotifer

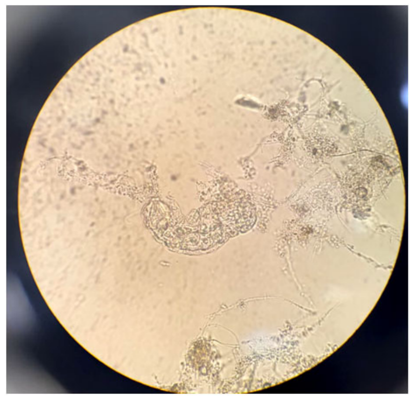
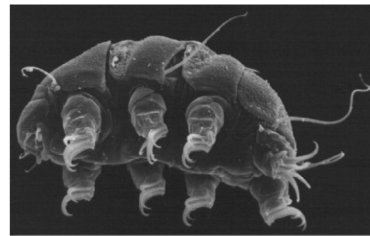
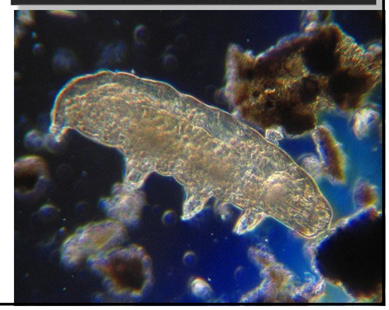


- Simple multi-celled organisms
- Need aerobic environment
- Don't like ammonia
- Consume solid food including bacteria
- In lagoons, they eat lots of algae
- Means happy, healthy population
- High numbers usually indicates an older sludge

- Over 80% are female
- Longer Sludge age
- Low BOD, Sufficient D.O.
- Tardigrade food
- Some move like snails others resemble free-swimming ciliates

Metazoa – Water Bear (Tardigrade)

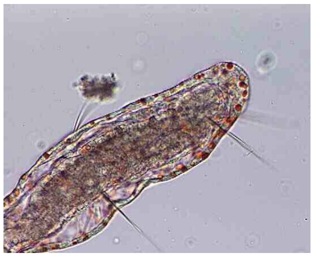
- Old sludge organism
- Feeds on smaller protozoa
- Does not like ammonia
  - Not found in presence of ammonia above 5ppm
- Extremely aerobic
- 8 legs – with 2 claws on each for holding
  - Prefer rotifers as a food source
- Water bears are typically not seen in industrial waste treatment systems

Metazoa – Nematode

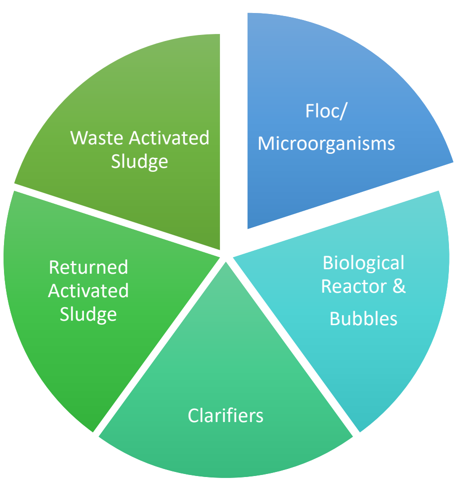

- Fast moving
- The poke around the floc
- Older sludge organisms that reproduce slowly
- Several are parasitic

Metazoa – Bristle Worm



- Aquatic earthworm
- They eat bacteria and protozoa
- They are relatively active. They have a red spot that are not visible here but can turn biomass red colored
- They have the capacity to make your biomass disappear

Components



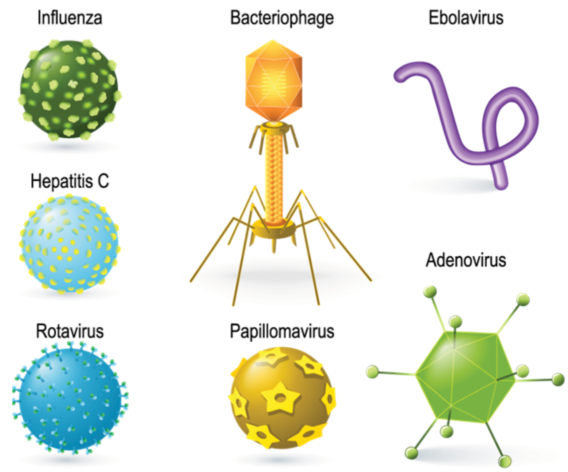
Flocculent slurry of sewage & wastewater and various naturally occurring soil & aquatic microorganisms

- Bacteria
- Protozoa
- **Viruses**
- Algae
- Metazoa
- Fungi

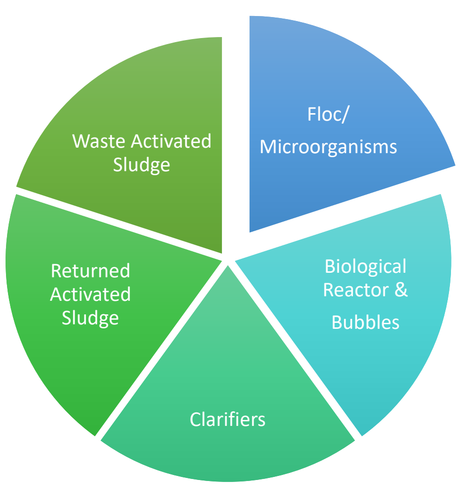
Viruses

- Infectious agent
- Very small (10-300 nm)
- Live inside of cells
- Require living hosts to survive and reproduce

- Ex. Poliovirus, Hepatitis A, rotavirus



Components



Flocculent slurry of sewage & wastewater and various naturally occurring soil & aquatic microorganisms

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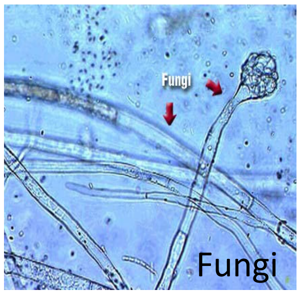
- Protozoa
- Viruses
- **Algae**
- Metazoa
- **Fungi**

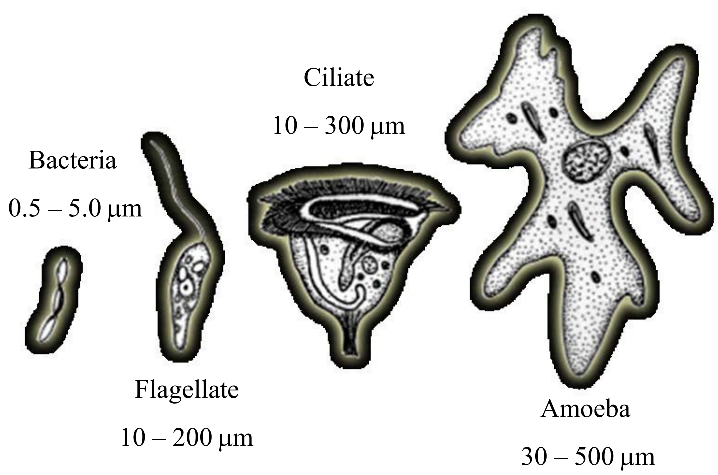
Fungi and Algae

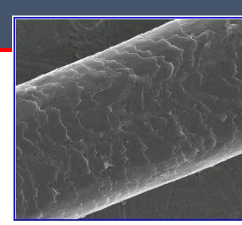


- Soil organisms
- Degrade dead organic matter (saprophytic)

- Photosynthetic
- Eutrophication can cause algal blooms in receiving streams
- Key in operation of wastewater ponds: produce oxygen needed by bacteria
- Nuisance in clarifiers, basins, etc.

Size Range of Microorganisms



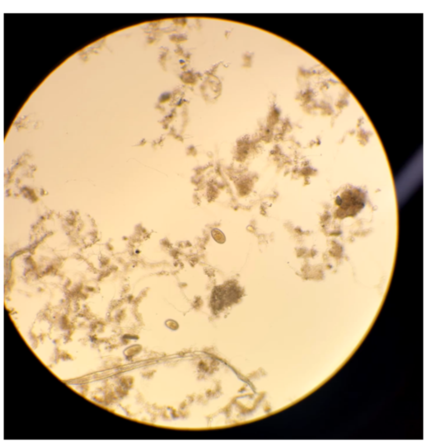


Human Hair sized 70-100 µm or 0.003-0.004 inch, (0.001 in = 25 µm)

Brightfield or Light Microscope

WHYYYYY SO important?????

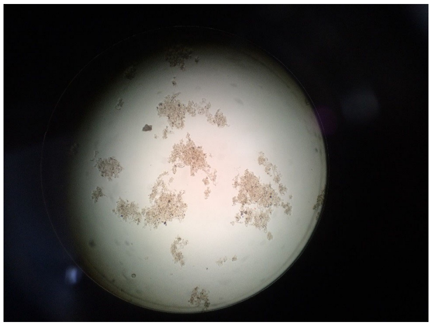
Brightfield or Light Microscope



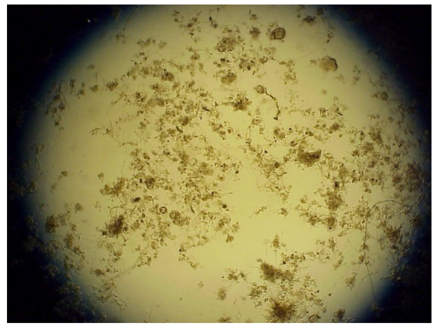
- ***Floc observation***
- Protozoa observation & count
- Filaments ~ yes or no
  - Nocardia - branched
  - Begattoa – large, spotted, and moves

Microscopic Exam

Medium irregular floc

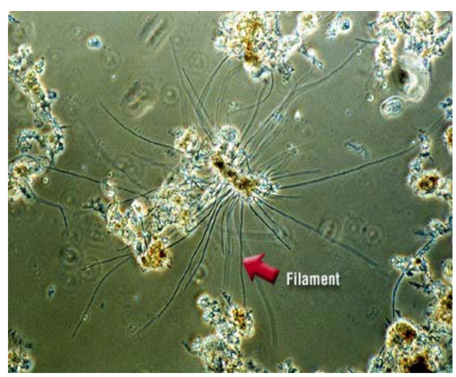


Open floc with filaments



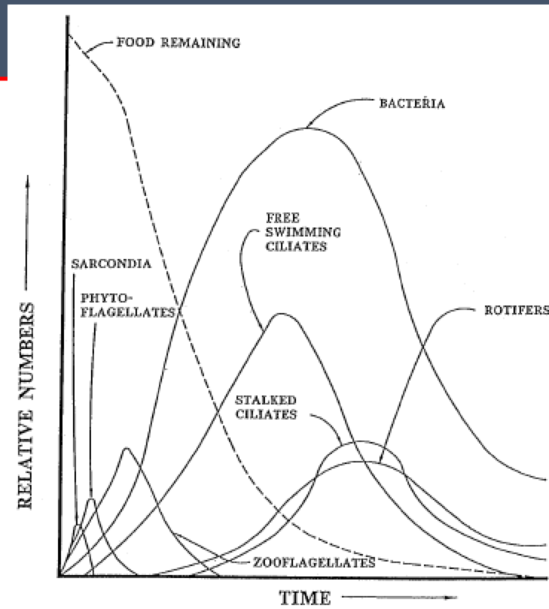
Micrograph of Floc and Filaments

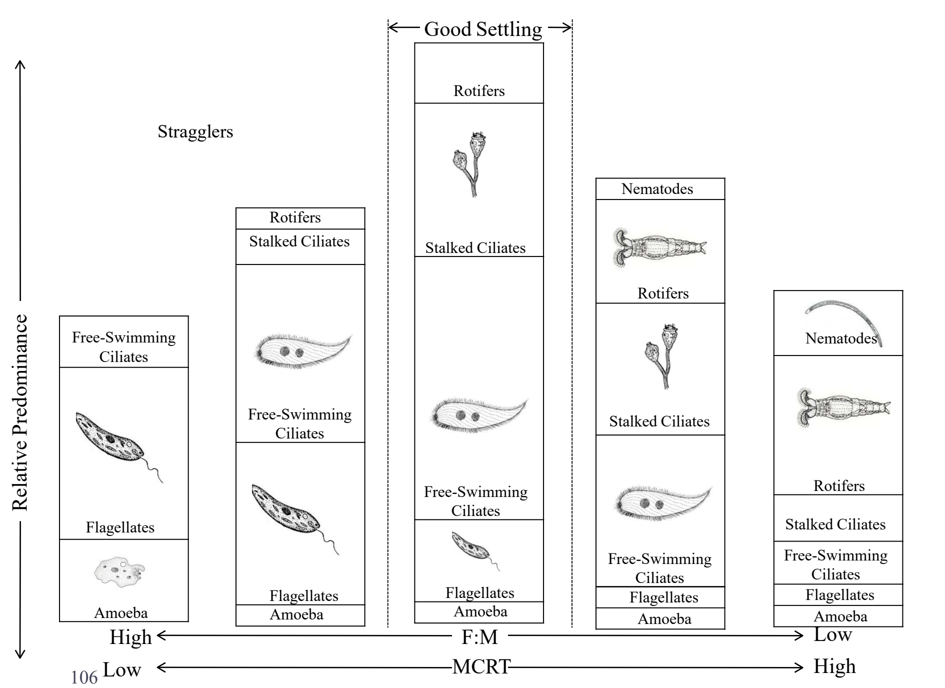
- Filamentous bacteria are not "floc formers" but are also of interest in WW treatment
- Small amounts of them can improve floc structure, acting as a back bone, providing mass to help in settling after treatment



- Large amounts can negatively affect performance of activated sludge systems by keeping floc apart and which makes it light and fluffy, therefore, not settling well (high SVI)

Bacteria Population vs. Sludge Age





Microorganisms Predominance

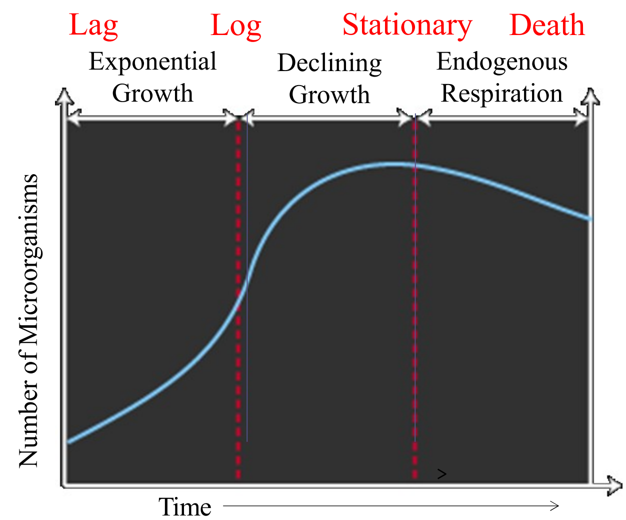
- During a start up, after an upset amoebas, and flagellates will predominate
  - The sludge will be young, display slow settling and leave behind straggler floc
- A large number of stalked ciliates, free-swimming ciliates and rotifers will indicate a stable and efficiently operated plant that produces a good settling sludge and a high quality effluent
- An old sludge is indicated by the predominance of rotifers and nematodes
  - The sludge will settle at a high rate and leave pin floc behind

Microorganisms Predominance

- If a conventional plant starts to see more rotifers and less free-swimming ciliates, you need to increase wasting to make old sludge go away

- If an extended aeration plant has pin floc and nematodes, you are holding your sludge too long

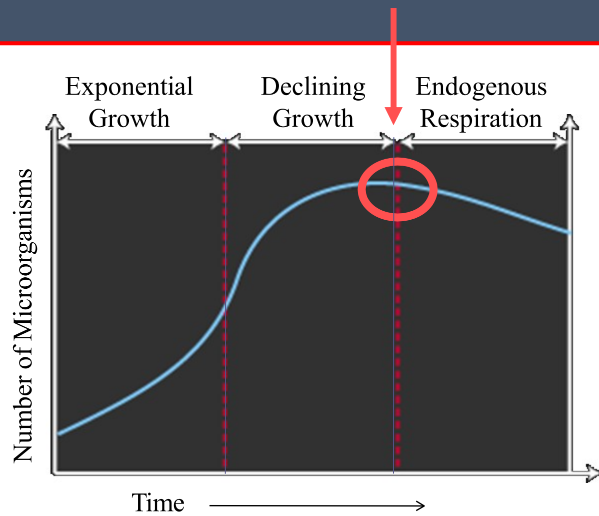
Phases of Microorganism's Life



Note

- ***Exponential Growth*** – The number of microorganisms in a culture broth will grow exponentially until an essential nutrient is exhausted. Typically the first organism splits into two daughter organisms, who then each split to form four, who split to form eight, etc…
- ***Declining Growth*** – As food supply declines, the microorganisms work harder to get their food
  - Reproduction rates gradually slow down
- ***Endogenous Respiration*** – There is inadequate food to maintain the biomass. Some microorganisms starve and die, others use their own stored energy to live

Most plants operate right before endogenous respiration.



TDEC - Fleming Training Center

Treatment Plant Variables

- The predominance, growth, and performance of your microbiological biomass (MLSS) is a function of:
  - **Influent Characteristics**
    - Flow, amount and type of CBOD, ammonia, TSS, pH, other pollutants
  - Reactor Design
    - Shape, Feed points, Aeration, Mixing
  - Environment
    - Climate, water chemistry
  - Operating Conditions
    - F:M, MCRT/SRT, DO, RAS rates

Influent sewage and wastewater

- Discharge from homes, businesses and industry
- Mostly water, but there are organics from feces, paper, food scraps, grease, soaps & surfactants, industrial chemicals - we measure as CBOD
- Inorganic pollutants include ammonia, metals, salts, industrial chemicals
- Storm water and ground water also enter the plant, sometimes on purpose, many times from defects
- We take most anything users can drain, flush, or discharge down the pipe including far too much I/I

Influent Impact and Control

- Influent volume and concentration impacts plants significantly
- Influent control:
  - Inflow & Infiltration
  - Sewer Use Ordinances
  - Ind. Pretreatment Program
    - Permitting
    - Testing
    - Inspections

Influent (PCE) Monitoring and Testing

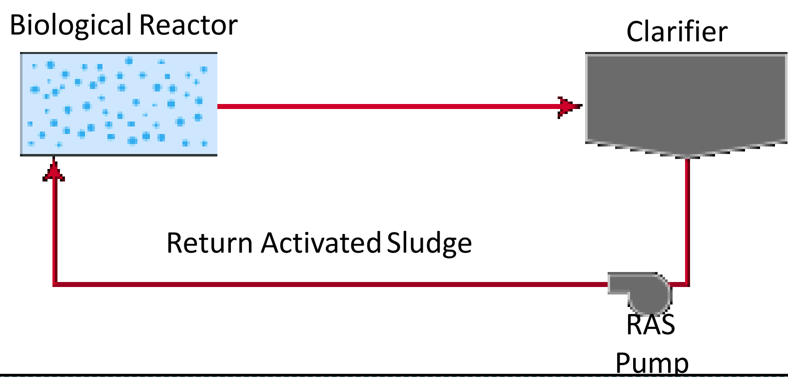
- Watch your Influent
- Is it normal or different?
  - Visual - color, volume, foam oil and grease, mixing
  - Odors
  - Tests
    - DO, pH, Temp, ORP
    - SS, Ammonia, TSS, TKN, COD
    - Toxicity
    - $CBOD_5$
    - Metals, complex organics

Typical Influent Test Values

Parameter	Influent	Effluent
BOD_5	100 – 300 mg/L	5 – 20 mg/L
TSS	100 – 300 mg/L	5 – 30 mg/L
Ammonia	10 – 30 mg/L	< 2 mg/L
pH	6.5 – 8.5	~ 7.0

Return Activated Sludge (RAS)

Return Activated Sludge (RAS) - settled solids from the bottom of the secondary clarifier that are collected and sent back to the beginning of the activated sludge process.



Return Activated Sludge (RAS)

- Enables solids to stay in the activated sludge process longer than the water.
  - ***Solids retention time (SRT)***
- SRT (sludge age) is independent of the amount of time water spends in the system.
- Gives microorganisms in the process more time to grow and reproduce
  - Leads to a high concentration of microorganisms
  - Reduces the time for treatment
  - Increases the load of BOD that can be processed

Note

The ***solids retention time (SRT)*** is the amount of time the solids remain in the treatment process. For a lagoon, the HDT and SRT are the same. For an activated sludge process, the SRT is much longer than the HDT.

SIMILAR TO MCRT

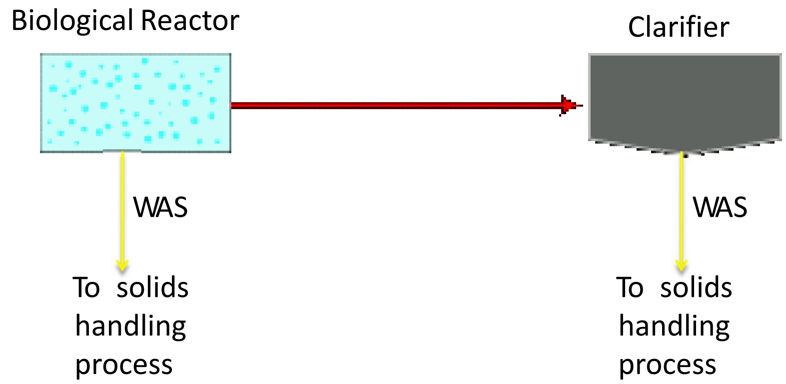
Internal Recycle Flows

Sources

- Digester decant/supernatant
- Sludge dewatering/thicken underflow/overflow
- Clarifier skimming
- Basin dewatering
- Sampler return
- Wash-down water
- Nutrient removal recycle

Waste Activated Sludge (WAS)

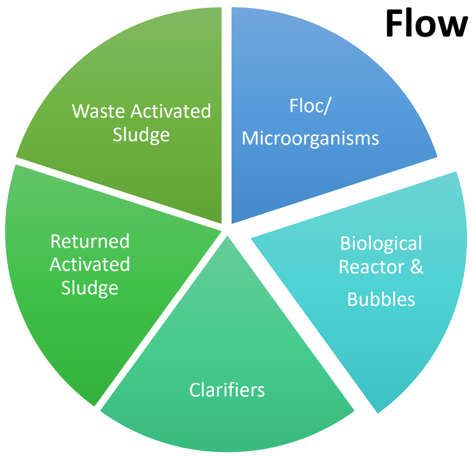
Waste Activated Sludge (WAS) - is the excess solids that are removed from the treatment process. Waste activated sludge is typically transferred to solids handling.

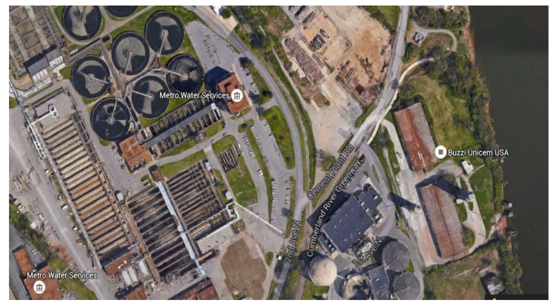


Waste Activated Sludge (WAS)

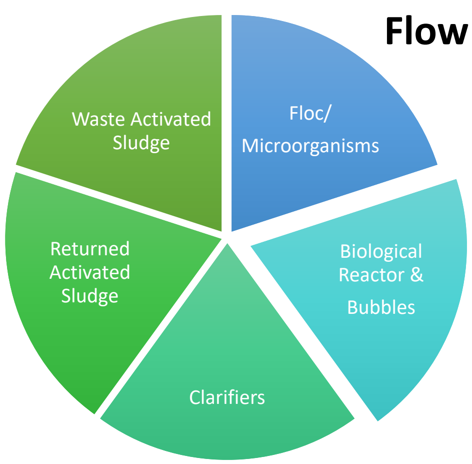
- Portion of settled solids removed from the system
- Adjust the mass of WAS removed to maintain a target sludge age.
- Prevents excess sludge from overwhelming the secondary clarifier and escaping in the final effluent
- WAS may be removed directly from the activated sludge basin, the RAS line, or through a dedicated WAS line.
- Excess sludge is transferred to solids handling.

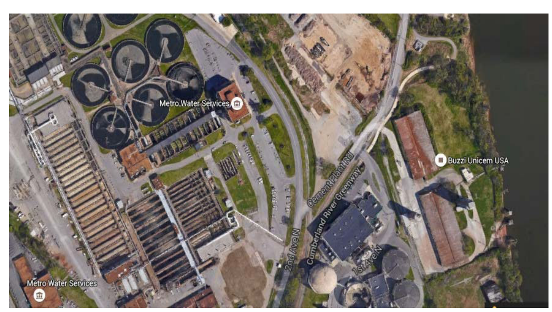
Activated Sludge Process Feeding and Flow Patterns





Activated Sludge Process Feeding and Flow Patterns





Activated Sludge Process Variations

- Categories:
  1. Loading:
     - High
     - Medium
     - Low
  2. Reactor Configuration
     - Number of reactors
     - Feed points
     - Aeration processes
     - Hydraulic detention times
     - MCRT

These often overlap.

Pair of 3 ring ditches

Note

Loading is the amount of organic material entering the plant

Can be calculated by:

$$BOD\ Loading, \frac{lbs}{day} = (Flow, MGD)(BOD, mg/L\ )(8.34\ lbs)$$

↑ Increase in loading ↑ Increase in organic material (BOD)

Activated Sludge Processes & Flow Patterns

- Reactor Shapes
- Physical Arrangement
- Flow Patterns
- Process Modifications
- Modes of Operation
- Feeding Points
- Hydraulic Detention Times
- Solids Retention Times

Activated Sludge Process Design

Variations of the activated sludge process have been designed to:

1. Minimize reactor sizes
2. Reduce capital costs
3. Simply operations
4. Adapt to site-specific conditions

- Plug-flow (conventional)
- Step Feed
- Contact Stabilization
- Bardenpho
- Kraus
- Pure Oxygen
- Complete mix
- Extended aeration
- Oxidation ditches
- High-rate aeration

Basin Configuration

2 Types of Flow Patterns

- Plug Flow
- Complete mix

Plug Flow

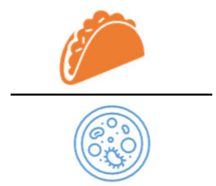
- Raw wastewater goes in as a "plug" and leaves as a "plug"
  - In an ideal plug-flow reactor, particles would leave the reactor in the same order they enter it, ensuring that wastewater has been in the reactor a sufficient time for complete treatment to occur
- Smaller foot print needed
- Highest DO requirement at inlet
  - There may be "tapered" aeration
- Highest ***F:M*** at inlet
- ***F:M*** decreases as you go through the process
- You usually have a primary clarifier

Also known as the Conventional Activated Sludge Process.

Note

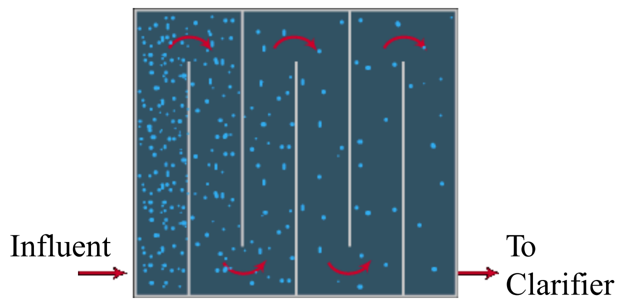
- ***Food to microorganism (F:M) ratio :*** is a measurement of the amount food (BOD) available per microorganism (MLVSS) in the system
  - ***Always <u>MLVSS</u> not MLSS***

$$F:M = \frac{BOD\ (lbs)}{MLVSS\ (lbs)}$$



Criteria for a Plug-Flow Reactor

- High length-to width ratio
- Air flow rate minimized to meet specific treatment needs
- Fairly high wastewater velocity through the reactor



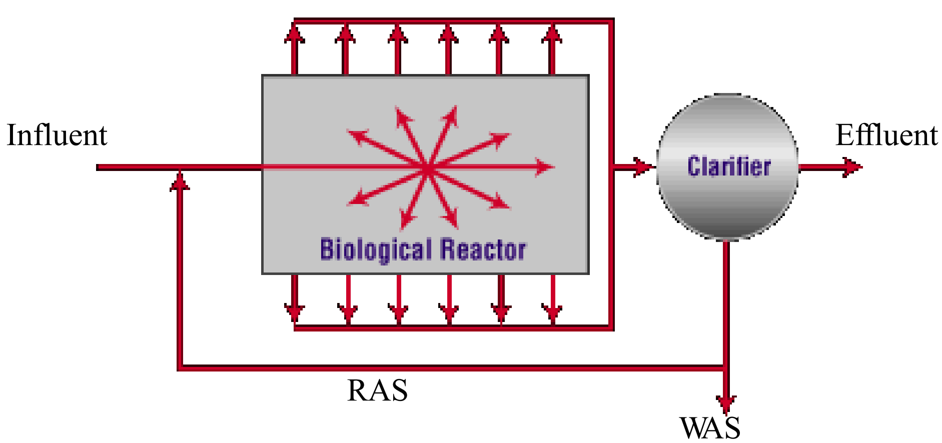
Plug Flow Design Parameters

Application	Domestic and Industrial
BOD Removal Efficiency	85 – 95%
Aeration Type	Diffused or Mechanical
MCRT	5 – 15 days
Aeration Time	4 – 12 hours
MLSS	1500 – 3000 mg/L
RAS Flow	25 – 75% of influent
F:M	0.25 – 0.5 lbs BOD/d/lbs MLVSS
Organic Loading	20 – 40 lbs BOD/d/1000 ft^3

Complete-mix

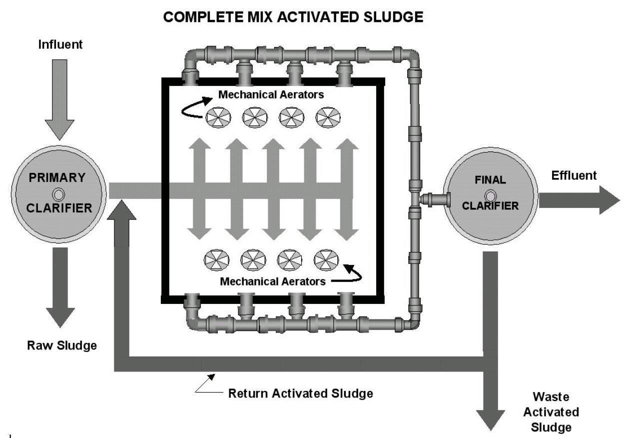
- If you take an MLSS sample at one corner, it should be the same at the opposite corner
- Can handle toxic loads or organic loads – dilutes them out
  - Primary reason to have one of these
- Oxygen demand same throughout
- Needs lots of air and/or mixing
- Susceptible to growth of filamentous bacteria due to food and/or nutrient deficiency (continuous low levels)
  - If organic loads stop coming in, this could become a problem

Complete Mix



Complete Mix

- Low length-to-width ratio
- High air flow rate or mixing power
- Low velocity through the reactor



~Complete Mix

Oxidation Ditch

Mechanical Surface Aeration

Complete Mix Design Parameters

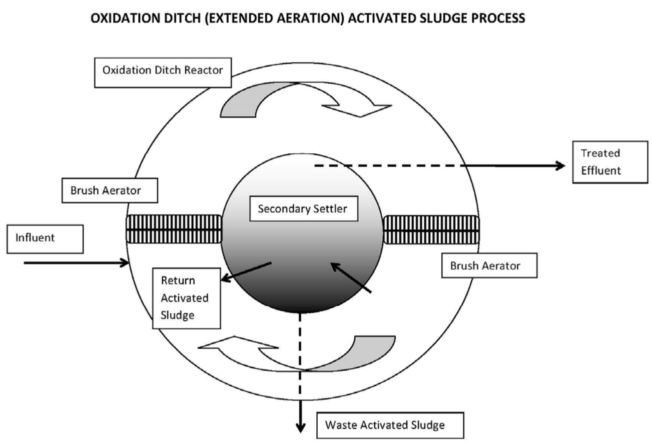
Application	Domestic and Industrial
BOD Removal Efficiency	85 – 95%
Aeration Type	Mechanical, Diffused
MCRT	5 – 15 days
Aeration Time	3 – 10 hours, Ox. Ditch 18-36 hours
MLSS	2000 – 5000 mg/L
RAS Flow	25 – 100% of influent
F:M	0.2 – 0.6 lbs BOD/d/lbs MLVSS
Organic Loading	20 – 80 lbs BOD/d/1000 ft^3

Basin Configuration

Designs

- Oxidation Ditch
- SBR
- Contact Stabilization
- Bardenpho
- Kraus
- Membrane Bioreactor

Oxidation Ditch



- Ring or oval shaped channel
- Equipped with mechanical aeration and mixing devices such as brush roters

Murfreesboro Wastewater Treatment Plant

Oxidation Ditch

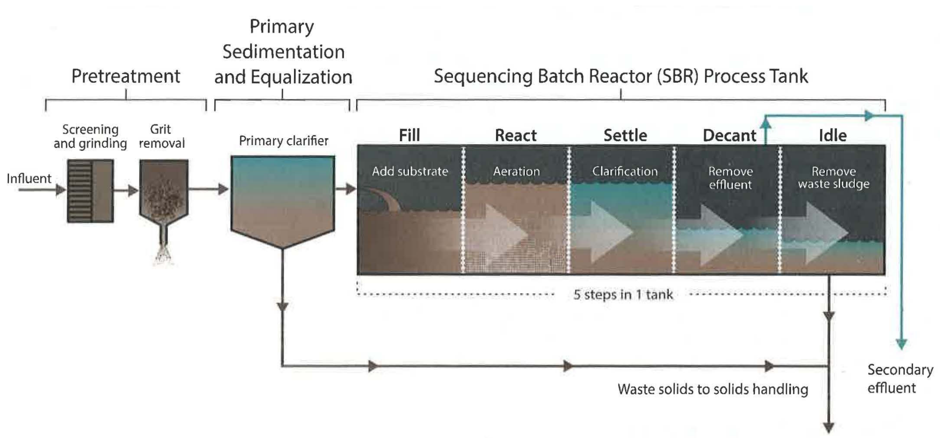
- Brush rotor – first oxidation ditch
  - To control DO, play with depth of water
    - Shaft always stays above water
    - The level of the rotors is fixed, but the deeper the rotor sits in the water, the greater the oxygen transfer from air to the water (greater DO)
    - The ditch outlet level control weir regulates the level of water in the oxidation ditch
  - Some brush rotors were covered to keep down air-borne diseases
  - Disk Rotors are also common and there are some surface and jet aeration systems in the state

Oxidation Ditch

- Velocity of 1 ft/sec
- Very low effluent BOD
- Large tank volume and high oxygen demand are disadvantages
- High MCRT and low F:M
- Low F:M filaments are common
- Energy Hog!

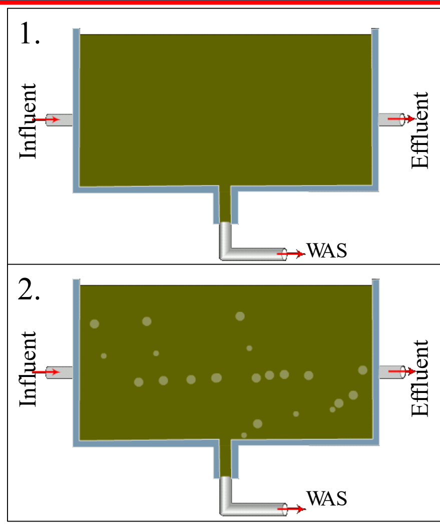
Sequencing Batch Reactor (SBR)

Sequencing Batch Reactor (SBR)



Source: Operation of Wastewater Treatment Plants, Vol I, 8th ed.

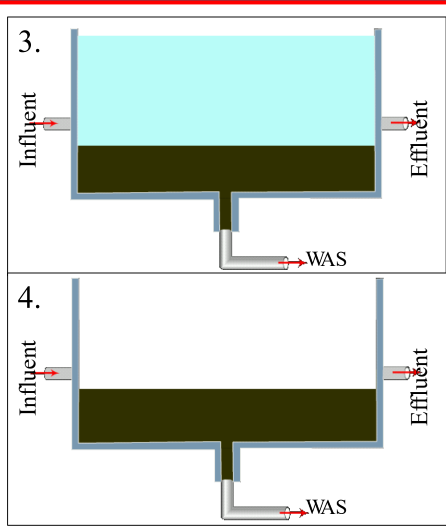
Sequencing Batch Reactor (SBR)



1. Fill – reactor is filled with wastewater

2. React – the wastewater is aerated

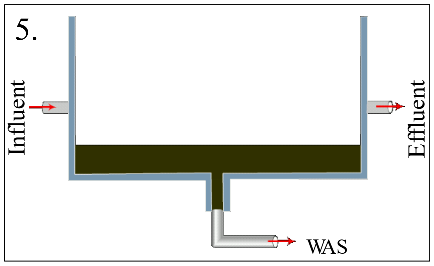
Sequencing Batch Reactor (SBR)



3. Settle – MLSS is separated

4. Decant – treated wastewater is removed

Sequencing Batch Reactor (SBR)



5. Idle – a portion of the waste sludge is removed with adequate sludge left in the tank to provide biomass for the next treatment cycle

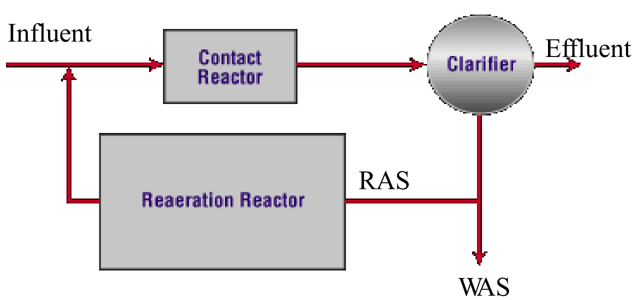
SBR Design Parameters

Application	Smaller Communities, There are big ones also. Cleveland TN
BOD Removal Efficiency	85 – 95%
Aeration Type	Diffused
MCRT	10 – 30 days
Aeration Time	12 – 50 hours
MLSS	1500 – 5000 mg/L
RAS Flow	N/A
F:M	0.05 – 0.3 lbs BOD/d/lbs MLVSS
Organic Loading	25 lbs BOD/d/1000 ft^3

Contact Stabilization

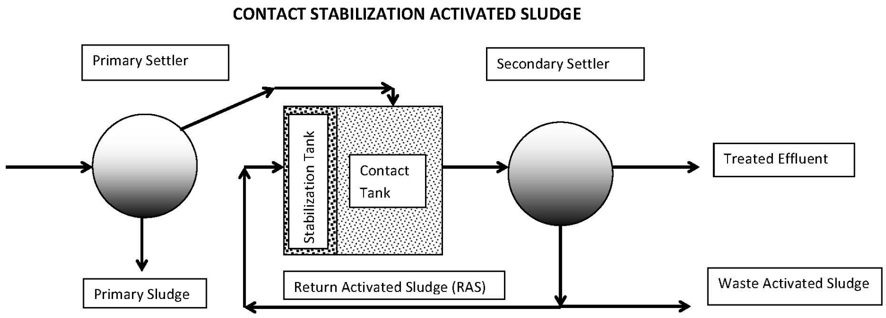
- Conventional plant – *but modified*
- The sludge rearation reactor provides the operator with some flexibility at peak flows to protect the biomass and prevents solids from washing out of the process
- If toxic load comes in, it will shock the contact tank and not affect the stabilization tank
- Both contact tank and reaeration tank are aerated
- Poor ammonia removal

Contact Stabilization



1. Reaeration tank is for RAS.
   - No new food is added
   - Organisms must use stored energy, once used up, they begin searching for more food, this is when they are moved on to the contact tank
2. Contact tank is where the organic load is applied
   - Attempts to have microorganisms take in and store large portions of influent waste in a short period of time (30-90 minutes)
     - Higher F:M than reaeration tank
   - Can avoid a complete wash-out when high flows or toxic load comes in

Contact Stabilization



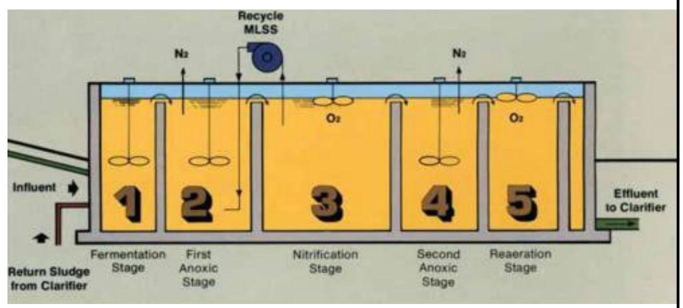
RAS only stays in the Contact Tank for a short time: about 30 – 90 minutes.

Contact Stabilization Design Parameters

Application	Modification of Existing Plant
BOD Removal Efficiency	80 – 90%
Aeration Type	Diffused or Mechanical
MCRT	5 – 15 days
Aeration Time	0.5 – 1.5 hour Contact 3 – 6 hours Reaeration
MLSS	1000 – 3000 mg/L Contact 4000 – 10000 mg/L Reaeration
RAS Flow	25 – 100% of influent
F:M	0.2 – 0.6 lbs BOD/d/lbs MLVSS
Organic Loading	30 – 75 lbs BOD/d/1000 ft^3

Bardenpho Process

- Bardenpho process is named by Dr. James L. **Bar**nardfor
  - **den**itrification and **pho**sphorus removal
- Used to remove between 90-95 percent of all the nitrogen present in the raw wastewater by recycling nitrate-rich mixed liquor from the aeration basin to an anoxic zone located ahead of the aeration basin
- Denitrification takes place in the anoxic zone in the absence of dissolved oxygen

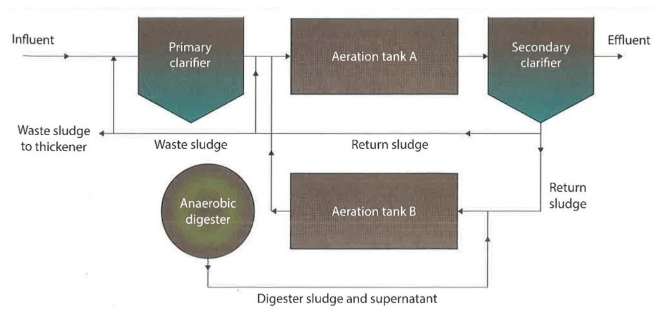


Bardenpho Process

- The degree of nitrate removal depends on the recycle rate
  - Some plants have 2x, 4x, and even 6x the average dry weather flow back to the anoxic zone
  - Usually 4x the average dry weather flow is sufficient
  - If the nitrate in the effluent rises above 1 mg/L, the recycle rate is too high because not enough detention time is provided in the anoxic zone for denitrification to occur
- If phosphorus removal is desired, a fermentation stage is added before the first anoxic zone
- Uses a Plug Flow/Conventional Pattern

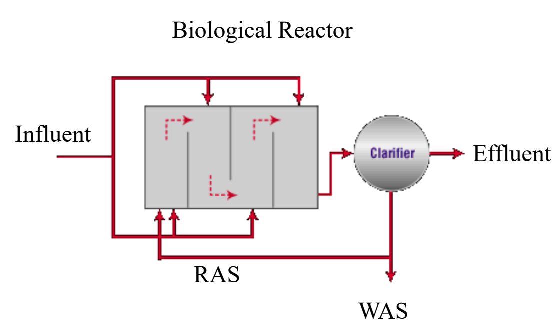
Kraus Process

- Conventional plant – but modified
- Used typically when the plant had a nutrient imbalance commonly caused by industrial wastes
  - Usually a nitrogen deficiency
- To correct this problem, supernatant from the anaerobic digester is fed back to the aeration tank to return the balance

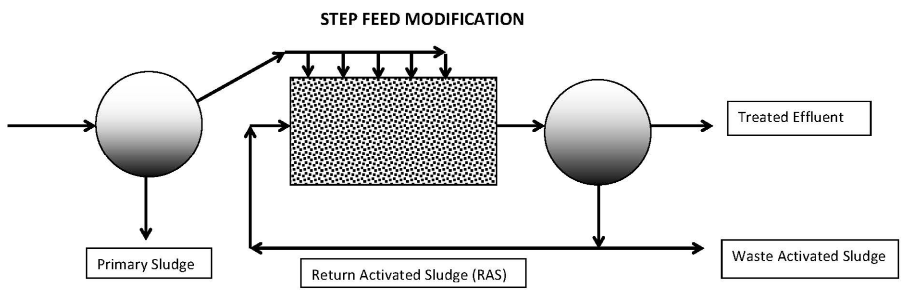


Step Feed

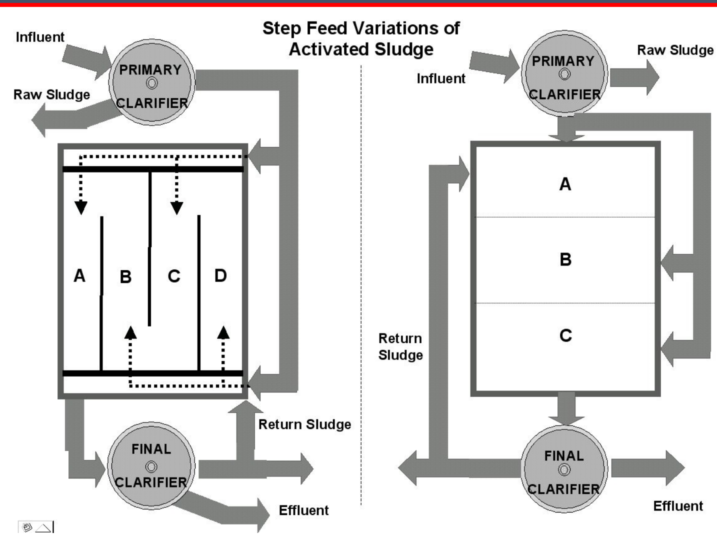
- Conventional plant – *but modified*
- Advantages over conventional operation:
  - Less aeration volume to treat same volume of wastewater
  - Better control in handling shock loads
  - Operator flexibility
  - Can handle more volume and loading than conventional, but does not product the same effluent quality
  - Potential for handling lower applied solids to the secondary clarifier



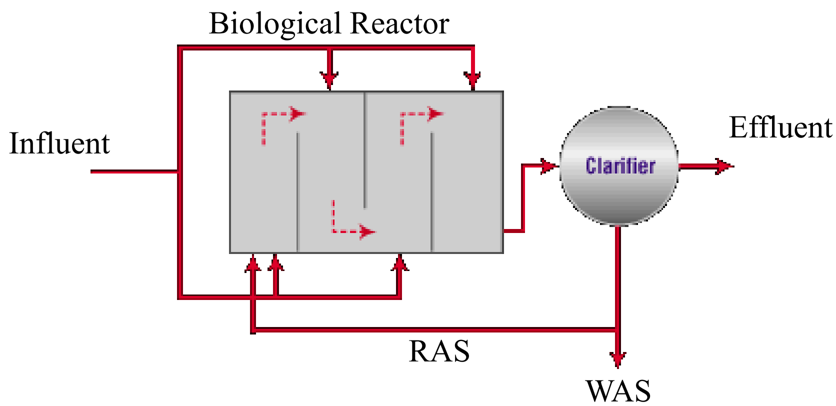
Step Feed



Step Feed - Variations



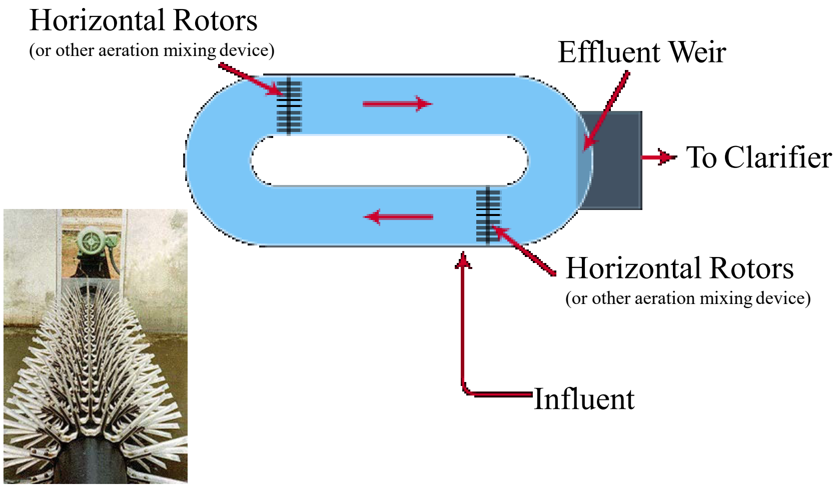
Step Feed



Step Feed Design Parameters

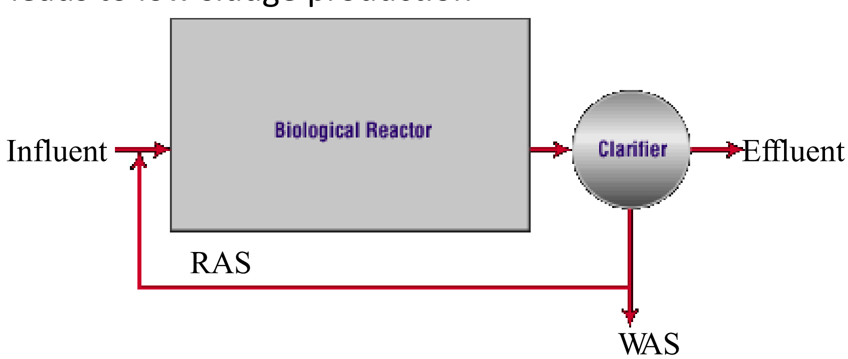
Application	Domestic and Industrial
BOD Removal Efficiency	85 – 95%
Aeration Type	Diffused
MCRT	5 – 15 days
Aeration Time	3 – 6 hours Flow 5 – 7.5 hours Solids
MLSS	1500 – 3000 mg/L
RAS Flow	25 – 75% of influent
F:M	0.2 – 0.5 lbs BOD/d/lbs MLVSS
Organic Loading	40 – 60 lbs BOD/d/1000 ft^3

Oxidation Ditch- low rate, complete mix



Extended Aeration- low rate

- The low organic loading on these systems requires that microorganisms compete for food and, at times, use their own cell mass for energy
- This is termed "endogenous respiration" and leads to low sludge production

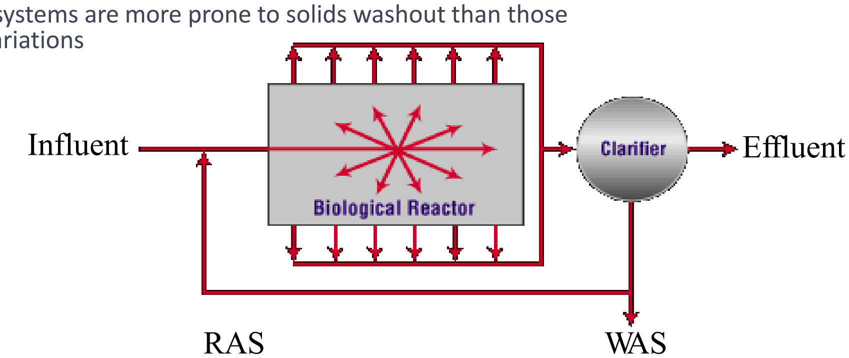


Extended Aeration Design Parameters

Application	Smaller Communities and Package Plants
BOD Removal Efficiency	85 – 95%
Aeration Type	Diffused or Mechanical
MCRT	10 – 30 days
Aeration Time	18 – 36 hours
MLSS	2000 – 6000 mg/L
RAS Flow	25 – 150% of influent
F:M	0.05 – 0.15 lbs BOD/d/lbs MLVSS
Organic Loading	10 – 25 lbs BOD/d/1000 ft^3

High-Rate Aeration

- A type of configuration with a high MLSS, High F:M, and shorter detention times
- Can produce effluent quality approaching that of a conventional system, high-rate systems must be operated with special care
  - Clarifiers in these systems are more prone to solids washout than those in other process variations

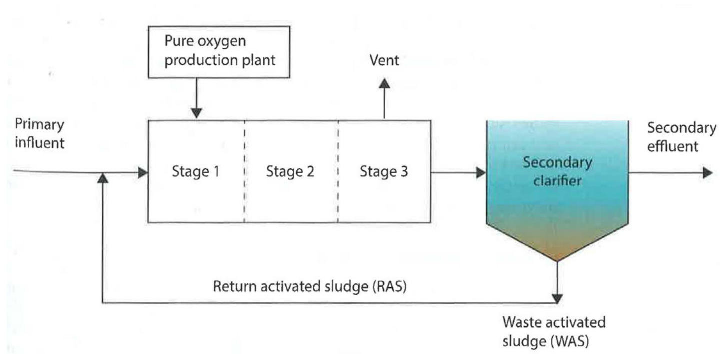


High-Rate Aeration Design Parameters

Application	Industrial
BOD Removal Efficiency	75 – 85%
Aeration Type	Mechanical or Diffused (rare)
MCRT	5 – 10 days
Aeration Time	2 – 4 hours
MLSS	4000 – 10000 mg/L
RAS Flow	100 – 500% of influent
F:M	0.4 – 1.5 lbs BOD/d/lbs MLVSS
Organic Loading	100 – 1000 lbs BOD/d/1000 ft^3

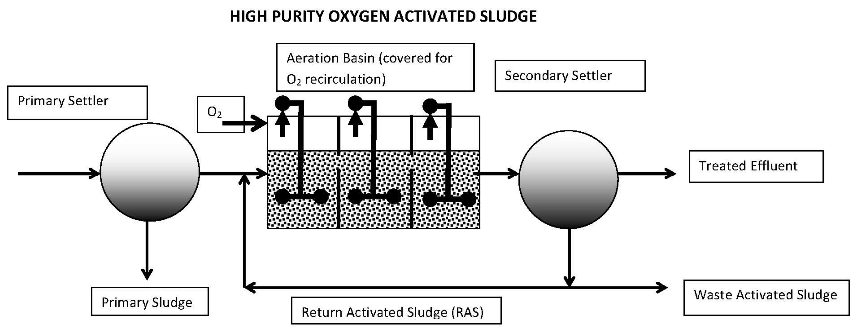
Pure Oxygen

- The use of oxygen gas makes it possible to obtain very high DO concentrations, which in turn allows a higher MLSS concentration to be maintained
- The most common pure oxygen process uses a plug flow reactor that is covered to retain oxygen and obtain a high degree of oxygen use



Source: Operation of Wastewater Treatment Plants, Vol I, 8th ed.

Pure Oxygen



Pure Oxygen Facility

- Liquid oxygen is a fire hazard (comes delivered at -300ºF)
- Continuously control oxygen feed rate depending on how active the microorganisms are
- Always has a covered tank to prevent costly pure oxygen from going off into the atmosphere (keeps it in the tank)
  - The wastewater, RAS, and oxygen feed gas enter the first stage of this system and flow concurrently through the reactor.
  - These systems can handle high organic loadings with shorter aeration periods because of their elevated MLSS concentrations
- Nitrification ability limited due to accumulation of CO_2 in gas headspace which causes low pH in mixed liquor

Pure Oxygen Facility

Oxygen for this process can be supplied by:

1. Trucked-in liquid oxygen (LOX)
   - Converted to gaseous O_2 using heat exchangers
2. Cryogenic oxygen generation
   - Produces liquid O_2 by liquefaction of air, followed by fractional distillation to separate the air components, mainly nitrogen and oxygen.
3. Pressure - swing adsorption generation
4. Vacuum - swing adsorption

Pure Oxygen Design Parameters

Application	Domestic and Industrial
BOD Removal Efficiency	85 – 95%
Aeration Type	Mechanical
MCRT	3 – 10 days
Aeration Time	1 – 3 hours
MLSS	2000 – 5000 mg/L
RAS Flow	25 – 50% of influent
F:M	0.25 – 1.0 lbs BOD/d/lbs MLVSS
Organic Loading	100 – 200 lbs BOD/d/1000 ft^3

Selectors

Anaerobic Selector for Phosphorus removal

- Units generally before the aeration basin
- Conditions may be: aerobic, anoxic, anaerobic
- Used for: filament control and nutrient removal
- Different environment that "selects" for or against certain microorganisms
- HDT~ 10-30 minutes

Combined/Coupled Systems

Trickling Filter/Solids Contact

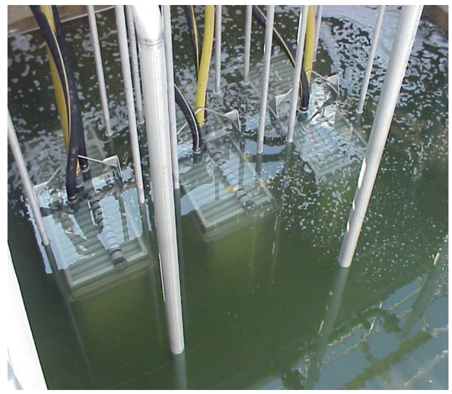
- AS combined with fixed film
  - Roughing filter
  - Trickling Filter/Solids Contact
- Coupled
  - Activated sludge with fixed film media inside the reactor, IFAS

Other Unique Designs

Package Plant

Package Plant Issues:
Temperature, Rust, Airlift
Pumps, Age

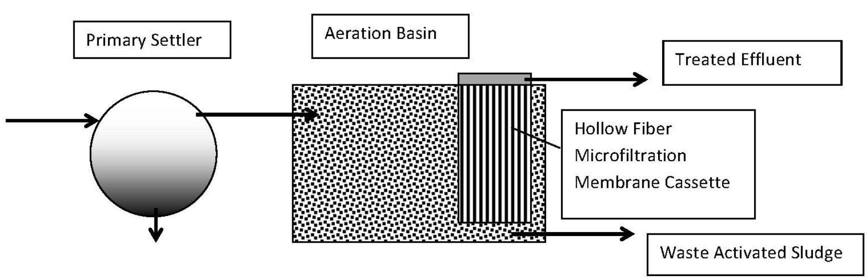
Membrane BioReactor, MBR



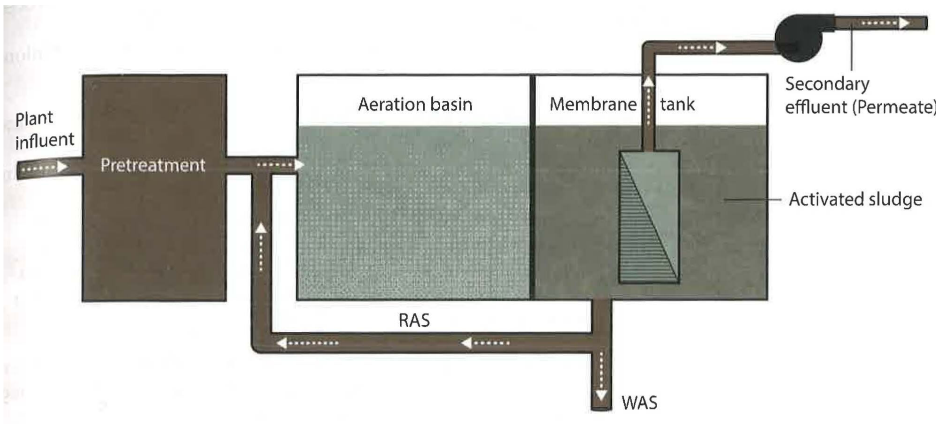
Super Energy Hog!

Membrane Bioreactor (MMBR)

MICROFILTER MEMBRANE BIOREACTOR (MMBR)



Membrane Bioreactor (MMBR)



Source: Operation of Wastewater Treatment Plants, Vol I, 8th ed.

Activated Sludge Foam

- All plants have some foam
- It's presence is not necessarily bad
- Foam is merely an indicator
- Normal Foam:
  - "Fresh, Crisp, Light Colored Foam“
  - What is normal for your plant?

Surfactant Foam

- ➢ Looks like soap suds
- ➢ May have soap odor also
- ➢ Most are degradable, but…

- ✓ Stop the discharge
- ✓ Divert & treat off line
- ✓ Slow or stop wasting
- ✓ Water spray and chemical defoamers
- ✓ Provide needed air but don't over aerate
- ✓ Are there internal sources such as polymers

Foaming Problems

- ➢ White, billowy foam is often caused by surfactant
- ➢ Development of white, billowy foam is also common under start-up conditions.

Old Sludge- High MCRT Foam

- Thick, stable, often dark
- Tough to break up with water hose or spray
- Generally will have *Nocardia* present
- Solution-Waste!

Nutrient Deficiency Foam

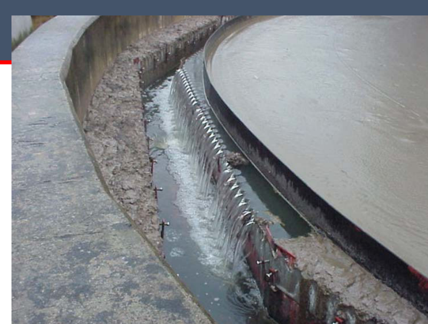
- Rare in Municipal Treatment
- More common in food processing
- White, stable, greasy foam
- Solution- add fertilizer

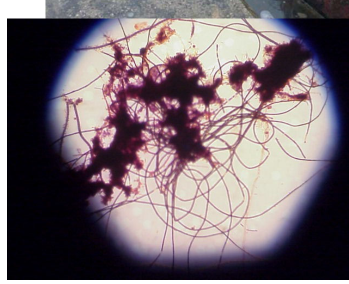
Foam Cleanup

- Act quickly
- Contain within the plant
- Water sprays
- Chemical defoamers for chemical foams
- TSP - Trisodium Phosphate cleaner

Second Foam/Scum Filament

- *Microthrix parvicella*
- M. Parvicella
- Gram positive
- Often the stain looks like purple spaghetti
- Favors colder weather
- Chlorinate the RAS





Process Goals

Successful activated sludge process performance is judged by effluent quality.

Goals of Activated Sludge

- Produce Clean Water (CleanWater Act)
- Remove Organic Pollutants (CBOD,other)
- Reduction of Pathogenic Organisms
- Removal of Nutrients & Inorganic Pollutants (Total Nitrogen & Phosphorus, NH_4,metals)
- Permit Limits- mg/L, lbs,% removal (85% monthly & 40% daily)

Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

Activated Sludge Vocabulary – Part 1

1. ______________________________ describes the taking in or soaking up of a substance into the body of another by molecular or chemical action.

2. A mass or clump of organic material consisting of living organisms feeding on the wastes in wastewater, dead organisms, and other debris is called _______________________________.

3. The biological wastewater treatment process that speeds up the decomposition of wastes, involving mixed liquor that is aerated and agitated before sedimentation, is called the _______________________________________.

4. The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another material is referred to as _____________________________.

5. The _____________________________ is where raw or settled wastewater is mixed with return sludge and aerated.

6. This type of bacteria can use either dissolved molecular oxygen or oxygen obtained from food materials such as sulfate or nitrate ions: ____________________________. In other words, these bacteria can live under aerobic or anaerobic conditions.

7. The suspended solids in the mixed liquor of an aeration tank are called _____________________________________.

8. ______________________________ bacteria must have molecular (dissolved) oxygen (DO) to survive. These are also called aerobes. In contrast, ____________________________ bacteria do not need molecular (dissolved) oxygen to survive. These are also called anaerobes.

9. ____________________________ bacteria grow in a thread-like or filamentous form and are a common cause of sludge bulking in the activated sludge process.

10. The organic or volatile suspended solids in the mixed liquor of an aeration tank are called _____________________________________. This volatile portion is used as a measure or indication of the microorganisms present.

11. An ____________________________ environment is oxygen deficient or lacking sufficient oxygen. Generally, it refers to an environment in which chemically bound oxygen, such as nitrate, is present.

12. A bacterial life phase that occurs when living organisms oxidize some of their own cellular mass due to an inadequate amount of food in their environment is called _____________________________.

13. 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 ______________________________ as long as it is in the aeration tank.

14. The jelly-like masses of bacteria that are found in both the trickling filter and activated sludge process are called ________________________ masses.

<u>Word Bank:</u>

Absorption

Mixed liquor

Endogenous respiration

Anaerobic

Facultative

Mixed Liquor Volatile Suspended Solids (MLVSS)

Aerobic

Aeration tank

Biomass

Zoogleal

Adsorption

Mixed Liquor Suspended Solids (MLSS)

Filamentous

Activated sludge process

Anoxic

CHAPTER 7

Activated Sludge

ACTIVATED SLUDGE

7.1 General

7.1.1 Applicability

The activated sludge process and its various modifications may be used where sewage is amenable to biological treatment. This process requires close attention and more competent operator supervision than some of the other biological processes. A treatability study may be required to show that the organics are amendable to the proposed treatment. For example, industrial wastewaters containing high levels of starches and sugars may cause interferences with the activated sludge process due to bulking.

Toxic loadings from industries and excessive hydraulic loadings must be avoided to prevent the loss or destruction of the activated sludge mass. If toxic influents are a possibility, a properly enforced industrial pretreatment program will prove extremely beneficial to the WWTP and will be required. It takes days and sometimes weeks for the plant to recover from a toxic overload and will likely result in permit violations. Flow equalization, as detailed in Chapter 4, may be required in some instances. These requirements shall be considered when proposing this type of treatment.

7.1.2 Process Selection

The activated sludge process and its several modifications may be employed to accomplish varied degrees of removal of suspended solids and reduction of BOD and ammonia. Choice of the process most applicable will be influenced by the proposed plant size, type of waste to the treated, and degree and consistency of treatment required. All designs should provide for flexibility to incorporate as many modes of operation as is reasonably possible.

Calculations and/or documentation shall be submitted to justify the basis of design for the following:

a. Process efficiency
b. Aeration tanks
c. Aeration equipment (including oxygen and mixing requirements)
d. Operational rationale (including maintenance)
e. Costs (capital and operating)

In addition, the design must comply with any requirements set forth in other chapters such as clarifiers, sludge processing, etc.

7.1.3 Pretreatment

Where primary settling tanks are not used, effective removal or exclusion of grit, debris, excessive oil or grease, and comminution or screening of solids shall be accomplished prior to the activated sludge process.

Where primary settling is used, provisions should be made for discharging raw sewage directly to the aeration tanks to facilitate plant start-up and operation during the initial stages of the plant's design life. Also, primary effluents are often low in D.O. This should be planned for in the design.

7.2 Types of Processes

Figure 7.1 shows the flow schematics of the major types of activated sludge processes, excluding pretreatment. The types that are simply modifications of these processes are not shown.

7.2.1 Conventional

Conventional activated sludge is characterized by introduction of influent wastewater and return activated sludge at one end of the aeration tank, a plug-flow aeration tank, and diffused aeration.

7.2.2 Complete Mix

Complete mix activated sludge is characterized by introduction of influent wastewater and return activated sludge throughout the aeration basin and the use of a completely mixed aeration tank. Complete mix aeration tanks may be arranged in series to approximate plug flow and conventional activated sludge.

7.2.3 Step Aeration

Step aeration activated sludge is characterized by introduction of the influent wastewater at two or more points in the aeration tank, use of a plug-flow aeration tank, and diffused aeration.

7.2.4 Tapered Aeration

Tapered aeration is similar to conventional activated sludge except that the air supply is tapered to meet the organic load within the tank. More air is added to the influent end of the tank where the organic loading and oxygen demand are the greatest.

7.2.5 Contact Stabilization

Contact stabilization activated sludge is characterized by the use of two aeration tanks for each process train, one to contact the influent wastewater and return activated sludge (contact tank) and the other to aerate the return activated sludge (stabilization tank) and promote the biodegradation of the organics absorbed to the bacterial flocs.

7.2.6 Extended Aeration

Extended aeration activated sludge is characterized by a low F/M ratio, long sludge age, and long aeration tank detention time (greater than 18 hours). For additional details on oxidation ditches see Section 7.7).

7.2.7 High-Rate Aeration

High-rate aeration activated sludge is characterized by high F/M ratio, low sludge age, short aeration tank detention time, and high mixed-liquor suspended solids. High-rate aeration should be followed by other BOD and suspended solids removal processes to provide secondary treatment.

7.2.8 High-Purity Oxygen

High-purity oxygen activated sludge is characterized by the use of high-purity oxygen instead of air for aeration.

7.2.9 Kraus Process

Kraus process activated sludge is characterized by use of an aeration tank to aerate a portion of the return activated sludge, digester supernatant, and digested sludge in order to provide nitrogen (ammonia) to a nitrogen-deficient wastewater.

7.2.10 Sequencing Batch Reactors (SBR)

The SBR process is a fill-and-draw, non-steady state activated sludge process in which one or more reactor basins are filled with wastewater during a discrete time period, and then operated in a batch treatment mode. SBR's accomplish equalization, aeration, and clarification in a timed sequence. For additional details see Section 7.6.

7.3 Aeration Tanks

7.3.1 Required Volume

The size of the aeration tank for any particular adaptation of the process shall be based on the food-to-microorganism (F/M) ratio, using the influent BOD (load per day) divided by the mixed-liquor volatile suspended solids. Alternatively, aeration tanks may be sized using sludge age. The calculations using the F/M ratio or sludge age shall be based on the kinetic relationships.

APPENDIX 7A shows the permissible range of F/M ratio, sludge age, mixed-liquor suspended solids, aeration tank detention time, aerator loading, and activated sludge return ratio for design of the various modifications of the activated sludge process. All design parameters shall be checked to determine if they fall within the permissible range for the selected F/M ratio or sludge area and the aeration tank size. Diurnal load variations and peak loadings must be considered when checking critical parameters.

7.3.2 Shape and Mixing

The dimensions of each independent mixed-liquor aeration tank or return sludge reaeration tank should be such as to maintain effective mixing and utilization of air when diffused air is used. Liquid depths should not be less than 10 feet or more than 30 feet except in special design cases. For plug-flow conditions using very small tanks or tanks with special configuration, the shape of the tank and/or the installation of aeration equipment should provide for elimination of short-circuiting through the tank.

Aerator loadings should be considered and the horsepower per 1,000 cubic feet of basin volume required for oxygen transfer should be limited to prevent excessive turbulence in the aeration basins, which might reduce activated sludge settleability.

7.3.3 Number of Units

Multiple tanks capable of independent operation may be required for operability and maintenance reasons, depending on the activated sludge process, size of the plant, and the reliability classification of the sewerage works (refer to Section 1.3.11).

7.3.4 Inlets and Outlets

7.3.4.1 Controls

Inlets and outlets for each aeration tank unit in multiple tank systems should be suitably equipped with valves, gates, stop plates, weirs, or other devices to permit control of the flow and to maintain reasonably constant liquid level. The hydraulic properties of the system should permit the maximum instantaneous hydraulic load to be carried with any single aeration tank unit out of service.

7.3.4.2 Conduits

Channels and pipes carrying liquids with solids in suspension should be designed to maintain self-cleaning velocities or should be agitated to keep such solids in suspension at all rates of flow within the design limits.

7.3.4.3 Hydraulics

Where multiple aeration tanks and secondary clarifiers are used, provisions should be made to divide the flow evenly to all aeration tanks in service and then recombine the flows, and to divide the flow evenly to all secondary clarifiers in service and then recombine the flows. Treatments plants using more than four aeration tanks and secondary clarifiers may divide the activated sludge systems into two or more process trains consisting of not less than two aeration tanks and secondary clarifiers per process train.

7.3.4.4 Bypass

When a primary settling tank is used, provisions shall also be made for discharging raw wastewater directly to the aeration tanks following pretreatment for start-ups.

7.3.5 Measuring Devices

For plants designed for less than 250,000 gallons per day, devices shall be installed for indicating flow rates of influent sewage, return sludge, and air to each aeration tank. For plants designed for greater than 250,000 gallons per day, devices shall be installed for totalizing, indicating, and recording influent sewage and returned sludge to each aeration tank. Where the design provides for all returned sludge to be mixed with the raw sewage (or primary effluent) at one location, the mixed-liquor flow rate to each aeration tank shall be measured, and the flow split in such a manner to provide even loading to each tank, or as desired by operations.

7.3.6 Freeboard and Foam Control

Aeration tanks shall have a freeboard of at least 18 inches. Freeboards of 24 inches are desirable with mechanical aerators.

Consideration shall be given for foam control devices on aeration tanks. Suitable spray systems or other appropriate means will be acceptable. If potable water is used, approved backflow prevention shall be provided on the water lines. The spray lines shall have provisions for draining to prevent damage by freezing.

7.3.7 Drain and Bypass

Provisions shall be made for dewatering each aeration tank for cleaning and maintenance. The dewatering system shall be sized to permit removal of the tank contents within 24 hours. If a drain is used, it shall be valved. The dewatering discharge shall be upstream of the activated sludge process.

Provisions shall be made to isolate each aeration tank without disrupting flow to other aeration tanks.

Proper precautions shall be taken to ensure the tank will not "float" when dewatered.

7.3.8 Other Considerations

Other factors that might influence the efficiency of the activated sludge process should be examined. Septic and/or low pH influent conditions are detrimental, particularly where primary clarifiers precede the activated sludge process or when the collection system allows the sewage to go septic. Often, the pH is buffered by the biological mass, but wide variations in the influent should be avoided and, if present, chemical addition may be necessary.

Aerobic organisms require minimum quantities of nitrogen and phosphorus. Domestic wastewater usually has an excess of nitrogen and phosphorus; however, many industrial wastewaters are deficient in these elements. A mass balance should be performed to see if the combined industrial and domestic influent contains sufficient nitrogen and phosphorus or if nutrient levels will have to be supplemented.

7.4 Aeration Equipment

7.4.1 General

Oxygen requirements generally depend on BOD loading, degree of treatment, and level of suspended solids concentration to be maintained in the aeration tank mixed liquor. Aeration equipment shall be designed to supply sufficient oxygen to maintain a minimum dissolved oxygen concentration of 2 milligrams per liter (mg/l) at average design load and 1.0 mg/l at peak design loads throughout the mixed liquor. In the absence of experimentally determined values, the design oxygen requirements for all activated sludge processes shall be 1.1 lbs oxygen per lb peak BOD_5 applied to the aeration tanks, with the exception of the extended aeration process, for which the value shall be 2.35. Aeration equipment shall be of sufficient size and arrangement to maintain velocities greater than 0.5 foot per second at all points in the aeration tank.

The oxygen requirements for an activated sludge system can be estimated using the following relationship:

O_2 = (a) (BOD) + b (MLVSS)

O_2 = pounds of oxygen required per day

BOD = pounds of BOD removed per day (5-day BOD)*

MLVSS = pounds of mixed liquor volatile suspended solids contained in the aeration basin

a= amount of oxygen required for BOD synthesis. "a" will range from 0.5 to 0.75 pound of oxygen per pound of BOD removed

b= amount of oxygen required for endogenous respiration or decay. "b" will range from 0.05 to 0.20 pound of oxygen per pound of MLVSS

*BOD removal shall be calculated as influent BOD_5 minus soluble effluent BOD_5.

For preliminary planning before process design is initiated, a rough estimate can be obtained by using 1.0 to 1.2 pounds of oxygen per pound of BOD removed (assuming no nitrification).

7.4.2 Diffused Air Systems

7.4.2.1 Design Air Requirements

The aeration equipment shall be designed to provide the oxygen requirements set forth above. Minimum requirements for carbonaceous removal are shown below. (Oxygen requirements for nitrification are in addition to that required for carbonaceous removal where applicable; i.e., low F/M.)

Process	Cubic Feet of Air Available per Pound of BOD Load Applied **to Aeration Tank**
Conventional	1,500
Step Aeration	1,500
Contact Stabilization	1,500
Modified or "High Rate" (depending upon BOD removal expected)	400 to 1,500
Extended Aeration	2,100

Air required for channels, pumps, or other air-use demand shall be added to the air volume requirements.

Manufacturers' specifications must be corrected to account for actual operation conditions (use a worst case scenario). Corrections shall be made for temperatures other than 20^{o}C and elevations greater than 2,000 feet.

7.4.2.2 Special Details

The specified capacity of blowers or air compressors, particularly centrifugal blowers, shall take into account that the air intake temperature might reach extremes and that pressure might be less than normal. Motor horsepower shall be sufficient to handle the minimum and maximum ambient temperatures on record.

The blower filters shall be easily accessible. Spare filters should be provided.

The blowers shall be provided in multiple units, arranged and in capacities to meet the maximum air demand with the single largest unit out of service. The design shall also provide for varying the volume of air delivered in proportion to the load demand of the plant.

The spacing of diffusers shall be in accordance with the oxygen and mixing requirements in the basin. If only one aeration tank is proposed, arrangement of diffusers should permit their removal for inspection, maintenance, and replacement without de-watering the tank and without shutting off the air supply to other diffusers in the tank.

Individual units of diffusers shall be equipped with control valves, preferably with indicator markings, for throttling or for complete shutoff. Diffusers in each assembly shall have substantially uniform pressure loss. The adjustment of one diffuser should have minimal influence on the air supply rate to any other diffusers.

Flow meters and throttling valves shall be placed in each header. Air filters shall be provided as part of the blower assembly to prevent clogging of the diffuser system. Means shall be provided to easily check the air filter so that it will be replaced when needed.

7.4.3 Mechanical Aeration Equipment

Power input from mechanical aerators should range from 0.5 to 1.3 horsepower per 1,000 cubic feet of aeration tank.

The mechanism and drive unit shall be designed for the expected conditions of the aeration tank in terms of the proven performance of the equipment.

Due to the high heat loss, consideration shall be given to protecting subsequent treatment units from freezing where it is deemed necessary. Multiple mechanical aeration unit installations shall be designed to meet the maximum oxygen demand with the largest unit out of service. The design shall normally also provide for varying the amount of oxygen transferred in proportion to the load demand on the plant.

A spare aeration mechanism shall be furnished for single-unit installations. Access to the aerators shall be provided for routine maintenance.

7.4.4 Flexibility and Energy Conservation

The design of aeration systems shall provide adequate flexibility to vary the oxygen transfer capability and power consumption in relation to oxygen demands. Particular attention should be given to initial operation when oxygen demands may be significantly less that the design oxygen demand. The design shall always maintain the minimum mixing levels; mixing may control power requirements at low oxygen demands.

Dissolved oxygen probes and recording should be considered for all activated sludge designs. Consideration will be given to automatic control of aeration system oxygen transfer, based on aeration basin dissolved oxygen concentrations, provided manual back-up operation is available. A dissolved oxygen field probe and meter is to be provided for all activated sludge installations.

Watt-hour meters shall be provided for all aeration system drives to record power usage.

Energy conservation measures shall be considered in design of aeration systems. For diffused aeration systems, the following shall be considered:

a. Use of small compressors and more units

b. Variable-speed drives on positive-displacement compressors

c. Intake throttling on centrifugal compressors

d. Use of timers while maintaining minimum mixing and D.O. levels (consult with manufacturer's recommendations for proper cycling)

e. Use of high-efficiency diffusers

f. Use of separate and independent mixers and aerators

For mechanical aeration systems, the following shall be considered:

a. Use of smaller aerators

b. Variable aeration tank weirs

c. Multiple-speed motors

d. Use of timers

7.5 Additional Details

7.5.1 Lifting Equipment and Access

Provisions shall be made to lift all mechanical equipment and provide sufficient access to permit its removal without modifying existing or proposed structures.

7.5.2 Noise and Safety

Special consideration shall be given to the noise produced by air compressors used with diffused aeration systems and mechanical aerators. Ear protection may be required. Silencers for blowers may be required in sensitive areas.

Handrails shall be provided on all walkways around aeration tanks and clarifiers.

The following safety equipment shall be provided near aeration tanks and clarifiers:

Safety vests
Lifelines and rings
Safety poles

Walkways near aeration tanks shall have a roughened surface or grating to provide safe footing and be built to shed water.

Guards shall be provided on all moving machinery in conformance with OSHA requirements.

Sufficient lighting shall be provided to permit safe working conditions near aerations tanks and clarifiers at night.

7.6 Sequencing Batch Reactors (SBRs)

SBRs shall be designed to meet all the requirements set forth in preceding sections on activated sludge. Special consideration shall be given to the following:

7.6.1 A pre-aeration, flow-equalization basin is to be provided for when the SBR is in the settle and/or draw phases. If multiple SBR basins are provided, a pre-aeration basin will not be needed if each SBR basin is capable of handling all the influent peak flow while another basin is in the settle and/or draw phase.

7.6.2 When discharging from the SBR, means need to be provided to avoid surges to the succeeding treatment units. The chlorine contact tank shall not be hydraulically overloaded by the discharge.

7.6.3 The effluent from the SBRs shall be removed from just below the water surface (below the scum level) or a device which excludes scum shall be used. All decanters shall be balanced so that the effluent will be withdrawn equally from the effluent end of the reactor.

7.6.4 Prevailing winds must be considered in scum control.

7.7 Oxidation Ditch

7.7.1 General

The oxidation ditch is a complete-mixed, extended aeration, activated sludge process which is operated with a long detention time. Brush-rotor (or disk type) aerators are normally used for mixing and oxygen transfer. All requirements set forth in previous sections and/or chapters must be met, with the exception of those items addressed below.

7.7.2 Special Details

7.7.2.1 Design Parameters

The design parameters shall be in the permissible range as set forth in Table 7.1 for F/M, sludge age, MLSS, detention time, aerator loading, and activated sludge return ratio.

7.7.2.2 Aeration Equipment

Aeration equipment shall be designed to transfer 2.35 pounds of oxygen per pound of BOD at standard conditions. The oxygen requirement takes into account nitrification in a typical wastewater. Also, a minimum average velocity of one foot per second shall be maintained, based on the pumping rate of the aeration equipment and the aeration basin cross-sectional area.

A minimum of two aerators per basin is required.

7.7.2.3 Aeration Tank Details

a. Influent Feed Location

Influent and return activated sludge feed to the aeration tank should be located just upstream of an aerator to afford immediate mixing with mixed liquor in the channel.

b. Effluent Removal Location

Effluent from the aeration channel shall be upstream of an aerator and far enough upstream from the injection of the influent and return activated sludge to prevent short-circuiting.

c. Effluent Adjustable Weir

Water level in the aeration channel shall be controlled by an adjustable weir or other means. In calculating weir length, use peak design flow plus maximum recirculated flow to prevent excessive aerator immersion.

d. Walkways and Splash Control

Walkways must be provided across the aeration channel to provide access to the aerators for maintenance. The normal location is above the aerator. Splash guards shall be provided to prevent spray from the aerator on the walkway. Bridges should not be subject to splash from the rotors.

e. Baffles

Horizontal baffles, placed across the channel, may be used on all basins with over 6 feet liquid depth, and may be used where the manufacturer recommends them to provide proper mixing of the entire depth of the basin.

Baffles should be provided around corners to ensure uniform velocities.

7.7.3 45-Degree Sloping Sidewall Tanks

7.7.3.1 Liquid Depth

Liquid depth shall be 7 to 10 feet, depending on aerator capability, as stated by the manufacturer.

7.7.3.2 Channel Width at Water Level

The higher ratios (channel width at water level divided by aerator length) are to be used with smaller aerator lengths.

3- to 15-foot-long rotors, ratio 3.0 to 1.8.

16- to 30-foot-long rotors, ratio 2.0 to 1.3

Above 30-foot-long rotors, ratio below 1.5

7.7.3.3 Center Island

When used, the minimum width of center island at liquid level, based on aerator length, should be as follows (with center islands below minimum width, use return flow baffles at both ends):

3- to 5-foot-long rotor, 14 feet

6- to 15-foot-long rotor, 16 feet

16- to 30-foot-long rotor, 20 feet

Above 30-foot-long rotors, 24 feet

7.7.3.4 Center Dividing Walls

Center dividing walls can be used but return flow baffles at both ends are required. The channel width, W, is calculated as flat bottom plus 1/2 of sloping sidewall. Baffle radius is W/2. Baffles should be offset by W/8, with the larger opening accepting the flow and the smaller opening downstream compressing the flow.

7.7.3.5 Length of Straight Section

Length of straight section of ditch shall be a minimum of 40 feet or at least two times the width of the ditch at liquid level.

7.7.3.6 Preferred Location of Aerators

Aerators shall be placed just downstream of the bend, normally 15 feet, with the long straight section of the ditch downstream of the aerator.

7.7.4 Straight Sidewall Tanks

7.7.4.1 Liquid Depth

Liquid depth shall be 7 to 12 feet, depending on aerators.

7.7.4.2 Aerator Length

Individual rotor length shall span the full width of the channel, with necessary allowance required for drive assembly and outboard bearing.

7.7.4.3 Center Island

Where center islands are used, the width should be the same as with 45-degree sloping sidewalls, or manufacturer's recommendation.

7.7.4.4 Center Dividing Walls

When a center dividing wall is used, return flow baffles are required at both ends. Return flow baffle radius is width of channel, W, divided by 2, W/2. Baffles should be offset by W/8, with the larger opening accepting the flow and the smaller opening downstream compressing the flow.

7.7.4.5 Length of Straight Section

Length of straight section downstream of aerator shall be near 40 feet or close to two times the aerator length. In deep tanks with four aerators, aerators should be placed to provide location for horizontal baffles.

7.7.4.6 Preferred Location of Aerators

Aerators should be placed just downstream of the bend with the long straight section of the tank downstream of the aerator. Optimal placement of rotors will consider maintaining ditch center line distance between rotors close to equal.

APPENDIX 7-A

Section 5
Fixed Film Systems

Section 5
Fixed Film Systems

Types of Fixed Film Systems

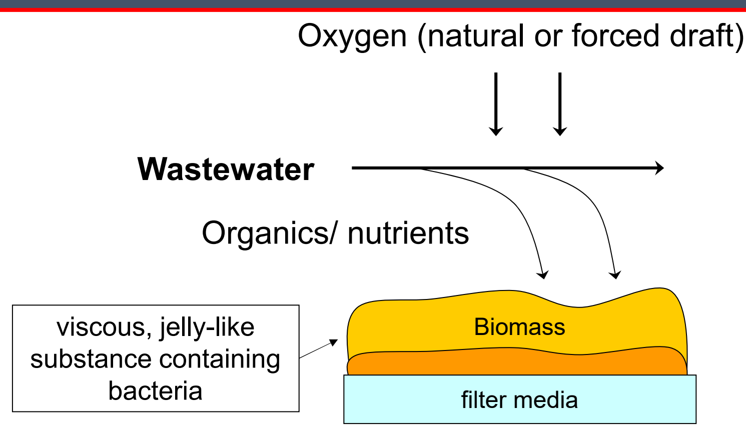
- Trickling Filters
- Rotating Biological Contactor (RBC)
- Moving-bed biofilm reactor (MBBR)
- Integrated Fixed Film Activated Sludge (IFAS)

Theory of Fixed Film Operation

Microorganisms are attached to a surface over which they grow

- Biomass attached to media (rock, plastic, etc.)
- Recycling of settled biomass is not required
  - However, trickling filters often recirculate/recycle

Theory of Fixed Film Operation



Biomass = “zoogleal mass” “Slime growth” or “Biofilm”
Filter media = rock, slag, coal, bricks, redwood blocks or molded plastic

Fixed Film Systems

What can this process do?

- Remove nutrients
- Removed dissolved organic solids
- Remove suspended organic solids

- Removal occurs primarily by converting soluble and colloidal material into a biological film that develops on the filter media

Just like a suspended growth system!

Fixed Film Systems

- Simplicity
- Lower maintenance
- Lower power/electrical costs
- Less production excess biological solids
- Resistance to shock loads

Fixed Film Systems

- Nutrient deficiency- industrial waste (specifically food processing)
  - 100 BOD:5N:1P ratio for producing biological cells
- More sensitive to temperature drops
  - Covers, windbreaks, forced ventilation, etc.
- Low DO (RBCs)
  - Filamentous bacteria

Trickling Filter

Trickling Filter

1. Media
   - Provides surface area for zoogleal film
   - Empty spaces (voids) for ventilation
2. Underdrain system
   - Sloping bottom leads to center channel to collect filter effluent
3. Distribution system
   - Rotary type (or fixed spray nozzle)
     1. Mechanical-type seals at center column
     2. Guy or stay rods for seasonal adjustment of arms
     3. Arm dump gates at end of arm for easy flushing

Trickling Filter

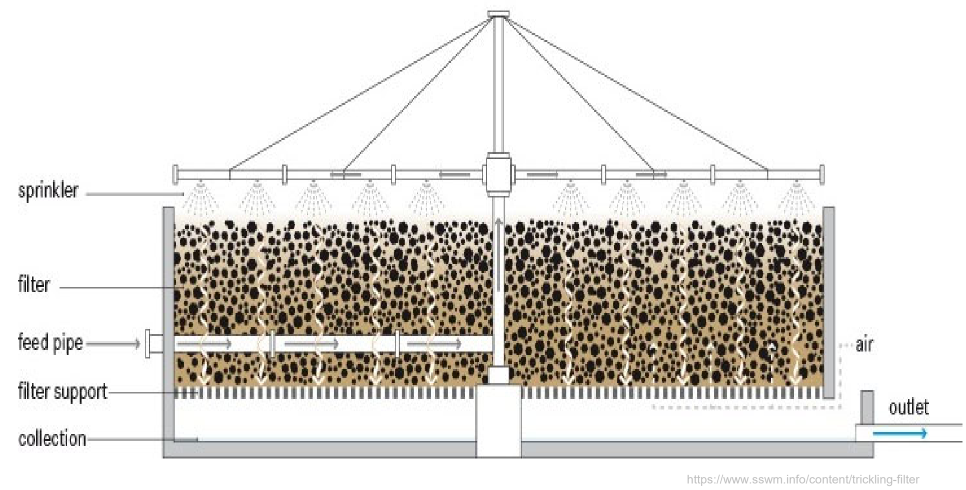
Rotating Distributor Arm

Plastic Media

Fixed Nozzle Spray

Support and Underdrain System

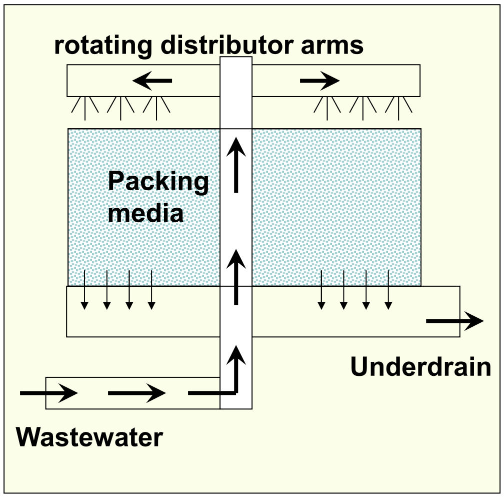
Components of a Trickling Filter



Components of a Trickling Filter

- Usually has a rotary-type distributor that consists of two or more horizontal pipes supported a few inches above the filter media by a central column
- WW is fed from column through horizontal pipes and distributed over media through orifices located along one side of pipes
- Rotation of arm is due to water-sprinkler reaction from WW flowing out orifices or by mechanical means
- Have quick-opening or arm dump gates at the end of each arm to permit easy flushing

Trickling Filter Side View



A rotating arm sprays wastewater over a filter medium

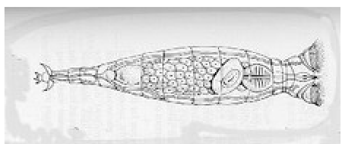
- Filter medium: rocks, plastic, or other material.

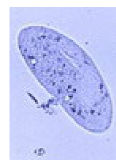
The water is collected at the bottom of the filter for further treatment

- Not really a filter, it does not work like sand or filter paper

What is Zoogleal Film (Biomass)?

- Collection of bacteria, protozoa, fungi, algae, and higher animals
- 95% bacteria
- Protozoa and higher animals are "grazers"
- Can approximate viable biomass by VSS





Managing Biofilm Thickness

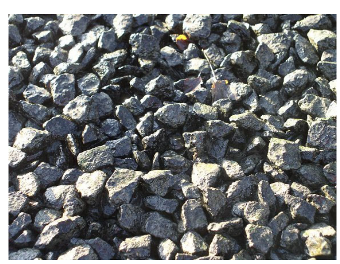
- Grazing by predators
  - Worms very important as grazers-
    - Keeps biomass healthy
    - Tunneling by worms aerates biofilm and causes excess to slough off
- Erosion (liquid shearing)
- Sloughing (weakening of biofilm)
  - *Sloughings* = TF slimes that have been washed off the filter media

Design Considerations

- Influent wastewater characteristics
- Degree of treatment anticipated (BOD & TSS removal)
- Temperature range of applied wastewater
- Preliminary and primary treatment processes
- Type of filter media
- Recirculation rate
- Hydraulic and organic loadings applied to the filter
- Underdrain and ventilation systems

Trickling Filter Media

- Crushed rock (river or aggregate)
  - Durable & insoluble
  - Locally available
  - Negative: reduce the void spaces for passage of air
  - Less surface area per volume for biological growth



Trickling Filter Media

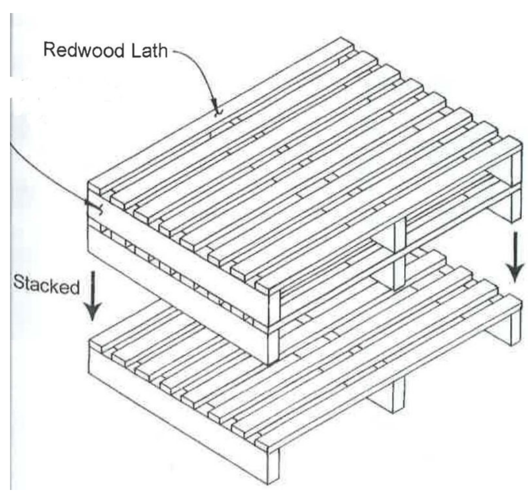
Plastic media

- Can be loaded at higher rates
- Larger void spaces
- Lighter
  - Random packing media
  - Modular packing media
  - Vertical-flow media
  - Cross-flow media
- Often referred to as Biotower

Trickling Filter Media

Redwood media

- Commercial wood media consists of rough sawn redwood slates stacked horizontally on wood spacers
- No longer manufactured but can be found in existing facilities

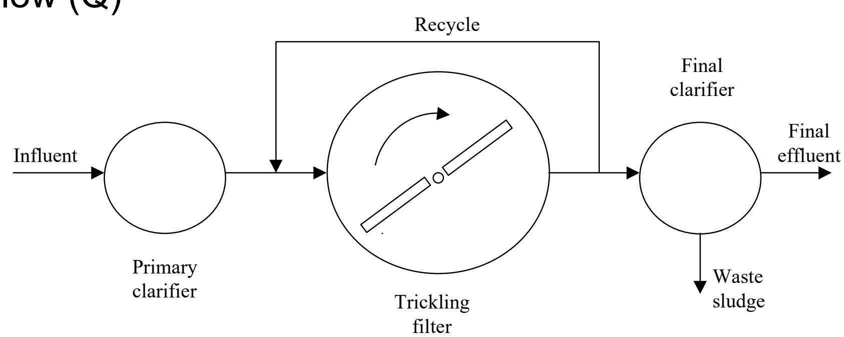


Trickling Filter Media Considerations

- The ideal filter packing is material that:
  - has a high surface area per unit of volume
  - is low in cost
  - has a high durability
  - has a high enough porosity so that clogging is minimized
  - provides good air circulation

Flow & Recirculation Rates

Recirculation= A portion of the TF effluent recycled through the filter
Recirculation ratio (R) = returned flow (Qr)/ influent flow (Q)



Recirculation Design Considerations

Recirculation is used to maintain a constant load on the filter and thus produce a better quality of effluent

- Increase efficiency
- Maintain constant wetting rate and hydraulic loading
- Dilute toxic wastes
- Increase air flow
- Recirculation flow dilutes the strength of raw wastewater & allows untreated wastewater to be passed through the filter more than once.
- Prevent freezing

Recirculation Design Considerations

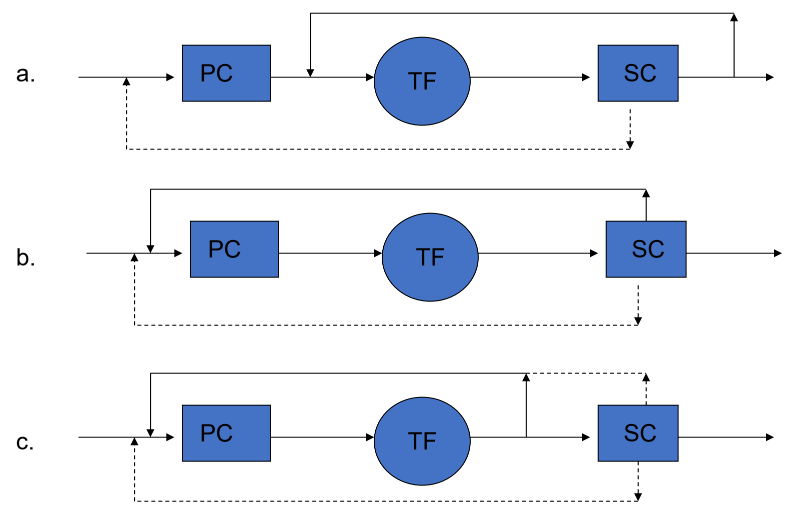
- During low-inflow periods = keep slime growths wet, minimize fly growth, and wash off excess sloughings
- Returning TF effluent to the 1°clarifier is an effective odor control measure
  - adds oxygen to incoming ww that is often septic
- A common range for recirculation ratio
  - 0.5~3.0
  - Use the lowest recirculation rate that will produce good effluent but not cause ponding

Classification of filters

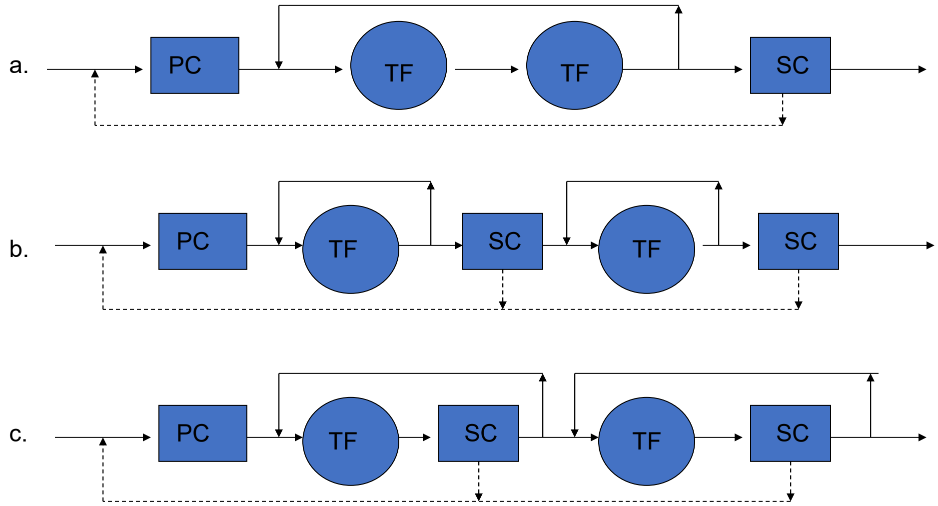
Depending upon the hydraulic and organic loadings applied:

1. Standard rate
2. High rate
   - Heavy flow of ww over the media = more uniform sloughing of filter growths
3. Roughing filters
   - Used primarily to reduce organic load on subsequent oxidation processes (ex: second stage filter or AS process)
   - Often used in plants that receive strong organic industrial wastes

Single stage



Two Stage



Two Stage

- Two stage desirable when:
  - High quality effluent is required
  - High strength WW is treated
  - Cold weather operation is needed
- Intermediate clarifier minimizes clogging of the second filter
- It is often preferred to recirculate clarifier effluent
  - Reduces chances of solids clogging the filter media
  - Most solids in the TF effluent will have settled in the clarifier
  - Risk is to hydraulically overload the clarifier

Underdrainage and Ventilation Systems

- Two purposes:
  1. to carry the filtered wastewater and the biomass lump (sloughed solids) from the filter to the final clarification process
  2. to provide for ventilation of the filter to maintain aerobic conditions.
- The underdrain system is generally designed to flow one-third to one-half full to permit ventilation of the system.

Ventilation System

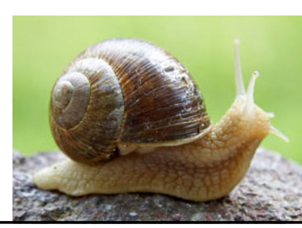
- In TF system:
  - Air is supplied by natural draft or forced draft ventilation
  - The forced draft fans have been applied to provide adequate oxygen

Secondary Clarification

- Removes excess biological solids (sloughings)
- Typically round with scraper units
- Thin sludge blanket controls denitrification
  - Less than 1 foot suggested
  - Sloughings contain large amount of organic matter that could go septic in a deeper blanket

Abnormal Conditions

- Ponding-filter plugging
- Odors
- Filter flies
- Uncontrolled periodic sloughing
- Poor effluent quality
- Icing on filter
  - Decrease recirculation
- Snails



Odors

- Organic overloading or inadequate air circulation
- Excess sloughing of biofilm
- Controlled by:
  - Covering filter
  - Air scrubbers
  - Masking agents

Odor Control

- Maintain aerobic conditions in sewer and in preceding plant processes
- Check filter ventilation
- Increase recirculation ratio
- Better housekeeping: wash down distributor splash plates and wall above media

Ponding in Trickling Filters

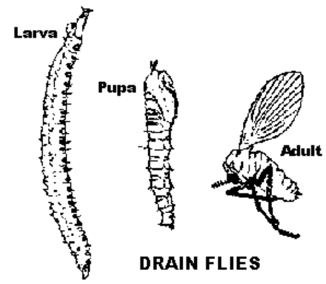
- Ponding can cause anaerobic conditions within the trickling filter
- Ensure preceding units operating properly
  - Excess SS, scum, BOD, trash from primary clarifier can cause problems
- Spray surface with high pressure water
- Rake filter surface manually
- Dose with chlorine at 5 mg/L (several hours)
- Flood filter for 24 hrs
- Increase recirculation rate = more oxygen and increased sloughing
- Replace media

Control of Insects, Snails, & Algae

- Visually inspect for ponding
- Increase recirculation ratio
- Flush filter & chlorinate
  - Chlorinate to residual of 1.0 mg/L for several hours.
- Algae: DON'T apply herbicide

Control of Flies

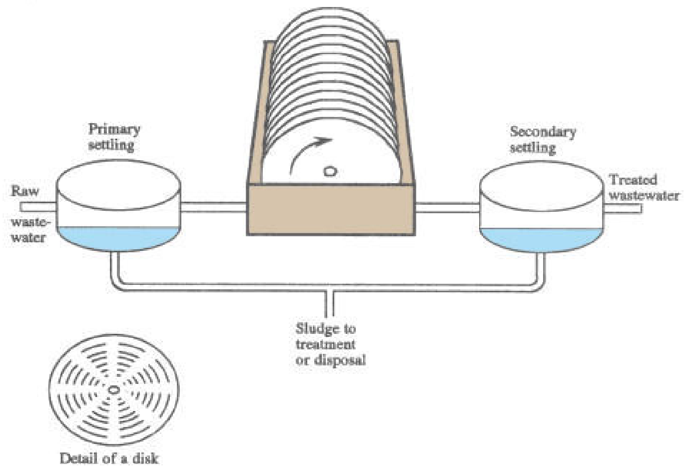
- Preferring an alternately wet and dry environment for development, the flies are found most frequently in low-rate filters and usually not much of a problem in high-rate filters.
- Larvicides
- Maintain hydraulic load of at least 200 gpd/ft^2
- Keep grass cut
- Shrubbery, weeds and tall grasses provide a natural sanctuary for filter flies.



Typical Loading Rates

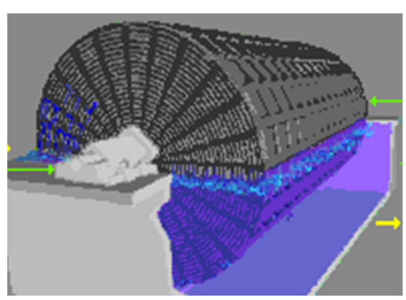
	Standard Rate Filter - Rock	High Rate Filter – Rock	High Rate Filter – Synthetic	Roughing Filter - Synthetic
Media	6-8 ft deep; Growth sloughs periodically	3-5 ft deep; Growth sloughs continuously	15-30 ft deep; Growth sloughs continuously	15-30 ft deep; Growth sloughs continuously
Hydraulic Loading	25-100 gpd/ft^2	100-1,000 gpd/ft^2	350-2,100 gpd/ft^2	1,400-4,200 gpd/ft^2
Organic (BOD) Loading	5-25 lbs BOD/ day/1,000 ft^3	25-100 lbs BOD /day/1,000 ft^3	50-300 lbs BOD /day/1,000 ft^3	100-over 300 lbs BOD/ day /1,000 ft^3
BOD Removal Range	80-90%	50-70%	65-85%	40-65%
Effluent BOD	20-25 mg/L	20-50 mg/L		

Rotating Biological Contactor (RBC)



Rotating Biological Contactor (RBC)

- Treats domestic and biodegradable industrial wastes
- Rotating steel shaft with HDPE disc media (drum)
- Mechanical or compressed air drive
- Drum rotates through WW for food then through air for oxygen



Rotating Biological Contactor (RBC)

Plants have been designed to treat flows ranging 18,000 gpd to 50 MGD, however the majority of plants treat flows of less than 5 MGD

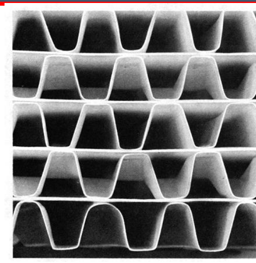
- Advantages of RBC's over Trickling Filters:
  - Elimination of the rotating distributor
  - Elimination of ponding problems
  - Elimination of filter flies
- Disadvantages:
  - Lack of recirculation ability
  - More sensitive to industrial wastes

Rotating Biological Contactor (RBC)

- Primary clarifier effluent enters RBC tank
- Organisms on biofilm treat WW
- Media rotates at 1.5 rpm
- Excess biofilm sloughs into WW and is removed in secondary clarifier
- Approximately 40% of media surface is immersed in the wastewater
- Usually the process operates on a "once-through" scheme, with no recycling

RBC Filter Media

- Media cross section.
- Spacing between sheets provides void space for distribution of air & WW
- HDPE plastic media sheets bonded onto horizontal shafts.
- Units typically 12 ft in diameter & 25 ft long



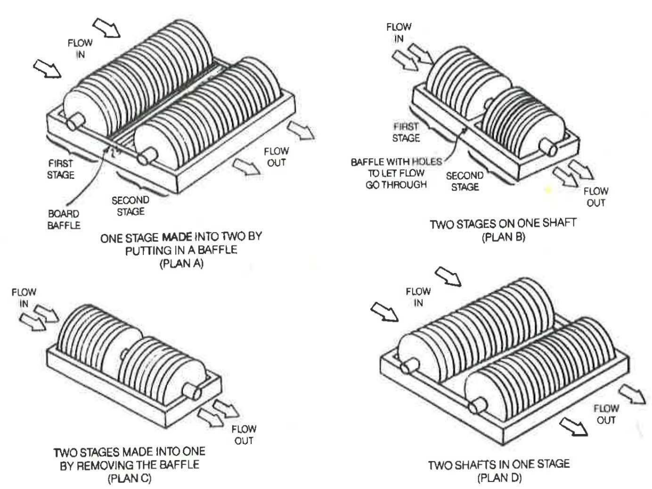
Stages of RBC

- The RBC is usually divided up into four or more different stages
- Each stage is separated by a removable baffle, concrete wall or cross-tank bulkhead
- Each bulkhead or baffle has an underwater orifice or hole to permit flow from one stage to the next
- Each section of media between bulkheads acts as a separate stage of treatment

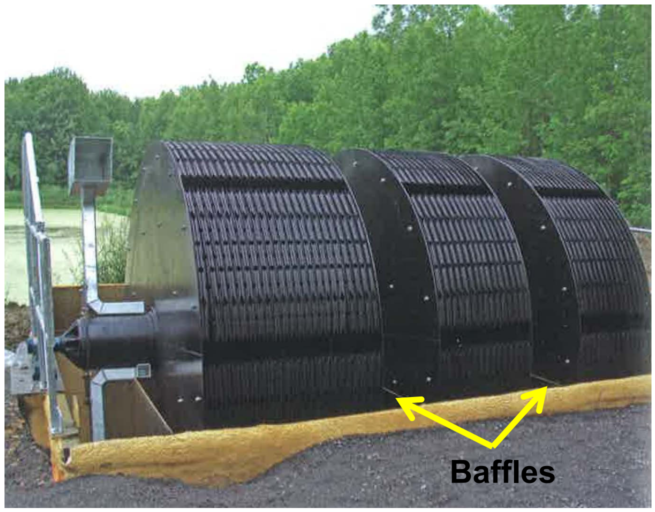
Stages of RBC

- Staging is used in order to maximize the effectiveness of a given amount of media surface area
- Organisms on the first-stage media are exposed to high levels of BOD and reduce the BOD at a high rate
- As the BOD levels decrease from stage to stage, the rate at which the organisms can remove BOD decreases and nitrification starts

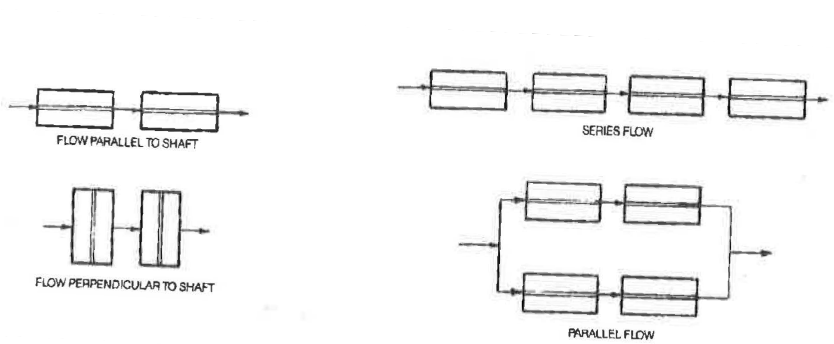
RBC Stage Arrangements



RBC with Baffles

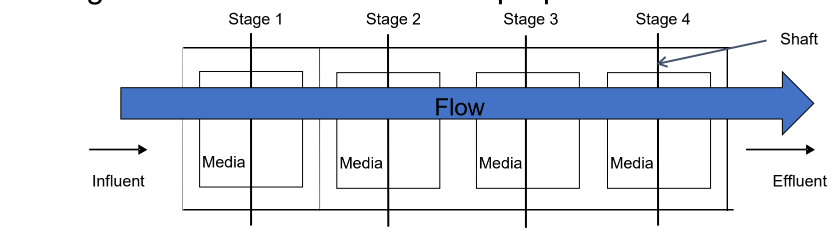


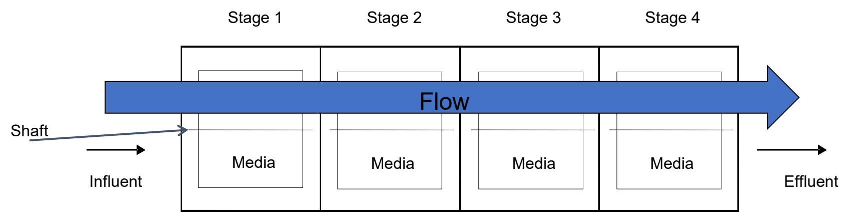
RBC Flow Patterns



RBC Flow Patterns

Four Stages with four shafts. Flow is perpendicular to the shafts.



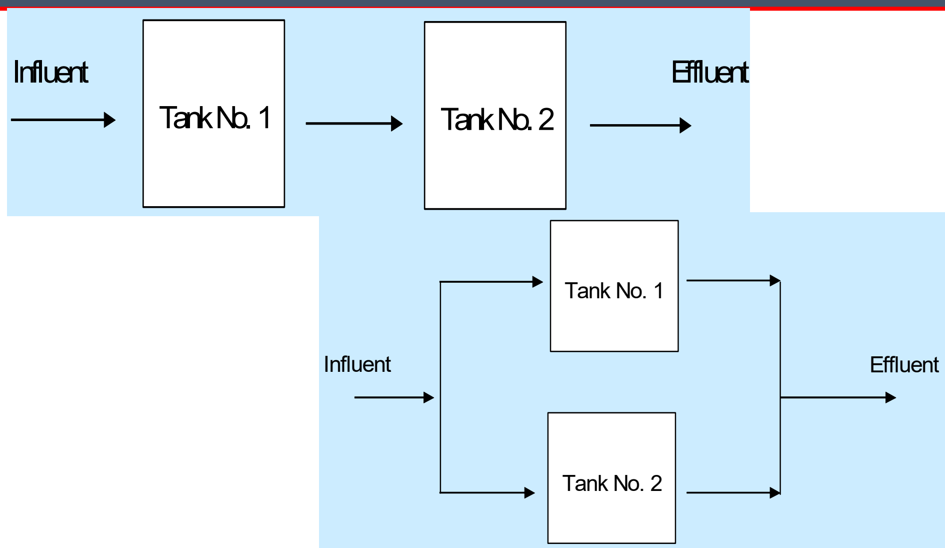


Four stages with four shafts. Flow is parallel to the shafts.

Series vs. Parallel Operation

- Treatment plants requiring four or more shafts of media usually are arranged so that each shaft serves as an individual stage of treatment
  - The shafts are arranged so the flow is perpendicular to the shafts
- Plants with fewer than four shafts are usually arranged with the flow parallel to the shaft

Series vs. Parallel Operation



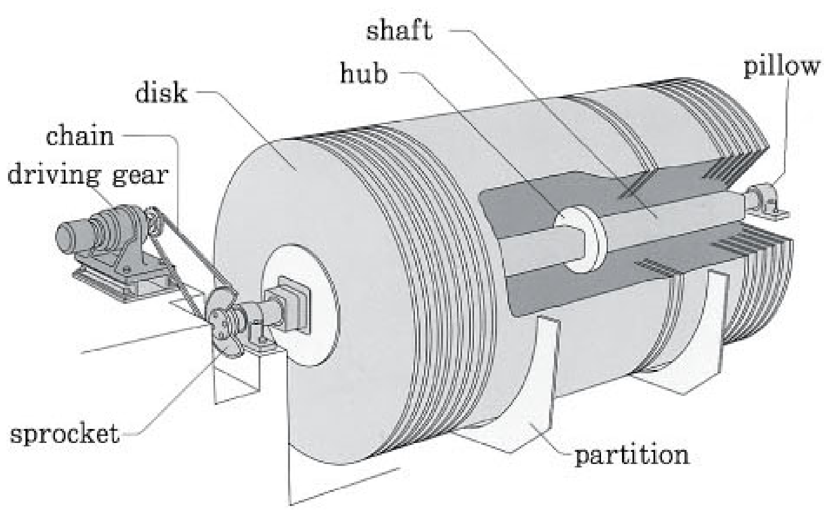
Air Driven Units

- Air control valve on shaft controls inlet air supply to each unit
- Course bubble air diffusers on headers on floor of concrete or steel tank force air to cause unit to rotate

Motor with Chain Drive Unit

- Inspection: bearing caps; roller chain alignment; belts; check for noise from bearings & drive package; main shaft bearing temperature (by hand)
- Periodically remove sludge & debris settling below media: reduces tank volume; cause septicity; scrape biofilm from media; can stall unit

Motor with Chain Drive Unit



Daily Inspection of Biomass

- Healthy = uniform, thin brown to gray, shaggy growth; no algae present
- Organic overload = heavy, shaggy brown to black
- Rusty Red color = nitrification
  - Completion of BOD removal
  - Can be irregular growth due to predator organisms

Daily Inspection of Biomass

- White slime:
  - Sulfur bacteria (Thiothrix)- poor settling sludge and low BOD removal
  - Result from industrial discharges containing sulfur compounds
  - Another cause may be sludge deposits that have accumulated in the bottom.

    To remove:
    - Drain basin, wash out sludge, and return to service

Daily Inspection of Biomass

- Control of snails:
  - Chlorinate off line at 50-70 mg/L, rotating filter, for 2-3 days, then dechlorinate before discharging with sulfur dioxide
  - Increase pH to 10 with sodium hydroxide, caustic soda or lime for 8 hours (kills snails without harming the microbial growth). May have to repeat every 1-2 months

High Hydrogen Sulfide

- Extreme overload first stage causes low D.O thereafter
- Septic influent – in collection system too long or industrial discharge
- Anaerobic sludge deposits in tank
- Low D.O due to warm weather

RBC Covers

- Protect biofilm from freezing
- Prevent rain from washing biofilm off of media
- Prevent media exposure to sunlight (& algae growth)
- Prevent UV rays from degrading media
- Provide protection for operators from the elements while maintaining equipment
- Eliminates fogging potential
- Can also enclose several units in building (must have ventilation, lights, humidity control)

Process Monitoring

- BOD: permit compliance; soluble BOD determined by filtering WW
- Suspended Solids: permit compliance
- Nitrogen: ammonia
- Phosphorus: filtered sample; BOD:N:P =100:5:1
- Dissolved Oxygen: throughout facility
- Heavy Metals
- Oil and Grease
- pH: neutral optimum

RBC Performance

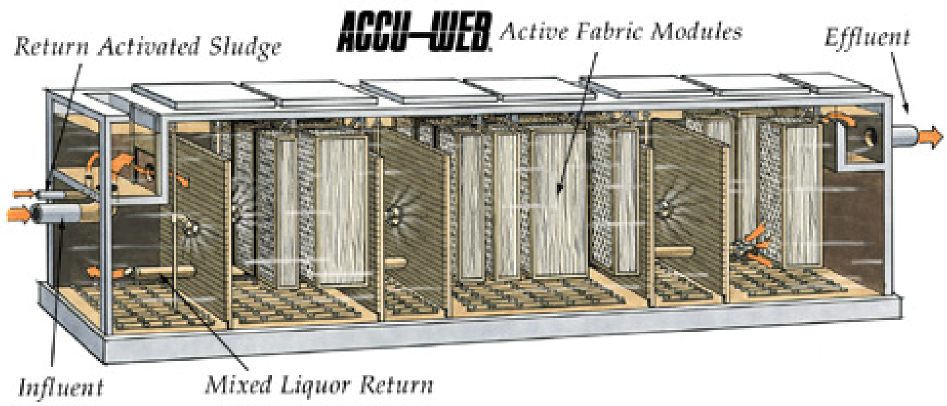
Characteristic	Range
Hydraulic Loading	
• BOD Removal	1.5 – 6 gpd/ft^2
• Nitrogen Removal	1.5 – 1.8 gpd/ft^2
Organic Loading	
• Soluble BOD	2.5 – 4 lbs BOD/day/1,000 ft^2
• BOD Removal	80 – 90%
• Effluent Total BOD	10 – 30 mg/L
• Effluent Soluble BOD	5 – 15 mg/L
• Effluent Ammonia Nitrogen	1 – 10 mg/L
• Effluent Nitrate Nitrogen	2 – 7 mg/L

Moving Bed Biofilm Reactor (MBBR)

Moving Bed Biofilm Reactor (MBBR)

- Internal suspended media for attached growth
- Small polyethylene cylinders maintained in reactor
- Aeration or mixing circulates packing (media)
  - No RAS flow & no backwash
  - Can be put in anoxic and aerobic tanks to maximize BOD removal, denitrification and nitrification

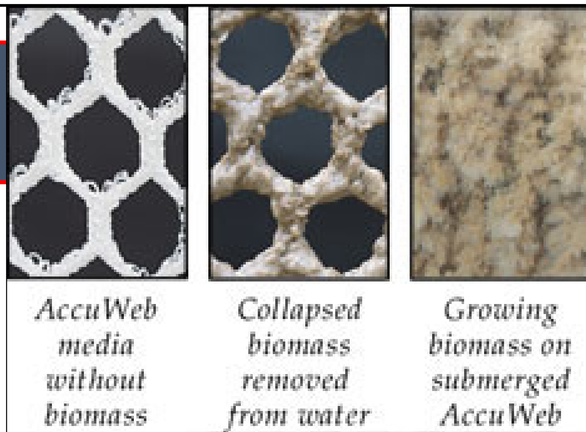
Integrated Fixed Film Activated Sludge (IFAS)



Integrated Fixed Film Activated Sludge (IFAS)

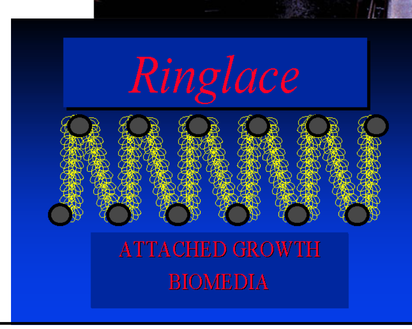
- Knitted fabric media placed in aeration basin
  - New or retrofit
- Increases activated sludge treatment cap
- Fixed biomass allows better handling of shock loads (organic & hydraulic)
- Fine bubble diffused aeration

Brentwood Industries



Integrated Fixed Film Activated Sludge (IFAS)

- Media place along one wall
- Increased treatment capacity: BOD & nitrification
- Additional tankage not needed
- Improves sludge settling in secondary clarifier
- Reduced waste sludge production



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TN Department of Environment & Conservation

Attached Growth Vocabulary

1. A mass or clump of organic material consisting of living organisms feeding on the wastes in wastewater, dead organisms, and other debris is referred to as _________________________. Another name for this, used specifically when referring to trickling filters and RBCs, is ___________________________ , which is defined as the complex populations of organisms that form a slime growth on the media and break down the organic matter in wastewater. These slimes consist of living organisms feeding on the wastes in wastewater, dead organisms, silt, and other debris; "slime growth" is a more common term.

2. A waste treatment process that is conducted under _____________________ conditions means that atmospheric or dissolved oxygen is present in the aquatic environment. In contrast, an _______________________ condition is one in which atmospheric or dissolved oxygen is *not* present in the aquatic environment.

3. The rotating mechanism that distributes the wastewater evenly over the surface of a trickling filter or other process unit is called the _______________________________.

4. The non-moving, cone-shaped spray nozzle used to distribute wastewater over the filter media, similar to a lawn sprinkling system, is called a _____________________________. A deflector or steel ball is mounted within the cone to spread the flow of water through the cone, thus creating a spraying action. This type of system is not as common as the rotary type and is commonly found only at small plants.

5. The aerobic process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate) is called___________________________.

6. The sloughed off particles of biomass from trickling filter media that are removed from the water being treated in secondary clarifiers is referred to as __________________________________.

7. Attached growth systems can be operated in two ways. When wastewater flows through one treatment unit and then flows through another similar unit, it is called _____________________________________. If the wastewater is split and a portion flows to one treatment unit while the remainder flows to another similar treatment unit, this is called _____________________________________.

8. A condition that occurs on trickling filters when the hollow spaces of media become plugged to the extent that water cannot pass through the filter is known as __________________________. This may be the result of excessive slime growths, trash, or media breakdown.

9. A method of increasing the efficiency of trickling filters is to add ______________________________. This is a process in which a part of the filter effluent is returned or recycled and brought into contact with the biological film once more.

10. The treatment process in which wastewater trickling over media enables the formation of zoogleal film (aka slime growth) or biomass, which contains microorganisms that feed upon and remove wastes from the water being treated, is called a ____________________________________.

11. In a ______________________________, two filters are used. Effluent from the first filter goes to the second filter, either directly or after passing through a clarifier.

12. The purpose of the ________________________ is to carry the filtered wastewater and the biomass lump (sloughed solids) from the filter to the final clarification process. In trickling filters, air is supplied by natural draft or forced draft ventilation, the purpose of this _______________________ system is to provide air flow to the filter to maintain aerobic conditions.

Word Bank

Biomass

Ponding

Nitrification

Parallel operation

Two-stage filter

Underdrain

Fixed-spray nozzle

Recirculation

Aerobic

Ventilation

Trickling filter

Distributor

Series operation

Zoogleal film

Anaerobic

Humus sludge

United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-00-014 September 2000

Wastewater Technology Fact Sheet
Trickling Filters

DESCRIPTION

Trickling filters (TFs) are used to remove organic matter from wastewater. The TF is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater. This type of system is common to a number of technologies such as rotating biological contactors and packed bed reactors (bio-towers). These systems are known as attached-growth processes. In contrast, systems in which microorganisms are sustained in a liquid are known as suspended-growth processes.

APPLICABILITY

TFs enable organic material in the wastewater to be adsorbed by a population of microorganisms (aerobic, anaerobic, and facultative bacteria; fungi; algae; and protozoa) attached to the medium as a biological film or slime layer (approximately 0.1 to 0.2 mm thick). As the wastewater flows over the medium, microorganisms already in the water gradually attach themselves to the rock, slag, or plastic surface and form a film. The organic material is then degraded by the aerobic microorganisms in the outer part of the slime layer.

As the layer thickens through microbial growth, oxygen cannot penetrate the medium face, and anaerobic organisms develop. As the biological film continues to grow, the microorganisms near the surface lose their ability to cling to the medium, and a portion of the slime layer falls off the filter. This process is known as sloughing. The sloughed solids are picked up by the underdrain system and transported to a clarifier for removal from the wastewater.

ADVANTAGES AND DISADVANTAGES

Some advantages and disadvantages of TFs are listed below.

Advantages

- Simple, reliable, biological process.
- Suitable in areas where large tracts of land are not available for land intensive treatment systems.
- May qualify for equivalent secondary discharge standards.
- Effective in treating high concentrations of organics depending on the type of medium used.
- Appropriate for small- to medium-sized communities.
- Rapidly reduce soluble BOD_5 in applied wastewater.
- Efficient nitrification units.
- Durable process elements.
- Low power requirements.
- Moderate level of skill and technical expertise needed to manage and operate the system.

Disadvantages

C Additional treatment may be needed to meet more stringent discharge standards.

C Possible accumulation of excess biomass that cannot retain an aerobic condition and can impair TF performance (maximum biomass thickness is controlled by hydraulic dosage rate, type of media, type of organic matter, temperature and nature of the biological growth).

C Requires regular operator attention.

C Incidence of clogging is relatively high.

C Requires low loadings depending on the medium.

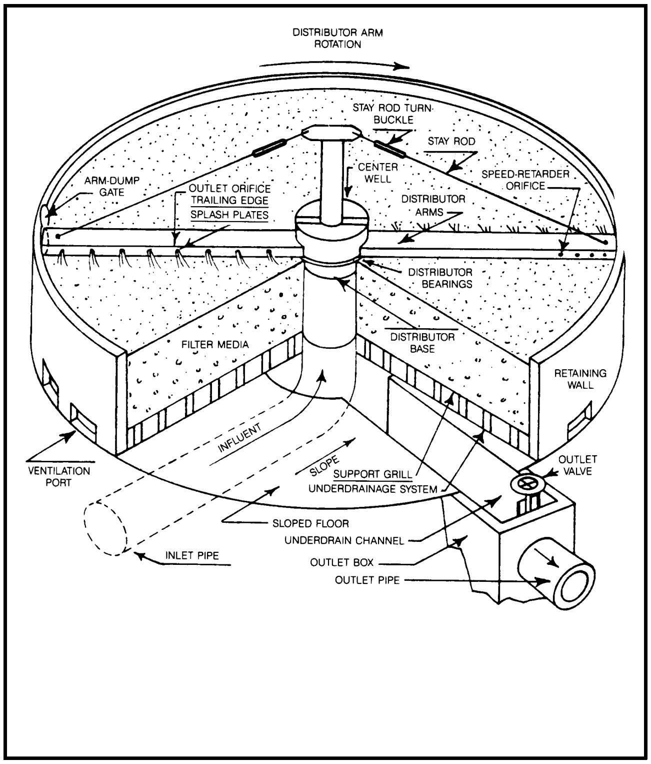
C Flexibility and control are limited in comparison with activated-sludge processes.

C Vector and odor problems.

C Snail problems.

DESIGN CRITERIA

A TF consists of permeable medium made of a bed of rock, slag, or plastic over which wastewater is distributed to trickle through, as shown in Figure 1. Rock or slag beds can be up to 60.96 meters (200 feet) in diameter and 0.9-2.4 meters (3 to 8 feet) deep with rock size varying from 2.5-10.2 cm (1 to 4 inches). Most rock media provide approximately 149 m^2/m^3 (15 sq ft/cu ft) of surface area and less than 40 percent void space. Packed plastic filters (bio-towers), on the other hand, are smaller in diameter (6 to 12 meters (20 to 40 feet)) and range in depth from 4.3 to 12.2 meters (14 to 40 feet). These filters look more like towers, with the media in various configurations (e.g., vertical flow, cross flow, or various random packings). Research has shown that cross-flow media may offer better flow distribution than other media, especially at low organic loads. When comparing vertical media with the 60 degree cross-flow media, the vertical media provide a nearly equal distribution of wastewater minimizing potential plugging at higher organic loads better than cross flow media. The plastic medium also required additional provisions, including ultraviolet protective additives on the top layer of the plastic medium filter, and increased plastic wall thickness for medium packs that are installed in the lower section of the filter where loads increase.



Source: Metcalf & Eddy, Inc. and Tchobonaglous, 1998.

FIGURE 1 TYPICAL TRICKLING FILTER

The design of a TF system for wastewater also includes a distribution system. Rotary hydraulic distribution is usually standard for this process, but fixed nozzle distributors are also being used in square or rectangular reactors. Overall, fixed nozzle distributors are being limited to small facilities and package plants. Recently some distributors have been equipped with motorized units to control their speed. Distributors can be set up to be mechanically driven at all times or during stalled conditions.

In addition, a TF has an underdrain system that collects the filtrate and solids, and also serves as a source of air for the microorganisms on the filter. The treated wastewater and solids are piped to a settling tank where the solids are separated. Usually, part of the liquid from the settling chamber is recirculated to improve wetting and flushing of the filter medium, optimizing the process and increasing the removal rate.

It is essential that sufficient air be available for the successful operation of the TF. It has been found that to supply air to the system, natural draft and wind forces are usually sufficient if large enough ventilation ports are provided at the bottom of the filter and the medium has enough void area.

The following four basic categories of filter design are based on the organic loading of the trickling filter.

Low-rate filters

Low-rate filters are commonly used for loadings of less than 40 kilograms five day biochemical oxygen demand (BOD_5)/100 meters cubed per day (25 lb BOD_5/1000cu ft/day). These systems have fewer problems than other filters with regards to filter flies, odors, and medium plugging because of the lower loading rate. Low-rate filters with a rock medium range in depth from 0.9 to 2.4 meters (3-8 ft.). Most low-rate filters are circular with rotary distributors, but some filters currently in use are rectangular. Both of these configurations are equipped with dosing syphons or periodic pumps to provide a high wetting rate for short intervals between rest periods. A minimum wetting rate of 0.4 liters per square meter-second (0.7 gal/sq ft/min) is maintained to prevent the high rate plastic filter medium from drying out. With a rock medium, the filters tend not to be hydraulically limited and have application limits ranging from 0.01 to 0.04 liters per square meter-second (0.02 to 0.06 gal/sq ft/min).

The sloughed solids from a low-rate filter are generally well-digested and as a result these filters yield less solids than higher rate filters. Secondary quality effluent is readily achievable if the low-rate trickling filter design incorporates filter media with bioflocculation capabilities or good secondary clarification.

Intermediate-rate filters

Intermediate rate filters can be loaded up to 64 kg BOD_5/100 m^3-d (40 lb BOD_5/1000cu ft/day). In order to ensure good distribution and thorough blending of the filter and secondary effluent, the system should recirculate the trickling filter effluent. The biological solids that slough from an intermediate trickling filter are not as well digested as those using a low-rate filter.

High-rate filters

High-rate filters are generally loaded at the maximum organic loading capabilities of the filter and receive total BOD_5 loading ranging from 64 to 160 kg BOD_5/100 m^3-d (40 to 100 lb. BOD_5/1000cu ft/day). Achieving a secondary quality effluent is less likely for a high-rate filter without a second-stage process. As a result, high-rate filters are often used with combined processes.

Roughing Filters

Roughing filters are designed to allow a significant amount of soluble BOD to bleed through the trickling filter. Filters of this type generally have a design load ranging from 160-480 kg BOD_5/100 m^3-d (100 to 300 lb. BOD_5/1000cu ft/day).

PERFORMANCE

Recent efforts have been made to combine fixed-film reactors with suspended growth processes to efficiently remove organic materials from wastewater. For example, the combination of a trickling filter with an activated-sludge process has allowed for the elimination of shock loads to the more sensitive activated sludge while providing a highly polished effluent that could not be achieved by a trickling filter alone. Table 1 shows the BOD_5 removal rates for the four filter types discussed.

Although the TF process is generally reliable, there is still potential for operational problems. Some of the common problems are attributed to increased growth of biofilm, improper design, changing wastewater characteristics, or equipment failure. Some common problems with TF function are discussed in the Operation and Maintenance section.

TABLE 1 BOD_5 REMOVAL RATES FOR VARIOUS FILTER TYPES

Filter Type	BOD_5 Removal (%)
Low Rate	80 - 90
Intermediate Rate	50 - 70
High Rate	65 - 85
Roughing Filter	40 - 65

Source: Environmental Engineers Handbook, 1997.

OPERATION AND MAINTENANCE

Disagreeable Odors from Filter

Potential Cause: Excessive organic load causing anaerobic decomposition in filter.
Remedy: Reduce loading; increase BOD removal in primary settling tanks; enhance aerobic conditions in treatment units by adding chemical oxidants, preaerating, recycling plant effluent, or increasing air to aerated grit chambers; scrub off gases; use plastic media instead of rock.

Potential Cause: Inadequate ventilation.
Remedy: Increase hydraulic loading to wash out excess biological growth; remove debris from filter effluent channels, underdrains, and the top of filter media; unclog vent pipes; reduce hydraulic loading if underdrains are flooded; install fans to induce draft through filter; check for filter plugging resulting from breakdown of the medium.

Ponding on Filter Media

Potential Cause: Excessive biological growth or foreign matter in or on the filter.
Remedy: Reduce organic loading; increase hydraulic loading to increase sloughing; use high-pressure stream of water to flush filter surface; maintain 1 to 2 mg/L residual chlorine on the filter for several hours; flood filter for 24 hours; shut down filter to dry out media; replace media if necessary; remove debris.

Filter Flies (Psychoda)

Potential Cause Inadequate filter media moisture.
Remedy: Increase hydraulic loading; unplug spray orifices or nozzles; use orifice opening at end of rotating distributor arms to spray filter walls; flood filter for several hours each week during fly season; maintain 1-2 mg/L residual chlorine on the filter for several hours.

Potential Cause: Poor housekeeping.
Remedy: Mow area surrounding filter and remove weeds and shrubs.

Icing

Potential Cause: Low temperature of wastewater.
Remedy: Decrease recirculation; use high-pressure stream of water to remove ice from orifices, nozzles, and distributor arms; reduce number of filters in service as long as effluent limits can still be met; reduce retention time in pretreatment and primary treatment units; construct windbreak or covers.

Rotating Distributor Slows Down or Stops

Potential Cause: Insufficient flow to turn distributor.
Remedy: Increase hydraulic loading; close reversing jets.

Potential Cause: Clogged arms or orifices.
Remedy: Flush out arms by opening end plates; remove solids from influent wastewater; flush out orifices.

Potential Cause: Clogged distributor arm vent pipe.
Remedy: Remove material from vent pipe by rodding or flushing; remove solids from influent wastewater.

Potential Cause: Distributor arms not level.
Remedy: Adjust guy wires at tie rods.

Potential Cause: Distributor rods hitting media.
Remedy: Level media; remove some media.

Rotary distributors are very reliable and easy to maintain. A clearance of 15.2-22.9 centimeters (6-9 inches) is needed between the bottom of the distributor arm and the top of the medium bed to allow the wastewater from the nozzles to spread out and cover the bed uniformly. This also helps prevent ice from accumulating during freezing weather.

Care should be taken to prevent leaks. Follow the manufacturer's operation and maintenance (O&M) instructions on pumps, bearings, and motors. All equipment must be tested and calibrated as recommended by the equipment manufacturer. A routine O&M schedule should be developed and followed for any TF system. It is critical that a TF system be pilot tested prior to installation to ensure that it will meet effluent discharge permit requirements for that particular site.

Disagreeable Odors from Filter

- Excessive organic load causing anaerobic decomposition in filter—Reduce loading; increase BOD removal in primary settling tanks; enhance aerobic conditions in treatment units by adding chemical oxidants, preaerating, recycling plant effluent, or increasing air to aerated grit chambers; scrub off-gases; use plastic media instead of rock

- Inadequate ventilation—Increase hydraulic loading to wash out excess biological growth; remove debris from filter effluent channels, underdrains, and the top of filter media; unclog vent pipes; reduce hydraulic loading if underdrains are flooded; install fans to induce draft through filter; check for filter plugging resulting from breakdown of media.

Ponding on Filter Media

- Excessive biological growth—Reduce organic loading; increase hydraulic loading to increase sloughing; use high-pressure stream of water to flush filter surface (recycled water); maintain 1 to 2 mg/L residual chlorine on the filter for several hours; flood filter for 24 hours; shut down filter to dry out media; replace media if necessary; remove debris.

Filter Flies (Psychoda)

- Inadequate moisture on filter media—Increase hydraulic loading; unplug spray orifices or nozzles; use orifice opening at end of rotating distributor arms to spray filter walls; flood filter for several hours each week during fly season; maintain 1 to 2 mg/L residual chlorine on the filter for several hours.

- Poor housekeeping—Mow area surrounding filter and remove weeds and shrubs.

Icing

- Low temperature of wastewater—Decrease recirculation; use high-pressure stream of water to remove ice from orifices, nozzles, and distributor arms; reduce number of filters in service as long as effluent limits can still be met; reduce retention time in pretreatment and primary treatment units; construct windbreak or covers.

Rotating Distributor Slows Down or Stops

- Insufficient flow to turn distributor—Increase hydraulic loading; close reversing jets.

- Clogged arms or orifices—Flush out arms by opening end plates; remove solids from influent wastewater; flush out orifices.

- Clogged distributor arm vent pipe—Remove material from vent pipe by rodding or flushing; remove solids from influent wastewater.

- Distributor arms not level—Adjust guy wires at tie rods.

- Distributor rods hitting media—Level media; remove some media.

Rotary distributors are very reliable and easy to maintain. A clearance of 15 to 23 cm (6 to 9 inches) is needed between the bottom of the distributor arm and the top of the media bed to allow the wastewater from the nozzles to spread out and cover the bed uniformly. This also prevents ice from accumulating during freezing weather.

Care should be taken to prevent leaks. Follow the manufacturer's operation and maintenance (O&M) instructions on pumps, bearings, and motors. All equipment must be tested and calibrated as recommended by the equipment manufacturer. A routine O&M schedule should be developed and followed for any TF system. It is critical that a TF system be pilot tested prior to installation to ensure that it will meet effluent discharge permit requirements for that particular site.

COST

The cost for a TF system are summarized in Table 2. These costs include construction, labor, total O&M, and materials needed. Since every TF system is unique to its site, the overall cost will be site specific.

REFERENCES

Other Related Fact Sheets

Trickling Filter Nitrification
EPA 832-F-00-015
September, 2000

Other EPA Fact Sheets can be found at the following web address:

http://www.epa.gov/owmitnet/mtbfact.htm

1. Liu and Liptak. 1997. *Environmental Engineering Handbook*. 2d ed. The CRC Press, LLC. Boca Raton Florida.

2. Martin, Edward J. and Edward T. Martin. *Technologies for Small Water and Wastewater Systems.* 1991. p. 122. New York, New York.

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5. U.S. EPA, 1991. *Assessment of Single-Stage Trickling Filter Nitrification*. EPA 430/09-91-005, EPA Office of Municipal Pollution Control. Washington, D.C.

6. U.S. EPA, 1993. *Manual: Nitrogen Control*. EPA Office of Research and Development. EPA/625/R-93/010. Cincinnati, Ohio. EPA Office of Water. Washington, D.C.

TABLE 2 COST SUMMARY FOR A TRICKLING FILTER

Wastewater Flow (MGD)	Construction Cost (Millions of Dollars)	Labor (Millions of Dollars)	O&M (Millions of Dollars)	Materials (Millions of Dollars)
1	0.76	0.05	0.063	0.009
10	6.34	0.23	0.15	0.05
50	25	0.5	0.70	0.1
100	63.40	1.0	1.3	0.2

Source: Adapted from Martin and Martin, 1990.

7. Water Environment Federation (WEF). 1996. *Operation of Municipal Wastewater Treatment Plants*. Manual of Practice No. 11. 5th ed. vol. 2. WEF. Alexandria, Virginia.

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The mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Environmental Protection Agency.

This fact sheet was developed in cooperation with the National Small Flows Clearinghouse whose services are greatly appreciated.

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CHAPTER 6

Fixed Film Reactors

FIXED FILM REACTORS

6.1 Trickling Filters

6.1.1 General

Trickling filters may be used for treatment of wastewater amenable to treatment by aerobic biological processes. This process is less complex and has a lower power requirement than some of the other processes.

6.1.2 Pretreatment

Trickling filters shall be preceded by effective clarifiers equipped with scum removal devices or other suitable pretreatment facilities. (See Chapters 4 & 5)

6.1.3 Types of Processes

Trickling filters are classified according to the applied hydraulic and organic loadings. The hydraulic loading is the total volume of liquid applied, including recirculation, per unit time per square unit of filter surface area. Organic loading is the total mass of BOD applied, including recirculation, per unit time per cubic unit of filter volume.

6.1.3.1 Low or Standard Rate

These are loaded at 1 to 4 million gallons per acre per day (mgad) and 5 to 25 pounds BOD per 1,000 cubic feet per day (lb BOD/1000 cu ft/day. Nitrification of the effluent often occurs.

6.1.3.2 Intermediate Rate

These are loaded at 4 to 10 mgad and 10 to 40 lb BOD/1000 cu ft/day. Nitrification is less likely to occur.

6.1.3.3 High Rate

These are loaded at 10 to 40 mgad and 25 to 300 lb BOD/1000 cu ft/day. Nitrification is not likely to occur.

6.1.3.4 Super Rate

These are loaded at 15 to 90 mgad (not including recirculation) and up to 300 lb BOD/1000 cu ft/day. Filters designed as super rate require a manufactured media. Nitrification is not likely to occur.

6.1.3.5 Roughing

These are loaded at 60 to 180 mgd (not including recirculation) and 100 lb BOD/1000 cu ft/day. Nitrification will not occur. Roughing filters shall be followed by additional treatment, and will be equipped with manufactured media.

6.1.4 Considerations for Design

The following factors should be considered when selecting the design hydraulic and organic loadings:

Characteristics of raw wastewater
Pretreatment
Type of media
Recirculation
Temperature of applied wastewater
Treatment efficiency required

The following table presents allowable ranges for the design of trickling filters. Modifications of these criteria will be considered on a case-by-case basis.

Design Loading Table					
Operating Characteristics	Low or Standard Rate	Intermediate Rate	High Rate	Super High Rate Manufactured Media	Roughing
Hydraulic Loading Mgd/acre gpd/ sq ft	1-4 25-90	4-10 90-230	10-40 230-900	15-90 350-2000*	60-180* 1400-4200*
Organic Loading lb BOD/acre-ft day lb BOD/1000ft3/day	200-1000 5-25	700-1400 10-40	1000-12,000 25-300	Up to 300	100+
Depth ft BOD Removal %	5-10 80-85	4-8 50-70	3-6 65-80	3-8 65-85	15-40 40-65
*does not include recirculation					

6.1.5. Estimation of Performance

A number of equations are available for use in estimating trickling filter performance.
Any design should evaluate several different formulas to compare the various parameters in different combinations with one another. Winter operating

conditions must be analyzed since winter operations normally result in lower efficiency than summer operations. The trickling filter design must evaluate the impacts of recirculation, air draft temperatures and medium.

6.1.5.1 Recirculation

Recirculation capability is required for all variations of the trickling filter process except roughing filters provided that minimum hydraulic loading rates are maintained at all times. The recirculation ratio should be in the range of 0.5 to 4.0. Recirculation should be provided for manufactured media to maintain 0.5 to 1.0 gallon per minute per square foot (gpm/sq ft) or the manufacturer's recommended minimum wetting rate at all times. Recirculation ratios greater than 4.0 should not be used to calculate effluent quality.

6.1.5.2 Staging

Staging of filters can be considered for high-strength wastes or for nitrification.

6.1.6 Special Details

6.1.6.1 Media

a.Rock, Slag, or Similar Media

Rock, slag, and similar media should not contain more than 5 percent by weight of pieces whose longest dimension is three times the least dimension. They should be free from thin, elongated and flat pieces, dust, clay, sand, or fine material and should conform to the following size and grading when mechanically graded over a vibrating screen with square openings:

Passing 4-1/2 inch screen: 100 percent by weight

Retained on 3-inch screen: 90-100 percent by weight

Passing 2-inch screen: 0-2 percent by weight

Passing 1-inch screen: 0 percent by weight

Hand-picked field stone should be as follows:

Maximum dimension of stone: 5 inches

Minimum dimension of stone: 3 inches

Material delivered to the filter site should be stored on wood-planked or other approved clean hard-surfaced areas. All material should be rehandled at the filter site, and no material should be dumped directly into the filter. Crushed rock, slag, and similar media should be rescreened or forked at the filter site to remove all fines. Such material should be placed by hand to a depth of 12 inches above the tile underdrains, and all materials should be carefully placed so as not to damage the underdrains. The remainder of the material may be placed by means of belt conveyors or equally effective methods approved by the engineer. Trucks, tractors, or other heavy equipment should not be driven over the filter during or after construction.

b.Manufactured Media

Application of manufactured media should be evaluated on a case-by-case basis. Suitability should be evaluated on the basis of experience with installations handling similar wastes and loadings.

Media manufactured from plastic, wood, or other materials are available in many different designs. They should be durable, resistant to spalling or flaking, and relatively insoluble in wastewater. They are generally applied to super high rate and roughing filter designs.

6.1.6.2 Underdrainage System

a. Arrangement

Underdrains with semicircular inverts or equivalent should be provided and the underdrainage system should cover the entire floor of the filter. Inlet openings into the underdrains should have an unsubmerged gross combined area equal to at least 15 percent of the surface area of the filter.

b.Slope

The underdrains should have a minimum slope of 1 percent. Effluent channels should be designed to produce a minimum velocity of 2 feet per second at average daily rate of application to the filter.

c.Flushing

Provision should be made for flushing the underdrains and effluent channel.
In small filters, use of a peripheral head channel with vertical vents is acceptable for flushing purposes. Inspection facilities should be provided.

d.Ventilation

The underdrainage system, effluent channels, and effluent pipe shall be designed to permit free passage of air. The size of drains, channels, and pipe should be such that not more than 50 percent of their cross-sectional area will be submerged under the design hydraulic loading. Provision should be made in the design of the effluent channels to allow for the possibility of increased hydraulic loading.

6.1.6.3 Dosing Equipment

a.Distribution

The sewage shall be distributed over the filter by rotary distributors or other suitable devices which will permit reasonably uniform distribution to the surface area. At design average flow, the deviation from a calculated uniformly distributed volume per square foot of the filter surface should not exceed plus or minus 10 percent at any point. Provisions must be made to spray the side walls to avoid growth of filter flies.

b.Application

Sewage may be applied to the filters by siphons, pumps, or by gravity discharge from preceding treatment units when suitable flow characteristics have been developed. Application of sewage should be practically continuous. Intermittent dosing shall only be considered for low or standard rate filters. In the case of intermittent dosing, the dosing cycles should normally vary between 5 and 15 minutes, with distribution taking place approximately 50 percent of the time. The maximum rest should not exceed 5 minutes, based on the design average flow.

c. Hydraulics

All hydraulic factors involving proper distribution of sewage on the filters should be carefully calculated. For reaction-type distributors, a minimum head of 24 inches between the low-water level in the siphon chamber and center of the arms should be required. Surge relief to prevent damage to distributor seals, should be provided where sewage is pumped directly to the distributors.

d. Clearance

A minimum clearance of 6 inches between medium and distributor arms should be provided. Greater clearance is essential where icing occurs.

e. Seals

The use of mercury seals is prohibited in the distributors of newly constructed trickling filters. If an existing treatment facility is to be modified, any mercury seals in the trickling filters shall be replaced with oil or mechanical seals.

6.1.6.4 Recirculation Pumping

Low-head, high-capacity pumps are generally used. Submersible pumps are commonly used. A means to adjust the flow is recommended in order to maintain constant hydraulic operation.

6.1.6.5 Waste Sludge Equipment

Pumps for trickling filter sludge should be capable of pumping material up to 6-percent solids (or more if needed) when pumping directly to the digester. Time clock controlled on-off control is desirable. When secondary sludge is pumped to the primary clarifier, the sludge pumps should be designed to pump material with low solid concentrations and high flow rates.

6.1.6.6 Miscellaneous Features

a. Flooding

Consideration should be given to the design of filter structures so that they may be flooded.

b. Maintenance

All distribution devices, underdrains, channels, and pipes should be installed so that they may be properly maintained, flushed, or drained.

c. Flow Measurement

A means shall be provided to measure recirculated flow to the filter.

6.2 Rotating Biological Contactors

6.2.1 General

6.2.1.1 Description

This section presents the requirements for fixed-film reactors using either partially submerged vertical media rotated on a horizontal shaft or other designs with similar concepts.

6.2.1.2 Applicability

Rotating biological contactors (RBC) may be used for treatment of wastewater amenable to treatment by aerobic biological processes. The process is especially applicable to small communities. These requirements shall be considered when proposing this type of treatment.

6.2.1.3 Pretreatment

Primary clarifiers or fine screens should be placed ahead of the RBC process to minimize solids settling in the RBC tanks. (See Chapters 4 & 5)

6.2.2 Media

6.2.2.1 Description

Typical media consists of plastic sheets of various designs with appropriate spacings to maximize the surface area, allow for entrance of air and wastewater, the sloughing of excess biological solids and prevention of plugging. The medium is mounted on a horizontal steel shaft. Other similar systems will be considered on a case-by-case basis.

6.2.2.2 Types

Two types of medium are currently available.

a. Standard Density

Standard-density medium is available in sizes up to 100,000 square feet (sq ft) per shaft. It should be used for all secondary treatment applications.

b. High Density

High-density medium is available in sizes up to 150,000 sq ft per shaft.
It should be used only for nitrification or effluent polishing where the influent BOD is sufficiently low to ensure that plugging of the medium will not occur.

6.2.3 Design Loadings

6.2.3.1 RBC Media

Design loadings should be in terms of total organic loading expressed as pounds BOD_5 per day per 1000 square feet of media surface area (lb BOD_5/day/1000 sq. ft.). The development of design loadings should consider influent BOD, soluble BOD, effluent BOD, flows, temperature, and the number of treatment stages. The design loading should generally range between 2.5 and 3.5 lb BOD_5/day/1000 sq. ft.

6.2.3.2 Final Clarifiers

The following requirements are in addition to those set forth in Chapter 5, "Clarifiers."

The overflow rate should be less than or equal to 600 gpd/sq ft at the average daily design flow.

6.2.4 Special Details

6.2.4.1 Enclosures

Enclosures should be provided for the RBC medium to prevent algae growth on the medium and minimize the effect of cold weather. Enclosures may be either fabricated individual enclosures or buildings enclosing several shafts. Buildings may be considered for installations with several shafts or, where severe weather conditions are encountered, to promote better maintenance.

a. Fabricated Individual Enclosures

Enclosures should be made of fiberglass or other material resistant to damage from humidity or corrosion. The exterior of the enclosures should be resistant to deterioration from direct sunlight and ultraviolet radiation. Access points should be provided at each end of the enclosure to permit inspection of shafts and to perform operation and maintenance. Enclosures shall be removable to allow removal of the shaft assemblies. Access around enclosures shall be sufficient to permit suitable lifting equipment access to lift covers and shafts.

b. Buildings

Adequate space should be provided to allow access to and removal of shafts from enclosures. Buildings should be designed with provisions to remove shafts without damage to the structure. Buildings should be designed with adequate ventilation and humidity control to ensure adequate atmospheric oxygen is available for the RBC shafts, provide a safe environment for the operating staff to perform normal operation and maintenance, and minimize the damage to the structure and equipment from excess moisture.

6.2.4.2 Hydraulic Design

The RBC design should incorporate sufficient hydraulic controls, such as weirs, to ensure that the flow is distributed evenly to parallel process units. RBC tank design should provide a means for distributing the influent flow evenly across each RBC shaft. Intermediate baffles placed between treatment stages in the RBC system should be designed to minimize solids deposition. The RBC units should be designed with flexibility to permit series or parallel operation.

6.2.4.3 Dewatering

The design should provide for dewatering of RBC tanks.

6.2.4.4 Shaft Drives

The electric motor and gear reducer should be located to prevent contact with the wastewater at peak flow rates.

6.2.4.5 Recycle

Effluent recycle should be provided for small installations where minimum diurnal flows may be very small. Recycle should be considered in any size plant where minimum flows are less than 30% of the average design flow.

6.2.4.6 Access

Access shall be allowed for lifting equipment to provide maintenance in the event of a failure.

6.3 Activated Biofilter

6.3.1 General

6.3.1.1 Description

The activated biofilter (ABF) process is a combination of the trickling filter process using artificial media and the activated sludge process.

6.3.1.2 Applicability

The activated biofilter process may be used where wastewater is amendable to biological treatment. This process requires close attention and competent operating supervision, including routine laboratory control. These requirements should be considered when proposing this type of treatment. The process is more adaptable to handling large seasonal loading variations, such as those resulting from seasonal industries or changes in population, than are some of the other biological processes. Where significant quantities of industrial wastes are anticipated, pilot plant testing should be considered.

6.3.2 ABF Media

Artificial media are used in the trickling filter portion of the process to allow high BOD and hydraulic loadings and permit recycle of activated sludge through the trickling filter without plugging. Either wood or plastic artificial medium may be used. Medium depth typically ranges from 7 to 25 feet.

6.3.3 Design

6.3.3.1 General

Calculations shall be submitted to justify the basis of design of the ABF tower pump station, ABF tower, aeration basin, aeration equipment, secondary clarifiers, activated sludge return equipment, and waste sludge equipment.

6.3.3.2 ABF Tower Pump Station

The ABF tower pump station shall be designed to pump the peak influent flow plus the maximum design ABF tower recirculation and return activated sludge flows. Application of wastewater to the ABF tower should be continuous.

6.3.3.3 ABF Tower

The ABF tower shall be designed based on organic loading expressed as pounds of influent BOD per 1,000 cubic feet per day (lb BOD/1,000 cu ft/day). The organic loading should be established using data from similar installations or pilot plant testing. A minimum hydraulic wetting rate should be maintained and be expressed as gallons per minute per square foot (gpm/sq ft).

Typical values for organic loading range from 100 to 350 lb BOD/1,000 cu ft/day (4,300 to 15,000 pounds BOD per acre-foot per day), and hydraulic wetting rates range from 1.5 to 5.5 gpm/sq ft, including recirculations and return flows.

6.3.3.4 Aeration Basin

The aeration basin should be designed in accordance with Chapter 7, "Activated Sludge," based on the food-to-microorganism (F/M) ratio expressed as pounds of influent BOD per day per pound of mixed liquor volatile suspended solids (MLVSS). The F/M ratio should be based on the influent total BOD to the ABF tower or the estimated soluble BOD leaving the ABF tower. Designs using total BOD to the ABF tower should be based on data from similar installations or pilot plant testing. Designs using the estimated soluble BOD leaving the ABF tower should use typical F/M ratios (presented in Chapter 7, "Activated Sludge"). Estimate of BOD removal in the ABF tower should be based on similar installations or pilot plant testing. Calculations of mixed-liquor suspended solids should include the influent suspended solids and solids sloughing from the ABF tower in addition to growth of activated sludge due to removal of soluble BOD. Determination of aeration basin volume should include consideration of aeration basin power levels (using aeration equipment horsepower) expressed as horsepower per 1,000 cubic feet of basin volume. Aeration basin power levels should be limited to prevent excessive turbulence, which may cause shearing of the activated sludge floc. Aeration prior to the ABF tower may also be considered.

6.3.3.5 Aeration Equipment

Oxygen requirements should be estimated as outlined in Chapter 7, "Activated Sludge," for the ABF tower effluent plus the oxygen requirements of the sloughed solids from the ABF tower.

6.3.3.6 Secondary Clarifiers

Secondary clarifiers should be equipped with rapid sludge withdrawal mechanisms and be designed in accordance with Chapter 5, "Clarifiers," and Chapter 7, "Activated Sludge."

6.3.3.7 Return Sludge Equipment

Return sludge equipment should be designed in accordance with Chapter 5, "Clarifiers."

6.3.3.8 Waste Sludge Equipment

Waste sludge equipment should be designed in accordance with Chapter 12, "Sludge Processing and Disposal."

6.3.3.9 ABF Tower Recirculation

ABF tower recirculation should normally be provided. At a minimum, recirculation capacity should meet the requirements for the minimum hydraulic wetting rate.

6.3.4 Special Details

6.3.4.1 ABF Tower

The ABF tower dosing equipment and underdrainage system should be designed in accordance with Section 6.1.6.3 "Dosing Equipment." Fixed or rotating distributors may be used. In addition, the design of the ABF tower should incorporate a skirt around the top to prevent spray from falling to the ground around the tower.

6.3.4.2 Maintenance Provisions

All distribution devices, underdrains, channels, and pipes should be installed so that they may be properly maintained, flushed, and drained.

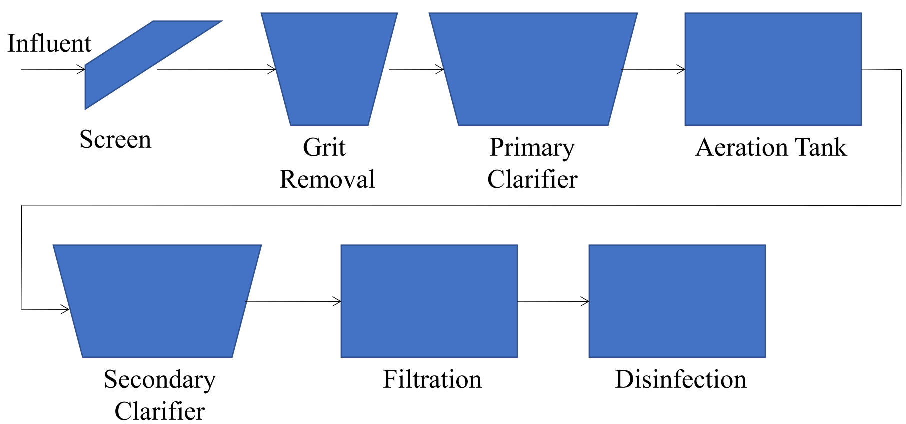
6.3.4.3 Flow Measurement

Devices should be provided to permit measurement of flow to the ABF towers, ABF tower recirculation, return activated sludge, and waste activated sludge flows.

Section 6
Sedimentation and Flotation

Section 6 Sedimentation and Flotation

Wastewater Process Overview



Sedimentation & Flotation

- Raw or untreated wastewater contains materials (solids) that easily settle to the bottom or float to the surface when the velocity is slowed
- Collection systems are designed to maintain a certain velocity (2 ft/sec) to keep solids from settling out
- In primary clarifier, velocity slowed to 1 – 2 ft/min

Note

Flotation = The process of raising suspended matter to the surface of the liquid in a tank where it forms a scum layer that can be removed by skimming.

The suspended matter is raised by aeration, gas, chemicals, electrolysis, heat, or bacterial decomposition

Sedimentation = The process of settling and depositing of suspended matter carried by water or wastewater.

Usually occurs by gravity when the velocity of the liquid is reduced below the point at which it can transport the suspended material.

Sedimentation

- Settling of solids out of suspension due to gravity.
  - Suspended particles include clay, silt, particles in natural state or modified by treatment (biological floc/sloughings)
- Occurs in a rectangular, square or round basin.

Sedimentation

- Other common names:
  - Sedimentation and floatation unit
  - Settling tank
  - Sedimentation tank
  - Clarifier
    - Primary (1°) Clarifier = comes after preliminary treatment and
    - Secondary (2°) Clarifier (can also be called Final Clarifier) = follows treatment, usually found after biological process

Sedimentation

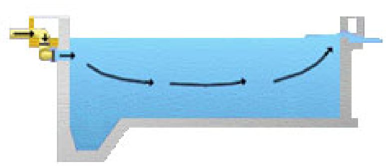
TN Design Criteria for Sewage Works (5.1.1) Purpose

- Clarifiers are designed to perform three (3) functions in a treatment scheme:

1. Remove solids from liquids by sedimentation
2. Remove scum from liquid by flotation
3. Thicken solids for removal and further treatment

Sedimentation

- Water flows slowly though the basin with as little turbulence and short-circuiting as possible.
- Floatables (scum) removed at surface
- Sludge collects at the bottom of the basin.
  - Sludge = the settleable solids separated from liquids during processing.



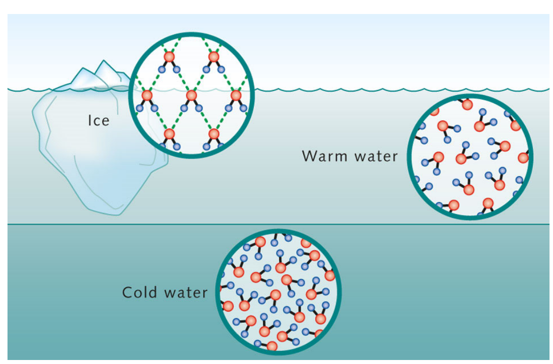
Factors Affecting Sedimentation

- Temperature
- Short circuits
- Detention time**
- Weir overflow rates**
- Surface loading rate**
- Solids loading**
- Toxic waste
- Storm flows
- Septic flows from collection system

**Mathematical ways to check clarifier performance

Temperature

- As water temperature increases, the settling of particles increases.
- As the water temperature decreases, so does the settling rate.



Short Circuiting

- *Short circuiting* = when the water entering a tank or basin flows along a nearly direct pathway from inlet to outlet
- Particles may be held in suspension and exit basin because they haven't had time to settle out
- Short circuiting may occur when the velocity is greater in some sections than others
- High velocity areas may decrease detention time in that area

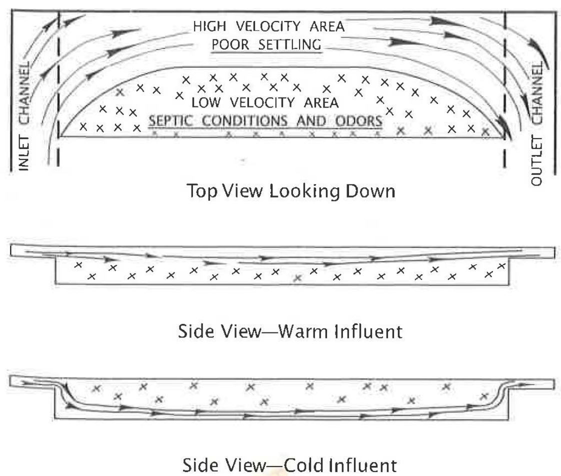
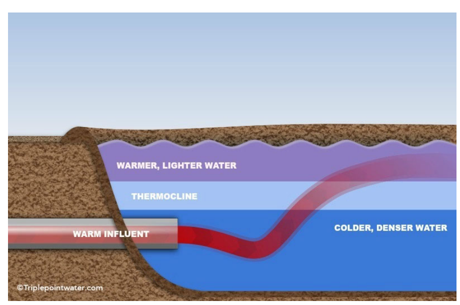


Fig. 5.8 Short-circuiting

Short Circuiting

- May be caused by turbulence and stratification due to temperature differences
- Different layers with different temperatures can cause short-circuiting when a warm influent flows across the top of cold water and vise-versa

- Can be prevented by weir plates, port openings and proper design of the inlet channel



Detention Time

- Wastewater should remain in the clarifier long enough to allow sufficient time for solid particles to fall or settle out
- Detention times are usually 2.0 to 3.0 hours
- The efficiency of a clarifier depends on the velocity and the detention time

Detention Time

- $Detention\ Time = \frac{Volume}{Flow}$
- $DT, hrs = \frac{(Volume\ of\ Tank,\ gal)(24)}{Flow,\ gpd}$
- The formula will calculate theoretical detention time, actual detention time is often less and measured by the use of dyes, tracers, or floats

Weir Overflow Rate

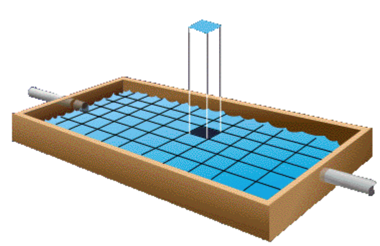
- The number of gallons of wastewater that flow over one lineal foot of weir per day
  - Lineal = the length in one direction of a line
- The number of lineal feet of weir in relation to flow is important to prevent short circuiting or high velocities (which could pull settled solids into the effluent)

$$\text{Weir overflow rate} = \frac{\text{Flow rate, GPD}}{\text{Weir length, ft}}$$

Surface Loading Rate

- Also called Surface Overflow Rate
- The number of gallons going through the settling tank each day for each square foot of surface area in the tank
- Also defined as the loading across the surface of your settling tank
- Depends on the nature of the solids and the treatment required

$$Surface\ Overflow\ Rate = \frac{Flow, {}^{gal}/_{day}}{Surface\ area, ft^2}$$



Solids Loading Rate

- "Solids Loading" refers to the amount of solids removed daily by a clarifier for each ft^2 of clarifier liquid surface area
- Expressed in pounds per day per ft^2 ($lbs/day/ft^2$)
- Depend on the nature of the solids and treatment requirements

$$SLR = \frac{\left(Solids\ Applied, {}^{lbs}/_{day}\right)}{\left(Surface\ area,\ ft^2\right)}$$

- If solids loading goes above design criteria, you could expect an increase in effluent solids

Primary Clarifiers

- Immediately follows preliminary treatment
- First clarifier in plant

  *TN Design Criteria 6.1.2 Pretreatment: "Trickling filters shall be preceded by effective clarifiers equipped with scum removal devices or other suitable pretreatment facilities."
- Some plants don't have one
- Most important function: to remove as much settleable and floatable material as possible

Primary Clarifiers

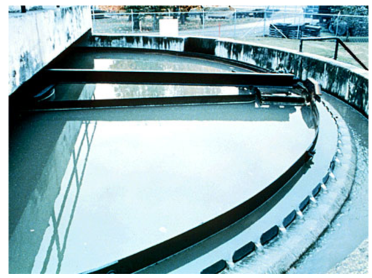
- Sludge tends to be more dense
  - The primary clarifier settled sludge is wasted to the digesters, which puts a tremendous load of untreated volatile organic food to the digester
- If there is an excessive dissolved oxygen drop across the primary clarifier, the sludge wasting rate should be increased
- Velocity is slowed down to a rate of 1-2 ft/min

Primary Clarifiers

- Long detention times cause:
  - Solids to become septic
  - Solids to float to the surface
  - High suspended solids level in primary effluent
  - Odors in primary effluent
- A good example of normal operation is:
  - Sludge collectors running constantly
  - Raw sludge pump runs for 10 minutes each hour
  - At start of pumping cycle, raw sludge has 7% solids and at the end has 5% solids
  - Tank and floor has a moderate sludge blanket

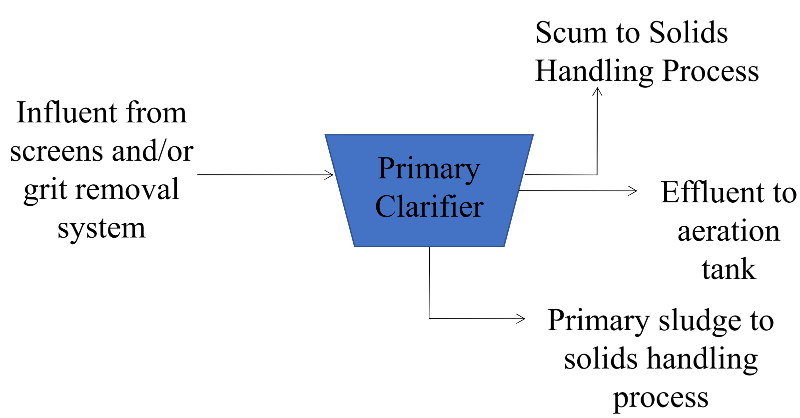
Primary Clarifiers

Water Quality Indicator	Expected Removal Efficiency
Settleable Solids	95 – 99 %
Suspended Solids	40 – 60 %
Total Solids	10 – 15 %
BOD	20 – 50 %
Bacteria	25 – 75 %



Note: Soluble BOD cannot be removed by primary clarifiers.

Primary Clarification



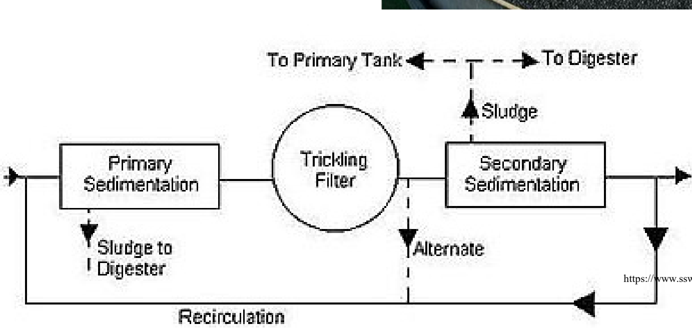
Secondary Clarifiers

- Usually located after a biological process
  - *Activated Sludge, Trickling Filters, Rotating Biological Contactors*
- Purpose: to remove the additional solids (and microorganisms) created during the biological treatment
- Cleaner effluent than primary effluent
- Must remove enough solids from bottom before they becomes septic or gasification occurs

Trickling Filter Clarifiers

- Settles out "sloughings"
  - Slime washed off the filter media
  - Quite high in BOD and will lower the effluent quality unless it is removed
- Loading rates for secondary clarifiers used after trickling filters:
  - Detention time – 2.0 to 3.0 hours
  - Surface loading – 800 to 1200 gpd/ft^2
  - Weir overflow – 5,000 to 15,000 gpd/ft

Trickling Filter Clarifier



https://www.sswm.info/content/trickling-filter

Activated Sludge Clarifiers

- Designed to handle large volumes of sludge
- Loading rates for secondary clarifiers used after activated sludge:
  - Detention time – 2.0 to 3.0 hours
  - Surface loading – 300 to 1200 gpd/ft^2
  - Weir overflow – 5,000 to 15,000 gpd/ft
  - Solids loading – 24 to 30 lbs/day/ft^2

Activated Sludge Clarifiers

- RAS to aeration tank & WAS to solids handling
  - The pumps used to remove sludge from these clarifiers are usually centrifuge type with variable-speed controls or large airlift type.
  - RAS rates can range from 15-150% of the plant influent flow
  - If return rates are too high, turbulence in the tank can upset the sludge blanket.

Activated Sludge Clarifiers

- During a period of high flow caused by rain fall or periods of hydraulic overloading, operators should decrease WAS
  - This will retain the microorganisms in the aeration basins for a quicker recovery if there is a washout.
- Hydraulic flow variations will have the most severe impact upon the activated sludge process.

Activated Sludge Clarifiers

- SVI indicates settleability:
  - SVI>100: light, fluffy; cone shaped blanket
  - SVI<100: more dense; bell shaped blanket
  - Desirable: 50-150 mL/g

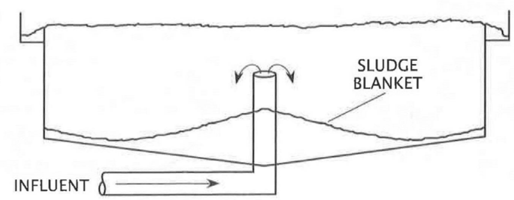


Fig. 5.12 Activated sludge settling near center of clarifier (bell-shaped pattern)

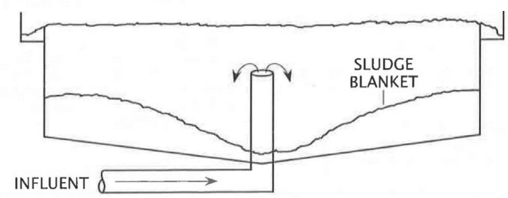


Fig. 5.13 Activated sludge settling near outer edge of clarifier (bowl-shaped pattern)

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Note

- ***SVI*** stands for ***Sludge Volume Index***

This Is a process control parameter to describe the settling characteristics of sludge in the aeration tank in Activated Sludge Process

It is used to determine the recycle rate of sludge

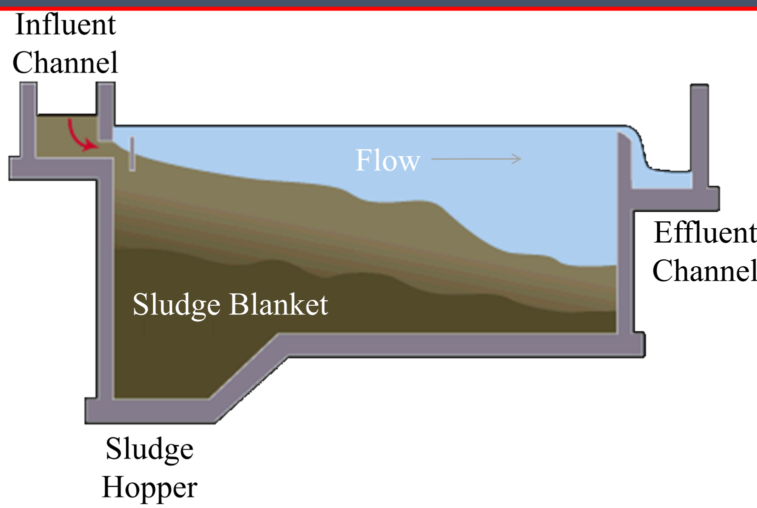
Activated Sludge Clarifiers

- Of all the different types of clarifiers, **secondary activated sludge clarifiers are the most critical** and require the most attention from operators
- The operator should monitor these:
  - Level of sludge blanket
  - Concentration of suspended solids in clarifier
  - Control and pacing of RAS flow
  - Level of turbidity in clarifier effluent
  - DO in clarifier effluent
  - pH

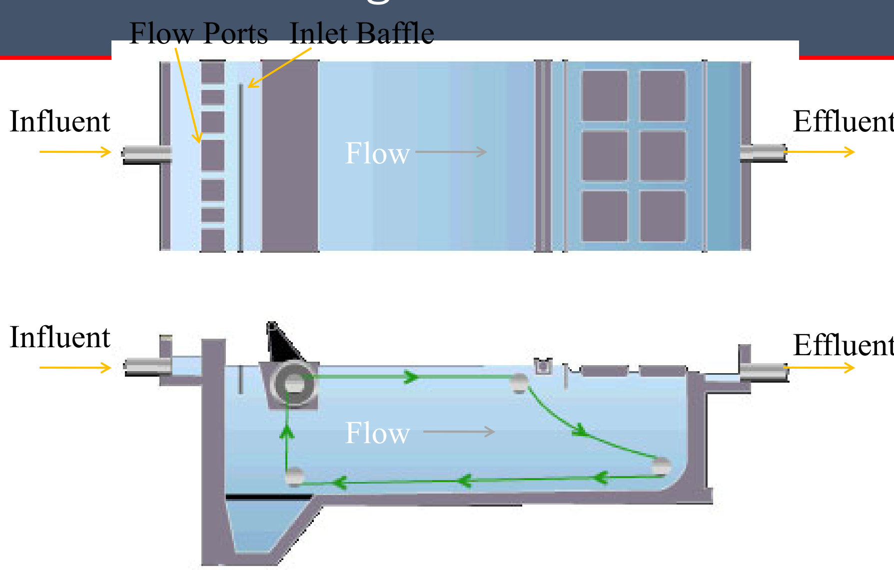
Gasification

- Indication of sludge septicity
  - Make sure accumulated settled solids are removed from bottom of clarifier before septicity and gasification take place
- Do not confuse with Denitrification -nitrogen gas bubbles rising to surface
  - Secondary Clarifiers

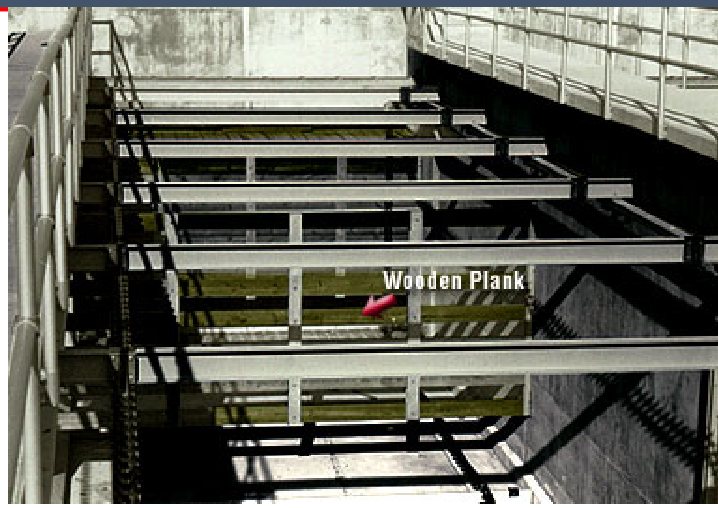
Rectangular Clarifier



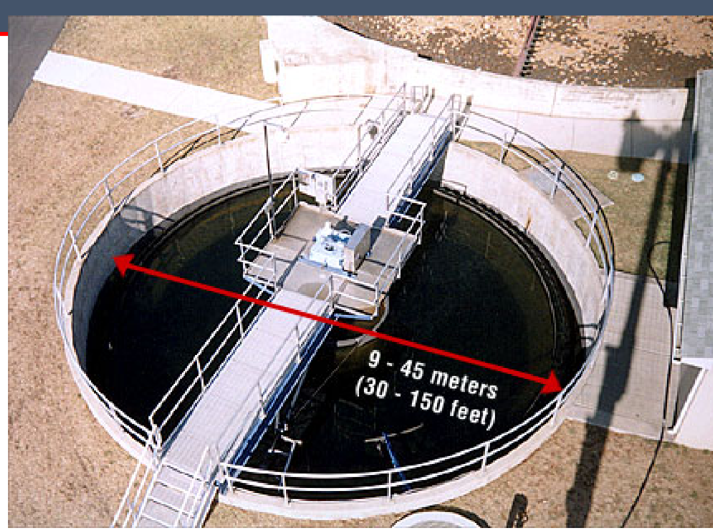
Rectangular Clarifier



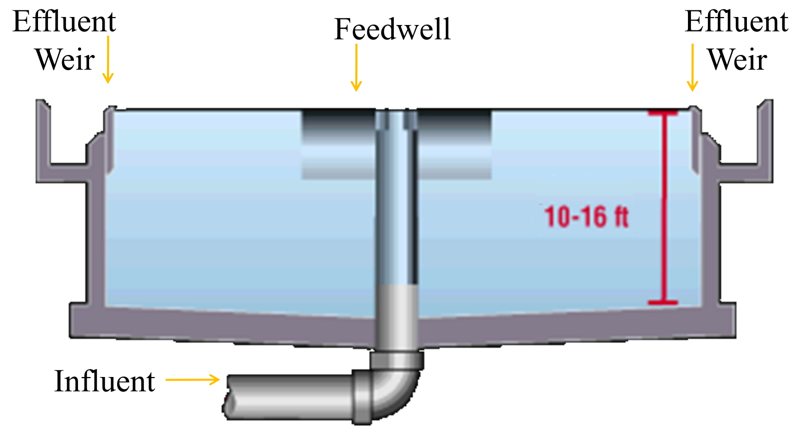
Wooden Baffles



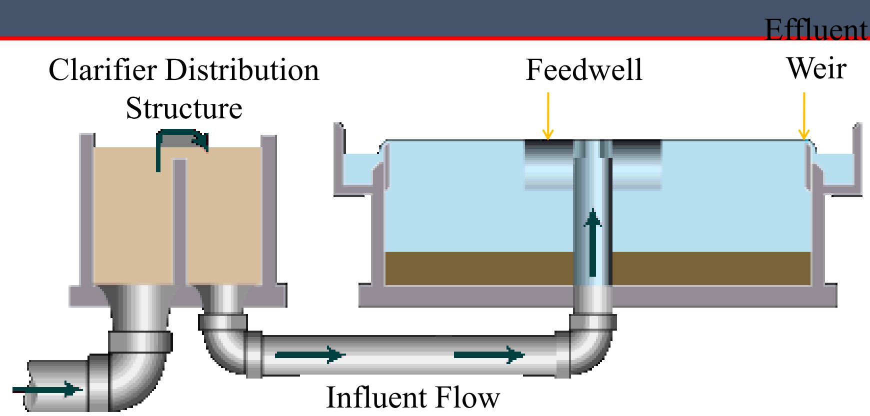
Circular Clarifier



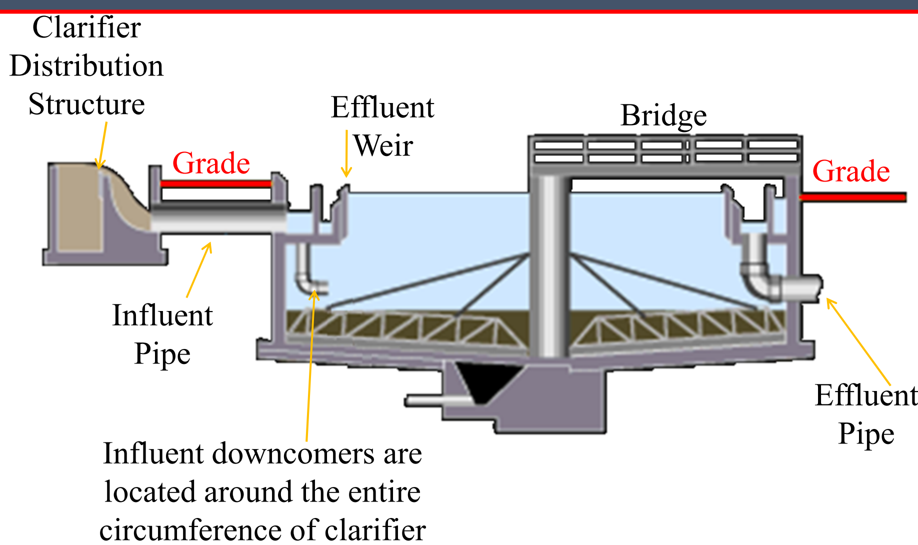
Circular Clarifier – Side Water Depth



Center-Feed Circular Clarifier



Peripheral-Feed Circular Clarifier

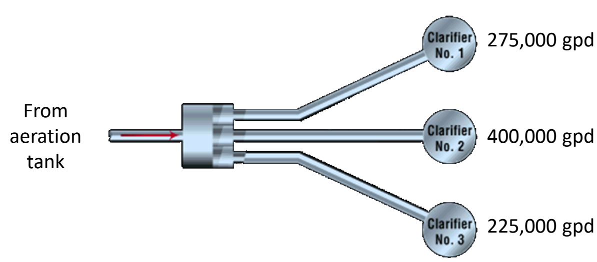


Feedwell

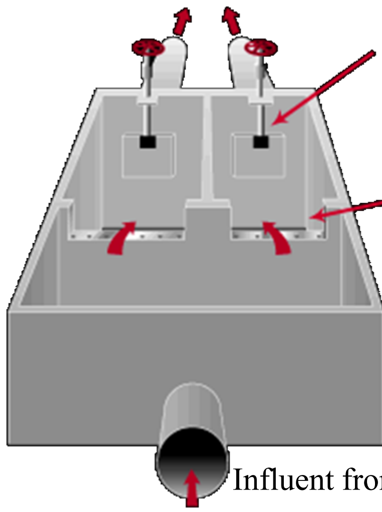
Effluent Launder

Uneven Split of Flow

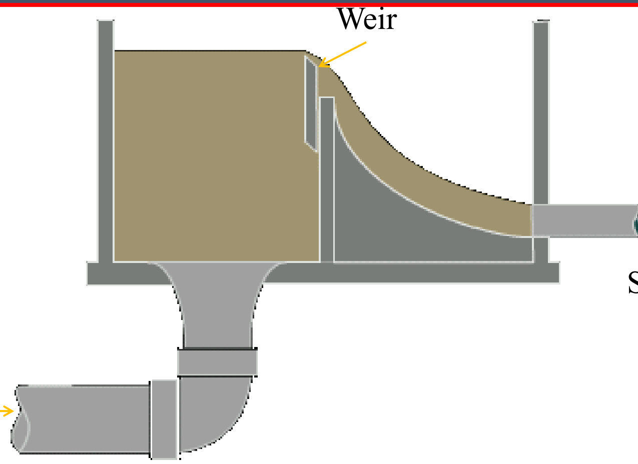
- The causes of uneven flow splitting include:
  - Poor design
  - Improper retrofit modifications



Distribution Box

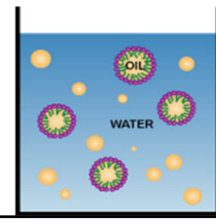


Cross Section of Clarifier Flow



Flotation Processes

- After 1° clarification, some suspended solids that neither settle not float always remain
- Colloids and emulsions are two forms of solids that are difficult to remove by sedimentation
  - Colloids are very small, finely divided solids that remain dispersed in liquid for a long time
  - An emulsion is a liquid mixture of two or more liquid substances not normally dissolved in one another
    - Usually grease, oil or fat



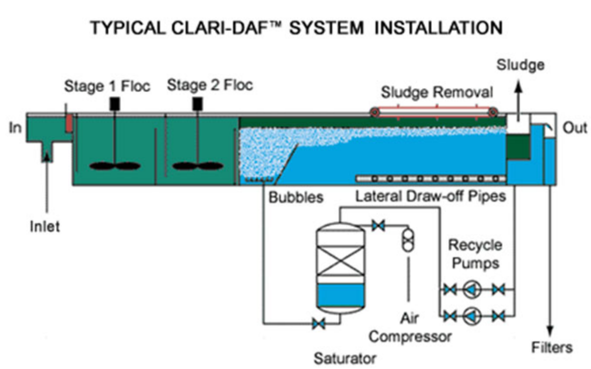
Flotation Processes

- Pumping air into mixture of emulsions and colloids to cause suspended material to float to surface where it can be skimmed off
- *Flocculation* = gathering together of fine particles after coagulation to form larger particles, clumping makes it easier to separate solids from water
- Particles flocculated with air or coagulants and carried to surface by air bubbles
  - Coagulant = a chemical that causes very fine particles to clump (floc) together into larger particles

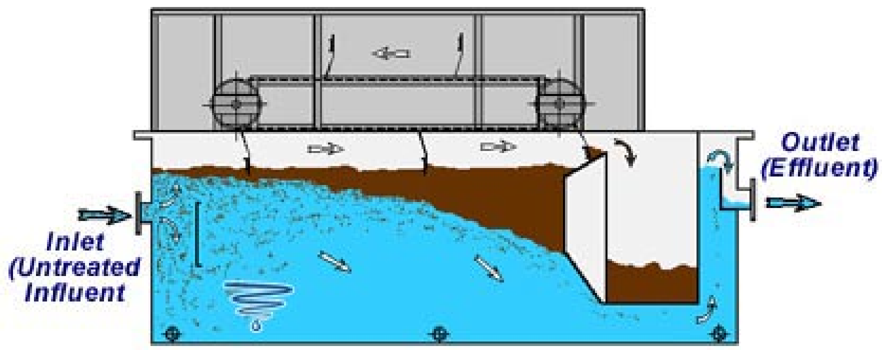
Dissolved Air Flotation

- Vacuum flotation
  - Aerated until saturated with dissolved air
  - Vacuum chamber then pulls air out and solids travel up with air bubbles
- Pressure flotation
  - Air is forced into wastewater
  - Dissolved air is then released because of change in pressure and solids are carried up with air bubbles

Pressure Flotation



Dissolved Air Flotation



Factors Affecting DAFs

- Type of sludge: heavier primary sludges harder to treat
- Age of feed sludge: older sludges float more readily
- Solids loading: 10-24 lbs/day/ft^2
- Hydraulic loading: 0.5-1.5 gpm/ft^2
- Air to solids ratio: 0.01-0.10 lb/lb
- Recycle rate: 100-200%
- Blanket depth: decreasing scraper speed concentrates sludge

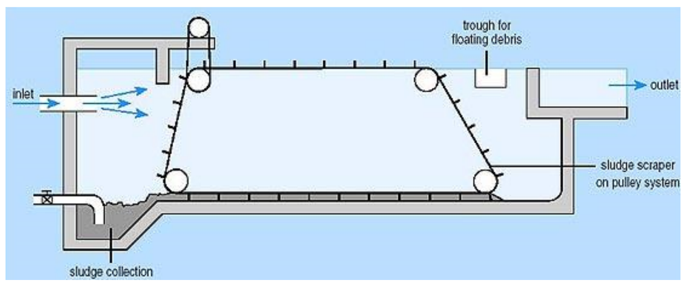
Clarifier Solids Removal

- The mechanisms for clarifier solids removal include:
  - Mechanical transport
    - Continuous flight (chain and flight)
    - Traveling bridge
  - Siphon removal
  - Suction removal

Mechanical Solids Removal

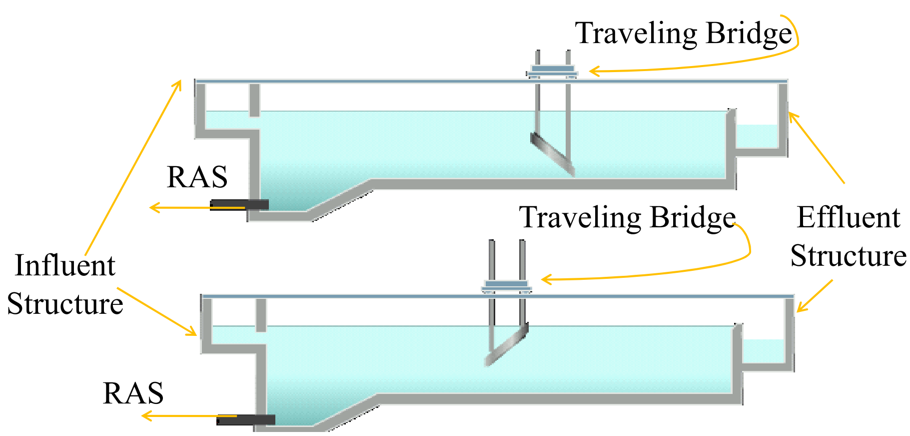
Chain and Flight

- Rectangular Basins – motor drives chain that pulls flight across basin floor, sweeps sludge to end of basin



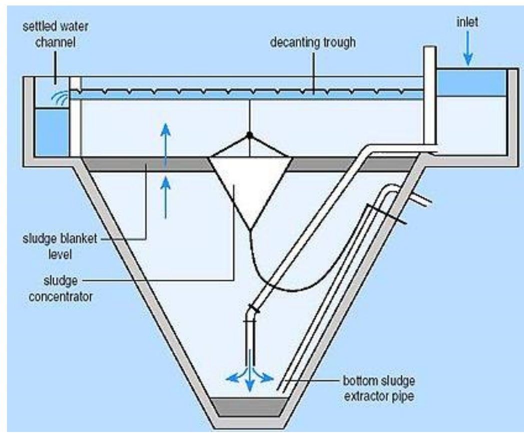
Traveling Bridge

- Moving bridge scrapes sludge to drain, skims scum



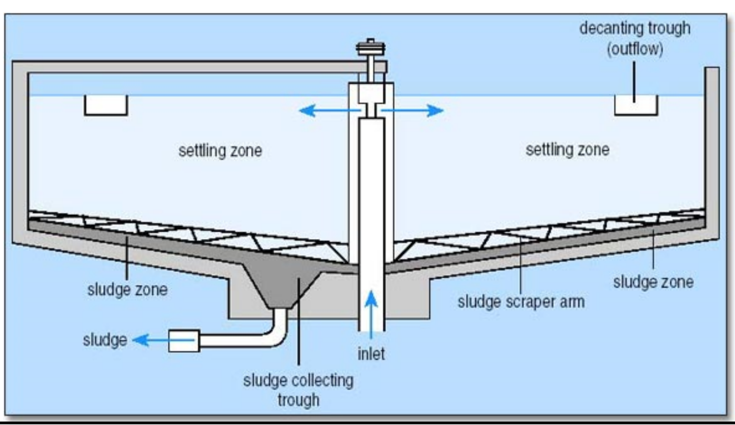
Floating Bridge Siphon Collector

- Uses suction pipes or submersible pump to withdraw sludge from basin
- Basin does not have to be taken out of service to clean

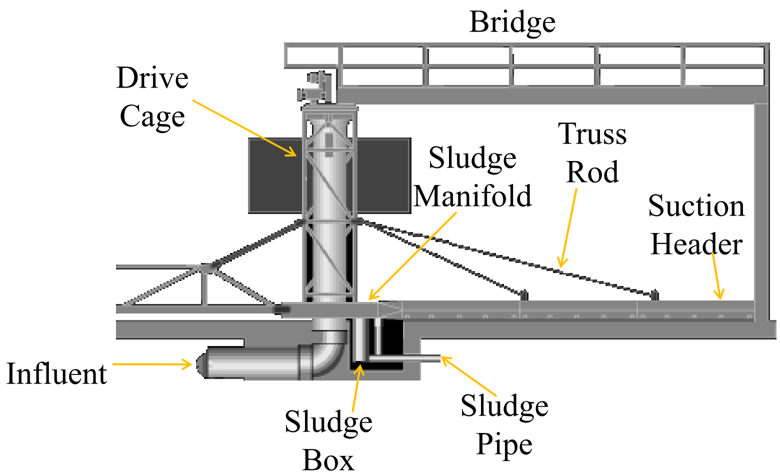


Circular or Square Basins

- Scrapers slant downward to center of basin
- Basin does not have to be taken out of service to clean



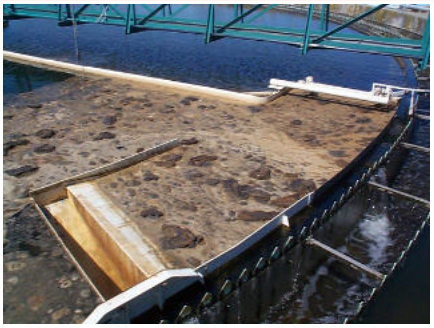
Solids Removal by Suction



Scum

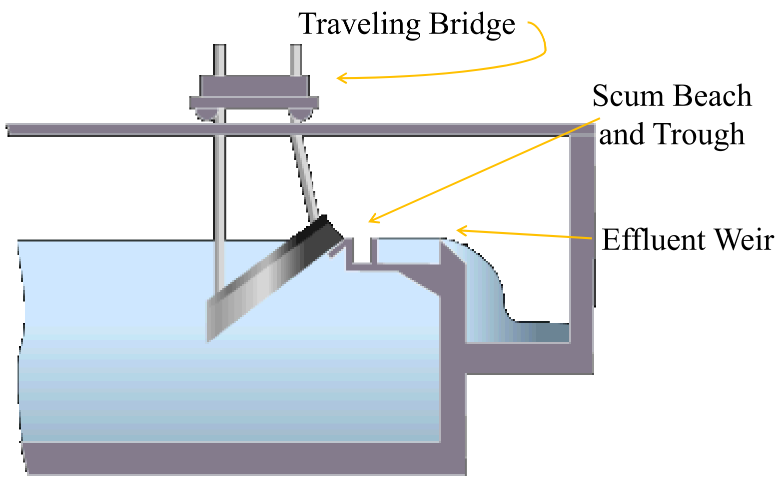
- Collected scum should be processed with the waste and primary sludges

Scum Skimmer



Scum Skimmer

Scum Removal for Traveling Bridge



Clarifier Monitoring

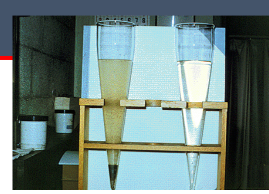
- Clarifier monitoring and control systems include sludge blanket monitoring and drive mechanism torque control.
- The continuous data being provided by these systems are very useful for process control.

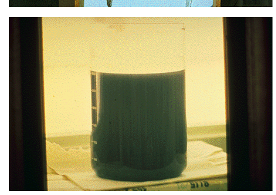
Clarifier Monitoring

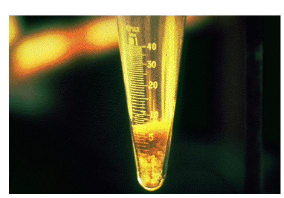
- Sludge blanket levels
- Suspended solids concentration in clarifier effluent
- Control of return sludge flows
- Turbidity in clarifier effluent
- DO levels in clarifier effluent
- pH

Monitoring the Process

- Primary clarifier: Imhoff cone
- Secondary clarifier: Settleometer; centrifuge spins
- Turbidity test also
- Visually checking for floc carry-over
- Visual check of how far floc particles are visible from inlet

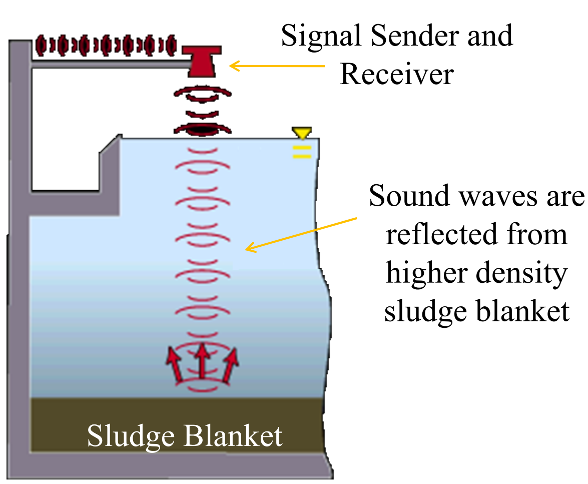






Manual Measurement of Sludge Blanket Depth

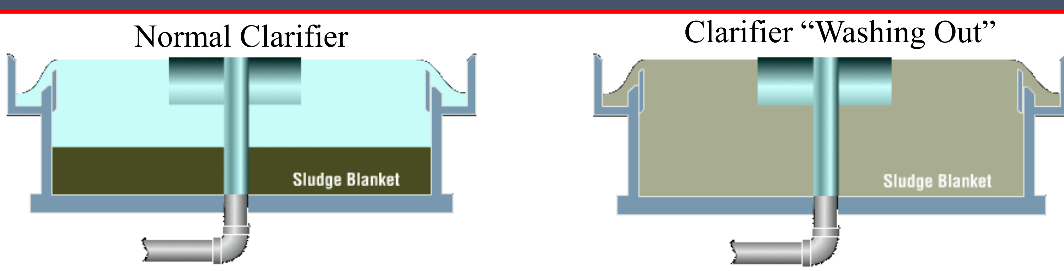
Sonic Measurement of Sludge Blanket Depth



Flow Management

- Activated sludge system components are sized for a specific design flow.
- Clarifiers can become overloaded

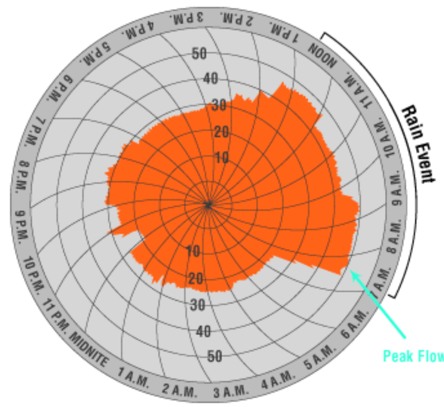
Clarifier "Washout"



NPDES definition:
For domestic wastewater plants only, a "washout" shall be defined as loss of Mixed Liquor Suspended Solids (MLSS) of 30.00% or more. This refers to the MLSS in the aeration basin(s) only. This does not include MLSS decreases due to solids wasting to the sludge disposal system. A washout can be caused by improper operation or from peak flows due to inflow and infiltration.

Peak Flows

- Operators need to minimize the impacts of peak flows on plant performance.



Flow Management

Operators must use:

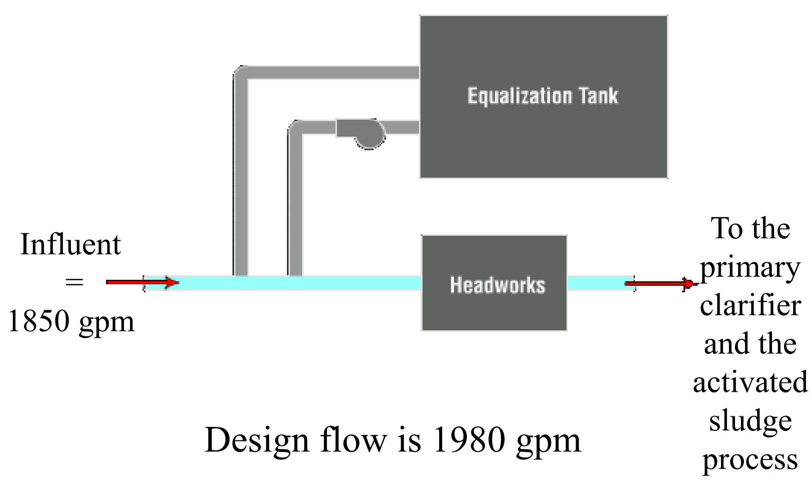
- Past history;
  - "March snow melts"
  - "August thunderstorms"
- Weather forecasts
  - "Hurricane Henry to hit"

to help them predict when high flows may occur.

Flow Management

- High flows can be managed by using:
  1. Flow-equalization basins
  2. Storage lagoons
  3. Alternate process modes such as contact stabilization or step feed.

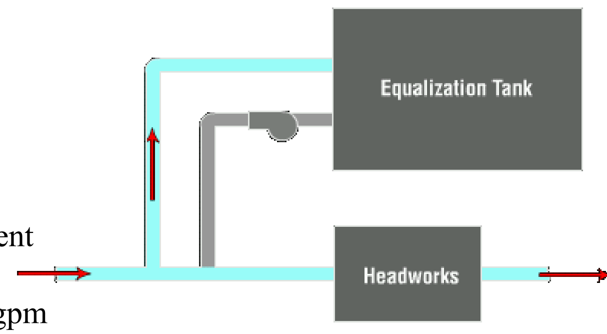
Flow Management



Design flow is 1980 gpm

Flow Management

Influent = 2380 gpm

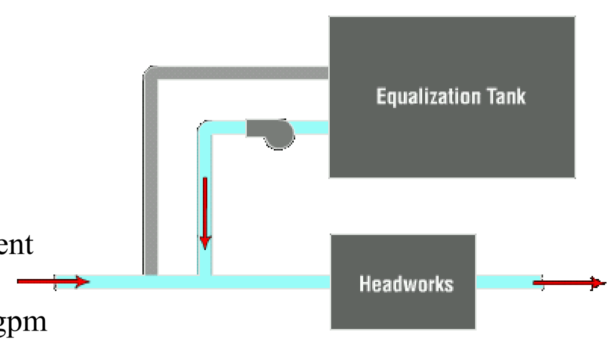


To the primary clarifier and the activated sludge process

Design flow is 1980 gpm

Flow Management

Influent = 1715 gpm



To the primary clarifier and the activated sludge process

Design flow is 1980 gpm

Flow Management

- Some plants have storage lagoons for wet weather flows.
- Stored wastewater is pumped to the head of the plant when flow rates decrease.

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TN Department of Environment & Conservation

Sedimentation and Flotation Vocabulary

1. The particles that settle to the floor of a clarifier are called _________________________.
2. ___________________________ is the term used to describe the clouds of billowing sludge that occur throughout secondary clarifiers when the sludge does not settle properly.
3. Sludge in primary clarifiers must be removed at regular intervals to prevent the sludge from turning _________________.
4. _____________________________ is the gathering together of fine particles after coagulation to form larger particles by a process of gentle mixing. This clumping together makes it easier to separate the solids from the wastewater by settling, skimming, draining, or filtering.
5. Large clumps of sludge floating to the surface of the water in a primary clarifier would indicate ____________________________________ is occurring due to anaerobic decomposition.
6. A chemical that causes very fine particles to clump or floc together into larger particles is a ________________________. This makes it easier to separate the solids from the liquids by settling, skimming, draining, or filtering. They can be used as part of the flotation process.
7. The clarifier that follows other types of treatment, usually a biological reactor, is the ________________________________. Its main function is to remove the additional solids that were converted to settleable form in the treatment processes that followed the primary clarifier.
8. ____________________________ is a condition that occurs in tanks or basins when the velocity of water flow is greater in some sections than in others. This is an undesirable situation since it may result in shorter contact time, detention times, reaction times, or settling rates.
9. Simply put, ________________________________ is defined as the hydraulic loading across the surface of your settling tank.
10. __________________________are very small, finely divided solids that do not dissolve and remain dispersed in a liquid for a long time due to their small size and electrical charge. DAF systems are designed to remove these particulates from wastewater.
11. _________________________________refers to the amount of solids removed daily by a clarifier for each square foot (ft^2) of clarifier liquid surface area.
12. Wastewater must remain in a clarifier long enough to allow sufficient time for particles to settle out. On average, the __________________________ is 2-3 hours for a settling tank.
13. Scraper boards made from rot-resistant wood or plastic that are used to collect and move settled sludge or floating scum are called _____________________________.

14. The anoxic process of nitrite or nitrate ions being reduced to nitrogen gas and producing nitrogen bubbles is called ________________________________. This condition can lead to rising sludge in secondary clarifiers, due to nitrogen bubbles attaching to the biological floc and floating the floc to the surface.

15. A _______________________is a wall or obstruction used to control flow from settling tanks and clarifiers to ensure a uniform flow rate and avoid short-circuiting.

16. Defined as the number of gallons of wastewater that flow over one lineal foot of weir per day, the ______________________________________ is generally lower in secondary clarifiers than in primary clarifiers.

17. The first clarifier in the plant that comes immediately after preliminary treatment (bar screen, comminutor, or grit channel) is the ____________________________________. Its main function is to remove settleable and floatable solids.

18. Sedimentation tank effluent troughs consisting of overflow weir plates are called _________________________.

19. The _______________________________ is a calculation that indicates the tendency of activated sludge solids to thicken or become concentrated during the sedimentation/thickening process.

20. The _______________________________ process involves pumping air into wastewater to cause the suspended solids to adhere to bubbles and float to the surface, where they can be skimmed off.

21. The slime that is washed off the filter media in a trickling filter, which is generally quite high in BOD, is called ____________________________.

<u>Word Bank:</u>

Short circuiting	Sludge Volume Index (SVI)	Flights
Bulking	Colloids	Primary clarifier
Launders	Secondary clarifier	Septic
Coagulant	Sludge	Weir overflow rate
Flotation	Weir	Solids loading rate
Flocculation	Sloughings	Sludge gasification
Denitrification	Surface loading rate	Detention time (aka Retention Time)

CHAPTER 5

Clarifiers

5.6 Operability, Flexibility, and Reliability

5.6.1 Scum Removal
5.6.2 Overflow Weirs
5.6.3 Unit Dewatering
5.6.4 Hydraulics
5.6.5 Sludge Removal
5.6.6 Other Design Considerations

CLARIFIERS

5.1 General Criteria

5.1.1 Purpose

Clarifiers (sedimentation basins, settling tanks) are designed to perform three (3) functions in a treatment scheme:

A. Remove solids from liquids by sedimentation
B. Remove scum from liquid by flotation
C. Thicken solids for removal and further treatment

Specific application of clarifier functions will be dependent upon the treatment process employed. This chapter does not attempt to set criteria for all types of clarifiers. If a unique clarifier is proposed, the design engineer shall submit operational and design data justifying its use.

5.1.2 Number of Units

Multiple units capable of independent operation shall be provided in all facilities where design flows exceed 250,000 gallons per day. Otherwise, the number of units required shall satisfy reliability requirements (see Section 1.3.11). Facilities not having multiple units shall include other methods to assure adequate operability and flexibility of treatment.

5.1.3 Arrangements

Clarifiers shall be arranged for greatest operating and maintenance convenience, flexibility, economy, continuity of maximum effluent quality, and ease of installation of future units.

5.1.4 Tank Configurations

Consideration should be given to the probable flow pattern in the selection of tank size and shape and inlet and outlet type and location.

5.1.5 Flow Distribution

Effective flow measuring devices and control appurtenances (i.e., valves, gates, splitter boxes, etc.) shall be provided to permit proper proportion of flow to each unit (see Section 13.2.1).

5.2 Design Loading

5.2.1 Primary Clarifiers

Primary clarifier designs are primarily based upon surface overflow rate. The following criteria are recommended for design:

Hydraulic Loading Rate	Surface Overflow Rate
Average Design Flow	800-1200 gpd/sq. ft.
Peak Design Flow	2000-3000 gpd/sq. ft.

If WAS is returned to the primary then

Hydraulic Loading Rate	Surface Overflow Rate
Average Design Flow	600-800 gpd/sq. ft.
Peak Design Flow	1200-1500 gpd/sq. ft.

Primary clarifier sizing shall be calculated for both flow conditions and the larger surface area derived shall be utilized. A properly designed primary clarifier should remove 30 to 35% of the influent BOD. However, anticipated BOD removal for wastewater containing high quantities of industrial wastewater should be determined by laboratory tests and considerations of the quantity and characteristics of the wastes.

5.2.2 Intermediate Clarifiers

Surface overflow rates for intermediate clarifiers should be based upon the following criteria:

Maximum Hydraulic Loading Rate	Surface Overflow Rate
Average Design Flow	1000 gpd/sq. ft.
Peak Design Flow	2500 gpd/sq. ft.

5.2.3 Final Clarifiers

Final clarifier designs shall be based upon the type of secondary treatment application used. Surface overflow and solids loading rates shall be the general basis for clarifier designs. Pilot studies of biological treatment is recommended when unusual wastewater characteristics are evident or when the proposed loading exceeds those noted in this section.

Table 5-1 depicts the criteria established for final clarifier surface overflow and solids loading rates. In activated sludge systems, the surface overflow rate for final clarifiers should be based on influent wastewater flows and not include return activated sludge flows (RAS). Solids loading rate criteria assume sludge recycle is 100% of the average design flow and the design mixed liquor suspended solids (MLSS) concentration.

TABLE 5-1
FINAL CLARIFIER DESIGN PARAMETERS

	Maximum Surface Overflow Rate gpd/sq.ft.		**Solids Loading Rate lbm/day-sq.ft.**	
Type of Process	**Average Design Flow**	**Peak Design Flow**	**Average Design Flow**	**Peak Design Flow**
Trickling Filter	600	1200	25	40
Activated Sludge	800 (600 for plants less than 1 MGD)	1200	30	50
Extended Aeration	400	1000	25	35
Nitrification	400	800	25	35
Pure Oxygen	700	1200	25	40

5.2.4 Weir Loading Rates

Weir loadings should not exceed 15,000 gallons per day per linear feet (gpd/li ft).

5.2.5 Depth/Detention Time

The sidewater depth (SWD) for clarifier designs associated with design surface overflow rates should dictate the hydraulic detention time of the clarifier. For design purposes, the following criteria in Table 5-2 are established specific to clarifier application:

TABLE 5-2 CLARIFIER DEPTH		
Type of Process	**Diameter [ft]**	**Minimum Sidewater Depth [ft]**
*Primary	-	8
Trickling Filter	-	10
**Activated Sludge	Less than 40	11
	40-70	12
	71-100	13
	101-140	14
	Over 140	15

*The hydraulic detention time in primary clarifiers is not recommended to be greater than 2.5 hours as a function of the surface overflow rate and SWD, since septic conditions resulting in poor performance and odor conditions can occur.

**For rectangular-shaped clarifiers following activated sludge treatment, the recommended SWD shall be no less than 12 feet at the shallow end.

5.3 Design Details

5.3.1 Inlets

Inlets should be designed to dissipate the influent velocity, to distribute the flow equally in both the horizontal and vertical vectors, and to prevent short-circuiting. Channels should be designed to maintain an inlet velocity of at least one (1) foot per second at one-half the design flow. Corner pockets and dead ends should be eliminated and corner fillets or channeling used where necessary. Provisions shall be made for elimination or removal of floating materials in inlet structures having submerged ports.

5.3.2 Submerged Surfaces

The tops of troughs, beams, and similar submerged construction elements shall have a minimum slope of 1.75 vertical to 1 horizontal. The underside of such structures should have a slope of 1 to 1 to prevent accumulation of scum and solids.

5.3.3 Weir Troughs

Weir troughs shall be designed to prevent submergence at
maximum design flow, and to maintain a velocity of at least one (1) foot per second at one-half design flow.

5.3.4 Freeboard

Walls of clarifiers shall extend at least six (6) inches above the surrounding ground surface and shall provide not less than twelve (12) inches of freeboard.

5.4 Sludge and Scum Removal

5.4.1 Scum Removal

Effective scum collection and removal facilities, including baffling ahead of the outlet weirs, shall be provided for all clarifiers. Provisions may be made for discharge of scum with sludge; however, other provisions may be necessary to dispose of floating materials which may adversely affect sludge handling and disposal. The unusual characteristics of scum which may adversely affect pumping, piping, sludge handling and disposal, should be recognized in the design. Scum piping should be glass lined or equivalent. Precautions should be taken to minimize water content in the scum.

5.4.2 Sludge Removal

Sludge collection and withdrawal facilities shall be designed to assure rapid removal of the sludge. Provisions shall be
made to permit continuous sludge removal from settling tanks. Final clarifiers in activated sludge plants shall be provided with positive scraping devices. Suction withdrawal should be provided for activated sludge plants designed for the reduction of nitrogenous oxygen demand.

5.4.3 Sludge Removal Piping

Each sludge hopper shall have an individually valved sludge withdrawal line at least six (6) inches in diameter if pumped and at least eight (8) inches in diameter if gravity flow is used. This does not apply to air lift methods of sludge removal, as this should be determined by the sludge removal rate. Static head available for sludge withdrawal shall be at least thirty (30) inches, as necessary, to maintain a three (3) feet per second velocity in the withdrawal pipe. Clearance between the end of the withdrawal line and the hopper walls shall be sufficient to prevent "bridging" of the sludge. Adequate provisions shall be made for rodding or back-flushing individual pipe runs.

***Air lift type sludge removal will not be approved for removal of primary sludges.

5.4.4 Sludge Removal Control

Sludge wells equipped with telescoping valves or other appropriate equipment shall be provided for viewing, sampling and controlling the rate of sludge withdrawal. A means for measuring the sludge removal rate and sludge return rate shall be provided. Sludge pump motor control systems shall include time clocks and valve activators for regulating the duration and sequencing of sludge removal. Gravity flow systems should have back-up pumping capabilities.

5.4.5 Sludge Hopper

The minimum slope of the side walls shall be 1.75 vertical to 1 horizontal. Hopper wall surfaces should be made smooth with rounded corners to aid in sludge removal. Hopper bottoms shall have a maximum dimension of two (2) feet. Extra-depth sludge hoppers for sludge thickening are not acceptable.

5.5 Protective and Service Facilities

5.5.1 Operator Protection

All clarifiers shall be equipped to enhance safety for operators. Such features shall appropriately include machinery cover lift lines, stairways, walkways, handrails and slip-resistant surfaces.

5.5.2 Mechanical Maintenance Access

The design shall provide for convenient and safe access to routine maintenance items such as gear boxes, scum removal mechanisms, baffles, weirs, inlet stilling baffle area, and effluent channels.

5.5.3 Electrical Fixtures and Controls

Electrical fixtures and controls in enclosed settling basins shall meet the requirement of the National Electrical Code. The fixtures and controls shall be located so as to provide convenient and safe access for operation and maintenance. Adequate area lighting shall be provided.

5.6 Operability, Flexibility, and Reliability

5.6.1 Scum Removal

5.6.1.1 A method of conveying scum across the water surface to a point of removal should be considered, such as water or air spray. Baffles should be designed to ensure capture of scum at minimum and maximum flow rates.

5.6.1.2 Facilities designed for flows of 0.1 MGD and greater should have mechanical scum removal equipment.

5.6.1.3.Scum holding tanks may be provided, with a method of removing excess water.

5.6.1.4 Large scum sumps should have a mixing device (pneumatic, hydraulic, or mechanical) to keep the scum mixed while being pumped.

5.6.1.5 Manual scum pump start-stop switches should be located adjacent to scum holding tanks.

5.6.2 Overflow Weirs

5.6.2.1 Since closely spaced multiple overflow weirs tend to increase hydraulic velocities, their spacing should be conservative.

5.6.2.2 Center-feed, peripheral draw-off clarifiers shall not have the overflow weir against the clarifier sidewall. Weir placement shall be 1/10 diameter or greater toward the center.

5.6.2.3 The up-flow rate shall not be greater than the surface overflow rate at any location within the solids separation zone of a clarifier.

5.6.2.4 Overflow weirs should be of the notched type; straight edged weirs will not be approved.

5.6.2.5 Overflow weirs shall be adjustable for leveling.

5.6.3 Unit Dewatering

5.6.3.1 The capacity of dewatering pumps should be such that the basin can be dewatered in 24 hours; eight hours is preferable.

5.6.3.2 The contents of the basin should be discharged to the closest process upstream from the unit being dewatered that can accept the flow.

5.6.3.3 Consideration shall be given to the need for hydrostatic pressure relief devices to prevent flotation of structures.

5.6.4 Hydraulics

5.6.4.1 Lift/pump stations located immediately upstream of secondary clarifiers shall have flow-paced controls to reduce shock loadings.

5.6.4.2 Square clarifiers with circular sludge withdrawal mechanisms shall be designed such that corner hydraulic velocities do not cause sludge carry-over.

5.6.5 Sludge Removal

5.6.5.1 When two or more clarifiers are used, provisions shall be made to control and measure the rate of sludge withdrawal from each clarifier.

5.6.5.2 Consideration should be given to removing activated sludge from the effluent end of rectangular clarifiers.

5.6.5.3 Consideration shall be given to chlorination of return activated sludge and digester supernate. Sufficient mixing and contact time should be provided.

5.6.6 Other Design Considerations

5.6.6.1 Designs should consider the possible need for future modifications to add chemicals such as flocculants.

5.6.6.2 A method of foam control should be considered for all inlet channels and feed wells in activated sludge systems.

Section 7
Ponds and Lagoons

Section 7
Ponds and Lagoons

Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

Advantages of Ponds

- Economical to operate
- Capable of handling high flows
- Adaptable to changing loads
- Accumulate sludge at a rate of 0.2 lbs per lb of BOD (much lower than conventional facilities where the accumulation rate is 0.5 lbs to 1.0 lbs of solids per lb of BOD removed.)

Advantages of Ponds

- Have an increased potential design life
- Serve as wildlife habitat
- Consume little energy
- Adaptable to land application

Disadvantages of Ponds

- May produce odors
- Require large land areas
- Are affected by climactic conditions
- May have high suspended solids levels in effluent
- Might contaminate groundwater

Note

- Ponds designed to receive wastes with no prior treatment =
  - "***Raw wastewater lagoons***"
  - ***"Sewage lagoons"***
  - ***"Stabilization ponds"***
- ***Oxidation Ponds*** are ponds that are used in series after primary treatment to provide further clarification, BOD removal, and disinfection
- ***Polishing Ponds*** are ponds used after Trickling Filter (serving as a form of tertiary treatment)

Types of Lagoons

- Aerobic
- Anaerobic
- Facultative
- Unaerated or Aerated

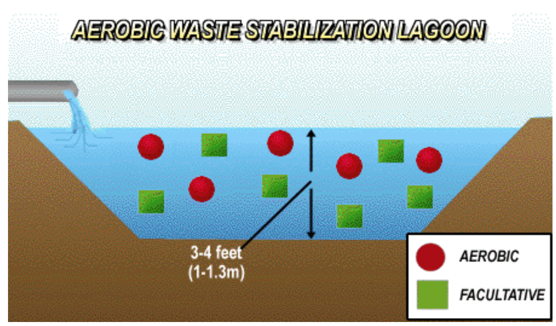
Types of Bacteria in Stabilization Lagoons

Aerobic Decomposition

Organics + O_2 + nutrients + inert matter → CO_2 + H_2O + new microorganisms + additional inert matter

Aerobic Pond

- Shallow: 3-4 ft deep
- D.O. throughout water column
- Flat terrain with much sunshine
- D.O. due to photosynthesis



Aerobic Pond

- Organic matter is used as food by aerobic bacteria, their waste product is carbon dioxide
  - The carbon dioxide and ammonia in the wastewater are important for algal growth
- By using sunlight for energy in the process of photosynthesis, the algae use the carbon dioxide (CO_2) in the water to produce free oxygen (O_2), making it available to the aerobic bacteria that inhabit the pond.

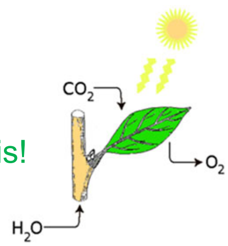
Algae

- Algae are simple microscopic plants
- Algae live on carbon dioxide and other nutrients in the wastewater.
- During the day, algae use CO_2, which raises the pH, while at night they produce CO_2 and the pH is lowered.
- At night, algae use up the O_2 by respiration and produce CO_2.
- The alternate use and production of oxygen and carbon dioxide can result in diurnal (daily) variations of both pH and DO.
- Each pound of algae in a healthy pond is capable of producing 1.6 pounds of oxygen on a normal summer day.

Photosynthesis

- Process of converting carbon dioxide (CO2) and inorganic substances into oxygen and additional plant material
- Plants with chlorophyll (and cyanobacteria)
- Uses sunlight as energy source
- All green plants grow by this process

Photosynthesis!



Photosynthesis vs. Respiration

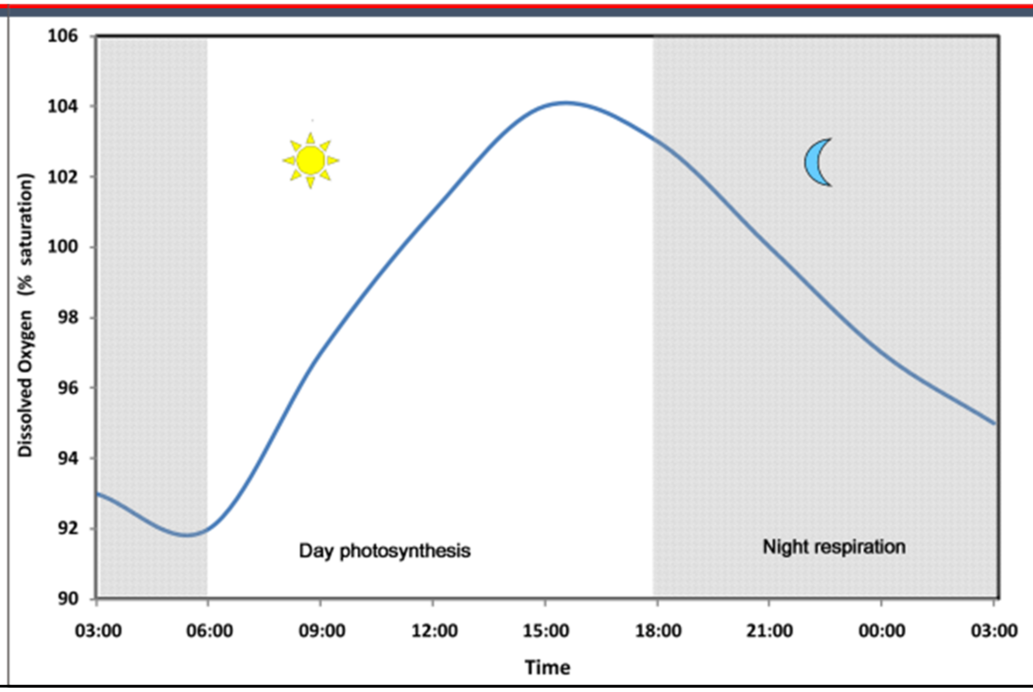
Photosynthesis →

$$CO_2 + H_20 \leftrightarrow O_2 + CH_2O$$

← Respiration

carbohydrate

Algae produce oxygen during periods of sunlight and consume oxygen during the night

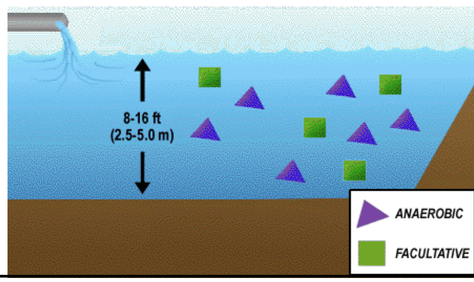


Anaerobic Decomposition

Organics + nutrients + inert → $CH_4 + CO_2 + NH_4 + H_2S$ + other products

Anaerobic Pond

- No dissolved oxygen (bound oxygen only)
- Treatment due to fermentation of sludge on bottom
- Highly efficient removal organic wastes
- Typically 8-16 ft deep



Anaerobic Pond

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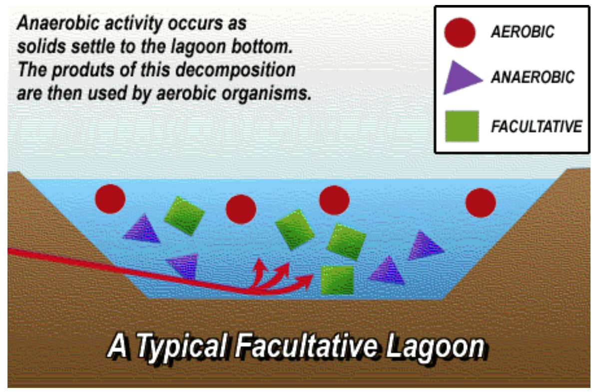
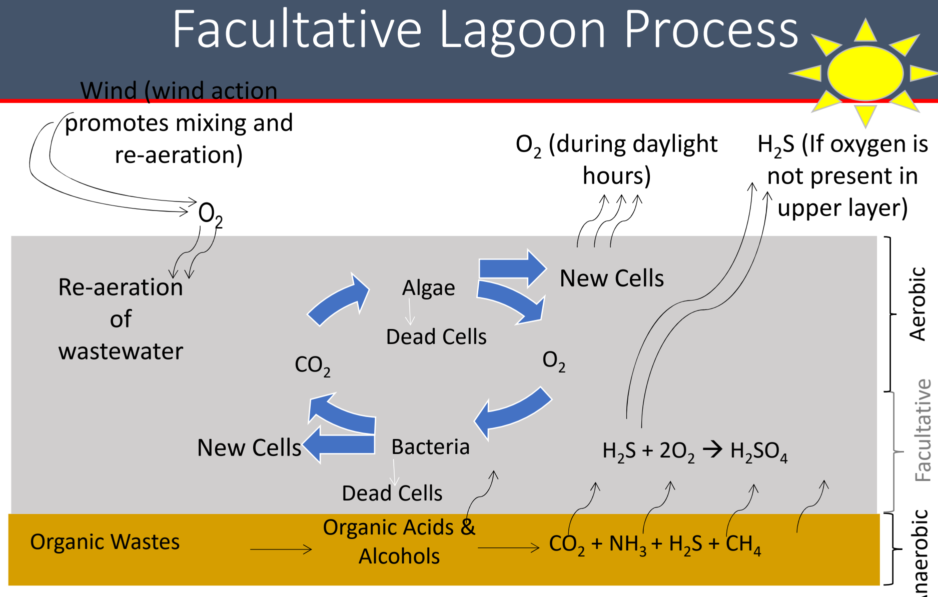
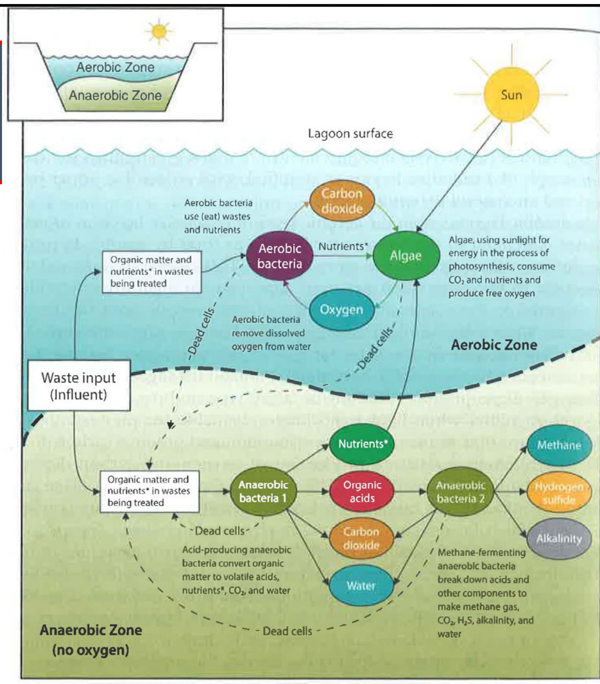
Facultative Lagoon

- Most common
- Upper portion aerobic
- Sludge layer anaerobic
- Depth: 4-8 ft
- DT: 5-30 day+
- Organic solids are decomposed by bacteria and the byproducts are used by algae



Facultative Lagoon Process





*Nutrients are nitrogen- and phosphorus-containing compounds (such as ammonia and phosphate) that are needed for microbial growth

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Aerated Lagoons

Aerated compared to Facultative:

- Shorter detention times
- Heavier loadings
- Do not depend on algal photosynthesis to furnish oxygen for bacterial respiration

Detention Times:

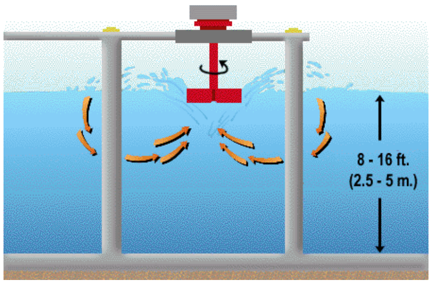
- Aerated Lagoons: 3-10 days
- Facultative Lagoons:
  - 5-30 days (typical)
  - 180 days (in cold climates)

Aerated Lagoons

Mechanically Aerated Ponds

Stationary or floating aerators

Allows for higher organic loading or shorter detention time in lagoon



Floating Surface Aerator

Floating Surface Aerator

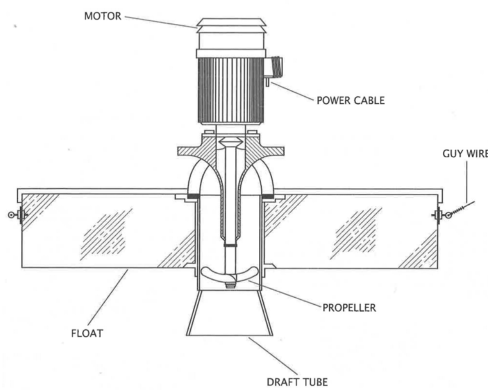
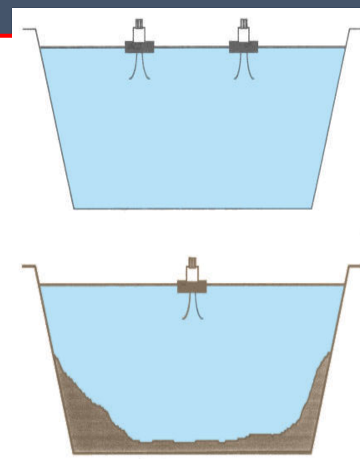


Fig. 9.6 Floating surface aerator
(Permission of Aqua-Jet)

Aerated Lagoons: Partial vs. Complete Mix

- Less land; constructed deeper
- Uniform D.O or partial mix
- Not dependent for D.O by sun/photosynthesis
- More maintenance required
- Greater energy costs to supply oxygen to bacteria
- Easily affected by temp.
- Require sedimentation unit after lagoon (complete mix)

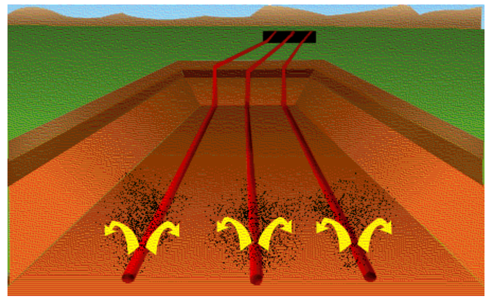


TN Design Criteria for Sewage Works

- 9.3.1.2
  - Round, square, or rectangular ponds should have a **length to width ratio of 1:1** for *complete mix ponds*
  - Rectangular ponds with a **length not exceeding 3 times the width** are considered the most desirable for *complete mix*
  - *Stabilization ponds* should be rectangular with a **length exceeding 3 times the width**, or be baffled to ensure full utilization of the basin.

Diffused Aeration Lagoons

Diffusers can become clogged and create maintenance problems



Less mixing; more efficient oxygen transfer

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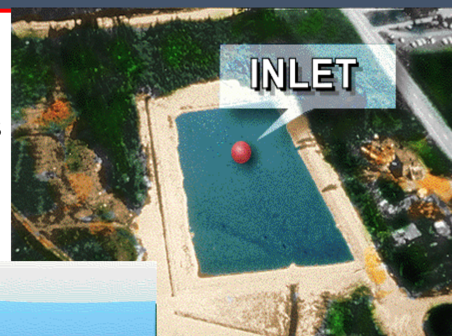
Typical Lagoon Design

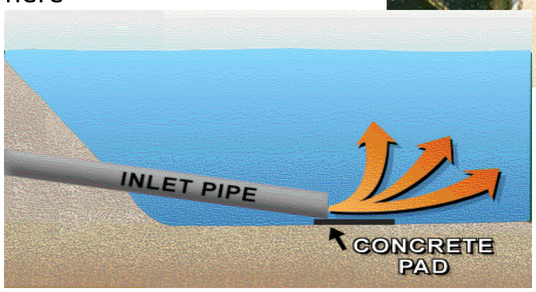
Parameter	Aerobic	Facultative	Anaerobic	Aerated
Size, acres	<10, multiples	2-10 multiples	0.5-2.0	2-10, multiples
Operation	Series or Parallel	Series or Parallel	Series	Series or Parallel
Detention Time, days	10-40	5-30*	20-50	3-10
Depth, ft	3-4	4-8	8-16	6-20
pH	6.5-10.5	6.5-8.5	6.5-7.2	6.5-8.0
Temperature Range, °C	0-30	0-50	6-50	0-30
Optimum Temperature, °C	20	20	30	20
BOD5 Loading, lb/ac/d	54-110	45-160	180-450	___
BOD5 Removal, %	80-95	80-95	50-85	80-95

*180 days in cold climates

Pond Structures: Inlet

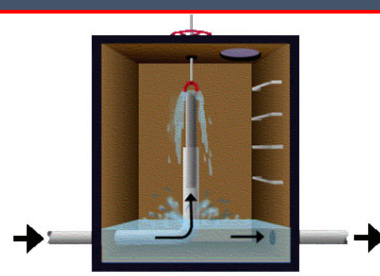
- Force main vs. gravity
- Single vs. multiple inlets
- Below surface best: prevents freezing
- Most sludge deposits occur here



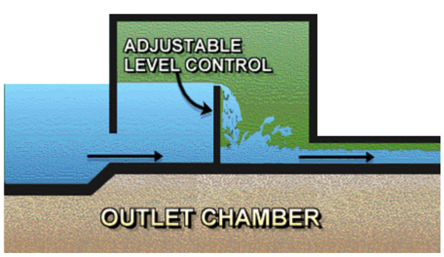


Pond Structures: Outlet

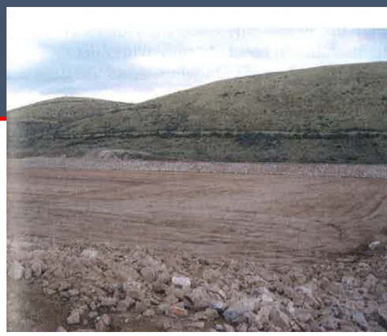
- Just below surface with scum baffle to minimize transfer of algae



Above: telescoping tube.



Left: flash boards



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- Synthetic liner
- Packed clay liner
- Berm or levee: grass and/or rip rap

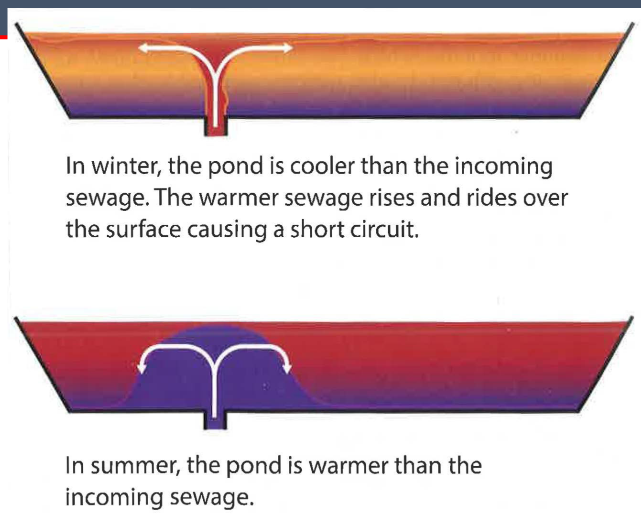
Factors Affecting Pond Operation

Physical:

- Type of soil
- Surface area
- Depth
- Wind
- Hydraulic load
- Short circuiting
- Type of aeration
- Temperature
- Inflow variations
- Sunlight

- Bioflocculation = clumping together of fine, dispersed organic particles by action of certain bacteria and algae
  - Pond has healthy algal and bacterial population
  - Will remove ~85% of both suspended and dissolved solids within hours
  - Accelerated by increased temperature, wave action, and high DO content

Short circuiting



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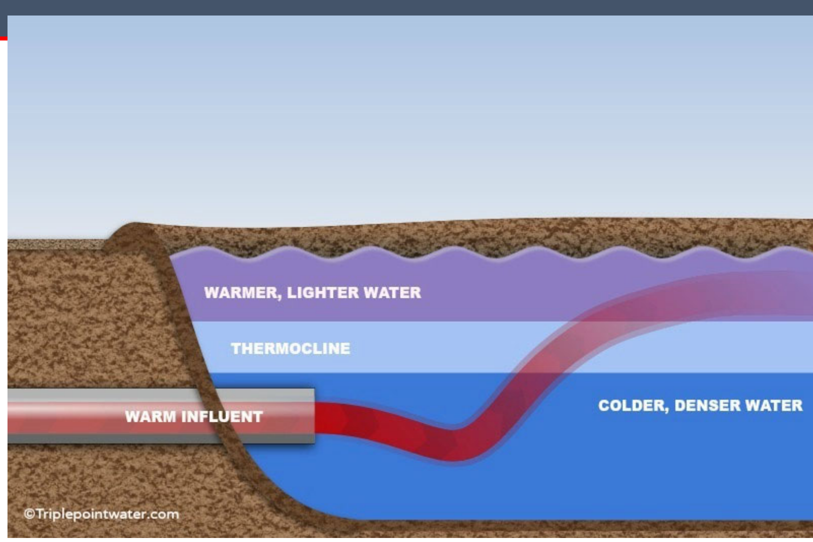
Short circuiting



Factors Affecting Pond Operation - Depth

- Pond depth less than 3 feet
  - Complete sunlight penetration
  - May be completely aerobic until enough solids collect
  - Discharges from shallow, aerobic ponds contain large amounts of algae
  - Can become infested with filamentous algae and mosses
- Pond depth 4 feet or more
  - Greater heat conservation – encourages biological activity
  - Provides physical storage of dissolved oxygen
  - Prevents tule and cattail growth

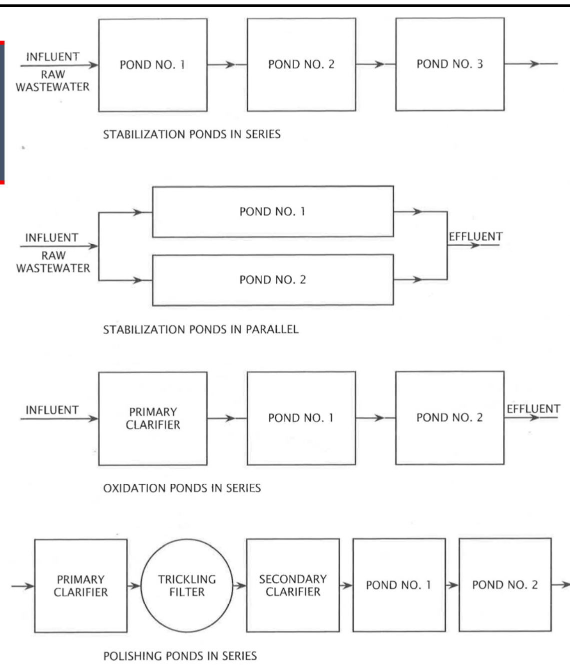
Factors Affecting Pond Operation

- Biochemical:
  - Organic loading rate
  - pH
  - Dissolved oxygen
  - Alkalinity
- Microbiological: bacteria, algae, etc.

Lagoons in Series or in Parallel

- Two types of operation

1. Series = wastewater flows into one primary cell, then into the next, and so on
   – Produces higher quality effluent
2. Parallel = distribution chambers or splitter boxes evenly divide wastewater influent streams into both primary cells



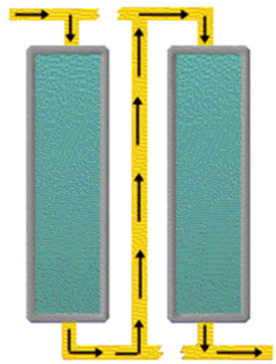
Operation of Wastewater Treatment Plants, Vol II, Seventh Edition p. 298 *Fig. 9.3 Pond classifications*

Lagoons in Series

Advantages
- Few algae and bacteria in final effluent
- Reduces short circuiting

Disadvantages
- First lagoon in series experiences heavy load and can become anaerobic

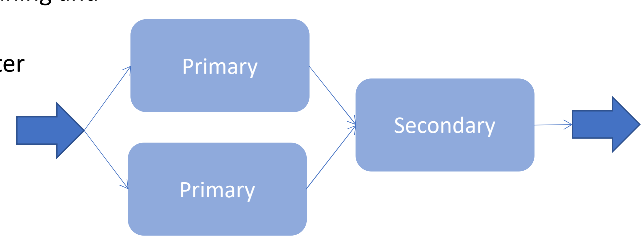
Series operation:



Lagoons in Parallel

Advantages
- Can take heavier loads without becoming anaerobic
- One lagoon can be closed for cleaning and maintenance
- Prevents organic overload in winter

Disadvantages
- May not produce as good an effluent as series arrangement

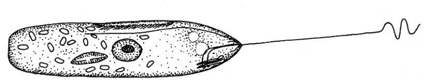


Microorganisms in Wastewater Treatment Lagoons

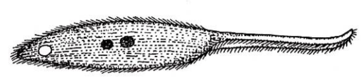
- Single Celled:
  - Bacteria: treat wastewater
  - Algae
  - Protozoa:
    - Flagellates
    - Free Swimming Ciliates
    - Stalked Ciliates
- Multi Celled:
  - Metazoa:
    - Rotifers
    - Crustaceans

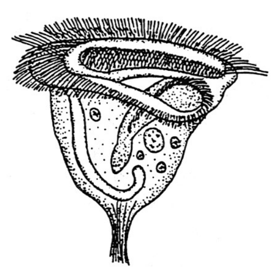
Protozoa

- Flagellates
  - Consume organic matter
  - Compete with bacteria



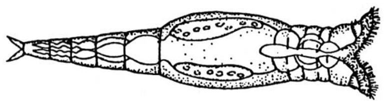
- Ciliates
  - Consume bacteria and algae in wastewater



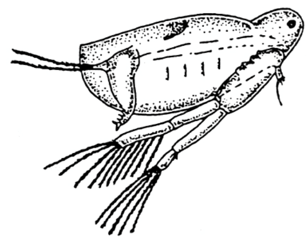


Metazoa

- Rotifers
  - Filter organic waste & bacteria
  - Indicate effective biological treatment

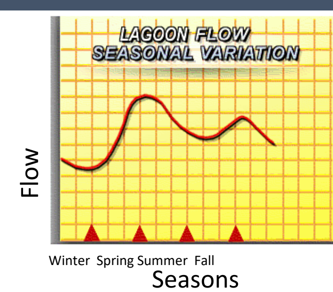


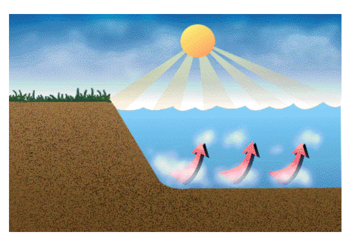
- Crustaceans feed on algae.



Monitoring Performance

- D.O. and pH: diurnal variation at several points in each cell and at several depths
  - Highest values in p.m.
- Seasonal flow variation
- Sludge production
- Actual detention time vs. design
- Spring Overturn/Turnover





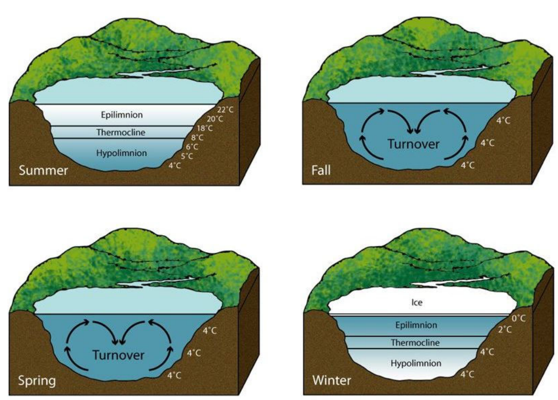
Overturn/Turnover

- Mixing of all layers in a reservoir when the water temperatures become similar from top to bottom
- May occur in Spring and/or Fall
- Spring: surface water warms to similar temp as bottom
- Fall: surface water cools to similar temp as bottom
- Wind plays a role

Overturn/Turnover

Epilimnion, Thermocline, Hypolimnion

- Thermocline = The middle, transitional layer of a reservoir that shows rapid temperature change
- Separates the warm surface waters from the cold, denser waters at the bottom



Sampling and Analysis

- pH and DO most important
- pH, temperature, and DO several times a week (and occasionally at night)
- Sparkling, deep green color indicates a high pH and good DO
  - Dull green, gray, or colorless indicates pH and DO are too low
- Samples should be collected from same point or location
  - 4 corners, 8 ft. from water's edge and 1 ft. deep
- Grab samples: temp, pH, DO, chlorine residual
- Composite samples: BOD and suspended solids

Daily Operation & Maintenance

Control of scum & mats of blue-green bacteria	Block sunlight; reduce green algae activity; odors; avian botulism	Agitation with water jets & rakes manually
Weeds	Mosquito breeding ground; scum accumulation; hinders circulation	Pull out young plants; maintain min. 3 ft depth; riprap; raise & lower water level
Insects	Nuisance; disease	Mosquito larvicide; surface aeration; addition *Gambusia* (mosquito fish)
Muskrats, groundhogs, turtles	Destroy berm walls by burrowing	Trap out; lower water level to expose den

Operations of Wastewater Treatment Plants, Vol I, 8th Ed

Interpreting Color

COLOR	APPEARANCE	CAUSE	SOLUTION
Green		Green algae is thriving	No problem Lagoon's healthy
Yellow/Dull Green		Blue - Gr algae is dominate	Raise pH or rest cell 2+ weeks
Grey/Black		Overloaded and is septic	Rest cell until recovery
Tan/Brown		brown/ tan algae	Check for erosion and I&I

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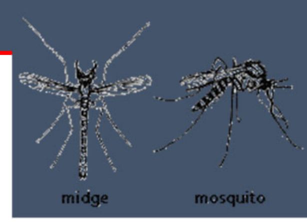
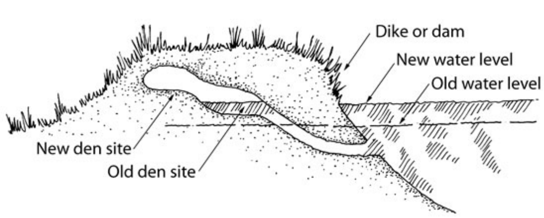
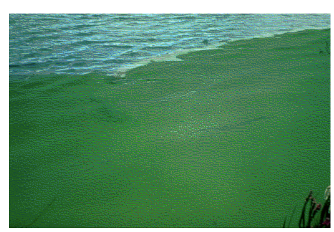
Daily O & M

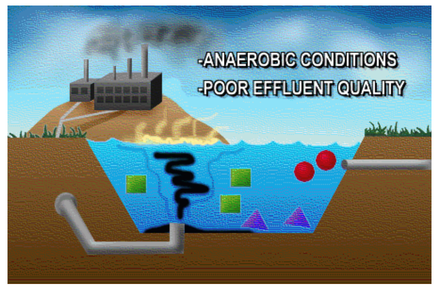






Causes of Poor Quality Effluent

- Aeration equipment failure
- Organic overload
- High total suspended solids (green algae)
- Toxic influent
- Loss of volume
- Short circuiting



Low D.O. in Lagoon

- Low algae growth
- Excess scum
- Aeration problems
- Organic overload
- Short circuiting

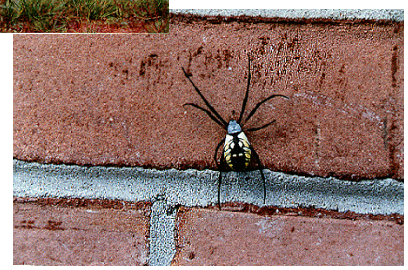
Odors in Lagoons

- Causes: overloading; poor housekeeping
  - Facultative ponds can have seasonal (spring and fall) odors due to turnover
- Treatment methods:
  - Add aeration
  - Feed sodium nitrate as oxygen source
  - Housekeeping- manual scum and algae removal
  - Masking agents
  - Chlorination

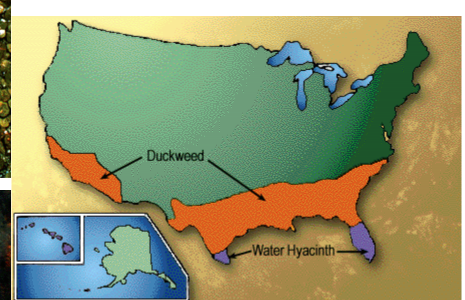
Lagoon Safety

- Never work around a lagoon alone
- Never perform maintenance from a boat
- Never take a boat onto the lagoon alone

Lagoon Safety



Lagoon Effluent Polishing with Duckweed



- Duckweed covers surface of polishing pond
- Prevents sunlight penetration, killing green algae

Polishing Pond

- Design Criteria:
- Organic Loading:
  - 20-25 lbs BOD/ac/day
- Hydraulic Loading:
  - 2350-2990 gpd/ac
- Water Depth
  - 5-6.5 ft

- Secondary Effluent Quality:
- BOD
  - < 30 ppm
- SS
  - < 30 ppm
- Total Nitrogen
  - < 15 ppm
- Total Phosphorous
  - < 6 ppm

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Ponds and Lagoons Vocabulary

1. Raw Wastewater Lagoons, which are also referred to as ____________________________, are ponds designed to receive wastes with no prior treatment.

2. A ___________________________ is used after a trickling filter plant, and it serves as a form of tertiary treatment.

3. The phenomenon known as _________________________ is the almost spontaneous mixing of all layers of water in a reservoir due to similar water temperature from top to bottom. This takes place in the fall/winter when the surface waters cool to the same temperature as the bottom waters; and also in the spring when the surface waters warm to the same temperature as the insulated bottom layer.

4. When distribution chambers or splitter boxes evenly divide wastewater influent streams into both primary cells of a lagoon system, it is said to be in ________________________ operation.

5. Characterized by having dissolved oxygen consistently distributed throughout their water column, _______________________ receive additional DO from algae during the daylight hours when photosynthesis takes place.

6. In _________________________, where no DO is present, degradation of wastes occurs via fermentation at the pond bottom. Methane, hydrogen sulfide, and carbon dioxide are byproducts of this process.

7. In a pond with a healthy algal and bacterial population, a phenomenon known as ________________________ can occur, in which certain bacteria and algae will cause the clumping together of fine, dispersed organic particles. This results in faster and more complete settling of the organic solids in wastewater.

8. When ponds are used in series (after a primary treatment) in order to provide additional clarification, BOD removal, and disinfection, they are referred to as __________________________.

9. The most common type of pond is the __________________________, which is divided into 2 layers.

10. The process in which organisms (with the aid of chlorophyll) convert carbon dioxide and inorganic substances into oxygen and additional plant material, using sunlight for energy, is called ___________________________. All green plants grow by this process.

11. _________________________ are microscopic plants containing chlorophyll that produce oxygen during the sunlight hours and use oxygen during the night hours. Their biological activities affect the pH, DO, and alkalinity of the pond.

12. The exact opposite equation of photosynthesis, plants use oxygen and produce carbon dioxide during _______________________. At night in a pond, algae are using up the oxygen (that was produced by photosynthesis earlier in the day) during this reaction.

13. When wastewater flows into one primary cell, then into the next primary cell, and so on, this set-up is called a ________________________ operation. This type of lagoon is used when a higher quality effluent is required because the quality of the effluent improves as it gets transported through each lagoon.

14. The transitional middle layer of a pond or reservoir that shows a rapid temperature change is called the ____________________________. It separates the warm surface waters from the denser cold waters at the bottom.

<u>Word Bank</u>

Stabilization ponds

Respiration

Oxidation ponds

Polishing pond

Photosynthesis

Thermocline

Parallel

Aerobic ponds

Anaerobic ponds

Facultative pond

Algae

Series

Bioflocculation

Overturn/Turnover

CHAPTER 9

Ponds and Aerated Lagoons

PONDS AND AERATED LAGOONS

9.1 General

This chapter describes the requirements for the following biological treatment processes:

a. Stabilization ponds

b. Aerated lagoons

Additionally, this chapter describes the requirements for use of hydraulic control release lagoons for effluent disposal.

A guide to provisions for lagoon design is the EPA publication Design Manual - Municipal Wastewater Stabilization Ponds, EPA-625/1-83-015.

9.1.1 Applicability

In general, ponds and aerated lagoons are most applicable to small and/or rural communities where land is available at low cost and minimum secondary treatment requirements are acceptable. Advantages include potentially lower capital costs, simple operation, and low O&M costs.

9.1.2 Supplement to Engineering Report

The engineering report shall contain pertinent information on location, geology, soil conditions, area for expansion, and any other factors that will affect the feasibility and acceptability of the proposed treatment system.

The following information should be submitted in addition to that required in the Chapter 1 section titled "Engineering Report and Preliminary Plans":

a. The location and direction of all residences, commercial development, and water supplies within 1/2 mile of the proposed pond

b. Results of the geotechnical investigation performed at the site

c. Data demonstrating anticipated seepage rates of the proposed pond bottom at the maximum water surface elevation

d. A description, including maps showing elevations and contours, of the site and adjacent area suitable for expansion

e. The ability to disinfect the discharge is required.

9.1.3 Effluent Requirements

See Chapter 1, Section 1.1.

9.2 Design Loadings

9.2.1 Stabilization Ponds

Stabilization ponds are facultative and are not artificially mixed or aerated. Mixing and aeration are provided by natural processes. Oxygen is supplied mainly by algae.

Design loading shall not exceed 30 pounds BOD per acre per day on a total pond area basis and 50 pounds BOD per acre per day to any single pond (from Middlebrooks).

9.2.2 Aerated Lagoons

An aerated lagoon may be a complete-mix lagoon or a partial-mix aerated lagoon. Complete-mix lagoons provide enough aeration or mixing to maintain solids in suspension. Power levels are normally between 20 and 40 horsepower per million gallons. The partial-mix aerated lagoon is designed to permit accumulation of settleable solids on the lagoon bottom, where they decompose anaerobically. The power level is normally 4 to 10 horsepower per million gallons of volume.

BOD removal efficiencies normally vary from 80 to 90 percent, depending on detention time and provisions for suspended solids removal.

The aerated lagoon system design for minimum detention time may be estimated by using the following formula; however, for the development of final parameters, it is recommended that actual experimental data be developed.

$$\frac{Se}{So} = \frac{1}{1 + 2.3K_1 t}$$

where:
t = detention time, days
K_1= reaction coefficient, complete system per day, base 10

For complete treatment of normal domestic sewage, the K_1 value will be assumed to be:

K_1 = 1.087 @20^{o}C for complete mix
K_1 = 0.12 @20^{o}C for partial mix
Se = effluent BOD_5, mg/l
So = influent BOD_5, mg/l

The reaction rate coefficient for domestic sewage that includes significant quantities of industrial wastes, other wastes, and partially treated sewage should be determined experimentally for various conditions that might be encountered in the aerated ponds. Conversion of the reaction rate coefficient to temperatures other than 20 degrees C should be according to the following formula:

$$K_1 = K_{20}\ 1.036^{(T-20)}$$ (T = temperature in degrees C)

The minimum equilibrium temperature of the lagoon should be used for design of the aerated lagoon. The minimum equilibrium temperature should be estimated by using heat balance equations, which should include factors for influent wastewater temperature, ambient air temperature, lagoon surface area, and heat transfer effects of aeration, wind, and humidity. The minimum 30-day average ambient air temperature obtained from climatological data should be used for design.

Additional storage volume shall be considered for sludge storage and partial mix in aerated lagoons.

Sludge processing and disposal should be considered.

9.3 Special Details

9.3.1 General

9.3.1.1 Location

a. Distance from Habitation

A pond site should be located as far as practicable from habitation or any area that may be built up within a reasonable future period, taking into consideration site specifics such as topography, prevailing winds, and forests. Buffer zones between the lagoon and residences or similar land use should be at least 300 feet to residential property lines, and 1000 feet to existing residence structures.

b. Prevailing Winds

If practical, ponds should be located so that local prevailing winds will be in the direction of uninhabited areas. Preference should be given to sites that will permit an unobstructed wind sweep across the length of the ponds in the direction of the local prevailing winds.

c. Surface Runoff

Location of ponds in watersheds receiving significant amounts of runoff water is discouraged unless adequate provisions are made to divert storm water around the ponds and protect pond embankments from erosion.

d. Water Table

The effect of the ground water location on pond performance and construction must be considered.

e. Ground Water Protection

Ground Water Protection's main emphasis should be on site selection and liner construction, utilizing mainly compacted clay. Proximity of ponds to water supplies and other facilities subject to contamination and location in areas of porous soils and fissured rock formations should be critically evaluated to avoid creation of health hazards or other undesirable conditions. The possibility of chemical pollution may merit appropriate consideration. Test wells to monitor potential ground water pollution may be required and should be designed with proper consideration to water movement through the soil as appropriate.

An approved system of ground water monitoring wells or lysimeters may be required around the perimeter of the pond site to facilitate ground water monitoring. The use of wells and/or lysimeters will be determined on a case-by-case basis depending on proximity of water supply and maximum ground water levels. This determination will be at the site approval phase (see Section 1.1).

A routine ground water sampling program shall be initiated prior to and during the pond operation, if required.

f. Floodwaters

Pond sites shall not be constructed in areas subject to 25-year flooding, or the ponds and other facilities shall be protected by dikes from the 25-year flood.

9.3.1.2 Pond Shape

The shape of all cells should be such that there are no narrow or elongated portions. Round, square, or rectangular ponds should have a length to width ratio near 1:1 for complete mix ponds. Rectangular ponds with a length not exceeding three times the width are considered most desirable for complete mix aerated lagoons. However, stabilization ponds should be rectangular with a length exceeding three times the width, or be baffled to ensure full utilization of the basin. No islands, peninsulas, or coves are permitted. Dikes should be rounded at corners to minimize accumulations of floating materials. Common dike construction should be considered whenever possible to minimize the length of exterior dikes.

9.3.1.3 Recirculation

Recirculation of lagoon effluent may be considered. Recirculation systems should be designed for 0.5 to 2.0 times the average influent wastewater flow and include flow measurement and control.

9.3.1.4 Flow Measurement

The design shall include provisions to measure, total, and record the wastewater flows.

9.3.1.5 Level Gauges

Pond level gauges should be located on outfall structures or be attached to stationary structures for each pond.

9.3.1.6 Pond Dewatering

All ponds shall have emergency drawdown piping to allow complete draining for maintenance.

Sufficient pumps and appurtenances should be available to facilitate draining of individual ponds in cases where multiple pond systems are constructed at the same elevation or for use if recirculation is desired.

9.3.1.7 Control Building

A control building for laboratory and maintenance equipment should be provided.

9.3.1.8 General Site Requirements

The pond area shall be enclosed with an adequate fence to keep out livestock and discourage trespassing, and be located so that travel along the top of the dike by maintenance vehicles is not obstructed. A vehicle access gate of width sufficient to accommodate mowing equipment and maintenance vehicles should be provided. All access gates shall be provided with locks. Cyclone-type fences, 5 to 6 feet high with 3 strands of barbed wire, are desirable, with appropriate warning signs required.

9.3.1.9 Provision for Sludge Accumulation

Influent solids, bacteria, and algae that settle out in the lagoons will not completely decompose and a sludge blanket will form. This can be a problem if the design does not include provisions for removal and disposal of accumulated sludge, particularly in the cases of anaerobic stabilization ponds and aerated lagoons. The design should include an estimate of the rate of sludge accumulation, frequency of sludge removal, methods of sludge removal, and ultimate sludge handling and disposal. Abandoning and capping of the lagoon is an acceptable solution (Re: The Division of Solid Waste Management guidelines for abandonment of a lagoon). However, the design life shall be stated in the report.

9.3.2 Stabilization Ponds

9.3.2.1 Depth

The primary (first in a series) pond depth should not exceed 6 feet. Greater depths will be considered for polishing ponds and the last ponds in a series of 4 or more.

9.3.2.2 Influent Structures and Pipelines

a. Manholes

A manhole should be installed at the terminus of the interceptor line or the force main and should be located as close to the dike as topography permits; its invert should be at least 6 inches above the maximum operating level of the pond to provide sufficient hydraulic head without surcharging the manhole.

b. Influent Pipelines

The influent pipeline can be placed at zero grade. The use of an exposed dike to carry the influent pipeline to the discharge points is prohibited, as such a structure will impede circulation.

c. Inlets

Influent and effluent piping should be located to minimize short-circuiting and stagnation within the pond and maximize use of the entire pond area.

Multiple inlet discharge points shall be used for primary cells larger than 10 acres.

All gravity lines should discharge horizontally onto discharge aprons. Force mains should discharge vertically up and shall be submerged at least 2 feet when operating at the 3-foot depth.

d. Discharge Apron

Provision should be made to prevent erosion at the point of discharge to the pond.

9.3.2.3 Interconnecting Piping and Outlet Structures

Interconnecting piping for pond installations shall be valved or provided with other arrangements to regulate flow between structures and permit variable depth control.

The outlet structure can be placed on the horizontal pond floor adjacent to the inner toe of the dike embankment. A permanent walkway from the top of the dike to the top of the outlet structure is required for access.

The outlet structure should consist of a well or box equipped with multiple-valved pond drawoff lines. An adjustable drawoff device is also acceptable. The outlet structure should be designed so that the liquid level of the pond can be varied from a 3.0- 5.0 foot depth in increments of 0.5 foot or less. Withdrawal points shall be spaced so that effluent can be withdrawn from depths of 0.75 foot to 2.0 feet below pond water surface, irrespective of the pond depth.

The lowest drawoff lines should be 12 inches off the bottom to control eroding velocities and avoid pickup of bottom deposits. The overflow from the pond shall be taken near but below the water surface. A two-foot deep baffle may be helpful to keep algae from the effluent. The structure should also have provisions for draining the pond.

A locking device should be provided to prevent unauthorized access to level control facilities. An unvalved overflow placed 6 inches above the maximum water level shall be provided.

Outlets should be located nearest the prevailing winds to allow floating solids to be blown away from effluent weirs.

The pond overflow pipes shall be sized for the peak design flow to prevent overtopping of the dikes.

9.3.2.4 Minimum and Maximum Pond Size

No pond should be constructed with less than 1/2 acre or more than 40 acres of surface area.

9.3.2.5 Number of Ponds

A minimum of three ponds, and preferably four ponds, in series should be provided (or baffling provided for a single cell lagoon design configuration) to insure good hydraulic design. The objective in the design is to eliminate short circuiting.

9.3.2.6 Parallel/Series Operation

Designs, other than single ponds with baffling, should provide for operation of ponds in parallel or series. Hydraulic design should allow for equal distribution of flows to all ponds in either mode of operation.

9.3.3 Aerated Lagoons

9.3.3.1 Depth

Depth should be based on the type of aeration equipment used, heat loss considerations, and cost, but should be no less than 7 feet. In choosing a depth, aerator erosion protection and allowances for ice cover and solids accumulation should be considered.

9.3.3.2 Influent Structures and Pipelines

The same requirements apply as described for facultative systems, except that the discharge locations should be coordinated with the aeration equipment design.

9.3.3.3 Interconnecting Piping and Outlet Structures

a. Interconnecting Piping

The same requirements apply as described for facultative systems.

b. Outlet Structure

The same requirements apply as described for facultative systems, except for variable depth requirements and arrangement of the outlet to withdraw effluent from a point at or near the surface. The outlet shall be preceded by an underflow baffle.

9.3.3.4 Number of Ponds

Not less than three basins should be used to provide the detention time and volume required. The basins should be arranged for both parallel and series operation. A settling pond with a hydraulic detention time of 2 days at average design flow must follow the aerated cells, or an equivalent of the final aerated cell must be free of turbulence to allow settling of suspended solids.

9.3.3.5 Aeration Equipment

A minimum of two mechanical aerators or blowers shall be used to provide the horsepower required. At least three anchor points should be provided for each aerator. Access to aerators should be provided for routine maintenance which does not affect mixing in the lagoon. Timers will be required.

9.4 Pond Construction Details

9.4.1 Liners

9.4.1.1 Requirement for Lining

The seepage rate through the lagoon bottom and dikes shall not be greater than a water surface drop of 1/4 inch per day. (Note: The seepage rate of 1/4 inch per day is 7.3×10^{-6} cm/sec coefficient of permeability seepage rate under pond conditions.) If the native soil cannot be compacted or modified to meet this requirement, a pond liner system will be required.

If a lagoon is proposed to be upgraded, it must be shown that it currently meets the 1/4-inch per day seepage rate before approval will be given.

9.4.1.2 General

Pond liner systems that should be evaluated and considered include (1) earth liners, including native soil or local soils mixed with commercially prepared bentonite or comparable chemical sealing compound, and (2) synthetic membrane liners.
The liner should not be subject to deterioration in the presence of the wastewater. The geotechnical recommendations should be carefully considered during pond liner design.
Consideration should also be given to construct test wells when required by the Department in any future regulations, or when industrial waste is involved.

9.4.1.3 Soil Liners

The thickness and the permeability of the soil liners shall be sufficient to limit the leakage to the maximum allowable rate of 1/4 inch per day. The evaluation of earth for use as a soil liner should include laboratory permeability tests of the material and laboratory compaction tests. The analysis should take into consideration the expected permeability of the soil when compacted in the field. All of the soil liner material shall have essentially the same properties.

The analysis of an earth liner should also include evaluation of the earth liner material with regard to filter design criteria. This is required so that the fine-grained liner material does not infiltrate into a coarser subgrade material and thus reduce the effective thickness of the liner.

If the ponds are going to remain empty for any period of time, consideration should be given to the possible effects on the soil liners from freezing and thawing during cold weather or cracking from hot, dry weather. Freezing and thawing will generally loosen the soil for some depth. This depth is dependent on the depth of frost penetration.

The compaction requirements for the liner should produce a density equal to or greater than the density at which the permeability tests were made. The minimum liner thickness should be 12 inches, to ensure proper mixing of bentonite with the native soil. The soil should be placed in lifts no more than 6 inches in compacted thickness. The moisture content at which the soil is placed should be at or slightly above the optimum moisture content.

Construction and placement of the soil liner should be inspected by a qualified inspector. The inspector should keep records on the uniformity of the earth liner material, moisture contents, and the densities obtained.

Bentonite and other similar liners should be considered as a form of earth liner. Their seepage characteristics should be analyzed as previously mentioned, and laboratory testing should be performed using the mixture of the native or local soil and bentonite or similar compound.

In general, the requirements for bentonite or similar compounds should include the following: (1) The bentonite or similar compound should be high swelling and free flowing and have a particle size distribution favorable for uniform application and minimizing of wind drift; (2) the application rate should be least 125 percent of the minimum rate found to be adequate in laboratory tests; (3) application rates recommended by a supplier should be confirmed by an independent laboratory; and (4) the mixtures of soil and bentonite or similar compound should be compacted at a water content greater than the optimum moisture content.

9.4.1.4 Synthetic Membrane Liners

Requirements for the thickness of synthetic liners may vary due to the liner material, but it is generally recommended that the liner thickness be no less than 20 mils; that is, 0.020 inch. There may be special conditions when reinforced membranes should be considered. These are usually considered where extra tensile strength is required. The membrane liner material should be compatible with the wastewater in the ponds such that no damage results to the liner. PVC liners should not be used where they will be exposed directly to sunlight. The preparation of the subgrade for a membrane liner is important. The subgrade should be graded and compacted so that there are no holes or exposed angular rocks or pieces of wood or debris. If the subgrade is very gravelly and contains angular rocks that could possibly damage the liner, a minimum bedding of 3 inches of sand should be provided directly beneath the liner. The liner should be covered with 12 inches of soil. This includes the side slope as well. No equipment should be allowed to operate directly on the liner. Consideration should be given to specifying that the manufacturer's representative be on the job supervising the installation during all aspects of the liner placement. An inspector should be on the job to monitor and inspect the installation.

Leakage must not exceed 1/4-inch per day.

9.4.1.5 Other Liners

Other liners that have been successfully used are soil cement, gunite, and asphalt concrete.

The performance of these liners is highly dependent on the experience and skill of the designer. Close review of the design of these types of liners is recommended.

9.4.2 Pond Construction

9.4.2.1 General

Ponds are often constructed of either a built-up dike or embankment section constructed on the existing grade, or they are constructed using a cut and fill technique. Dikes and embankments shall be designed using the generally accepted procedures for the design of small earth dams. The design should attempt to make use of locally available materials for the construction of dikes. Consideration should also be given to slope stability and seepage through and beneath the embankment and along pipes.

9.4.2.2 Top Width

The minimum recommended dike top width should be 12 feet on tangents and 15 feet on curves to permit access of maintenance vehicles. The minimum inside radius of curves of the corners of the pond should be 35 feet.

9.4.2.3 Side Slopes

Normally, inside slopes of either dikes or cut sections should not be steeper than 3 horizontal to 1 vertical. Outer slopes should not be steeper than 2 horizontal to 1 vertical. However, in many instances, the types of material used, maintenance considerations, and seepage conditions can indicate that other slopes should be used.

9.4.2.4 Freeboard

There should be sufficient freeboard to prevent overtopping of the dike from wave action and strong winds. A minimum of one foot is required.

9.4.2.5 Erosion Control

Erosion control should be considered for the inside slopes of the dike to prevent the formation of wavecut beaches in the dike slope. In the event that earth liners or membrane liners with earth cover are used, consideration should be given to erosion protection directly beneath aeration units. If the currents are strong enough, considering the type of material used for the earth cover, erosion pads may be necessary beneath the aeration units. Erosion control should also be considered wherever influent pipes empty into the pond.

If a grass cover for the outer slopes is desired, they should be fertilized and seeded to establish a good growth of vegetative cover. This vegetative cover will help control erosion from runoff. Consideration should also be given to protection of the outer slopes in the event that flooding occurs. The erosion protection should be able to withstand the currents from a flood.

9.4.3 Prefilling

The need to prefill ponds in order to determine the leakage rate shall be determined by the Department and incorporated into the plans and specifications. The strongest consideration for prefilling ponds will be given to ponds with earth liners. Ponds in areas where the surrounding homes are on wells will also be given strong consideration for prefilling.

9.4.4 Utilities and Structures Within Dike Sections

Pipes that extend through an embankment should be bedded up to the springline with concrete. Backfill should be with relatively impermeable material. No granular bedding material should be used. Cutoff collars should be used as required. No gravel or granular base should be used under or around any structures placed in the embankment within the pond. Embankments should be constructed at least 2 feet above the top of the pipe before excavating the pipe trench.

9.5 Hydrograph Controlled Release (HCR) Lagoons

All lagoons requirements apply to HCR lagoons with the following additional concerns:

HCR lagoons control the discharge of treated wastewater in accordance with the stream's assimilative capacity. Detention times vary widely and must be determined on a case-by-case basis.

HCR sites require much receiving stream flow pattern characterization. For this purpose, EPA Region IV has developed a computer design program. The Division of Water Pollution Control can assist in sizing the HCR basin using this program. HCR sites may be more economical if the design is combined with summertime land application. Their design is more economical if summer/winter or monthly standards are available.

The design and construction of the in-stream flow measurement equipment are critical components of an HCR system. The United States Geological Survey (USGS) should be contacted during the design phase. The USGS also has considerable construction experience concerning in-stream monitoring stations, although construction need not necessarily be done or supervised by the USGS.

9.6 Polishing Lagoons

Polishing lagoons following activated sludge are not permissible in Tennessee due to the one-cell algae interference.

9.7 Operability

Once a pond is designed, little operation should be required. However, to avoid NPDES permit violations, pond flexibility is needed. Operation flexibility is best facilitated by the addition of piping and valves to each pond which allows isolation of its volume during an algal bloom.

9.8 Upgrading Existing Systems

There are approximately sixty existing lagoons in Tennessee which were built utilizing standards and criteria from the 1960 period. Most are single- or double-cell units which need upgrading. Many are required to meet tertiary standards. The upgrade case should, in general, utilize the guidance in this chapter or proven configurations. It is noted, however, that there are many lagoon combinations available, such as complete-mix pond, partial-mix pond, stabilization pond, HCR pond and marsh-pond (wetlands)concepts. The combination of these alternatives should be based upon the effluent permit design standards as well as site economics.

Section 8
Nitrogen Removal

Section 8
Nitrogen Removal

Where does nitrogen come from?

- Most abundant compound in the atmosphere
  - N_2: 79% of air volume
  - Key component of proteins and nucleic acids
- Major sources:
  - Plant, animal, human origin – decaying matter
    - Protein and nucleic acids – ammonia formation
    - Organic nitrogen released during plant decay
  - Industrial and agricultural origin
    - Nitrous oxides and nitric acid
    - Fertilizers – urea, ammonium phosphate, ammonium sulfate, ammonium nitrate
  - Atmospheric origin

2

Nitrogen in Wastewater

- Most common forms:
  - Ammonia (NH_3)
  - Ammonium ion (NH_4^+)
  - Nitrogen gas (N_2)
  - Nitrite (NO_2^-)
  - Nitrate (NO_3^-)
  - Organic Nitrogen

Oxidized forms (Nitrite, Nitrate)

Inorganic forms (Ammonia, Ammonium ion, Nitrogen gas, Nitrite, Nitrate)

- Municipal – NH_4^+ and organic nitrogen
  - Domestic wastewater TKN - ~60% NH_4^+, ~40% organic
  - Organic N converted to NH_4^+ via ammonification

3

Nitrogen in Wastewater

- Total Nitrogen (TN) = Ammonia + Organic + Nitrite + Nitrate
  - TKN = Organic + Ammonia
  - TN = TKN + Oxidized forms
- TKN in raw wastewater typically 25 – 45 mg/L

4

Why must nitrogen be removed?

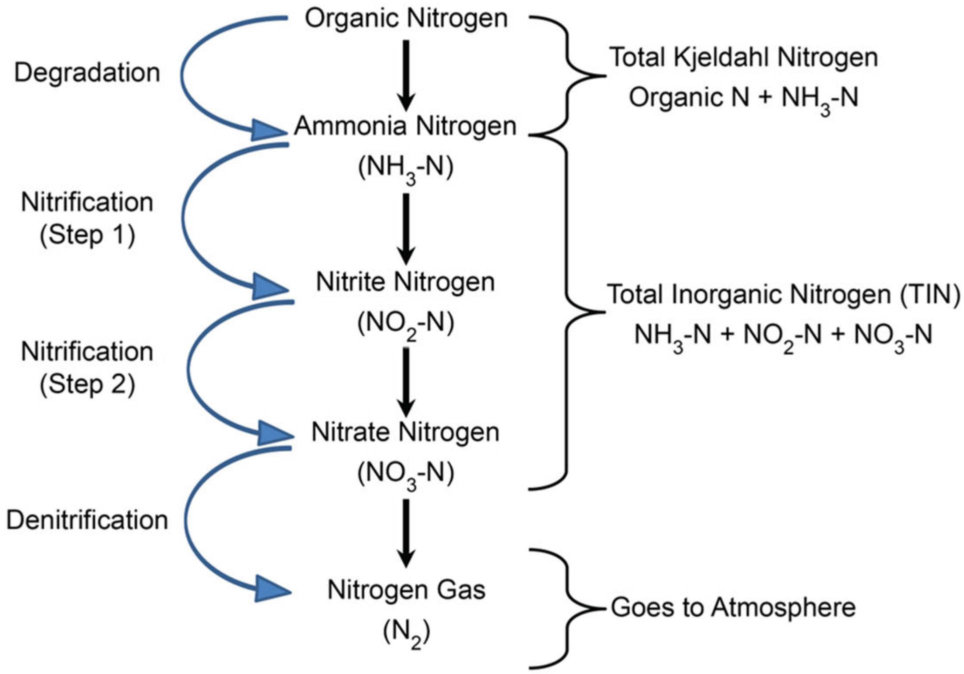
- Inorganic nitrogen provides a nutrient or food source for algae
  - Combination of nitrogen and phosphorus in receiving waters = rapid algal growth
- Dead and decaying algae = oxygen depletion problems
  - Fish kills
  - Taste and odor issues in drinking water
- By removing nitrogen, the receiving stream will have one less nutrient essential for algal growth

5

NPDES Permit limits

- EPA requires that wastewater plants remove nitrogen in effluent to eliminate nutrient from plant food chain
  - Sensitive waters
- Nitrogenous compounds must be controlled in plant effluent to prevent:
  - Ammonia toxicity – impact on fish
  - Reduction in chlorine disinfection efficiency
  - Increase in dissolved oxygen depletion in receiving waters
  - Adverse public health effects – nitrates in groundwater
  - Reduction in water's suitability for reuse

6



NPDES Permit limits

- Most nitrogen limits expressed as Total Nitrogen (TN)
  - 3 tests: TKN, nitrite, nitrate
- Nitrate+Nitrite (mostly industrial)
- Nitrate limits (ex: explosives manufacturers)

8

Types of Nitrogen Removal Systems

Biological Methods

1. Nitrification
2. Denitrification
3. Modified Activated Sludge
4. Overland Flow → physical method
5. Ammonia Stripping
6. Breakpoint Chlorination
7. Ion Exchange

Chemical methods

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Nitrification

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Biological Nutrient Removal - Nitrification

- Nitrification = the conversion of ammonia to nitrate
- Accomplished primarily by 2 types of microorganisms*:
  1. Nitrosomonas
  2. Nitrobacter
- Autotrophic – use inorganic materials for energy and growth
  - Derive carbon for their cellular growth from inorganic sources (Ex: CO_2 and bicarbonate alkalinity (HCO_3^-))

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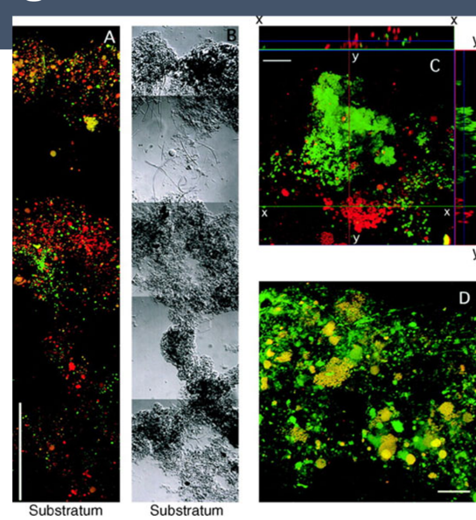
Genera of Nitrifying Bacteria

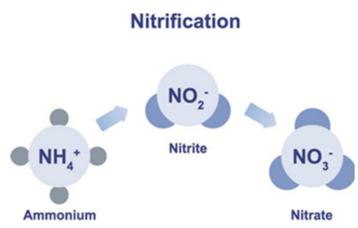
- Ammonia Oxidizers
- "AOB's"
  - *Nitrosomonas*
  - *Nitrosococcus*
  - *Nitrosospira*
  - *Nitrosorbio*
- Nitrite Oxidizers
- "NOB's"
  - *Nitrobacter*
  - *Nitrospira*
  - *Nitrococcus*
  - *Nitrospina*



C - Ammonia oxidizers appear red and *Nitrospira* appear green

Biological Nutrient Removal – Nitrification

- First step: Conversion of Ammonia (NH_3) or Ammonium (NH_4^+) to Nitrite (NO_2^-) by *Nitrosomonas*
- Second step: Conversion of Nitrite to Nitrate (NO_3^-) by *Nitrobacter*



$$2NH_4^+ + 3O_2 \xrightarrow[\text{bacteria}]{\text{Nitrosomonas}} 2NO_2^- + 4H^+ + 2H_2O + \text{Energy}$$

$$2NO_2^- + O_2 \xrightarrow[\text{bacteria}]{\text{Nitrobacter}} 2NO_3^- + \text{Energy}$$

Nitrification

- Step 1 – Ammonia (NH_3) or ammonium (NH_4^+) gets converted to nitrite (NO_2^-) by the N*itrosomonas* bacteria.

$2NH_4^+$	+	$3O_2$	→	$2NO_2^-$	+	$2H_2O$	+	$4H$
Ammonium		Oxygen		Nitrite		Water		Strong Acid

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Nitrification

- Step 2 – The second step is conversion of nitrite to nitrate (NO_3^-) by the *Nitrobacter* bacteria.v

$$\underset{\text{Nitrite}}{2NO_2^-} + \underset{\text{Oxygen}}{O_2} \rightarrow \underset{\text{Nitrate}}{2NO_3^-}$$

Biological Nutrient Removal – Nitrification

- Can be accomplished in either
  1. Suspended growth reactors – aeration basin
     - Basin must be large enough and MCRT long enough
  2. Attached growth reactors (fixed film)
     - Trickling Filters, RBCs, and Packed Bed or Packed Tower reactors
     - Media surface - contact time between the microbes and the wastewater
     - Supply of oxygen (natural draft or forced draft) and sufficient primary treatment to reduce BOD load
     - Recycling or recirculation of reactor effluent is important

Biological Nutrient Removal – Nitrification

- Factors affecting biological nitrification:

1. Dissolved Oxygen
2. pH
3. Wastewater temperature
4. Nitrogenous food
5. Detention time
6. MCRT, F:M, or Sludge Age
7. Toxic materials (Inhibition)

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Biological Nutrient Removal – Nitrification

1. Dissolved Oxygen

- Nitrification exerts a substantial oxygen requirement
  - Each pound ammonium-nitrogen that is nitrified requires ~4.6 pounds of oxygen
  - Can increase required oxygenation by 30 – 40%
- 1.0 – 4.0 mg/L
  - Never fall below 1.0 mg/L (Sacramento manual)
  - At least 0.5 mg/L, typically 2 – 3 mg/L (WEF, Activated Sludge OM-9)

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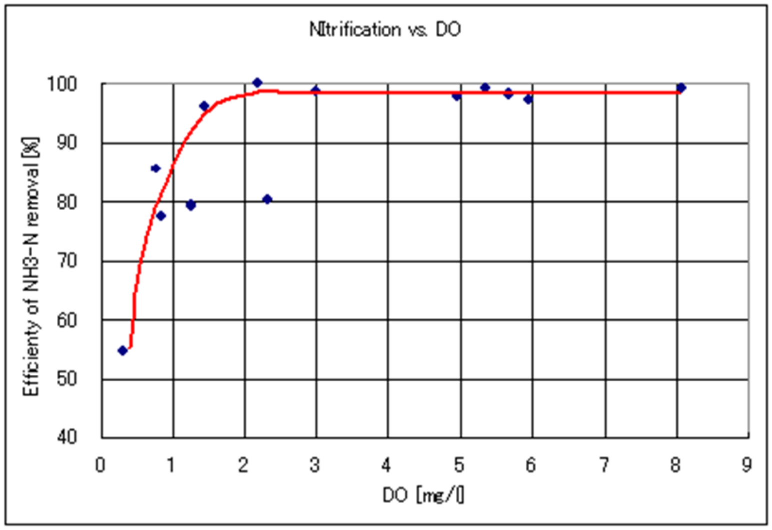
Effect of Dissolved Oxygen on the Rate of Nitrification



Biological Nutrient Removal – Nitrification

2. pH

- There must be sufficient alkalinity in the wastewater to balance the acid produced by nitrification
- 7.5 - 8.5 considered optimal
  - Rates rapidly depressed as pH is reduced below 7.0
- ~ 7.2 pounds of alkalinity are destroyed per pound of ammonia-nitrogen oxidized
- Caustic or lime addition may be required to supplement alkalinity
  - Maintain min. effluent alkalinity of at least 50 mg/L

Effect of pH on the Rate of Nitrification

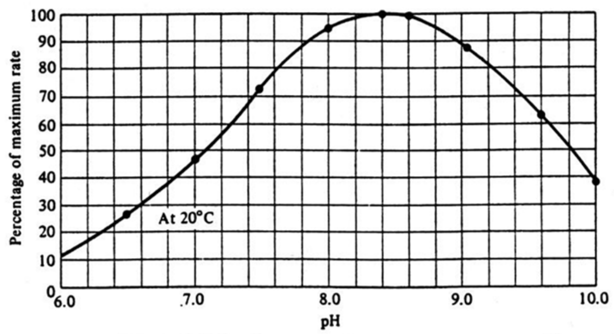


FIGURE 13-18 Rate of nitrification versus pH at constant temperature. [Source: H. E. Wild, Jr., C. N. Sawyer, and T. C. McMahon, "Factors Affecting Nitrification Kinetics," *J. Water Poll. Control Fed.* 43, no. 9 (1971): 1852.]

Biological Nutrient Removal – Nitrification

3. Temperature
- 60 - 90°F (15 - 35°C) considered optimal
- Nitrification rate doubles for every 8 -10°C rise
- Nitrification is inhibited at low temps
  - Up to 5x as much detention time may be needed to accomplish "complete nitrification" in the winter
- Growth rate of nitrifiers increases as temp increases (and vice versa)
  - Operational controls: increasing MLVSS conc, MCRT, etc. to compensate

Effect of Temperature on the Rate of Nitrification

- Growth rate increases exponentially with temperature
  - Maximum at 30-35°C
  - Declines at 40°C
- Process variables that an operator does can adjust to compensate for slower winter growth rates in the nitrification process
  - Adjust pH to higher levels
  - Increase the MCRT
  - Increase the MLVSS

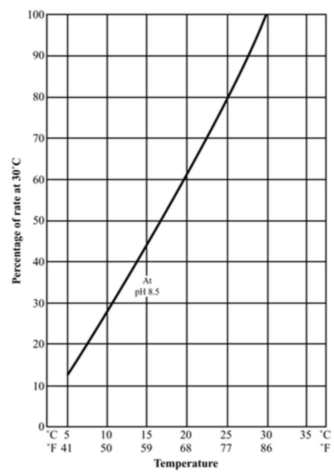
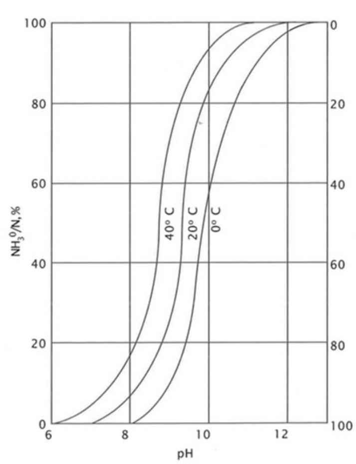


FIGURE 13-17 Rate of nitrification at all temperatures compared to the rate at 30°C. [Source: H. E. Wild, Jr., C. N. Sawyer, and T. C. McMahon, "Factors affecting Nitrification Kinetics," *J. Water Poll. Control Fed.* 43, no. 9 (1971): 1852.]

Effects of pH and Temperature on Equilibrium between NH_4^+ and NH_3



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Source: Advanced Waste Treatment, 5th ed., p. 537

Fig. 6.11 Effects of pH and temperature on equilibrium between ammonium ion (NH_4^+) and ammonia gas (NH_3^0)

Biological Nutrient Removal – Nitrification

4. Nitrogenous Food

- Population of nitrifiers will be limited by amount of nitrogenous food in influent
  - Organic N and Phosphorus-containing compounds
  - Trace elements
- 100:5:1 (BOD:Nitrogen:Phosphorus)
- Perform TKN and P in lab
  - Supplemental nutrient if necessary

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Biological Nutrient Removal – Nitrification

5. Detention Time

- Time required for nitrification is directly proportional to the amount of nitrifiers in the system
- Rate of oxidation of NH_3-N is essentially linear or constant, so short circuiting must be prevented.
- Flow should follow plug-flow model
  - Detention time of at least 4 hours, preferably 8 hours
  - Not all AS process mode modifications are appropriate for nitrification

Biological Nutrient Removal – Nitrification

- Activated sludge process modes that <u>are</u> suitable for nitrification:

✓ Plug Flow or Conventional
  - Long, narrow aeration tank provides adequate detention time
    - pH level may drop during DT since nitrification destroys alkalinity

✓ Extended Aeration
  - Long aeration time and long sludge age

✓ Step-Feed Aeration
  - Can accomplish partial nitrification
    - Addition of influent at various points along aeration basin means the contact time is not long enough for complete nitrification to occur

Biological Nutrient Removal – Nitrification

6. MCRT, F:M, or Sludge Age

- MCRT must be long enough to allow nitrifiers sufficient time to grow
  - Usually at least 4 days
- Nitrification can only be maintained when rate of growth of nitrifying bacteria is rapid enough to replace organisms lost through sludge wasting
  - If they can't keep pace with carbonaceous bacteria, ability to nitrify decreases

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Biological Nutrient Removal – Nitrification

- When reviewing performance of your plant for the selection of optimum MCRT, F:M, or Sludge Age:
  - Oxygen requirements of carbonaceous bacteria should be considered along with nitrification requirements
  - If NH_3-N permit limit is exceeded: MCRT or Sludge Age should be increased
    - Will increase MLSS and decrease F:M
    - Growth of cell mass from the oxidation of NH3 is ~0.5 lb per lb of NH_3-N oxidized
    - Thus, degree of nitrification will have little effect on the net sludge yield and WAS rates

Biological Nutrient Removal – Nitrification

7. Toxic Materials
   - Halogen-substituted phenolic compounds, 0.0 mg/L
   - Halogenated solvents, 0.0 mg/L
   - Heavy metals, 10 – 20 mg/L

- Pretreatment program is important
- Lime primary treatment is very effective in removing heavy metals

Biological Nutrient Removal – Nitrification

- Alkalinity and pH
- Alkalinity changes in the nitrification process stream and the final effluent reliably indicate what is happening in the plant
  - Alkalinity tests are one of the best process control tests
- Hydrogen ions produced in some reactors may reduce buffering capacity
  - The measure of a solution to neutralize acids or bases (resistance to changes in pH)

Biological Nutrient removal – Nitrification

- Alkalinity and pH
- At a pH of 7, nitrification may be inhibited since little buffer capacity remains
- If alkalinity drops so low that the low pH interferes with nitrification
  - Add lime, soda ash, etc
  - Overdosing with alkaline materials can also cause nitrification inhibition due to ammonia toxicity
    - Shifts the NH_4^+ toward NH_3

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Nitrification

- Troubleshooting Example:
  - You ran tests on your effluent and you have the following results:
    - Ammonia – 3 mg/L
    - Nitrate – 4 mg/L
    - Nitrite – 21 mg/L
  - What do you think is happening here?

$$2NH_4^+ + 3O_2 \quad 2NO_2^- + 2H_2O + 4H$$

Ammonia Oxygen Nitrite Water Strong Acid

$$2NO_2^- + O_2 \quad 2NO_3^-$$

Nitrite Oxygen Nitrate

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Denitrification

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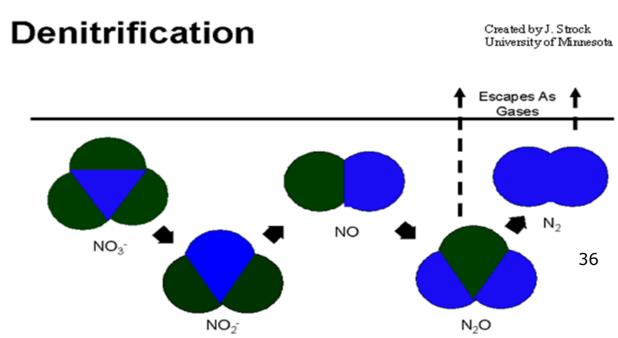
Biological Nutrient Removal – Denitrification

- Denitrification = process by which microorganisms reduce nitrate (NO_3^-) to nitrogen gas (N_2) that is released to the atmosphere
- Denitrifiers are heterotrophic
  - Several species
- When placed in anoxic environment containing a carbon food source, denitrifiers will reduce NO_3^- to N_2 by breaking down the nitrate to obtain the oxygen
  - Waste products: primarily N_2, minor amounts of nitrous oxide (N_2O) or nitric oxide (NO)

Biological Nutrient Removal – Denitrification

- Step 1 – Nitrate (NO3) is reduced to nitrite (NO2)
- Step 2 – Nitrite is reduced to nitric oxide (NO), nitrous oxide (N_2O) or nitrogen gas (N_2)



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Biological Nutrient Removal – Denitrification

- Denitrifiers (heterotrophic) require organic carbon

Anoxic Denitrification(no free dissolved oxygen, but using Nitrate as an oxygen source)

$$cBOD + NO_3 + nutrients \xrightarrow{bugs} N_2\uparrow + CO_2 + H_2O + new\ bugs$$

- Using methanol as the carbon source, the overall energy reaction is:

$$6NO_3^- + 5CH_3OH \quad 5CO_2 + 3N_2 + 7H_2O + 6OH^-$$

- Methanol to nitrogen ratio 3:1

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Biological Nutrient Removal – Denitrification

- This nitrogen gas is then released to the atmosphere once it gets to an aerated tank
- This can also occur in secondary clarifiers

Biological Nutrient Removal – Denitrification

- Affected by:
  - Nitrate
  - Carbon source
  - Dissolved oxygen concentrations

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Nitrification vs Denitrification

- Nitrification
  - $NH_4 + O_2 \rightarrow NO_2$ + acid
  - $NO_2 + O_2 \rightarrow NO_3$
  - Uses 4.6 mg of O_2 and 7.14 mg of Alkalinity
- Denitrification
  - NO_3 + cBOD $\rightarrow N_2\uparrow$
  - Get back 2.9 mg of O_2 and 3.57 mg Alkalinity

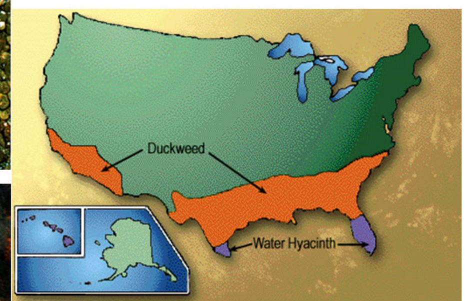
Systems for Nitrogen Removal

System	Operation Considerations
Physical Treatment Methods	Expensive
• Sedimentation	
• Gas Stripping	
Chemical Treatment Methods	Expensive
• Breakpoint Chlorination	
• Ion Exchange	
Biological Treatment Methods	
• Activated Sludge Process	• Operational control. • Additional cost for oxygen to produce nitrification.
• Trickling Filter Process	
• Rotating Biological Contactor Process	
• Oxidation Pond Process	
• Land Treatment Process (Overland Flow)	• Land Requirements. • Suitable Temperatures. • Control of plants.
• Wetland Treatment Systems	

Lemna Duckweed System

- Use of aquatic duckweed plants for wastewater treatment
- Used effectively as a polishing pond after a conventional wastewater treatment pond
- The duckweed cover the polishing pond's surface, preventing sunlight to get to the algae and the algae die off
- Duckweed are capable of removing phosphorus and nitrogen from the water

Lagoon Effluent Polishing with Duckweed



- Duckweed covers surface of polishing pond
- Prevents sunlight penetration, killing green algae

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Oxidation Reduction Potential

- Allows evaluation of biological conditions with or without DO available
- Simple and cheap
  - Portable pH meter
  - ORP probe
  - Immerse probe in tank and read
- Responds to chemical ion concentrations

ORP Control *(Goronzy, 1992)*

Process	Range, mV	e^- Acceptor
cBOD oxidation	+50 to +200	O_2
Poly-P production	+40 to +250	O_2
Nitrification	+150 to +350	O_2
Denitrification	-50 to +50	NO_3^-
Poly-P breakdown	-40 to -175	NO_3^-, SO_4^{-2}
Sulfide formation	-50 to -250	SO_4^{-2}
Acid formation	-40 to –200	Organics
Methane formation	-200 to -350	Organics

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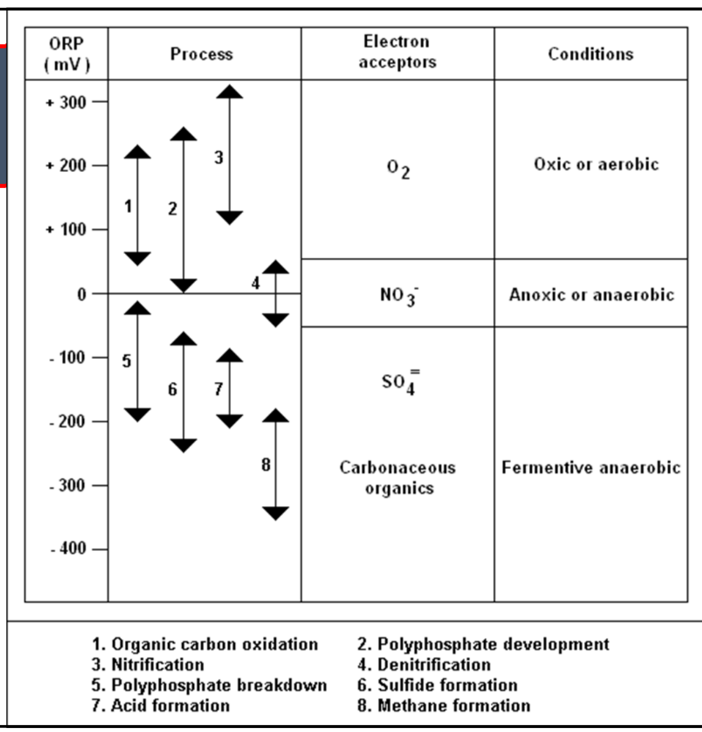

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Section 9
Phosphorous Removal

Section 9
Phosphorus Removal

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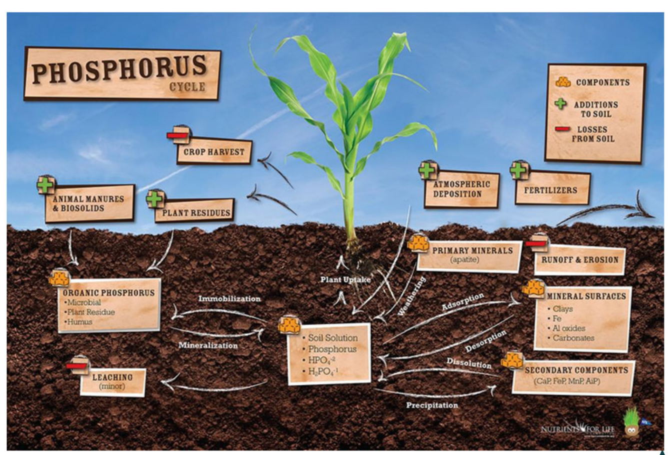
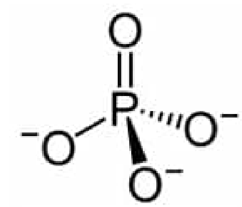
Where does phosphorus come from?

- Fertilizers
- Manure
- Organic wastes in sewage and industrial effluent
- Soil erosion from banks is a major contributor of phosphorus in streams
  - Attaches to soil particles
- Essential element for plant life
  - Usually the limiting nutrient



Types of Phosphorus in Wastewater

- ***Orthophosphate***
  - Simplest form of phosphate
  - Readily available to organisms
  - soluble but can be adsorbed to particles



- In Wastewater
  - This makes up 50% of total influent P

Types of Phosphorus in Wastewater

- ***Polyphosphates*** (condensed phosphates)
  - Converted to orthophosphates via hydrolysis reactions (slow)

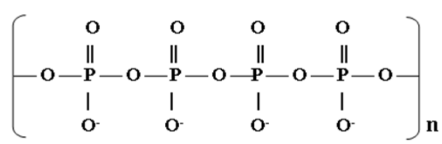
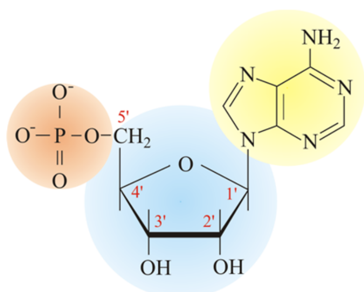


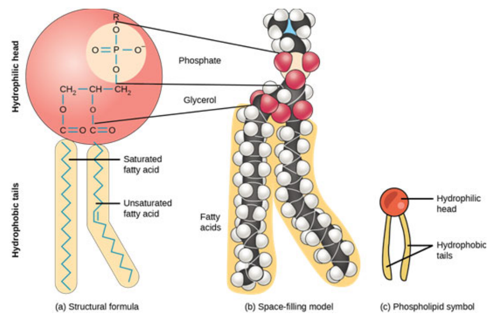
Figure. 1.1: Linear structure of polyphosphate

- In Wastewater
  - Make up 33% of total influent P
  - soluble but can be adsorbed to particles
  - are converted to orthophosphate during biological treatment

Types of Phosphorus in Wastewater

- ***Organic phosphates*** (phospholipids and nucleotides)
  - Maybe soluble, colloidal, or particulate
  - In WW: 15% of total influent P
  - are converted to orthophosphate during biological treatment





Types of Phosphorus in Wastewater

- Phosphate species and their abundance - function of pH
- In conventional WW treatment:
  - Total Phosphorous (TP) in raw wastewater typically 4 – 8 mg/L
  - ~5 – 10% P removed during primary setting/secondary clarification
  - ~20 – 25% P taken up in AS process during bacterial growth

Why must phosphorus be removed?

- Nutrient and food source for algae
- When combined with inorganic Nitrogen = ***Eutrophication***

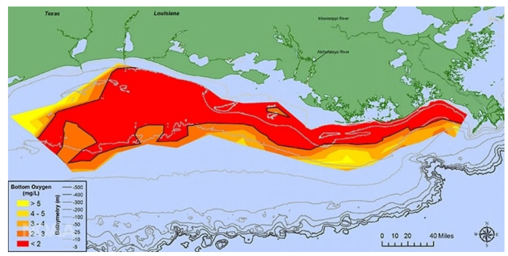
- By removing phosphorus, the receiving stream will have one less nutrient that is essential for algae growth
  - **Reduction in essential nutrient = reduction in algae**

Note

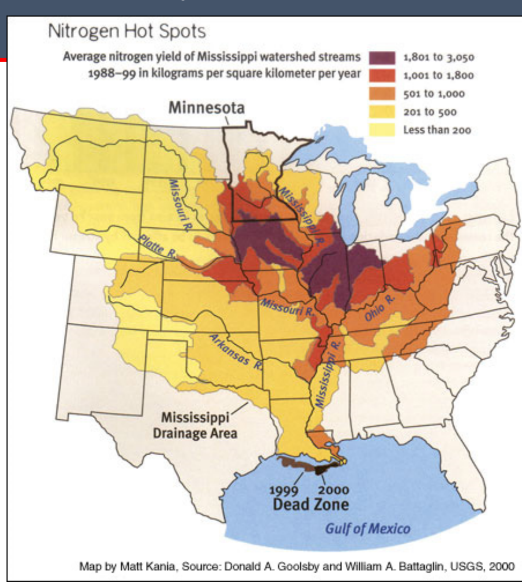
- ***Eutrophication*** is an increase in chemical nutrients (compounds containing nitrogen or phosphorus) in an ecosystem, and may occur on land or in water.
- However, the term is often used to mean the resultant increase in the ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.
- Once algae blooms, it will die off and as the algae decay bacteria will consume it and use up all the oxygen.

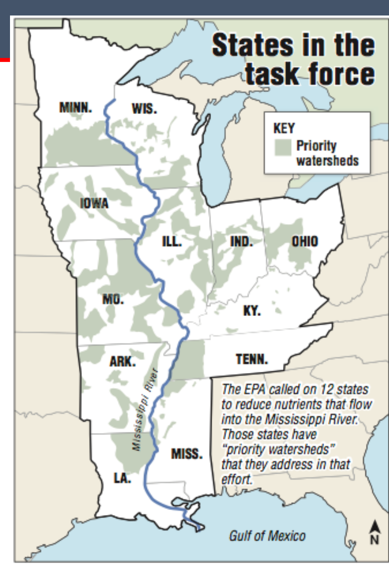
Eutrophication

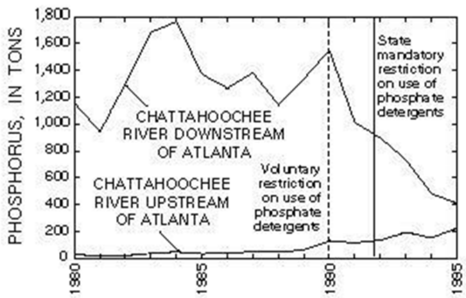
- Gulf of Mexico
  - Currently the most notorious dead zone is a 8,543 mi² region in the Gulf of Mexico, where the Mississippi River dumps high- nutrient runoff from its vast drainage basin, which includes the heart of U.S. agribusiness, the Midwest.
  - The drainage of these nutrients are affecting important shrimp fishing grounds.
  - This is equivalent to a dead zone the size of New Jersey.

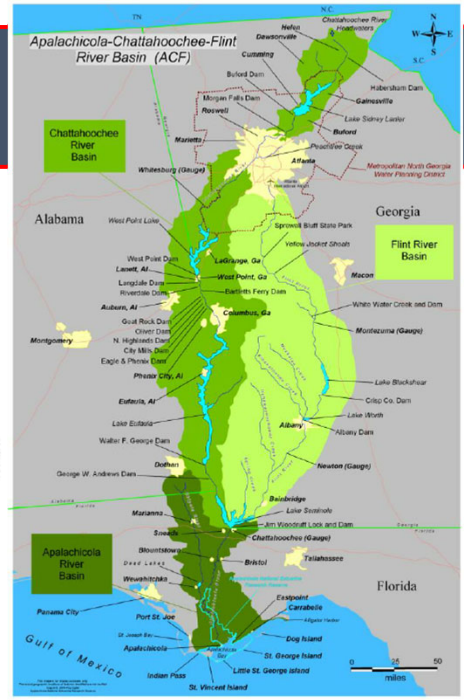


Eutrophication

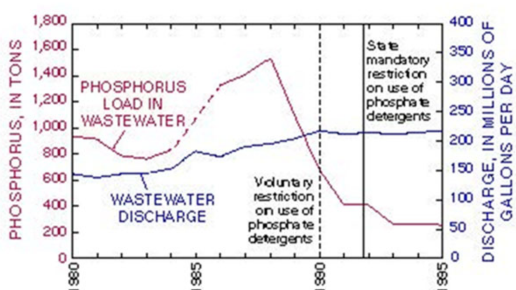








Source: www.water.usgs.gov/edu/phoshorus.html



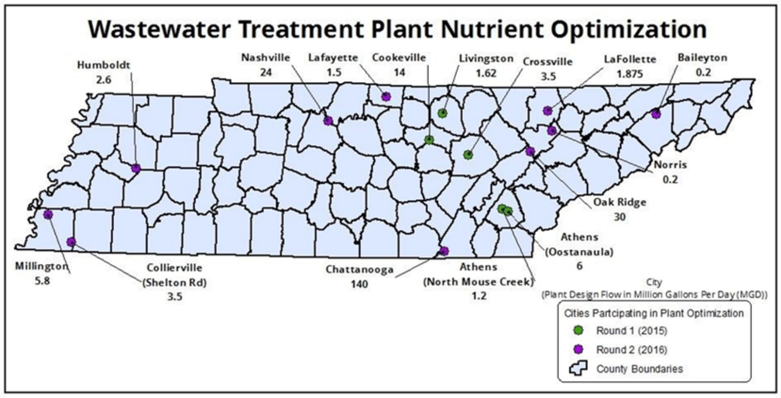
NPDES Permit Limits

- Plants that discharge into smaller receiving streams already have NPDES permit limits
- Reported as P
- Plants may be required to report, but no limits (yet)
- Some plants monitoring, but no limits (yet)

Tennessee Nutrient Reduction Framework

- Prioritize watersheds
  - Set watershed nutrient reduction goals
- Ensure effective point source permits
- Devise effective agricultural BMPs
- Encourage reduction from non MS4s
- Watershed monitoring
- Document and report activities

Tennessee Nutrient Reduction Framework



Types of phosphorus removal systems

Most common:

1. Biological Phosphorus Removal
   - Phosphorus contained within cells of microorganisms
   - "Luxury uptake"
2. Lime Precipitation
   - Addition of lime
   - Flocculation and precipiation
3. Filtration following Aluminum Sulfate Flocculation
   - Addition of aluminum sulfate
   - Similar to lime precipitation, with addition of a filter after the clarifier

Other types:

- Bardenpho process
  - Removes both Nitrogen and Phosphorus
  - Modification of the activated sludge process

Biological Phosphorus Removal

- 2 Elements of all biological treatment systems:

1. Biomass
   - Suspended Growth - Contained in a reactor/basin
   - Fixed Growth – attached to inert media
2. Liquid-Solids Separation

- Oxygen level is key
  - Aerobic –
  - Anoxic –
  - Anaerobic –

Biological Phosphorus Removal

- ***Selector***
  - A reactor or basin that contains compartments
    - Baffles or other devices
  - The environment can be controlled to “select” for microbial populations
    - Environmental conditions (ex: food, lack of dissolved oxygen) are intended to favor the growth of certain organisms over others

- ***Mean Cell Residence Time (MCRT)***
  - The average time a microorganism will spend in the activated sludge process or specific process phase

Biological Phosphorus Removal

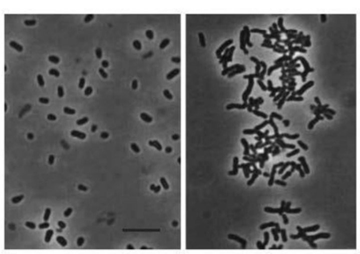
- Types of Microorganisms:
1. Autotrophs

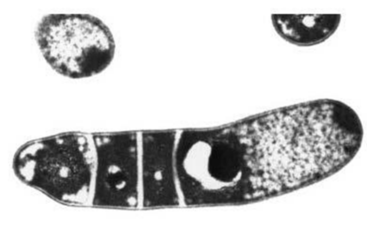
2. Heterotrophs

- Both types of organisms can be:
  - **Obligate aerobes –**
  - **Obligate anaerobes –**
  - **Facultative organisms** –

Biological Phosphorus Removal

- ***Phosphate-Accumulating Organisms (PAOs)***
  - *Heterotrophic* and *Facultative*
  - Through design and operational conditions, they are given selective advantage to grow and function
  - *Accumulibacter*
  - *Tetrasphaera*





Quiz

- What elements do all biological treatment systems have in common?
- Briefly define the following terms:
  - Aerobic or oxic
  - Anoxic
  - Anaerobic
- How does an operator "select" the organisms needed to meet a particular processing objective?

Biological Phosphorus Removal

- 2 General process layouts are used:

1. Mainstream
   - Anaerobic selector at the beginning of the process
2. Sidestream
   - Sidestream anaerobic stripper and a phosphorus extractor or a clarifier

- The way the organisms remove the phosphorus is the same in both layouts

Biological Phosphorus Removal

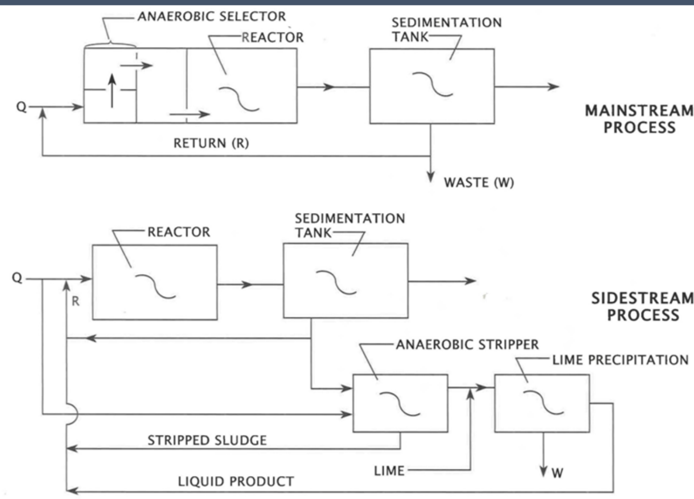


Fig. 5.1 Biological phosphorus removal process layouts

Source: Advanced Waste Treatment, 5th ed, p.479

Biological Phosphorus Removal – Mainstream Layout

- Advantages:

1. Complete and thorough mixing of entire wastestream with biomass in the anaerobic contactor
2. Relatively simple design

Biological Phosphorus Removal – Sidestream Layout

- Advantages:

1. Hydrolysis and volatile acid formation may be better
   - However, this advantage could be offset by incomplete mixing
2. Provides for routine phosphorus extraction
   - Less dependent on sludge production and metabolic limits
3. Can potentially achieve lower P limits

Biological Phosphorus Removal – Luxury Uptake

- ***Luxury uptake*** = the process in which microorganisms take excess P into their bodies
- Microbes routinely remove some P
  - Required for survival
  - They can be forced to remove/uptake more than they actually need
  - Aerobic, then anaerobic environment

Biological Phosphorus Removal – Luxury Uptake

1. In aerobic conditions, the microbes will take up and store P in their cells
   - Stored as Polyphosphate
2. Once they have stored maximum amount of P in their cells, they are transferred to anaerobic environment
3. Microbes chemically convert some of the carbon materials in their cells to get the oxygen they need for metabolism
   - The energy used in this chemical reaction comes from the polyphosphate stored in it’s cells
   - As a result, phosphorus is released from the cells

Biological Phosphorus Removal – Luxury Uptake

4. After releasing the P, they are returned to the aeration tank
   - Lots of food, oxygen, P
5. Since they just used up all the P in their cells, they will take up and store large quanities of P
   - “luxury uptake”
6. Remain in aerobic phase until they are completely revived
7. Sequence is repeated

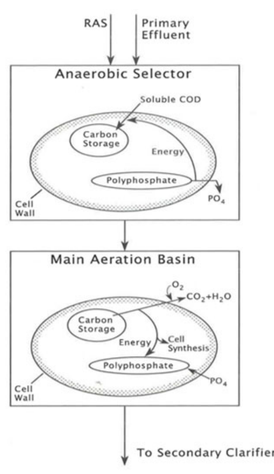
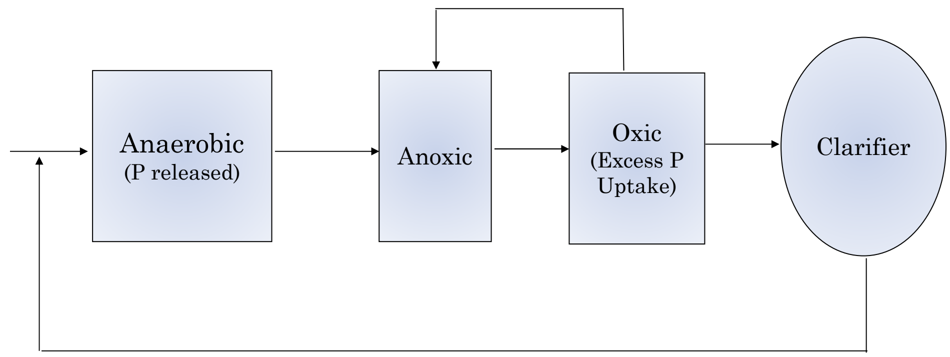


Fig. 5.2 Microorganism cell reactions during phosphorus release and luxury uptake processes

Biological Phosphorus Removal



Biological Phosphorus Removal

- Phosphate Accumulating Organism (PAO)
- ***Volatile Fatty Acids*** (VFA) - produced during digestion/fermentation
  - The preferred food for the PAO
  - PAO's expend energy to transform VFA's into a chemical form for storage
  - That energy comes from breaking P bonds, results in P release

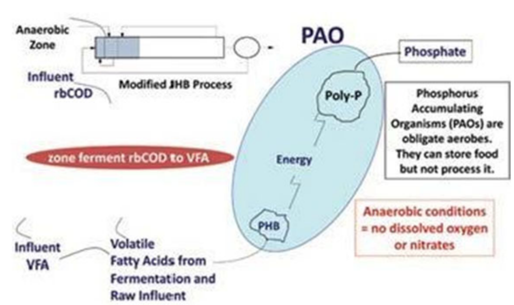
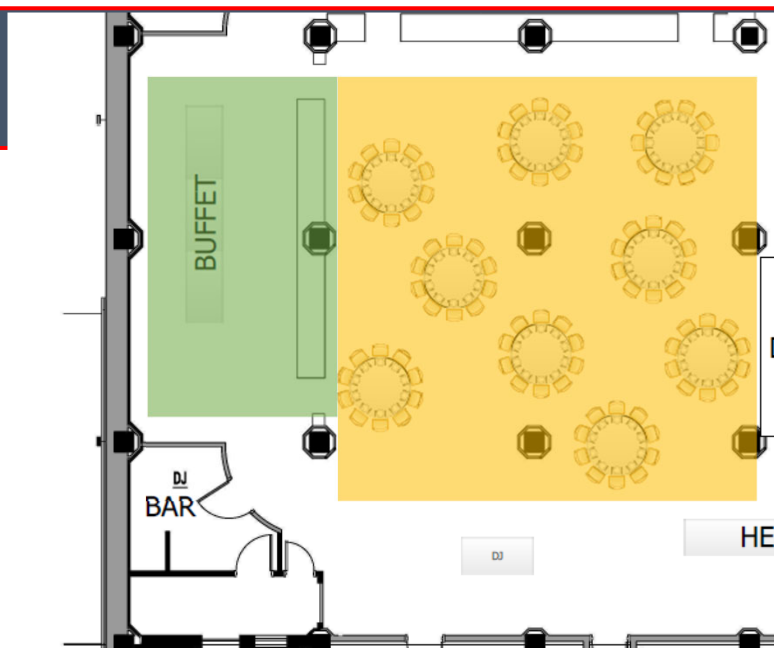


Figure 1. PAO Phosphorus Release in Anaerobic Zone

Note

Volatile fatty acids (VFAs) are produced by fermentation of CBOD under anaerobic conditions. VFAs are chemical compounds that contain five carbons or less, such as acetic acid (2 carbons), propionic acid (3 carbons), and butyric acid (4 carbons). Acetic acid is more commonly known as vinegar.



Biological Phosphorus Removal

- Lime can be added to supernatant from P stripping tank
  - P precipitates out in clarifier
  - Polymers can be added to improve coag/floc
- Sludge from stripping tank (contains microbes) is returned to aerobic reactor
  - This is in contrast to the mainstream layout, where microbes are removed entirely from waste stream

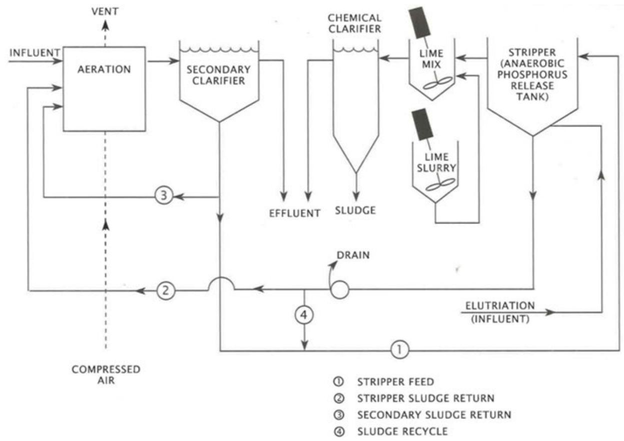
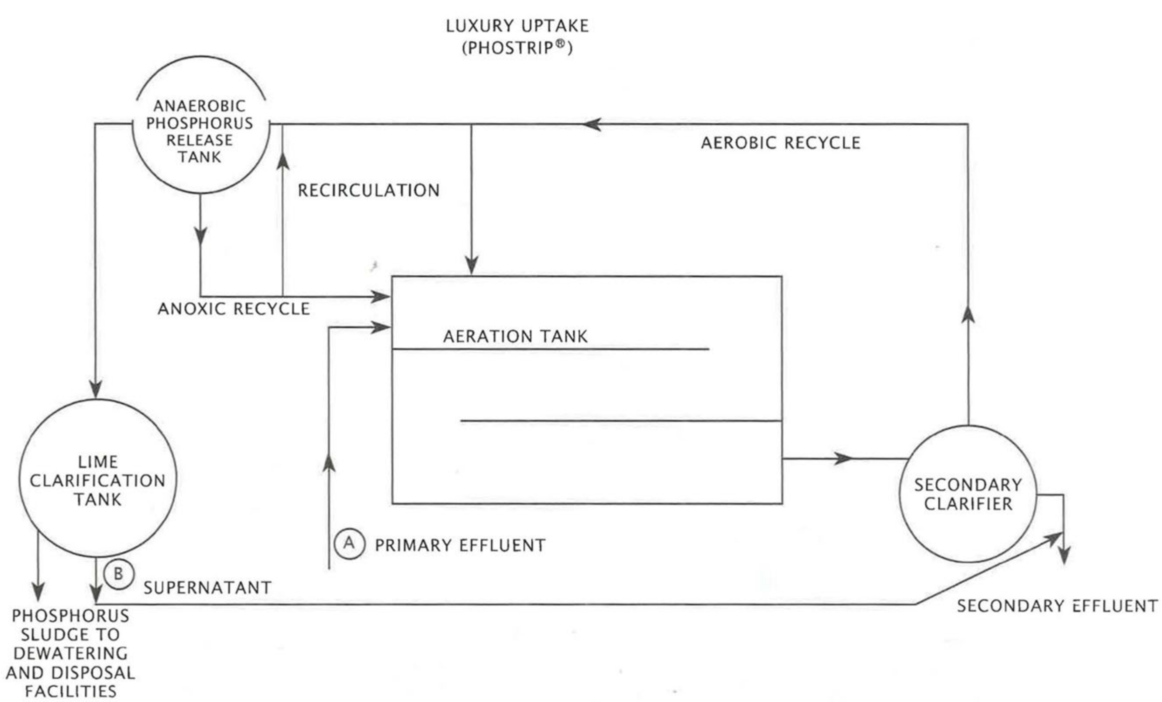
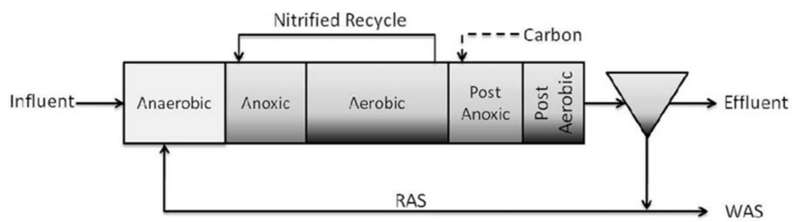


Fig. 5.3 Luxury uptake of phosphorus (elevation flow diagram)

Source: Advanced Waste Treatment, 5th ed, p.481



Biological Phosphorus Removal



Five-stage Bardenpho process

Biological Phosphorus Removal – Luxury Uptake

- Key Principles:
  - Will only occur in very controlled environment
  - Strict anaerobic conditions must be maintained in stripping tank at all times!
  - Operators must carefully regulate detention time so it is long enough to remove as much P as possible, but not so long that the microbes will die of starvation
  - Sludge recycle time is very important

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Section 10
Disinfection

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Section 10
Disinfection

Disinfection

- The MAIN purpose of disinfection is to destroy pathogenic microorganisms and thus prevent spread of disease
- ***Pathogenic*** = disease-causing
- Ultimate measure of effectiveness is bacteriological result

Removal of Pathogenic Microorganisms

- Wastewater treatment removes some of the pathogenic microorganisms through these processes:
  - Physical removal through sedimentation and filtration
  - Natural die-off in an unfavorable environment
  - Destruction by chemicals introduced for treatment purposes

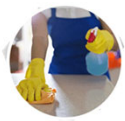
Effectiveness of Microorganism Removal

Treatment Process	Microorganism Removal, %
Screening	10 – 20 %
Grit Channel	10 – 25 %
Primary Sedimentation	25 – 75 %
Chemical Precipitation	40 – 80 %
Trickling Filters	90 – 95 %
Activated Sludge	90 – 98 %
Chlorination	98 – 99 %
Ozone	98.5 – 99.5 %*
UV Radiation	99 – 99.9 %**

*Depends on microorganisms and contact time
**Depends on microorganisms and UV intensity and contact time

Disinfection vs. Sterilization

Disinfection is the destruction of all pathogenic microorganisms



Chlorination of wastewater is considered adequate when the
Fecal coliform count has been reduced to 200 cfu*/100 mL or less
E. coli count has been reduced to 126 cfu/100 mL or less

Sterilization is the destruction of ALL microorganisms

*cfu = colony forming unit

Disinfection

- The main objective of disinfection is to prevent the spread of disease by protecting:
  - Public water supplies
  - Receiving waters used for recreational purposes
    - Protect water where human contact is likely
  - Fisheries and shellfish growing areas
  - Irrigation and agricultural waters
  - Receiving waters that are a source of beneficial water reuse

Methods of Disinfection

Chlorine | UV | Ozone | PAA

Chlorine Chemicals

- Elemental chlorine (Cl_2)
  - Yellow-green gas or amber liquid
  - 100% chlorine
- Sodium hypochlorite – Bleach (NaOCl)
  - Clear, pale yellow liquid
  - 5-15% chlorine
- Calcium hypochlorite – HTH ($Ca(OCl)_2$)
  - White, pale yellow granules or tablets
  - 65% chlorine
- Chlorine dioxide (ClO_2)
  - Green-yellow gas generated on-site

Chlorine

- Is highly reactive!! Reacts with:
  - Hydrogen sulfide (H_2S)
  - Iron
  - Manganese
  - Nitrite
  - Phenols
  - Ammonia
  - And lastly used for disinfection

} Chlorine Demand

Note

Chlorine demand is the difference between the amount of chlorine added to water and the amount of residual remaining after a given contact time.

Demand = Dose - Residual

Chlorine demand may change with dosage, time, temperature, pH, and the nature/amount of impurities in the water

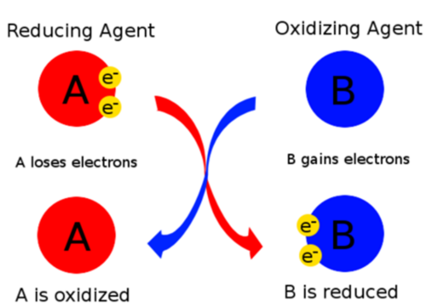
Chemistry of Chlorination

- Each form of chlorine (Cl_2, OCl^-, ClO_2) has a similar reaction with water and forms:

Hypochlorous Acid or Hypochlorite

- Adding any form of chlorine to wastewater results in hydrolysis
  - *Hydrolysis* = a chemical reaction in which a compound is converted into another compound by taking up water

Chemistry of Chlorination



- ***Oxidizing agent*** = any substance (ex: oxygen [O_2] or chlorine [Cl_2]) that will readily add (take on) ***electrons***
  - When O_2 or Cl_2 is added to water, organic substances are oxidized
- ***Reducing agent*** = any substance (ex: base metal such as iron or the sulfide ion [S^{2-}]) that will readily donate (give up) ***electrons***

Note

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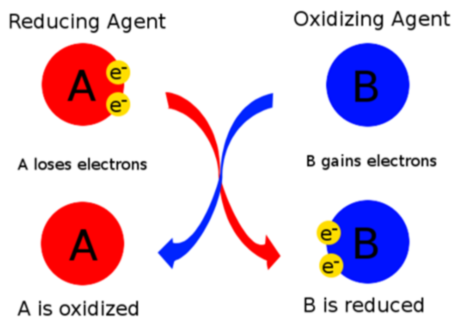
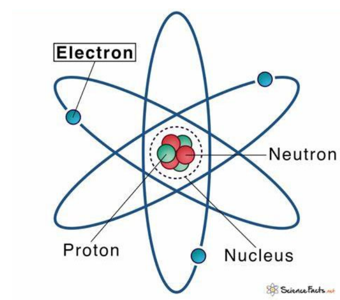




Chemistry of Chlorination

$Cl_2 + H_2O \longrightarrow HOCl + HCl$

chlorine + water = hypochlorous acid & hypochloric acid

- Hypochlorous acid
  - Most effective disinfectant
    - 40 – 80 times greater disinfection potential than OCl^-
  - Prevalent at pH less than 7
    Dissociates at higher pH:

$HOCl \longrightarrow H^+ + OCl^-$

hypochlorite ion

Chemistry of Hypochlorination

$NaOCl + H_2O \longrightarrow HOCl + NaOH$

hypochlorous acid

- Sodium hypochlorite will slightly raise the pH because of the sodium hydroxide (NaOH)

$$Ca(OCl)_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2HOCl$$

- Calcium hypochlorite does the same

Chlorine Dioxide (ClO_2): Chemistry

- Made onsite and very unstable

$2NaClO_2 + Cl_2 \longrightarrow 2NaCl + 2ClO_2$

Sodium Chlorite + Chlorine → Sodium Chloride + Chlorine Dioxide

- $2ClO_2 + H2O \longrightarrow ClO_3^- + ClO_2^- + 2H^+$

Chlorine dioxide + Water → Chlorate Ion + Chlorite Ion + Hydrogen Ion

Chlorine Dose

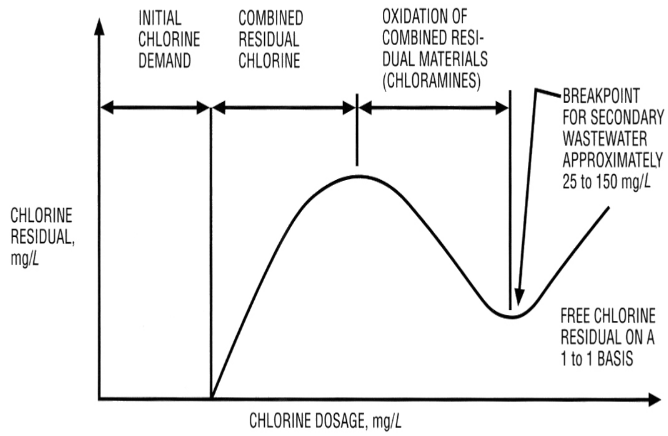
- Chlorine Dose = Chlorine Demand + Chlorine Residual
- Chlorine Residual = Combined Chlorine forms + Free Chlorine
- *Free chlorine residual* = the residual formed after the chlorine demand has been met
- *Combined chlorine residual* = residual chlorine produced by the reaction of chlorine with substances in the water (it can be combined with ammonia, organic nitrogen, or both)
  - Chloramines and Chlororganics
  - It is still available to oxidize organic matter and kill bacteria, but not as effective as free residual

Chlorine and Ammonia

- Ammonia (NH_3) is present in all domestic wastewater
- When chlorine is added to water with NH_3, the NH_3 reacts with HOCl to form:
  - Monochloramine
  - Dichloramine
  - Trichloramine

  (Chloramines)
- Breakpoint chlorination occurs when the chlorine to ammonia ratio exceeds ~ 8:1
  - At this point the Cl_2 has oxidized the NH_3 to nitrate or other end products

Breakpoint Chlorination Curve



Chlorine Residual

- Must use approved method
- Limits are in NPDES permit
- Microorganism population usually estimated by determining **MPN** (Most Probable Number)
  - Coliform group of organisms as indicator organisms

Factors Influencing Disinfection

- Injection point and method of mixing
- Design or shape of contact chamber
- Contact time
  - Most contact chambers are designed to give 30 min contact time
- Effectiveness of upstream processes
  - The lower the SS, the better the disinfection
- Temperature
- Dose and type of chemical
- pH
- Numbers and types of microorganisms

Chlorine Demand

- Chlorine demand can be caused by environmental factors such as:
  - Temperature
  - pH
  - Alkalinity
  - Suspended solids
  - Biochemical and chemical oxygen demand
  - Ammonia nitrogen compounds

Chlorine Dosages for Adequate Chlorine Residual

Application Points for Chlorination:

- Collection system
- Prechlorination
- Plant chlorination
- Chlorination before filtration
- Post-chlorination

Application	Dosage Range, mg/L
Collection System – Slime control	1 - 15
Treatment – Grease Removal	1 - 10
Activated Sludge – Bulking	1 - 10
Digester – Supernatant	20 - 150
Disinfection – Raw Wastewater	10 - 130
Disinfection – Primary Clarifier Effluent	5 - 20
Disinfection – Trickling Filter Effluent	3 - 20
Disinfection – Activated Sludge Effluent	2 - 8
Disinfection – Advanced Treatment	1 - 5

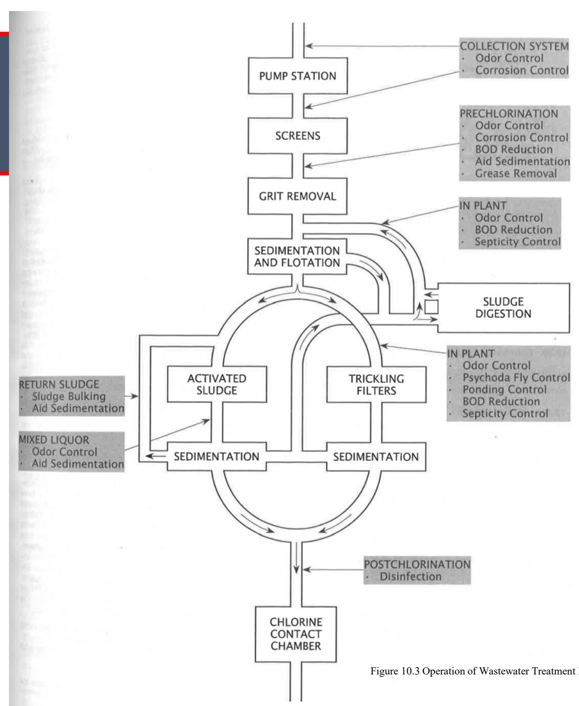


Figure 10.3 Operation of Wastewater Treatment Plants, Vol II, Seventh edition, p.355

Prechlorination

- The addition of chlorine to wastewater at the entrance to the treatment plant, ahead of settling units and prior to the addition of other chemicals
  - Aids in:
    - Odor control
    - Decrease BOD load
    - Settling
    - Oil removal

Note

Ns%ymj%htqqjhynts%x~xyjr ?

- Odor control
  - Aeration may be most cost efficient
- Corrosion control
- BOD control
  - Decrease the load imposed on the STP

Plant Chlorination

- Chlorine can be added to wastewater during treatment
  - The point of application depends on the desired results
- Emergency measure only, use extreme care when chlorinating in the treatment process because you may interfere or inhibit biological treatment processes
- Aids in:
  - Control of odors
  - Corrosion
  - Sludge bulking
  - Digester foam
  - Filter flies
  - Trickling Filter Ponding

Chlorination Before Filtration

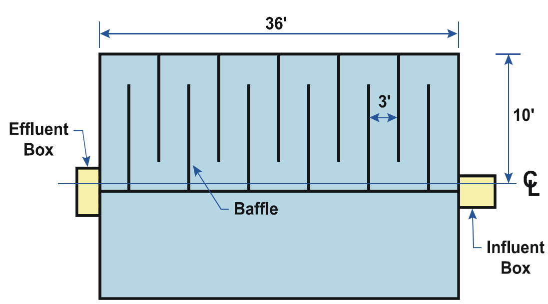
- Kills algae and other large biological organisms in water or in filters
  - Biological growth may cause filters to clog which would cause the need to backwash more frequently

Post-chlorination

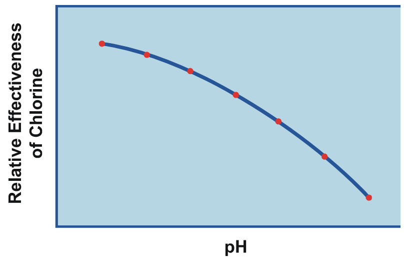
- Post-chlorination is defined as the addition of chlorine to municipal or industrial wastewater following other treatment processes
  - Point of application should be before a Chlorine Contact Chamber or Basin and after the final clarifier
  - Sole purpose is disinfection
  - A highly nitrified effluent can be difficult to disinfect, adding 1.5 mg/L of ammonia to the effluent of the nitrification process can correct the problem

Typical Layout - Contact Basin

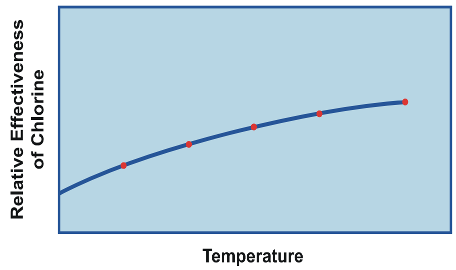
- Design Criteria (10.2.2.4-5):
  - Minimum 30:1 length to width ratio
    - The total length of the channel created by the baffles should be 30 times the distance between the baffles
  - 15 min. detention time at daily peak design flow
  - 30 min. detention time at average design flow



Relative Effectiveness

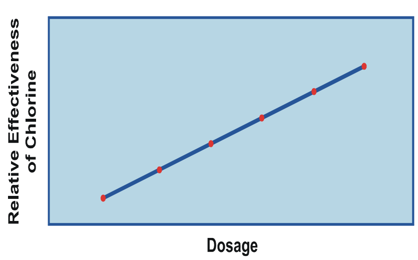


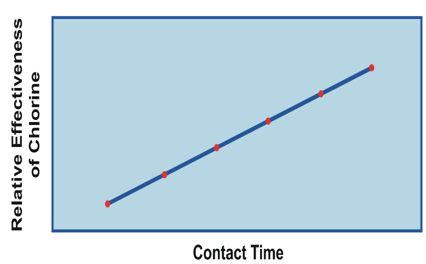
The lower the ph (<7), the disinfection action increases because hypochlorous acid is formed from chlorine and has 40 to 80 times greater disinfection potential.



When the temperature increases the disinfection action of chlorine increases.

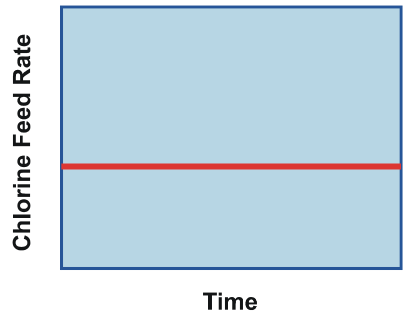
Relative Effectiveness



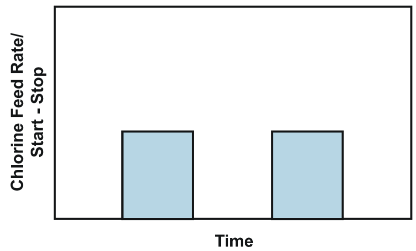


Types of Feed Control

Manual Control

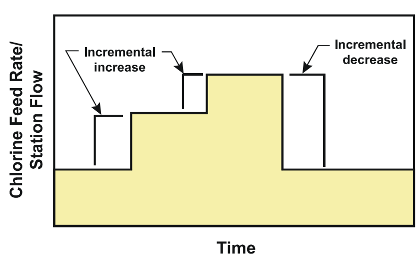


Start Stop Control

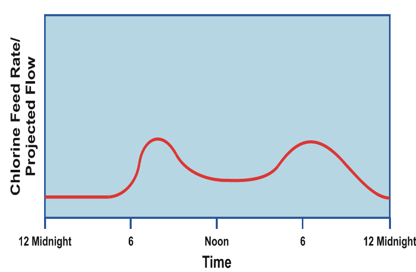


Types of Feed Control

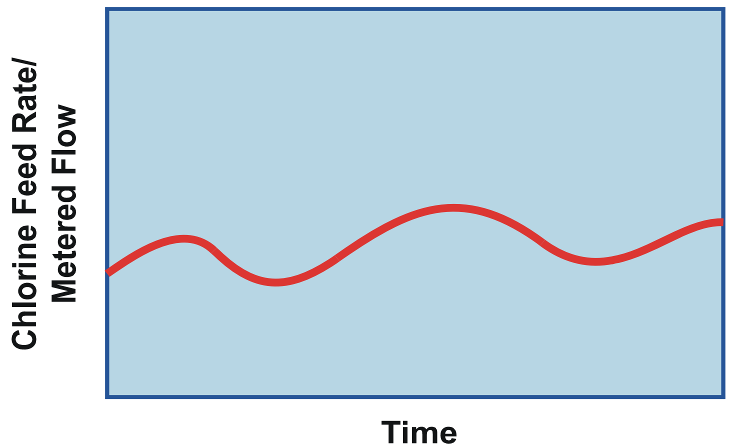
Step Rate Control



Timed Program Control

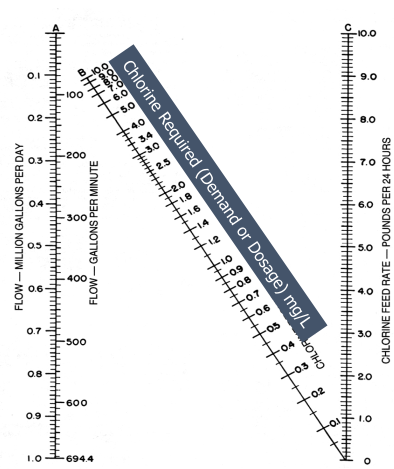


Flow Proportional Control



Chlorination Control Nomograph

- Nomogram is a chart or diagram containing three or more scales used to solve problems with three or more variables



Chlorine Hazards

- Chlorine gas is:
  - 2.5 times heavier than air
  - Extremely toxic
  - Corrosive in moist atmospheres
- Exhaust fans should be located at floor level in the chlorine room.
- Self-contained air (SCBA) required
  - Should be on-site, located **outside** of Cl_2 room

Chlorine Leaks

- To locate chlorine leaks you should use a commercial ammonia water (containing 28-30% ammonia as NH_3 which is the same as 58% ammonium hydroxide, NH_4OH, or commercial 26º Baumé)
  - The ammonia water can be put in a polyethylene squeeze bottle about half full and squeeze the ammonia vapors around potential Cl_2 leak.
  - When ammonia vapor comes in contact with chlorine, a white cloud of ammonia chloride is formed.
  - A 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.

Chlorine Leaks

- To shut down a gas chlorination system for maintenance:
  - Turn off the chlorine gas supply
  - Wait for the rotameter ball to drop to 0 lbs
  - Turn off the injector water supply to insure that all gas has been expelled

Physiological Response to Chlorine Gas

Effect	Parts of Chlorine Gas per Million Parts of Air by Volume (ppm)
Slight symptoms after several hours' exposure	1*
Detectable odor	0.08 – 0.4
60-min inhalation without serious effects	4
Noxiousness	5
Throat irritation	15
Coughing	30
Dangerous from ½ - 1 hour	40
Death after a few deep breaths	1,000
*OSHA regs specify that exposure to chlorine shall at NO time exceed 1 ppm.	

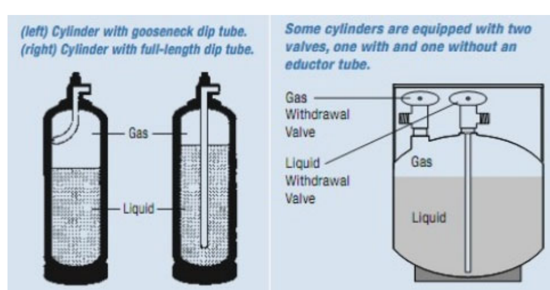
Chlorine

- Chlorine is available in:
  - 150 lb cylinders
  - 1 ton containers
  - Up to 90 ton railroad cars



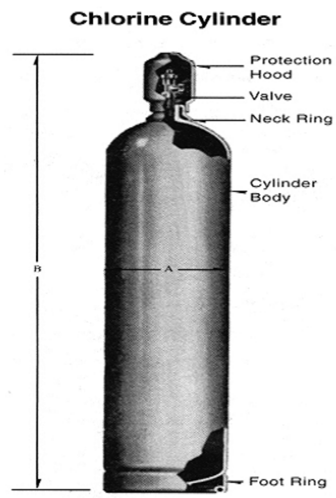
Chlorine

- These containers under normal conditions of temperature and pressure contain chlorine as a liquid and a gas form.
  - If you take chlorine from the bottom of the container, it will be liquid
  - If you take chlorine from the top of the container, it will be gas
- Liquid chlorine expands in volume by 460 times as a gas at atmospheric pressure



Chlorine Cylinder (100 or 150 lb.)

- The fusible plug melts at 158-165°F to prevent build-up of excessive pressure and possible rupture
- Move cylinders with properly balanced hand truck with clamp supports that fasten at least 2/3 of the way up the cylinder
- Cylinders must be kept away from direct heat
- It is not advisable to draw more than 40 lbs of chlorine in a 24-hr period because of the danger of freezing and slowing down the chlorine flow



Ton Container

- Ton tanks weigh ~ 3,700 pounds
- Most ton tanks have 6-8 fusible plugs that are designed to melt at the same temperature range as the safety plug in the cylinder valve
- Ton tanks should be stored and used on their sides, above the floor or ground on steel or concrete supports
- Ton tanks should be placed on trunnions
- The upper valve will discharge chlorine gas and he lower valve will discharge liquid chlorine
- The max withdrawal rate for a ton container is 400 lbs/day.

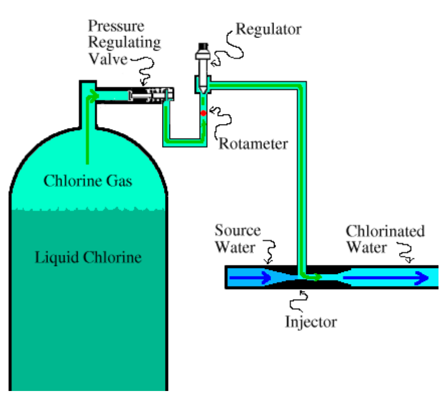
Chlorine Repair Kits

Kit A 150-pound cylinders	Kit B Ton Container	Kit C Cargo Tank
		

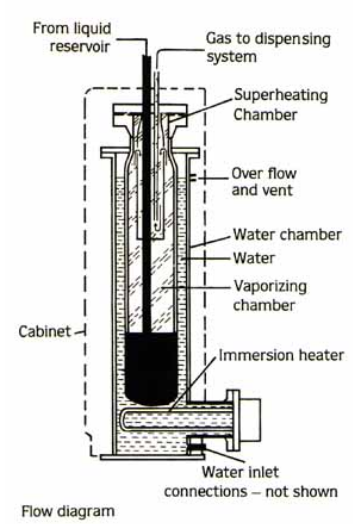
Chlorination Equipment

Chlorinator

- Vacuum fed (safer)
- Used to establish a feed rate in pounds per day
- Components include:
  - Differential regulating valve
  - V-Notch orifice with plug positioner
  - Rotameter



Chlorination Equipment



Evaporator

- Installed where large amounts of chlorine are fed
- An evaporator is a hot water heater surrounding a steel tank and the liquid chlorine is evaporated to gas at 110-120°F

Dechlorination

- Dechlorination is the physical or chemical removal of all traces of residual chlorine remaining after the disinfection process and prior to the discharge of the effluent to the receiving waters
- Removal methods:
  - Aeration
  - Sunlight
  - Long detention time
  - Chemicals

Chemicals Used for Dechlorination

- Sulfur dioxide
  - SO_2
  - One-to-one basis
  - Most popular
- Sodium sulfite
  - Na_2SO_3

- Sodium bisulfate
  - $NaHSO_3$
- Sodium metabisulfite
  - $Na_2S_2O_5$
- Sodium Thiosulfate
  - $Na_2S_2O_3$

Sulfur Dioxide (SO_2)

- Colorless gas with a characteristic pungent odor
- Not flammable or explosive
- Not corrosive unless in a moist environment (can form sulfuric acid)
- Detecting for sulfur dioxide leaks is done the same way for chlorine by using ammonia vapor dispenser or ammonia soaked rags.

SO_2 Chemical Reaction

- Reacts almost instantaneously
- Conversion of all active positive chlorine ions to the nonactive negative chloride ions
- Organic materials present may require extra SO_2
- Excess SO_2 dosage should be avoided because it will lead to:
    1. reduction in DO
    2. drop in pH
    3. increase in BOD/COD

Dechlorination Application Point

- The typical application point is just before discharge into receiving stream
- This allows for maximum time for disinfection to take place

Physiological Response to Sulfur Dioxide

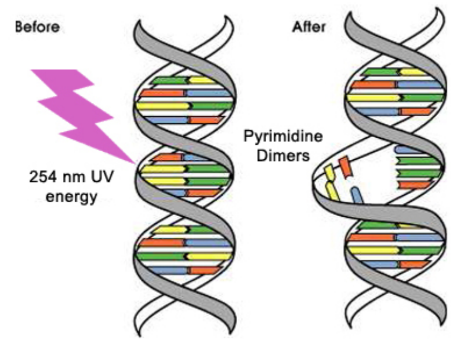
Effect	Concentration
Lowest concentration detectable by odor	3-5 ppm
Lowest concentration immediately irritating to throat	8-12 ppm
Lowest concentration immediately irritating to eyes	20 ppm
Lowest concentration causing coughing	20 ppm
Maximum allowable concentration for 8-hr exposure	10 ppm
Maximum allowable concentration for 1-hr exposure	50-100 ppm
Tolerable (briefly)	150 ppm
Immediately dangerous concentration	400-500 ppm
OSHA 8-hour TWA (Time Weighted Average) is 2 ppm and the 15-minute STEL (Short Term Exposure Limit) is 5 ppm	

Ultraviolet Radiation

- Ultraviolet radiation is commonly referred to as ultraviolet light or UV
- With growing concern with safety of chlorine handling and the possible health effects of chlorination by-products, UV is gaining popularity
- UV disinfection is a practical alternative to chlorine disinfection

Ultraviolet Radiation

- A UV system transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material.
  - When UV radiation penetrates the cell wall of an organism, it destroys the cell's ability to reproduce
  - UV radiation, generated by an electrical discharge through mercury vapor, penetrates the genetic material of microorganisms and retards their ability to reproduce.

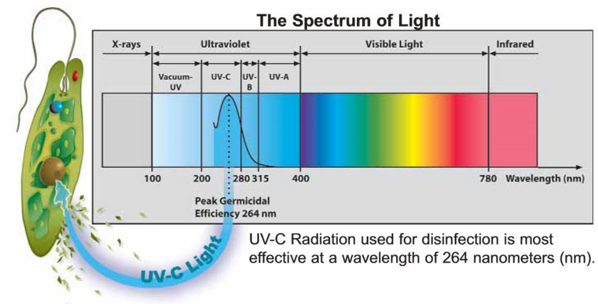


UV – System Components

- Mercury arc lamps
- Ballast
  - to provide power
- Reactor
  - Single or multiple banks mounted in a vessel
- Source of UV can either be low-pressure or medium pressure mercury arc lamp with low or high intensities.

Ultraviolet Radiation

- The effectiveness of a UV system depends on:
  - Characteristics of the WW
  - Intensity of the UV radiation
  - Amount of time the microorganisms are exposed to the radiation
  - Reactor configuration



UV – System Components

- The optimum wavelength to effectively inactivate microorganisms is in the range of 250-270 nm.
- The intensity of the radiation emitted from the lamp dissipates as the distance from the lamp increases.
- Low-pressure lamps emit essentially monochromatic light at a wavelength of 253.7 nm.
- Standard lengths of the low-pressure lamps are 0.75 and 1.5 meters with diameters of 1.5-2.0 cm.
- The ideal lamp wall temperature is between 95-122º

Low Pressure UV Lamps

- Lamp assemblies mounted in a rack(s) that are immersed in flowing water
- Can be enclosed in a vessel or in an open channel
  - Enclosed in vessels in pressure systems
- Placed either horizontal and parallel to flow or vertical and perpendicular to flow
- Number of lamps determines water depth in channel

UV – System Components

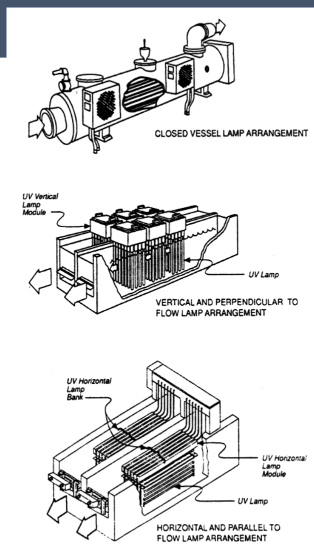
- Medium-pressure lamps are generally used for large facilities
- They have approximately 15-20 times the germicidal UV intensity of low-pressure lamps
- The medium-pressure lamp disinfect faster and has greater penetration capability because of its higher intensity.
- However, these lamps operate at higher temperatures with higher energy consumption

UV Operation

- Lamp output declines as they age
  - Operators must monitor output and replace bulbs that no longer meet design standards
- Turbidity and flow must be monitored
  - Suspended particles can shield microorganisms from the UV light
  - Flows should be somewhat turbulent to ensure complete exposure of all organisms to the bulbs
- UV light does NOT leave a residual like chlorine
  - Bacteriological tests must be run frequently to ensure adequate disinfection is taking place
  - Microorganisms that were not killed may be able to heal themselves

Typical UV Lamp Configurations

- Closed vessel lamp arrangements are more typically found in drinking water plants
- Wastewater plants normally have UV bulbs placed in an open channel either horizontal or perpendicular to flow



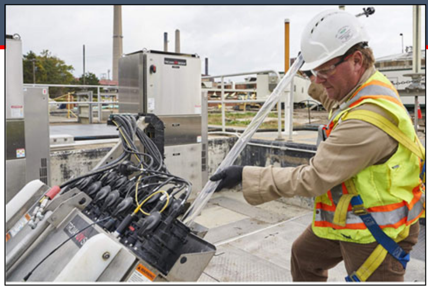
Safety with UV Systems

- The light from a UV lamp can cause serious burns to your eyes and skin
- Always take precautions to protect your eyes and skin
- NEVER look into the uncovered sections of the UV chamber without protective glasses
- UV lamps contain mercury vapor, which is a hazardous substance that can be released if the lamp is broken

Maintenance

- Quartz sleeves
  - Cleaning frequency depends on water quality and treatment chemicals
  - Dip modules in nitric acid or phosphoric acid for 5 minutes to remove scale
  - Cleaned by removing modules from channel or by in-channel cleaning
  - In-channel cleaning requires back-up channel and greater volume of cleaning solution
    - Precautions should be taken to protect concrete walls of channel from being damaged by acid

Maintenance



- UV lamps
  - Service life ranges from 7,500 – 20,000 hours
  - Depends on
    - Level of suspended solids
    - Frequency of on/off cycles
    - Operating temperature of lamp electrodes
  - Lamp output drops 30-40% in first 7,500 hours
  - Lamp electrode failure is most common cause of lamp failure
  - Do not throw used lamps in garbage can
    - Must be disposed properly due to mercury content

UV - Advantages

- Effective at inactivating most viruses, spores and cysts
- Physical process rather than a chemical disinfectant
  - Eliminates the need to generate, handle, transport or store toxic/hazardous or corrosive chemicals
- No residual effect that can be harmful to humans or aquatic life
- User-friendly for operators
- Shorter contact time when compared with other disinfectants
  - Approximately 20-30 seconds with low-pressure lamps
- Requires less space than other methods

UV - Disadvantages

- Low dose may not effectively inactivate some viruses, spores or cysts
- Organisms can sometimes repair and reverse the destructive effects of UV through a “repair mechanism” known as photo reactivation, or in the absence of light known as “dark repair”
- Preventive maintenance program is necessary to control fouling of tubes
- Turbidity and TSS in the WW can render UV disinfection ineffective
  - UV disinfection with low-pressure lamps is not as effective for secondary effluent with TSS levels above 30 mg/L
- Not as cost-effective as chlorination, bust costs are competitive when chlorination and dechlorination is used and fire codes are met

Ozone

- Ozone forms naturally in the atmosphere

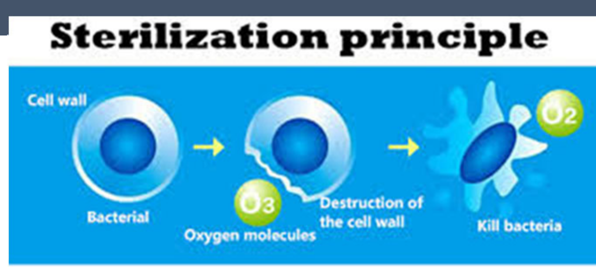
$$\mathbf{O_2 + Energy \rightarrow O + O}$$
$$\mathbf{O + O_2 \rightarrow O_3}$$

- Wastewater disinfection systems typically produce ozone by electrical methods
  - Extremely dry air containing oxygen molecules (O_2)exposed to high-voltage discharge creates ozone (O_3)
- Very strong oxidant and virucide
- Ozone is generated on-site because it is unstable and decomposes to elemental oxygen in a short amount of time after generation.

Ozonation

- Ozone's increased use as a disinfectant is being spurred by increasing regulations around the world on the discharge of pharmaceuticals and endocrine-disrupting pollutants
- Research into ozone's efficacy in eliminating these pollutants and producing safe reuse water may lead to more common use of ozone

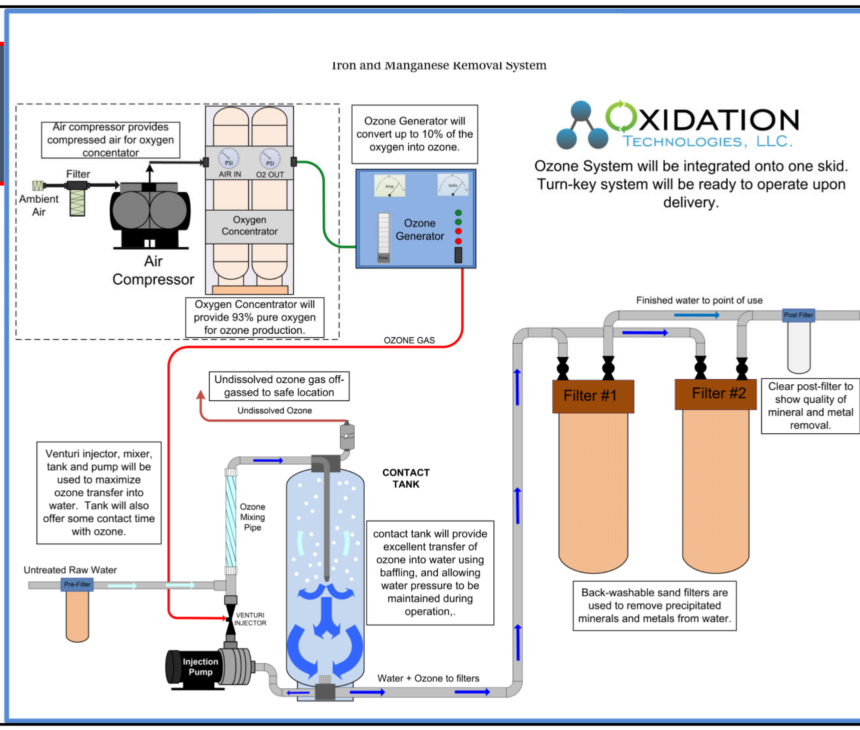
Effects of Ozone on Bacteria



- Direct oxidation/destruction of cell wall
- Reactions with radical byproducts of ozone decomposition
- Damage to nucleic acids (purines and pyrimidines) inside the cell, which alters genetic material and prevents cell replication
- It is generally believed that the bacteria are destroyed by cell lysis

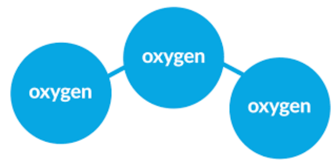
Ozone

- Ozone is fed into a down-flow contact chamber to transfer ozone from the gas bubble into the bulk liquid while providing sufficient contact time for disinfection
- Because it is consumed quickly, it must be contacted uniformly in a near plug flow contactor
- Residual ozone measured by the iodometric method
- Dissolved ozone measured by Indigo test



Ozone

- Effectiveness depends on:
  - Susceptibility of the target organisms
  - Contact time
  - Concentration of ozone
- The key process control guidelines are dose, mixing, and contact time



Maintenance

- Inspect electrical equipment and pressure vessels monthly
- Conduct a yearly preventive maintenance program
  - Should be done by a factory representative or an operator trained by the manufacturer
- Lubricate moving parts according to manufacturer's recommendations

Safety

- Ozone is a toxic gas and is a hazard to plants and animals
- When ozone breaks down in the atmosphere, the resulting pollutants can be very harmful
- Ozone contactors must have a system to collect ozone off-gas.
  - Ozone generating installations must include a thermal or catalytic ozone destroyer

Ozone - Advantages

- More effective than chlorine in destroying viruses and bacteria
- Short contact time (10-30 min)
- No harmful residues left in water
- No re-growth of microorganisms
  - Except for those protected by particulates in water
- Generated on-site
  - Fewer safety problems associated with shipping and handling
- Elevates DO levels in effluent
  - Can eliminate needs for post aeration
  - Can raise DO levels in receiving stream

Ozone - Disadvantages

- Low dose may not effectively inactivate some viruses, spores and cysts
- More complex technology
  - Requiring more complex equipment and efficient contacting systems
- Very reactive and corrosive
  - Requiring corrosive-resistant materials such as stainless steel
- Not economical for WW with high levels of solids, BOD, COD or total organic carbon (TOC)
- Extremely irritating and possibly toxic to humans at concentrations of 1 ppm or greater in air
- Cost can be high in capital and power intensiveness

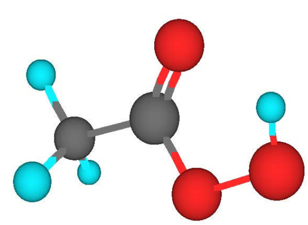
Peracetic Acid (PAA)

- A mixture of acetic acid and hydrogen peroxide and water

$$CH_3\overset{O}{\overset{\|}{C}}OH + H_2O_2 \longleftrightarrow CH_3\overset{O}{\overset{\|}{C}}OOH + H_2O$$

Acetic Acid, Hydrogen Peroxide, Peracetic Acid, Water

- Strong "vinegar" smell
- Oxidation results in pathogenic cell lysis



Peracetic Acid (PAA) - Advantages

- Alternative to chlorine
  - No disinfection byproducts (DBPs) that could be toxic to aquatic life
    - THMs, HAAs
- No removal step (ex: dechlorination)
- Simple to operate
- Chlorine contact chambers can often be retrofitted
- Safety in transportation/storage
- Lower freezing point/more stable than chlorine

Peracetic Acid (PAA) - Disadvantages

- More expensive
- PAA seems to be less effective for spores, viruses and protozoa (Giardia and Cryptosporidium)
- Can present an oxygen demand

Peracetic Acid (PAA)

- Effectiveness depends on:
  - Susceptibility of the target organisms
  - Contact time
  - Concentration of PAA

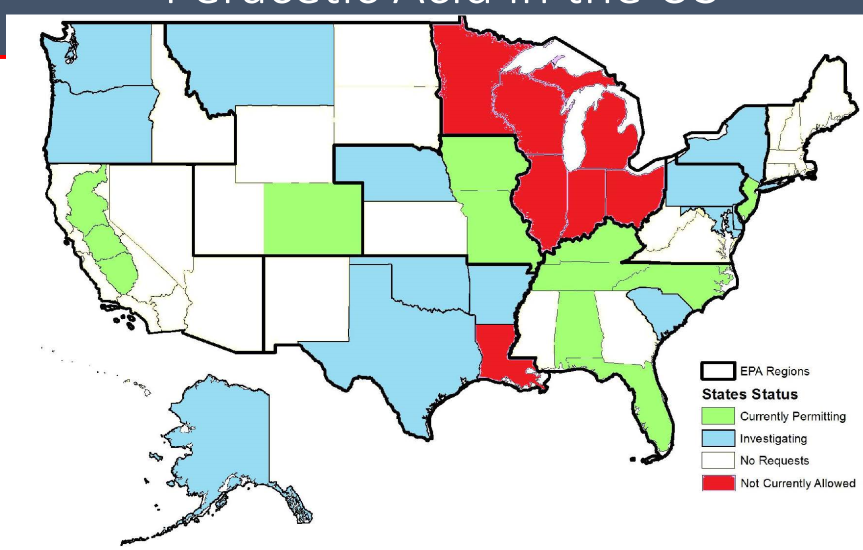
Peracetic Acid (PAA)

- Approval Process for Tennessee:
  - Tennessee does not have numeric water quality criteria
  - Bench-scale, partial pilot scale or full scale pilot test to determine the efficacy of the disinfection within the PAA concentration restriction imposed by the WET test results in the receiving stream using a specific PAA formulation
  - We recommend you contact the division early in the process to understand the specific expectations

Peracetic Acid - Limits

- There is not currently a water quality criteria so limits are site specific based on the study results.
- Monitor and Report
  - Hydrogen Peroxide
  - Peracetic Acid
- The is a 1 mg/L limit published by the industries

Peracetic Acid in the US



PAA in TN

6.5. CHLORINATION AND PERACETIC ACID

The facility switched to using Peracetic Acid permanently in 2016 and no longer use chlorination at the site. After a phone call with the permittee, the chlorination equipment and chemicals have been permanently removed. The facility is utilizing PeroxyChem's VigorOx® WWT II peracetic acid solution which contains 15% peracetic acid by weight and 23% hydrogen peroxide as delivered. The IC25 toxic concentration for Ceriodaphnia dubia was 0.38 mg/L (reproduction), based on the June 29, 2015, report from PeroxyChem. The permit limitation for PAA, based on the stream dilution factor of 1.09, is 0.41 mg/L.

Peracetic Acid

The peracetic acid limit of 0.41 mg/L daily maximum will continue to apply to this permit. Previously required instream biomonitoring requirements for PAA and Hydrogen peroxide were removed from the current, modified, permit expiring June 2022 per request of the permittee. The Division approved of this after reviewing in-stream monitoring data from the permittee and saw that the sampled concentrations were well below the alert concentrations established in the initial permit authorizing use of PAA.

As stated in the addendum to rationale of the current permit:

"...Twice weekly sampling of peracetic acid hydrogen peroxide in the last two years produced sample concentrations below the alert values for both parameters. In addition to routine NetDMR submittals, a summary of monitoring data has been provided with this request:

	Hydrogen Peroxide [mg/L]	Peracetic Acid [mg/L]
Average (St. Dev.)	0.036 (0.08)	0.007 (0.03)
Maximum	0.56	0.19
Alert level	0.63	0.38

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TN Department of Environment & Conservation

Disinfection Vocabulary

1. Disease-causing microorganisms, including bacteria, viruses, and parasites, are referred to as ________________________ organisms. If this type of organism is found in water, it is capable of causing a ___________________________________, such as Typhoid.

2. The destruction of all pathogenic microorganisms is called _________________________, which is not to be confused with ________________________________, in which all microorganisms (pathogenic and nonpathogenic) are destroyed.

3. Elemental chlorine (Cl_2), which is in a liquid or gaseous form, is also known as _________________ ______________________. It combines with water to form hypochlorous (HOCl) and hydrochloric (HCl) acids. In wastewater, it will combine with ammonia or nitrogen (or other organic compounds) to form combined chlorine compounds.

4. ___________________________________ is the concentration of residual chlorine that is produced by the reaction of chlorine with substances in the water (ex: combined with ammonia, organic nitrogen, or both as a chloramine) and yet is still available to oxidize organic matter and kill bacteria, although it is not as effective as free residual.

5. Any substance, such as oxygen (O_2) or chlorine (Cl_2), that will readily add (take on) electrons is called an _____________________________________. When O_2 or Cl_2 is added to water or wastewater, organic substances are oxidized. The opposite is a Reducing Agent.

6. The residual formed after the chlorine demand has been met is ______________________________.

7. The addition of chlorine to the plant discharge or effluent, following plant treatment, is called ________________________________.

8. The concentration of chlorine present in water after the chlorine demand has been satisfied is the __________________________________. Expressed in terms of total chlorine residual, it includes both the free and combined/chemically bound chlorine residuals.

9. Any substance, such as base metal (iron) or the sulfide ion (S^{2-}),that will readily donate (give up) electrons is called a ________________________________. The opposite is an Oxidizing Agent.

10. The demand by inorganic and organic materials is referred to as ______________________________. In other words, it is the difference between the amount of chlorine added to water or wastewater and the amount of residual chlorine remaining after a given contact time.

11. The addition of chlorine in the collection system, at the headworks, or prior to any other treatment processes (mainly for odor and corrosion control) is called___________________________________.

12. ____is defined as the addition of chlorine to water or wastewater until the chlorine demand has been satisfied. At this point, further additions of chlorine will result in a free chlorine residual.

13. This alternate type of disinfection is more effective than chlorine, leaves no harmful residuals, and is generated onsite by exposing oxygen molecules to an energy source and converting them to an unstable gas: ___________________________

14. The process of adding chlorine to water to kill disease-causing organisms is known as _____________________. Generally the purpose is disinfection, but frequently it is used to accomplish other biological or chemical results.

15. _______________________________ uses ultraviolet light to destroy microorganisms by damaging their genetic material.

Word Bank:

Chlorination

Pathogenic

Residual chlorine (aka Chlorine residual)

Oxidizing agent

Combined chlorine residual

Postchlorination

Free chlorine residual

UV disinfection

Chlorine demand

Waterborne disease

Free chlorine

Disinfection

Prechlorination

Reducing agent

Ozonation

Sterilization

Breakpoint Chlorination

CHAPTER 10

Disinfection

DISINFECTION

10.1 General

10.1.1 Requirement for Disinfection

Proper disinfection of treated wastewater before disposal is required for all plants (with the exception of some land application systems) to protect the public health.

Disinfection as a minimum shall:

a. Protect public water supplies

b. Protect fisheries and shellfish waters

c. Protect irrigation and agricultural waters

d. Protect water where human contact is likely

10.1.2 Methods of Disinfection

10.1.2.1 Chlorination

Chlorination using dry chlorine (see definition in following section) is the most commonly applied method of disinfection and should be used unless other factors, including chlorine availability, costs, or environmental concerns, justify an alternative method.

10.1.2.2 Ozonation

Ozonation may be considered as an alternative to chlorination for the reasons described above. Ozonation is considered as Developmental Technology, and should only be considered for very large installations.

10.1.2.3 Other

Other potential methods of disinfection, such as by ultraviolet light, are available and their application will be considered on a case-by-case basis.

10.1.3 Dechlorination

Capability to add dechlorination should be considered in all new treatment plants. Dechlorination of chlorinated effluents shall be provided when permit conditions dictate the need.

10.2 Chlorination

10.2.1 General

10.2.1.1 Forms of Chlorine

a. Dry Chlorine

Dry chlorine is defined as elemental chlorine existing in the liquid or gaseous phase, containing less than 150 mg/l water. Unless otherwise stated, the word "chlorine" wherever used in this section refers to dry chlorine.

b. Sodium Hypochlorite

Sodium hypochlorite may be used as an alternative to chlorine whenever dry chlorine availability, cost, or public safety justifies its use. The requirements for sodium hypochlorite generation and feeding will be determined on a case-by-case basis.

c. Other

Other chlorine compounds such as chlorine dioxide or bromine chloride may be used as alternatives to chlorine whenever cost or environmental concerns justify their use. The acceptability of other chlorine compounds will be determined on a case-by-case basis.

10.2.1.2 Chlorine Feed Equipment

Solution-feed vacuum-type chlorinators are generally preferred for large installations. The use of hypochlorite feeders of the positive displacement type may be considered. Dry chlorine tablet type feeders may also be considered for small flows, into large streams.

Liquid chlorine evaporators should be considered where more than four 1-ton containers will be connected to a supply manifold.

10.2.1.3 Chlorine Supply

a. Cylinders

Cylinders should be considered where the average daily chlorine use is 150 pounds or less. Cylinders are available in 100-pound or 150-pound sizes.

b. Containers

The use of 1-ton containers should be considered where the average daily chlorine consumption is over 150 pounds.

c. Large-Volume Shipments

At large installations, consideration should be given to the use of truck or railroad tank cars, or possibly barge tank loads, generally accompanied by gas evaporators.

10.2.1.4 Chlorine Gas Withdrawal Rates

The maximum withdrawal rate for 100- and 150- pound cylinders should be limited to 40 pounds per day per cylinder.

When gas is withdrawn from 2,000-pound containers, the withdrawal rate should be limited to 400 pounds per day per container.

10.2.2 Design Considerations

10.2.2.1 General

Chlorination system designs should consider the following design factors:

Flow

Contact time

Concentration and type of chlorine residual

Mixing

pH

Suspended solids

Industrial wastes

Temperature

Concentration of organisms

Ammonia concentration

10.2.2.2 Capacity

Required chlorinator capacities will vary, depending on the use and point of application of the chlorine. Chlorine dosage should be established for each individual situation, with those variables affecting the chlorine reaction taken into consideration. For normal wastewater, the following dosing capacity may be used as a guideline.

Type of Treatment	**Dosage Capacity* (mg/l)**
Prechlorination for Odor Control	20-25
Activated Sludge Return	5-10
Trickling Filter Plant Effluent (non-nitrified)	3-15
Activated Sludge Plant Effluent (non-nitrified)	2-8
Tertiary Filtration Effluent	1-6
Nitrified Effluent	2-6
Stabilization Pond Effluent	Up to 35

*** Based on Average Design Flow.**

The design should provide adequate flexibility in the chlorination equipment and control system to allow controlled chlorination at minimum and peak flows over the entire life of the treatment plant. Special consideration should be given to the chlorination requirements during the first years of operation to ensure the chlorination system is readily operable at less than design flows without overchlorination. Chlorination equipment should operate between 25% and 75% of total operating range, to allow for adjusting flexibility at design average flow.

10.2.2.3 Mixing

The mixing of chlorine and wastewater can be accomplished by hydraulic or mechanical mixing.

Hydraulic mixing is preferred in smaller plants over mechanical mixing and should be done according to the following criteria.

a. Pipe Flow:

A Reynolds Number of greater than or equal to 1.9×10^4 is required.

Pipes up to 30 inches in diameter: chlorine injected into center of pipe.

Pipes greater than 30 inches in diameter: chlorine injected with a grid-type diffuser.

Chlorine applied at least 10 pipe diameters upstream from inlet to contact tank.

b. Open channel flow:

A hydraulic jump with a minimum Froude Number of 4.5 is necessary to provide adequate hydraulic mixing. Point of chlorine injection must be variable because jump location will change with changes in flow.

When mechanical mixing must be used, the following criteria apply:

Use where Reynolds Number for pipe flow is less than 1.9×10^4 or for open channel flow without a hydraulic jump.

A mixer-reactor unit is necessary that provides 6 to 18 seconds contact.

Inject chlorine just upstream from mixer.

Mixer speed a minimum of 50 revolutions per minute (rpm).

Jet Chlorinators may be used in a separate chamber from the contact chamber.

The contact chamber shall conform to Section 10.2.2.4 with an average design flow minimum detention time reduced to 15 minutes and a peak detention time of 7.5 minutes.

10.2.2.4 Contact Period

Contact chambers shall be sized to provide a minimum of 30 minutes detention at average design flow and 15 minutes detention at daily peak design flow, whichever is greater. Contact chambers should be designed so detention times are less than 2 hours for initial flows.

10.2.2.5 Contact Chambers

The contact chambers should be baffled to minimize short-circuiting and backmixing of the chlorinated wastewater to such an extent that plug flow is approached. It is recommended that baffles be constructed parallel to the longitudinal axis of the chamber with a minimum length-to-width ratio of 30:1 (the total length of the channel created by the baffles should be 30 times the distance between the baffles). Shallow unidirectional contact chambers should also have cross-baffles to reduce short-circuiting caused by wind currents.

Provision shall be made for removal of floating and settleable solids from chlorine contact tanks or basins without discharging inadequately disinfected effluent. To accomplish continuous disinfection, the chlorine contact tank should be designed with duplicate compartments to permit draining and cleaning of individual compartments. A sump or drain within each compartment, with the drainage flowing to a raw sewage inlet, shall be provided for dewatering, sludge accumulation, and maintenance. Unit drains shall not discharge into the outfall pipeline. Baffles shall be provided to prevent the discharge of floating material.

A readily accessible sampling point shall be provided at the outlet end of the contact chamber.

In some instances, the effluent line may be used as chlorine contact chambers provided that the conditions set forth above are met.

10.2.2.6 Dechlorination

a. Sulfur Dioxide

Sulfur dioxide can be purchased, handled, and applied to wastewater in the same way as chlorine. Sulfur dioxide gas forms sulfurous acid, a strong reducing agent, when combined with water. When mixed with free and combined chlorine residuals, sulfurous acid will neutralize these active chlorine compounds to the nontoxic chloride ion.
Sulfur dioxide dosage required for dechlorination is 1 mg/l of SO_2 for 1 mg/l of chlorine residual expressed as Cl_2. Reaction time is essentially

instantaneous. Detention time requirements are based on the time necessary to assure complete mixing of the sulfur dioxide.

b. Other Methods

For very small treatment systems, detention ponds should be considered for dechlorination.

Design rationale and calculations shall be submitted upon request to justify the basis of design for all major components of other dechlorination processes.

10.2.2.7 Sampling, Instrumentation, and Control

For treatment facility designs of 0.5 mgd and greater, continuously modulated dosage control systems should be used. The control system should adjust the chlorine dosage rate to accommodate fluctuations in effluent chlorine demand and residual caused by changes in waste flow and waste characteristics with a maximum lag time of five minutes. These facilities should also utilize continuous chlorine residual monitoring.

Flow proportional control is preferred over manual control for smaller facilities and may be required on a case-by-case basis. The design shall shut off the chlorination for small systems where the flow is zero, such as late at night.

In all cases where dechlorination is required, a compound loop control system or equivalent should be provided.

All sample lines should be designed so that they can be easily purged of slimes and other debris and drain or be protected from freezing.

Alarms and monitoring equipment that adequately alert the operators in the event of deficiencies, malfunctions, or hazardous situations related to chlorine supply metering equipment, leaks, and residuals may be required on a case-by-case basis.

Design of instrumentation and control equipment should allow operation at initial and design flows.

10.2.2.8 Residual Chlorine Testing

Equipment should be provided for measuring chlorine residual.
There are five EPA accepted methods for analysis of total residual chlorine and they are:

1) Ion Selective Electrode,
2) Amperometric End Point Titration Method,
3) Iodometric Titration Methods I & II,
4) DPD Colormetric Method and,
5) DPD Ferrous Titrimetric Method.

Where the discharge occurs in critical areas, the installation of facilities for continuous automatic chlorine residual analysis and recording systems may be required.

10.2.3 Design Details

10.2.3.1 Housing

a. General

An enclosed structure shall be provided for the chlorination equipment.

Chlorine cylinder or container storage area shall be shaded from direct sunlight.

Chlorination systems should be protected from fire hazards, and water should be available for cooling cylinders or containers in case of fire.

Any building which will house chlorine equipment or containers should be designed and constructed to protect all elements of the chlorine system from fire hazards. If flammable materials are stored or processed in the same building with chlorination equipment (other than that utilizing hypochlorite solutions), a firewall should be erected to separate the two areas.

If gas chlorination equipment and chlorine cylinders or containers are to be in a building used for other purposes, a gastight partition shall separate this room from any other portion of the building. Doors to this room shall open only to the outside of the building and shall be equipped with panic hardware. Such rooms should be at or above ground level and should permit easy access to all equipment.

A reinforced glass, gastight window shall be installed in an exterior door or interior wall of the chlorinator room to permit the chlorinator to be viewed without entering the room.

Adequate room must be provided for easy access to all equipment for maintenance and repair. The minimum acceptable clearance around and in back of equipment is 2 feet, except for units designed for wall or cylinder mounting.

b. Heat

Chlorinator rooms should have a means of heating and controlling the room air temperature above a minimum of 55° F. A temperature of 65° F is recommended.

The room housing chlorine cylinders or containers in use should be maintained at a temperature less than the chlorinator room, but in no case less than 55° F unless evaporators are used and liquid chlorine is withdrawn.

All rooms containing chlorine should also be protected from excess heat.

The room containing ozone generation units shall be maintained above 35°F at all times.

c. Ventilation

All chlorine feed rooms and rooms where chlorine is stored should be force-ventilated, providing one air change per minute, except "package" buildings with less than 16 square feet of floor space, where an entire side opens as a door and sufficient cross-ventilation is provided by a window. For ozonation systems, continuous ventilation to provide at least 6 complete air changes per hour should be installed. The entrance to the air exhaust duct from the room should be near the floor and the point of discharge should be so located as not to contaminate the air inlet to any building or inhabited areas. The air inlet should be located to provide cross-ventilation by air at a temperature that will not adversely affect the chlorination equipment.

Chlorinators and some accessories require individual vents to a safe outside area. The vent should terminate not more than 25 feet above the chlorinator or accessory and have a slight downward slope from the highest point. The outside end of the vent should bend down to preclude water entering the vent and be covered with a screen to exclude insects.

d. Electrical

Electrical controls for lights and the ventilation system should operate automatically when the entrance doors are opened. Manually controlled override switches should be located adjacent to and outside of all entrance doors, with an indicator light at each entrance. Electrical controls should be excluded, insofar as possible, from rooms containing chlorine cylinders, chlorine piping, or chlorination equipment.

e. Dechlorination equipment (SO2) shall not be placed in the same room as the Cl2 equipment. SO2 equipment is to be located such that the safety requirements of handling Cl2 are not violated in any form or manner.

10.2.3.2 Piping and Connections

a. Dry Chlorine

Piping systems should be as simple as possible, with a minimum number of joints; piping should be well supported, adequately sloped to allow drainage, protected from mechanical damage, and protected against temperature extremes.

The piping system to handle gas under pressure should be constructed of Schedule 80 black seamless steel pipe with 2,000-pound forged steel fittings. Unions should be ammonia type with lead gaskets. All valves should be Chlorine Institute-approved. Gauges should be equipped with a silver protector diaphragm.

Piping can be assembled by either welded or threaded connections. All threaded pipe must be cleaned with solvent, preferably trichlorethylene, and dried with nitrogen gas or dry air. Teflon tape should be used for thread lubricant in lieu of pipe dope.

b. Injector Vacuum Line

The injector vacuum line between the chlorinator and the injector should be Schedule 80 PVC or fiber cast pipe approved for moist chlorine use.

c. Chlorine Solution

The chlorine solution lines can be Schedule 40 or 80 PVC, rubber-lined steel, saran-lined steel, or fiber cast pipe approved for moist chlorine use. Valves should be PVC, PVC-lined, or rubber- lined.

10.2.3.3 Water Supply

An ample supply of water shall be available for operating the chlorinator. Where a booster pump is required, duplicate equipment shall be provided, and, when necessary, standby power as well. When connection is made from domestic water supplies, equipment for backflow prevention shall be provided. Where treated effluent is used, a wye strainer shall be required. Pressure gauges should be provided on chlorinator water supply lines.

10.2.3.4 Standby Equipment and Spare Parts

Standby chlorination capabilities should be provided which will ensure adequate disinfection with any unit out of operation for maintenance or repairs. An adequate inventory of parts subject to wear and breakage should be maintained at all times.

10.2.3.5 Scales

Scales shall be provided at all plants using chlorine gas. At large plants, scales of the indicating and recording type are recommended. Scales shall be provided for each cylinder or container in service; one scale is adequate for a group of cylinders or containers connected to a common manifold. Scales should be constructed of or coated with corrosion-resistant material. Scales shall be recommended for day tanks when using HTH.

10.2.3.6 Handling Equipment

Handling equipment should be provided as follows for 100- and 150-pound cylinders:

A hand truck specifically designed for cylinders

A method of securing cylinders to prevent them from falling over

Handling equipment should be provided as follows for 2,000-pound containers:

Two-ton-capacity hoist

Cylinder lifting bar

Monorail or hoist with sufficient lifting height to pass one cylinder over another cylinder trunnions to allow rotating the cylinders for proper connection.

10.2.3.7 Container Space

Sufficient space should be provided in the supply area for at least one spare cylinder or container for each one in service.

10.2.3.8 Automatic Switchover of Cylinders and Containers

Automatic switchover of chlorine cylinders and containers at facilities having less than continuous operator attendance is desirable and will be required on a case-by-case basis.

10.2.4 Safety

10.2.4.1 Leak Detection and Controls

A bottle of 56% ammonium hydroxide solution shall be available for detecting chlorine leaks.

All installations utilizing 2,000-pound containers and having less than continuous operator attendance shall have suitable continuous chlorine leak detectors. Continuous chlorine leak detectors would be desirable at all installations. Whenever chlorine leak detectors are installed, they should be connected to a centrally located alarm system and shall automatically start exhaust fans.

10.2.4.2 Breathing Apparatus

At least one gas mask in good operating condition and of a type approved by the National Institute for Occupational Safety and Health (NIOSH) as suitable for high concentrations of chlorine gas shall be available at all installations where chlorine gas is handled and shall be stored outside of any room where chlorine is used or stored. Instructions for using, testing, and replacing mask parts, including canisters, shall be posted. At large installations, where 1-ton containers are used, self- contained air breathing apparatus of the <u>positive pressure type</u> shall be provided.

10.2.4.3 Container Repair Kits

All installations utilizing 1-ton containers should have Chlorine Institute Emergency Container Kits. Other installations using cylinders should have access to kits stored at a central location.

10.2.4.4 Piping Color Codes

It is desirable to color code all piping related to chlorine systems.

10.3 Alternate Methods

10.3.1 Ozonation

10.3.1.1 Application

Ozonation may be substituted for chlorination whenever chlorine availability, cost, or environmental benefits justify its application.

Ozone is generated on-site from either air or high-purity oxygen. Ozonation should be considered if high-purity oxygen is available at the plant for other processes.

10.3.1.2 Design Basis

The design requirements for ozonation systems should be based on pilot testing or similar full-scale installations.

As a minimum, the following design factors should be considered:

a. Ozone dosage

b. Dispersion and mixing of ozone in wastewater

c. Contactor design

All design criteria shall be submitted upon request to justify the basis of design of the ozonation system. The detailed design requirements will be determined on a case-by-case basis.

10.3.2 Ultraviolet Disinfection

10.3.2.1 Application

UV disinfection may be substituted for chlorination, particularly whenever chlorine availability, cost, or environmental benefits justify its application. For tertiary treatment plants where dechlorination is required or chlorine toxicity is suspected, UV disinfection is a viable alternative.

10.3.2.2 Design Basis

In the design of UV disinfection units there are three basic areas that should be considered:

a. Reactor hydraulics

b. Factors affecting transmission of UV light to the microorganisms

c. Properties of the wastewater being disinfected.

UV disinfection is considered as Developmental Technology and all design criteria shall be submitted upon request to justify the basis of the UV disinfection system. The detailed design requirements will be determined on a case-by-case basis.

Section 11
Effluent Disposal

Section 11
Effluent Disposal

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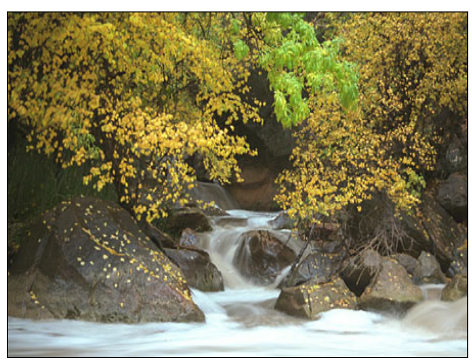
Effluent Disposal

- Dilution
  - Lakes
  - Rivers
  - Streams
- Wastewater Reclamation
  - Land application
  - Underground disposal
  - Groundwater recharge basins



Note

Wastewater Reclamation is the treatment or processing of wastewater to make it reusable with definable treatment reliability and meeting appropriate water quality criteria

Disposal by Dilution

- Treatment required prior to discharge:
  - Stabilize waste
  - Protect public health
  - Meet discharge requirements

- Site specific
- Most common method of effluent disposal

Disposal by Dilution

- Diffusers
- Cascading outfalls
  - Increase D.O.
  - Remove chlorine
  - Remove sulfur dioxide
- Surface discharge

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Land Treatment of Wastewater Effluent

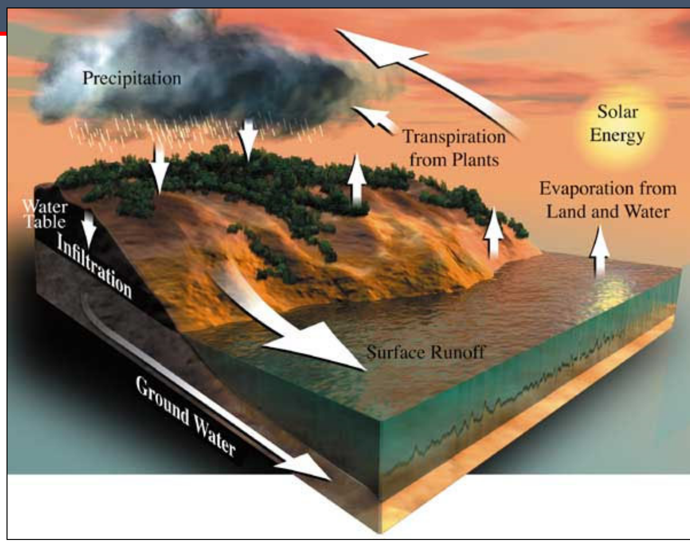
Land Treatment Systems

- When high-quality effluent or even zero-discharge is required, land treatment offers a means of reclamation or ultimate disposal
- Land treatment = the controlled application of wastewater to the land surface to achieve a designed degree of treatment through physical, chemical, and biological processes within the plant-soil-water matrix.
  - Soil texture, soil structure, permeability, infiltration, available water capacity, and cation exchange capacity
  - Adsorption and precipitation are the main processes involved in the retention of wastes in the soil

Land Treatment Systems

- Simulate natural pathways of treatment
- Use soil, plants, and bacteria to treat and reclaim wastewater
- Treatment is provided by natural processes as effluent moves through soil and plants
- Some of wastewater is lost by evaporation and transpiration
- Remainder returns to hydrologic cycle through surface runoff or percolation to groundwater

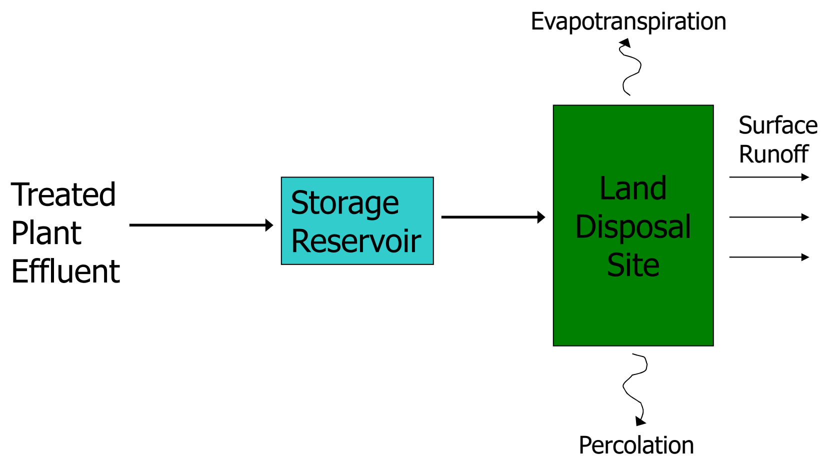
Hydrologic Cycle



Land Application System

- Treatment prior to application
- Transmission to the land treatment site
- Storage
- Distribution over the site
- Runoff recovery system
- Crop systems

Land Application System



3 Major Land Treatment Processes

1. Slow rate
   - Irrigation, ridge-and-furrow, border strip flooding
     - Vegetation uses portion of flow, some goes to groundwater
     - Organic wastes removed by filtration and adsorption
     - Designed for no surface runoff
2. Rapid infiltration
     - Moderately and highly permeable soils by spreading basins or sprinklers (vegetative cover not used)
     - Treated effluent collected by drain tiles and discharged to surface water or it enters groundwater
3. Overland flow
     - Highly impermeable soils, applied at upper reaches of grass covered slopes, flows over vegetation, surface runoff collected

Site Considerations

- Control of ponding problems
  - Percolation
  - Crop selection
  - Drainage tiles
- Install PVC laterals below ground
- Potential odor release with spray systems
- Routine inspection of equipment
- Plan "B" in case system fails
- Nitrogen is the major limiting factor

Wastewater Reclamation: Land Application

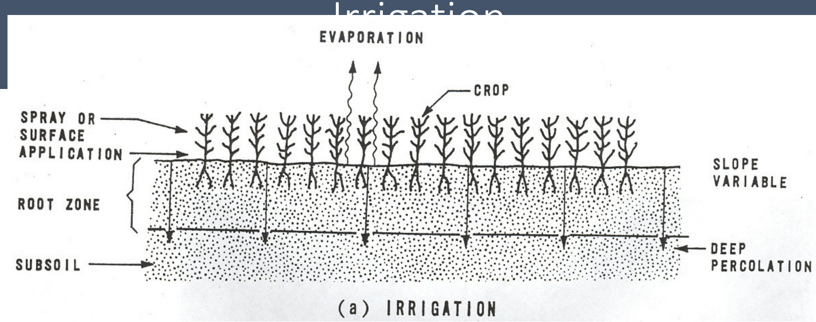
- Irrigation most common:
  - Ridge and furrow
  - Sprinklers
  - Surface/drip systems
  - Border strip flooding
- Overland flow
  - Wetlands treatment

Wastewater Treatment Plant & Poplar Tree Reuse System; Woodburn, Oregon

Irrigation

- Method depends on crop grown, 3 groups:
  1. Forage crops (ex: grasses and alfalfa)
  2. Field crops (ex: corn)
  3. Forests
- Water & nutrients enhance plant growth for beneficial use
- Water removed by:
  - Surface evaporation & plant transpiration
  - Deep percolation to subsoil

Irrigation



- Irrigation application of wastewater over relatively flat area, usually by spray (sprinklers) or surface spreading
- Water and nutrients are absorbed by plants and soil
- In soil, organic matter is oxidized by bacteria

Irrigation

- Most common land treatment in US
- Spray: fixed or moving
- Surface spreading: controlled flooding or ridge & furrow
- Climate affects efficiency
  - If ground freezes, subsurface seepage is greatly reduced.
  - Therefore storage of treated wastewater may be necessary
- Ex: lawns, parks, golf courses, pastures, forests, fodder crops (corn, alfalfa), fiber crops, cemeteries

Irrigation - Spray Systems

3 categories:

1. Solid set (Fixed)
   - Buried or on surface
   - Cultivated crops or woodlands
2. Portable
3. Continuously moving
   - Moving - center pivot

- Maximum slope in TN (TN Design Criteria 16.1.4):
  - Row crops 8%
  - Forage crops 15%
  - Forests 30 %

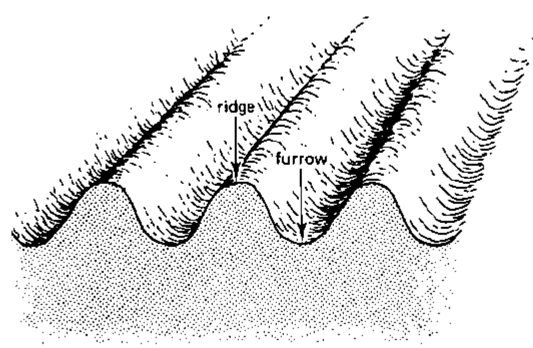
Irrigation - Spray Systems

Center pivot, moving spray irrigation

Fixed spray irrigation on risers

Irrigation – Ridge & Furrow

- Ridge and Furrow = a series of interconnected ditches (furrows) which allow for the distribution, infiltration, and treatment of wastewater
- Wastewater flows through furrows between rows of crop
- Wastewater slowly percolates into soil
- Wastewater receives partial treatment before it is absorbed by plants



Irrigation – Ridge & Furrow

Irrigation ditch in foreground supplying water to furrows

Gated pipe applying flow to furrows

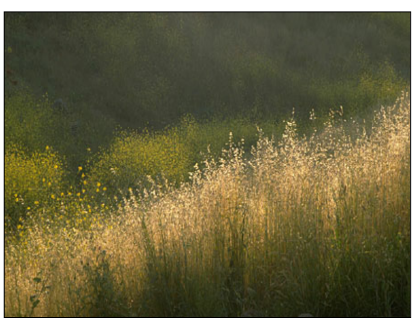
Irrigation – Removal Efficiencies

Parameter	% Removal
BOD	98
COD	80
Suspended Solids	98
Nitrogen	85
Phosphorus	95
Metals	95
Microorganisms	98

Irrigation – Removal Efficiencies

- Under normal circumstances:
  - Water and nitrogen are absorbed by crops
  - Phosphorus and metals are adsorbed by soil particles
  - Bacteria is removed by filtration
  - Viruses are removed by adsorption
- Nitrogen cycle
  - Secondary effluent contains ammonia, nitrate and organic nitrogen
  - Ammonia and organic nitrogen are retained in soil by adsorption and ion exchange, then oxidized to nitrate
  - Major removal mechanisms are ammonia volatilization, crop uptake and denitrification

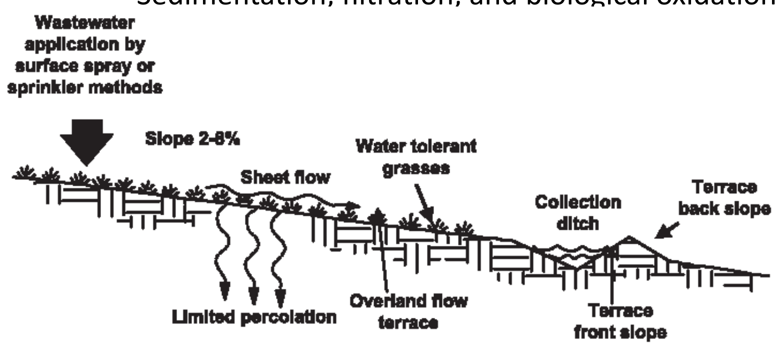
Overland Flow



- Spray or surface application
  - 6-12 hours/day
  - 5-7 days/week
- 2-8% slope
- Slow surface flow treats wastewater
- Water removed by evaporation & percolation
- Runoff collection

Overland Flow

- Wastewater is applied intermittently at top of terrace
  - Runoff collected at bottom (for further treatment)
  - Treatment occurs through direct contact with soil
    - Sedimentation, filtration, and biological oxidation

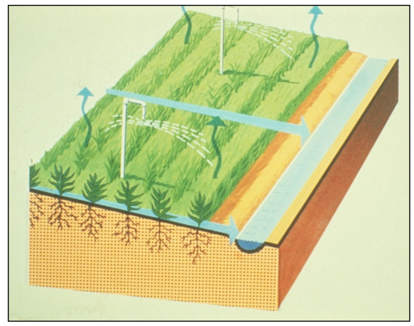


Overland Flow

- Highly impermeable soils
- High nitrogen removal (70-90%)

Overland Flow

- Low pressure sprays
  - <20 psi
  - Low energy costs
  - Good wastewater distribution
  - Nozzles subject to plugging
- Surface distribution
  - Generate minimal aerosols
  - Higher energy costs
  - Hard to maintain uniform distribution



Distribution Methods

	Methods	Advantages	Limitations
Surface Methods	General	Low energy costs Minimize aerosols and wind drift Small Buffer zones	Difficult to achieve uniform distribution Moderate erosion potential
Surface Methods	Gated Pipe	Same as General, plus: Easy to clean Easiest to balance hydraulically	Same as General, plus: Potential for freezing and settling
Surface Methods	Slotted or Perforated Pipe	Same as General	Same as Gated Pipe, plus: Small openings clog Most difficult to balance hydraulically
Surface Methods	Bubbling Orifices	Same as General, plus: Not subject to freezing/settling Only the orifice must be leveled	Same as General, plus: Difficult to clean when clogged
Low-pressure Sprays		Better distribution than surface methods Less aerosols than sprinkler Low energy costs	Nozzles subject to clogging More aerosols and wind drift than surface methods
Sprinklers		Most uniform distribution	High energy costs Aerosol and wind drift potential Large buffer zones

Suitable Grasses

	Common Name	Perennial or Annual	Rooting Characteristics	Method of Establishment	Growing Height (cm)
Cool Season Grass	Reed canary	Perennial	sod	seed	120-210
	Tall fescue	Perennial	bunch	seed	90-120
	Rye grass	Annual	sod	seed	60-90
	Redtop	Perennial	sod	seed	60-90
	KY bluegrass	Perennial	sod	seed	30-75
	Orchard grass	Perennial	bunch	seed	15-60
Warm Season	Common Bermuda	Perennial	sod	seed	30-45
	Coastal Bermuda	Perennial	sod	sprig	30-60
	Dallis grass	Perennial	bunch	seed	60-120
	Bahia	Perennial	sod	seed	60-120

Suitable Grasses

- Well established plant cover is essential for efficient performance of overland flow
- Primary purpose of plants is to facilitate treatment of wastewater
- Planting a mixture of different grasses usually gives best results
- Ryegrass used as a nurse crop; grows quickly until other grasses are established

Suitable Grasses

- Cool Season Grass – plant from Spring through early Summer or early Fall to late Fall
- Warm Season Grass – generally should be planted from late Spring through early Fall
- Planting time affected by expected rainfall, location, climate, grass variety, etc
- Amount of seed required to establish cover depends on:
  - Expected germination
  - Type of grass
  - Water availability
  - Time available for crop development

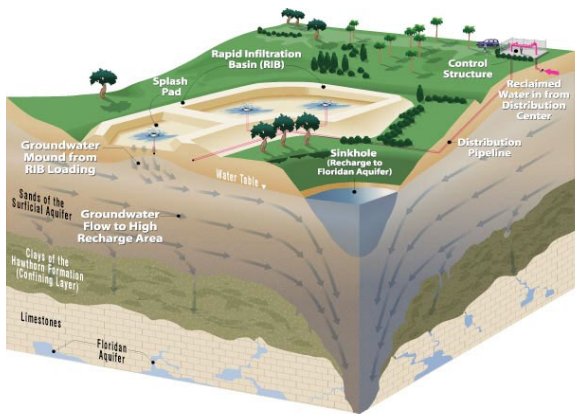
Overland Flow – Removal Efficiencies

Parameter	% Removal
BOD	92
Suspended Solids	92
Nitrogen	70-90
Phosphorus	40-80
Metals	50

- Treatment by oxidation and filtration
  - SS removed by filtration through vegetative cover
  - BOD oxidized by microorganisms in soil and on vegetative debris
  - Nitrogen removal by denitrification and plant uptake

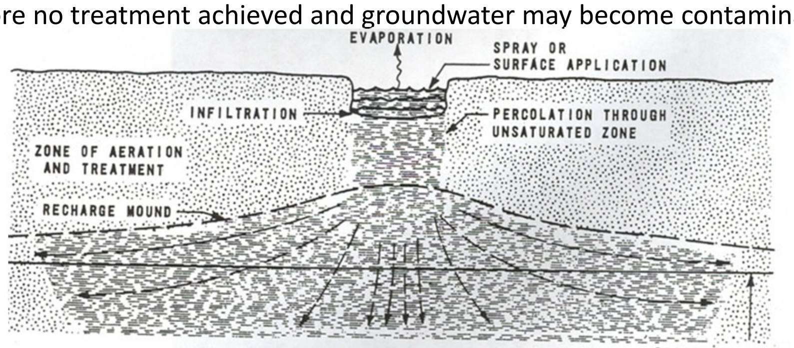
Rapid Infiltration

- Primary objective is to recharge the groundwater
- Wastewater is applied to spreading basins or seepage basins and allowed to percolate through the soil
- No plants are used or desired



Rapid Infiltration

- Treated effluent collected by drain tiles and discharged to surface water or it enters groundwater
- Not approved in Tennessee
  - Due to Karst topography – cracks in limestone provide direct route of infiltration to groundwater and therefore no treatment achieved and groundwater may become contaminated



(b) INFILTRATION–PERCOLATION

Rapid Infiltration

- Top– Picture of a seepage basin in Nevada
- Bottom - Large volumes of reclaimed water, which have undergone advanced secondary treatment, are reused through land-based applications in a 40-square-mile area near Orlando, Florida.

Land Treatment Limitations

- Sealing soil surface due to high SS in final effluent
  - More common in clay soils
  - Disk or plow field to break mats of solids
  - Apply water intermittently and allow surface mat to dry and crack
- Build up salts in soil
  - Salts are toxic to plants
  - Leach out the salts by applying fresh water
  - Rip up the soil 4 – 5 ft deep to encourage percolation

Land Treatment Limitations

- Excessive nitrate ions reach groundwater
  - Rain can soak soil so that no treatment is achieved
  - Do not apply nitrate in excess of crop's nitrogen uptake ability
  - Excessive nitrate in groundwater can lead to methylmoglobenemia (blue baby syndrome)
    - Too much nitrate consumed by child leads to nitrate in stomach and intestines where nitrogen is absorbed into bloodstream and it bonds to red blood cells preventing them from carrying oxygen.
    - Baby becomes oxygen deprived, turns blue and suffocates

Monitoring Requirements

Area	Test	Frequency
Effluent and groundwater or seepage	BOD	Two times per week
	Fecal coliform	Weekly
	Total coliform	Weekly
	Flow	Continuous
	Nitrogen	Weekly
	Phosphorus	Weekly
	Suspended solids	Two times per week
	pH	Daily
	Total dissolved solids (TDS)	Monthly
	Boron	Monthly
	Chloride	Monthly
Vegetation	- - - variable depending on crop - - -	
Soils	Conductivity	Two times per month
	pH	Two times per month
	Cation Exchange Capacity (CEC)	Two times per month

Water Quality Indicators

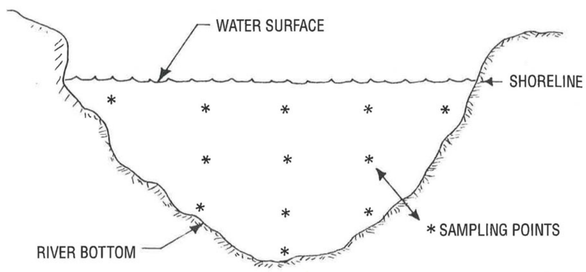
- Receiving water measurements = tests used to determine the effect of discharge on the receiving waters and on the beneficial uses (water supply, recreation, fishery) of the receiving waters after effluent has mixed with receiving waters
- To measure impact:
  - Take a measurement upstream (not affected) and downstream (affected) and compare the two results
- "Oxygen profile" (Dissolved oxygen) to get a good measure of the effect of the effluent
  - Measure the DO at several different cross sections downstream from discharge to find out where the lowest DO level occurs

Water Quality Indicators

- To determine impact, the following questions must be answered:

1. What are the characteristics upstream?
   - Temperature
   - Dissolved oxygen (DO)
2. What are the characteristics downstream?
3. If upstream and downstream are different, does the discharge cause the difference?
4. Are the downstream characteristics in violation of established standards or objectives
5. If downstream is in violation, did the discharge cause it?

Water Quality Indicators – DO profile



NOTE: Sampling points should be located near the shoreline and approximately one foot (0.3 m) below the water surface and one foot (0.3 m) above the bottom. The number of sampling points between the water surface and the bottom will depend on the depth of the water, and the number of vertical sampling sections will depend on the width of the stream. Total number of sampling points also will depend on budget, time, water quality indicators being sampled, and desired accuracy.

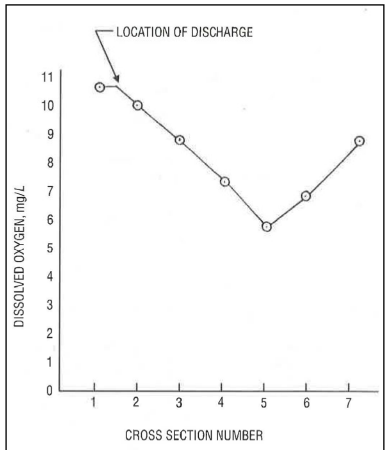


Fig. 13.4 Dissolved oxygen profile

Source: Operation of Wastewater Treatment Plants, Vol II, seventh ed., p.250-251

Water Quality Indicators

- If results do not look correct, do not reject outright. Investigate and attempt to identify the reasons for the result.
  - Sampling errors, testing errors, recording errors
- Sudden drop in DO downstream (without a similar drop upstream) indicates that the plant's BOD removal efficiency has decreased
- Sudden drop in DO could be caused by increase in temperature due to an industrial or stormwater discharge
- Sudden changes in effluent may be due to:

1. Process failure
2. Sudden increase in flow quantity
3. Change in influent characteristics such as industrial waste discharges into the system

Water Quality Indicators

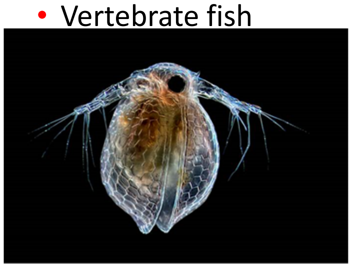
- Plant effluent analyzed prior to discharge:
  - In-stream: pH, D.O., temperature
  - In laboratory: BOD, COD, suspended solids, fecal coliforms, *E. coli*, N, P
- Disposal by dilution may require analysis of receiving stream upstream & downstream
  - WET testing (Whole Effluent Toxicity)

Whole Effluent Toxicity (WET) Testing

- Whole Effluent Toxicity (WET) test refers to the combined toxic effect to aquatic organisms from all pollutants contained in a wastewater effluent
  - Looks at the effluent as a single component
- WET tests measure wastewater's effects on specific test organisms' ability to survive, grow and reproduce
- Acute toxicity
  - Short term, lethal effects
  - "End of pipe" conditions
- Chronic toxicity
  - Long term, sub-lethal effects
  - Mixed water conditions
  - More sensitive test

Whole Effluent Toxicity (WET) Testing

- NPDES permit limits found in Sections 3.4, 3.5
- Methods for compliance with NPDES permits in 40 CFR 136.3
- Test organisms:
  - Water flea *(Ceriodaphnia dubia)*
    - Invertebrate crustacean
  - Fathead Minnow *(Pimephales promelas)*
    - Vertebrate fish



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Effluent Discharge, Reclamation, and Reuse Vocabulary

1. The term ______________________________ is used to describe any rivers, streams, lakes, estuaries, or oceans into which wastewater effluent is discharged. Direct discharge into these waters is the most common reuse method.
2. Chemicals are added to a sample in the field to prevent the water quality indicators of interest from changing before the analysis can be conducted in the laboratory; this is known as a ________________________________.
3. A ________________ sample is a single sample of water collected at a particular time and place that represents the composition of the water only at that time and place.
4. A collection of individual samples obtained at regular intervals – usually every one or two hours during a 24 hour period- which are combined to form a representative sample is known as a __________________________ sample.
5. The process in which an organism takes in oxygen for its life processes and gives off carbon dioxide is called ____________________________.
6. The process by which water vapor is released to the atmosphere from living plants; includes the total water removed by plants and by evaporation from soil, snow, and water surfaces. _________________________________
7. The most common form of land treatment for effluent disposal is ____________________, which includes ridge and furrow, sprinklers, surface/drip systems, and border strip flooding.
8. A type irrigation method, _____________________________ is a series of interconnected ditches (furrows) which allow for the distribution, infiltration, and treatment of wastewater.
9. Another form of irrigation, ____________________________ are broken into 3 categories: solid set (fixed), portable, or continuously moving.
10. This form of irrigation is used on highly impermeable soils; where wastewater is applied intermittently at top of terrace, slowly runs down the slope, and runoff is collected at the bottom for further treatment: ______________________________
11. One way to gauge the impact that effluent discharge is having on the receiving waters is to measure DO at several different cross sections downstream from the discharge to determine the lowest level; this is called a ______________________________.

12. The point, location, or structure where wastewater discharges from a sewer, drain, or other conduit is called the __________________________. These locations will be identified and numbered in your NPDES permit.

Word Bank

Composite

Irrigation

Surface waters

Ridge and furrow

Dissolved Oxygen profile (aka Oxygen profile)

Overland flow

Evapotranspiration

Respiration

Spray systems

Grab

Fixed sample

Outfall

Section 12
References & Need to Know

Grade 1 Wastewater Treatment Operator
Need-To-Know Criteria (Subject Areas)

The following list of categories suggests topics of information which are important to know in order to be a successful and proficient Grade 1 Wastewater Treatment Operator. The list may not be all inclusive, and knowledge of additional topics may be of benefit to the operator.

Category of Information: Processes

Collection Systems
- Types
- Inflow, Infiltration, Exfiltration
- Sources of wastewater
- Pre-treatment
- Pump stations

Flow
- Measurement
- Flow equalization

Screening
- Bar screens (hand-cleaned and mechanically cleaned)
- Static screen
- Microscreen
- Rotating screens

Grinding
- Grinders
- Comminutors
- Barminutors

Grit Removal
- Hand-cleaned grit chambers
- Mechanically-cleaned grit chambers
- Aerated grit chambers
- Vortex

Clarification
- Primary (Rectangular; Circular)
- Secondary

Attached Growth/Fixed Film
- Trickling Filters
  - Standard Rate
  - High Rate
  - Roughing
- Rotating Biological Contactor (RBC)
- Activated Biofilter (ABF)

Lagoons
- Aerobic
- Facultative
- Anaerobic
- Aerated
- Discharging
- Total Containment

Activated Sludge
- Conventional
- Step Feed
- Contact Stabilization
- Extended aeration
- Tapered aeration
- Oxidation ditch
- Types of aeration
- Sequencing Batch Reactor (SBR)
- Membrane Biological Reactor (MBR)

Solids handling
- Sludge conditioning
- Sludge thickening
- Anaerobic digesters
- Aerobic digesters
- Dewatering
- Drying beds
- Land application
- Composting
- 503 Regulations

Disinfection/ Use of Chlorine
- Chlorination
- Dechlorination
- UV
- Other methods

Advanced Treatment
- Nitrogen removal
- Biological

Effluent Disposal
- Discharge
- Direct Use
- Irrigation
- Underground Disposal
- NPDES Permit

Cross- Connection
- Prevention
- Types of devices

Category of Information: Support Systems

Motors
- Single Phase
- Poly Phase
- Variable Speed

Drives
- Coupled
- Direct (Shaft; Gear)
- Speed Reducer (Fixed; Variable)
- Right Angle

Pumps
- Air Lift
- Centrifugal
- Positive Displacement
  - Piston Plunger
  - Progressive Cavity
  - Diaphragm
- Screw
- Turbine
- Metering
- Ejector

Blowers and Compressors
- Centrifugal
- Positive Displacement (Rotary; Piston)

Generators – AC & DC

Engines – Gasoline, Diesel, Gas

Joints
- Flanged
- Compression
- Dresser
- Victualic
- Fused
- Threaded

Valves
- Ball
- Check
- Globe
- Gate
- Plug
- Petcock
- Pressure Control
- Vacuum Relief
- Mud
- Butterfly
- Multiport
- Telescoping
- Sluice Gate
- Air Release
- Foot
- Altitude

Fittings
- Coupling
- Union
- Plug/Caps
- Corporation (Ferrell; Cock)
- Curb Stop
- Special

Measuring/ Control
- Signal Generators
  - Kennison Nozzle
  - Magnetic Flowmeter
  - Parshall Flume
  - Proportional Weir
  - Rectangular Weir
  - Venturi
  - Propeller Meter
  - Ultrasonic
  - Pitot Tube
- Signal Transmitters
  - Electric
  - Pneumatic
  - Hydraulic
  - Mechanical
  - Telemetry
- Signal Receivers
  - Counters
  - Indicators
  - Log Scale Indicators
  - Totalizers
  - Recorders
  - Combination Recorders
- Meters
  - Hydraulic – Rotameter
  - Electrical – Amp
  - Electrical – Watt
  - Electrical – Watt – Hour
  - Electrical – Multi.
  - Electrical – VOM
  - Electrical – Megger
  - Mechanical – RPM
- Alarms
- Controls
  - Pneumatic
  - Float
  - Hydraulic
  - Electrical
  - Telemetry
  - Timers

Chemical Feeders
- Solids
- Liquids
- Evaporators
- Gas
- Slurry

Category of Information: Support Systems (continued)

Odor Control
- Biofilters
- Chemical Additives
- Scrubbers

Rolling Stock
- Service Vehicles
- Trucks
- Lawn Mowers
- Loaders
- Portable Pumps
- Generators

HVAC
- Fans

Safety Equipment
- Personal Protection Gear
- Traffic Control (Warning Devices; Barricades)
- Hazard Detectors
- First Aid/Hygiene

Category of Information: Lab Tests

Routine Tests
- B.O.D.
- Ammonia
- Chlorine Residual
- Coliform (Fecal)
- Dissolved oxygen
- E. coli
- Total Kjedahl nitrogen
- pH
- Phosphorus
- Solids
  - Settleable
  - Suspended
  - Total dissolved
  - Total
  - Volatile

Control Tests
- Centrifuge
- Alkalinity
- C.O.D.
- Nutrients
- Micro exam
- Nitrate - nitrite
- Oil and Grease
- Surfactants
- Temperature
- Total organic carbon
- Turbidity
- Volatile acids
- Settleability

Special Tests:
- Metals
- Chlorinated organics
- Cyanide
- Phenol
- Sulfate - sulfide
- Biomonitoring

Category of Information: General Information

Units of expression
- Define units
- Convert units

Sources and characteristics
- Characterize
- Quality/quantity
- Physical/chemical/biological
- Effects
- Pre-aeration
- Chemical pre-treatment
- Grease control

Electrical (Basic)

Hydraulics (Basic)

Maps/plans – Interpretation and use

WWT Processes
- Sketch sequence
- Describe processes
- Explain why treated
- Goals of WWT (protect public; protect environment)

Grade 2 Wastewater Treatment Operator
Need-To-Know Criteria (Subject Areas)

The following list of categories suggests topics of information which are important to know in order to be a successful and proficient Grade 2 Wastewater Treatment Operator. The list may not be all inclusive, and knowledge of additional topics may be of benefit to the operator.

Category of Information: Processes

Collection Systems
- Types
- Inflow, Infiltration, Exfiltration
- Sources of wastewater
- Pre-treatment
- Pump stations

Flow
- Measurement
- Flow equalization

Screening
- Bar screens (hand-cleaned)
- Bar screens (mechanically cleaned)
- Microscreen

Grinding
- Grinders
- Comminutors
- Barminutors

Grit Removal
- Hand-cleaned grit chambers
- Mechanically-cleaned grit chambers
- Aerated grit chambers
- Vortex

Clarification
- Primary (Rectangular; Circular)
- Secondary
- SBR Clarification

Attached Growth/Fixed Film
- Trickling Filters
    - Standard Rate
    - High Rate
    - Roughing
- Rotating Biological Contactor (RBC)
- Activated Biofilter (ABF)

Lagoons
- Aerobic
- Facultative
- Anaerobic
- Aerated
- Discharging
- Total Containment

Activated Sludge
- Conventional
- Step Feed
- Contact Stabilization
- Extended aeration
- Tapered aeration
- Complete mix
- Pure oxygen
- Oxidation ditch
- Types of aeration
- Sequencing Batch Reactor (SBR)
- Membrane Biological Reactor (MBR)

Solids handling
- Sludge conditioning
- Sludge thickening
- Anaerobic digesters
- Aerobic digesters
- Dewatering
- Incineration
- Drying beds
- Land application
- Composting
- 503 Regulations

Disinfection/ Use of Chlorine
- Chlorination
- Dechlorination
- UV
- Other methods

Advanced Treatment
- Filtration
- Nitrogen removal
- Phosphorus removal
- Biological

Effluent Disposal
- Discharge
- Direct Use
- Irrigation
- Underground Disposal
- NPDES Permit

Cross- Connection
- Prevention
- Types of devices

Category of Information: Support Systems

Motors

- Single Phase
- Poly Phase
- Variable Speed

Drives

- Coupled
- Direct (Shaft; Gear)
- Speed Reducer (Fixed; Variable)
- Right Angle

Pumps

- Air Lift
- Centrifugal
- Positive Displacement
    - Piston Plunger
    - Progressive Cavity
    - Diaphragm
- Screw
- Turbine
- Metering
- Ejector

Blowers and Compressors

- Centrifugal
- Positive Displacement (Rotary; Piston)

Generators – AC & DC

Engines – Gasoline, Diesel & Gas

Joints

- Flanged
- Compression
- Dresser
- Victualic
- Fused
- Threaded

Valves

- Ball
- Check
- Globe
- Gate
- Plug
- Petcock
- Pressure Control
- Vacuum Relief
- Mud
- Butterfly
- Multiport
- Telescoping
- Sluice Gate
- Air Release
- Foot
- Altitude

Fittings

- Coupling
- Union
- Plug/Caps
- Corporation (Ferrell; Cock)
- Curb Stop
- Special

Measuring/ Control

- Signal Generators
    - Kennison Nozzle
    - Magnetic Flowmeter
    - Parshall Flume
    - Proportional Weir
    - Rectangular Weir
    - Venturi
    - Propeller Meter
    - Ultrasonic
    - Pitot Tube
- Signal Transmitters
    - Electric
    - Pneumatic
    - Hydraulic
    - Mechanical
    - Telemetry
- Signal Receivers
    - Counters
    - Indicators
    - Log Scale Indicators
    - Totalizers
    - Recorders
    - Combination Recorders
- Meters
    - Hydraulic – Rotameter
    - Electrical – Amp
    - Electrical – Watt
    - Electrical – Watt – Hour
    - Electrical – Multi.
    - Electrical – VOM
    - Electrical – Megger
    - Mechanical – RPM
- Alarms
- Controls
    - Pneumatic
    - Float
    - Hydraulic
    - Electrical
    - Telemetry
    - Timers

Category of Information: Support Systems (continued)

Chemical Feeders
- Solids
- Liquids
- Evaporators
- Gas
- Slurry

Odor Control
- Biofilters
- Chemical Additives
- Scrubbers

Rolling Stock
- Service Vehicles
- Trucks
- Lawn Mowers
- Loaders
- Portable Pumps
- Generators

HVAC
- Heat Exchangers
- Dehumidifiers
- Fans
- Compressors

Safety Equipment
- Personal Protection Gear
- Traffic Control (Warning Devices; Barricades)
- Hazard Detectors
- First Aid/Hygiene

Category of Information: Lab Tests

Routine Tests
- B.O.D.
- Ammonia
- Chlorine Residual
- Coliform (Fecal)
- Dissolved oxygen
- E. coli
- Total Kjedahl nitrogen
- pH
- Phosphorus
- Solids
  - Settleable
  - Suspended
  - Total dissolved
  - Total
  - Volatile

Control Tests
- Centrifuge
- Alkalinity
- C.O.D.
- Color
- Conductance
- Nutrients
- Micro exam
- Nitrate - nitrite
- Oil and Grease
- Surfactants
- Temperature
- Total organic carbon
- Turbidity
- Volatile acids
- Settleability

Special Tests:
- Metals
- Chlorinated organics
- Cyanide
- Phenol
- Sulfate - sulfide
- Biomonitoring

Category of Information: General Information

Units of expression
- Define units
- Convert units

Sources and characteristics
- Characterize
- Quality/quantity
- Physical/chemical/biological
- Effects
- Pre-aeration
- Chemical pre-treatment
- Grease control

Electrical (Basic)

Hydraulics (Basic)

Category of Information: General Information(continued)

Maps/plans – Interpretation and use

WWT Processes

- Sketch sequence
- Describe processes
- Explain why treated
- Goals of WWT (protect public; protect environment)

Grade 3 Wastewater Treatment Operator
Need-To-Know Criteria

The following list of categories suggests topics of information which are important to know in order to be a successful and proficient Grade 4 Wastewater Treatment Operator. The list may not be all inclusive, and knowledge of additional topics may be of benefit to the operator

Category of Information: Processes

Collection Systems
- Types
- Inflow, Infiltration, Exfiltration
- Pre-treatment
- Sources of wastewater
- Pump stations

Flow
- Measurement
- Flow equalization

Screening
- Bar screens (hand-cleaned)
- Bar screens (mechanically cleaned)
- Static screen
- Microscreen

Grinding
- Grinders
- Comminutors
- Barminutors

Grit Removal
- Hand-cleaned grit chambers
- Mechanically-cleaned grit chambers
- Aerated grit chambers
- Vortex

Clarification
- Primary (Rectangular; Circular)
- Secondary
- SBR Clarification

Attached Growth/Fixed Film
- Trickling Filters
    - Standard Rate
    - High Rate
    - Roughing
- Rotating Biological Contactor (RBC)
- Activated Biofilter (ABF)

Lagoons
- Aerobic
- Facultative
- Anaerobic
- Aerated
- Discharging

Activated Sludge
- Conventional
- Step Feed
- Contact Stabilization
- Extended aeration
- Tapered aeration
- Complete mix
- Pure oxygen
- Oxidation ditch
- Types of aeration
- Sequencing Batch Reactor (SBR)
- Membrane Biological Reactor (MBR)

Solids handling
- Sludge conditioning
- Sludge thickening
- Anaerobic digestors
- Aerobic digestors
- Dewatering
- Incineration
- Drying beds
- Land application
- Composting
- 503 Regulations

Disinfection/ Use of Chlorine
- Chlorination
- Dechlorination
- UV
- Other methods

Advanced Treatment
- Filtration
- Nitrogen removal
- Phosphorus removal
- Biological

Effluent Disposal
- Discharge
- Direct Use
- Irrigation
- Underground Disposal
- NPDES Permit

Cross- Connection
- Prevention
- Types of devices

Category of Information: Support Systems

Motors

- Single Phase
- Poly Phase
- Variable Speed

Drives

- Coupled
- Direct (Shaft; Gear)
- Speed Reducer (Fixed; Variable)
- Right Angle

Pumps

- Air Lift
- Centrifugal
- Positive Displacement
    - Piston Plunger
    - Progressive Cavity
    - Diaphragm
- Screw
- Turbine
- Metering
- Ejector

Blowers and Compressors

- Centrifugal
- Positive Displacement (Rotary; Piston)

Generators – AC & DC

Engines – Gasoline, Diesel & Gas

Joints

- Flanged
- Compression
- Dresser
- Victualic
- Fused
- Threaded

Valves

- Ball
- Check
- Globe
- Gate
- Plug
- Petcock
- Pressure Control
- Vacuum Relief
- Mud
- Butterfly
- Multiport
- Telescoping
- Sluice Gate
- Air Release
- Foot
- Altitude

Fittings

- Coupling
- Union
- Plug/Caps
- Corporation (Ferrell; Cock)
- Curb Stop
- Special

Cathodic Protection Devices

- Anode Rod/Bags
- Cathode Rod/Bags
- Rectifiers
- Potentiometers

Measuring/ Control

- Signal Generators
    - Kennison Nozzle
    - Magnetic Flowmeter
    - Parshall Flume
    - Proportional Weir
    - Rectangular Weir
    - Venturi
    - Propeller Meter
    - Ultrasonic
    - Pitot Tube
- Signal Transmitters
    - Electric
    - Pneumatic
    - Hydraulic
    - Mechanical
    - Telemetry
- Signal Receivers
    - Counters
    - Indicators
    - Log Scale Indicators
    - Totalizers
    - Recorders
    - Combination Recorders
- Meters
    - Hydraulic – Rotameter
    - Electrical – Amp
    - Electrical – Watt
    - Electrical – Watt – Hour
    - Electrical – Multi.
    - Electrical – VOM
    - Electrical – Megger
    - Mechanical – RPM
- Alarms
- Controls
    - Pneumatic
    - Float
    - Hydraulic
    - Electrical
    - Telemetry
    - Timers

Category of Information: Support Systems (continued)

Chemical Feeders

- Solids
- Liquids
- Evaporators
- Gas
- Slurry

Odor Control

- Biofilters
- Chemical Additives
- Scrubbers

Rolling Stock

- Service Vehicles
- Trucks
- Tractors
- Trailers
- Lawn Mowers
- Loaders
- Portable Pumps
- Generators

HVAC

- Heat Exchangers
- Dehumidifiers
- Fans
- Compressors
- Condensers
- Boilers

Safety Equipment

- Personal Protection Gear
- Traffic Control (Warning Devices; Barricades)
- Hazard Detectors
- First Aid/Hygiene

Category of Information: Lab Tests

Routine Tests

- B.O.D.
- Ammonia
- Chlorine Residual
- Coliform (Fecal)
- E. coli
- Dissolved oxygen
- Total Kjedahl nitrogen
- pH
- Phosphorus
- Solids
  - Settleable
  - Suspended
  - Total dissolved
  - Total
  - Volatile

Control Tests

- Centrifuge
- Alkalinity
- C.O.D.
- Color
- Conductance
- Nutrients
- Micro exam
- Nitrate - nitrite
- Oil and Grease
- Surfactants
- Temperature
- Total organic carbon
- Turbidity
- Volatile acids
- Settleability
- Specific Oxygen Uptake Rate (SOUR)

Special Tests:

- Metals
- Chlorinated organics
- Cyanide
- Phenol
- Sulfate - sulfide
- Biomonitoring

Category of Information: General Information

Units of expression
- Define units
- Convert units

Electrical (Basic)

Hydraulics (Basic)

Maps/plans – Interpretation and use

Sources and characteristics
- Characterize
- Quality/quantity
- Physical/chemical/biological
- Effects
- Pre-aeration
- Chemical pre-treatment
- Grease control

WWT Processes
- Sketch sequence
- Describe processes
- Explain why treated
- Goals of WWT (protect public; protect environment)

Grade 4 Wastewater Treatment Operator
Need-To-Know Criteria (Subject Areas)

The following list of categories suggests topics of information which are important to know in order to be a successful and proficient Grade 4 Wastewater Treatment Operator. The list may not be all inclusive, and knowledge of additional topics may be of benefit to the operator.

Category of Information: Processes

Collection Systems
- Types
- Inflow, Infiltration, Exfiltration
- Pre-treatment
- Sources of wastewater
- Pump stations

Flow
- Measurement
- Flow equalization

Screening
- Bar screens (hand-cleaned)
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- Static screen
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- Grinders
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- Hand-cleaned grit chambers
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- Vortex

Clarification
- Primary (Rectangular; Circular)
- Secondary
- SBR Clarification

Attached Growth/Fixed Film
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Lagoons
- Aerobic
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- Aerated
- Discharging

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- Conventional
- Step Feed
- Contact Stabilization
- Extended aeration
- Tapered aeration
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- Sludge thickening
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- Incineration
- Drying beds
- Land application
- Composting
- 503 Regulations

Disinfection/ Use of Chlorine
- Chlorination
- Dechlorination
- UV
- Other methods

Advanced Treatment
- Filtration
- Nitrogen removal
- Phosphorus removal
- Biological

Effluent Disposal
- Discharge
- Direct Use
- Irrigation
- Underground Disposal
- NPDES Permit

Cross- Connection
- Prevention

- Types of devices

Category of Information: Support Systems

Motors

- Single Phase
- Poly Phase
- Variable Speed

Drives

- Coupled
- Direct (Shaft; Gear)
- Speed Reducer (Fixed; Variable)
- Right Angle

Pumps

- Air Lift
- Centrifugal
- Positive Displacement
    - Piston Plunger
    - Progressive Cavity
    - Diaphragm
- Screw
- Turbine
- Metering
- Ejector

Blowers and Compressors

- Centrifugal
- Positive Displacement (Rotary; Piston)

Generators – AC & DC

Engines – Gasoline, Diesel & Gas

Joints

- Flanged
- Compression
- Dresser
- Victualic
- Fused
- Threaded

Valves

- Ball
- Check
- Globe
- Gate
- Plug
- Petcock
- Pressure Control
- Vacuum Relief
- Mud
- Butterfly
- Multiport
- Telescoping
- Sluice Gate
- Air Release
- Foot
- Altitude

Fittings

- Coupling
- Union
- Plug/Caps
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Cathodic Protection Devices

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- Cathode Rod/Bags
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    - Rectangular Weir
    - Venturi
    - Propeller Meter
    - Ultrasonic
    - Pitot Tube
- Signal Transmitters
    - Electric
    - Pneumatic
    - Hydraulic
    - Mechanical
    - Telemetry
- Signal Receivers
    - Counters
    - Indicators
    - Log Scale Indicators
    - Totalizers
    - Recorders
    - Combination Recorders
- Meters
    - Hydraulic – Rotameter
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    - Electrical – Watt – Hour
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    - Electrical – VOM
    - Electrical – Megger
    - Mechanical – RPM
- Alarms
- Controls
    - Pneumatic
    - Float
    - Hydraulic
    - Electrical
    - Telemetry
    - Timers

Category of Information: Support Systems (continued)

Chemical Feeders
- Solids
- Liquids
- Evaporators
- Gas
- Slurry

Odor Control
- Biofilters
- Chemical Additives
- Scrubbers

Rolling Stock
- Service Vehicles
- Fork Lifts
- Trucks
- Tractors
- Trailers
- Lawn Mowers
- Loaders
- Portable Pumps
- Generators

HVAC
- Heat Exchangers
- Dehumidifiers
- Fans
- Compressors
- Condensers
- Boilers

Safety Equipment
- Personal Protection Gear
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- Hazard Detectors
- First Aid/Hygiene

Category of Information: Lab Tests

Routine Tests
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- E. coli
- Dissolved oxygen
- Total Kjedahl nitrogen
- pH
- Phosphorus
- Solids
    - Settleable
    - Suspended
    - Total dissolved
    - Total
    - Volatile

Control Tests
- Centrifuge
- Alkalinity
- C.O.D.
- Color
- Conductance
- Nutrients
- Micro exam
- Nitrate - nitrite
- Oil and Grease
- Surfactants
- Temperature
- Total organic carbon
- Turbidity
- Volatile acids
- Settleability
- Specific Oxygen Uptake Rate (SOUR)

Special Tests:
- Metals
- Chlorinated organics
- Cyanide
- Phenol
- Sulfate - sulfide
- Biomonitoring

Category of Information: General Information

Units of expression
- Define units
- Convert units

Electrical (Basic)

Hydraulics (Basic)

Sources and characteristics
- Characterize
- Quality/quantity
- Physical/chemical/biological
- Effects
- Pre-aeration
- Chemical pre-treatment
- Grease control

Maps/plans – Interpretation and use

WWT Processes
- Sketch sequence
- Describe processes
- Explain why treated
- Goals of WWT (protect public; protect environment)

Suggested Wastewater Treatment Exam References

The following are approved as reference sources for the ABC wastewater treatment examinations. Operators should use the latest edition of these reference sources to prepare for the exam.

Textbooks

California State University, Sacramento (CSUS) Foundation, Office of Water Programs (www.owp.csus.edu)

- Operation of Wastewater Treatment Plants, Volume I and II
- Advanced Waste Treatment
- Manage for Success

National Environmental Training Center for Small Communities (NETCSC)

- Protecting Your Community's Assets: A Guide for Small Wastewater Systems
  A PDF version of this guide is available from: www.nesc.wvu.edu/training.cfm

Water Environment Federation (www.wef.org)

- Operation of Municipal Wastewater Treatment Plants - Manual of Practice No. 11
- Activated Sludge - Manual of Practice OM-9

Regulations

- National Pollutant Discharge Elimination System (NPDES) Permit, State of Tennessee, Department of Environment and Conservation, Division of Water Resources, Nashville, TN, 1977, Latest Revision.

- Design Criteria for Sewage Works, State of Tennessee, Department of Environment and Conservation, Division of Water Resources, Nashville, Latest Revision.

- Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, Chapter 400-49-01, Latest Revision.

- State of Tennessee General Water Quality Criteria, and Permits, and Effluent Limitations and Standards State of Tennessee, Department of Environment and Conservation, Division of Water Resources, Nashville, TN, latest versions, Chapter 400-40-03 and Chapter 400-40-05.

- State of Tennessee Cross-Connection Control Manual, State of Tennessee Department of Environment and Conservation, Division of Water Resources, Latest Revision.

- Water and Wastewater Operator Certification Act T.C.A. Section 68-221-901. T.C.A. Section 68-221-915.
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Section 13
Answers

Section 1 Introduction

1. Water Pollution
2. Inflow
3. Nutrient
4. Coliforms
5. Stabilization
6. BOD
7. Primary Treatment
8. Infiltration
9. Sanitary, Stormwater, Combined
10. Organic
11. Secondary Treatment
12. Receiving waters
13. Effluent
14. Inorganic

Section 2 Preliminary Treatment

1. Diffuser
2. Grit
3. Hydrogen Sulfide
4. Mechanically, Screen
5. Fine
6. Wedgewire
7. Rotary Drum
8. Escalating Step Screen
9. Comminutor
10. Paint Filter Test
11. Septage
12. Grit Channel
13. Aerated Grit Chamber
14. Cyclonic Grit
15. Adsorption
16. Absorption
17. Flow Equalization

Section 3 Flow Measurement

1. Flow
2. Open Channel
3. Weir
4. Flume
5. Palmer-Bowlus
6. Converging Section
7. Throat
8. Closed Channel
9. Primary
10. Diverging
11. Parshall Flume
12. Head loss
13. Secondary
14. Flow Equalization

Section 4 Activated Sludge Systems

1. Absorption
2. Biomass
3. Activated Sludge
4. Adsorption
5. Aeration Basin
6. Facultative
7. MLSS
8. Aerobic, Anaerobic
9. Filamentous
10. MLVSS
11. Anoxic
12. Endogenous Respiration
13. Mixed Liquor
14. Zoogleal

Section 5 Fixed Film Systems

1. Biomass, Zoogleal film
2. Aerobic, Anaerobic
3. Distributor
4. Fixed-spray Nozzle
5. Nitrification
6. Humus Sludge
7. Series Operation, Parallel Operation
8. Ponding
9. Recirculation
10. Trickling Filter
11. 2 Stage Filter
12. Underdrain, Ventilation

Section 6 Sedimentation and Flotation

1. Sludge
2. Bulking
3. Septic
4. Flocculation
5. Gasification
6. Coagulant
7. Secondary clarifier
8. Short circuiting
9. Surface Loading Rate
10. Colloid
11. Solids Loading Rate
12. Detention time
13. Flights
14. Denitrification
15. Weir
16. Weir Overflow Rate
17. Primary Clarifier
18. Launder
19. SVI
20. Flotation
21. Sloughings

Section 7 Ponds and Lagoons

1. Stabilization Ponds
2. Polishing Pond
3. Overturn/Turnover
4. Parallel
5. Aerobic Ponds
6. Anaerobic Ponds
7. Bioflocculation
8. Oxidation Ponds
9. Facultative Ponds
10. Photosynthesis
11. Algae
12. Respiration
13. Series
14. Thermocline

Section 8 Disinfection

1. Pathogenic, Waterborne Disease
2. Disinfection, Sterilization
3. Free Chlorine
4. Combined Chlorine
5. Oxidizing Agent
6. Free Chlorine Residual
7. Post Chlorination
8. Chlorine Residual
9. Reducing Agent
10. Chlorine Demand
11. Prechlorination
12. Breakpoint Chlorination
13. Ozonation
14. Chlorination
15. UV Disinfection

Section 9 Effluent Disposal

1. Surface Waters
2. Fixed Sample
3. Grab
4. Composite
5. Respiration
6. Evapotranspiration
7. Irrigation
8. Ridge and Furrow
9. Spray Systems
10. Overland Flow
11. D.O. profile
12. Outfall

Section 10 WWTP Administration and Management

1. Authority
2. Organizing
3. Responsibility
4. Tailgate Safety Meeting
5. Ethics
6. Accountability
7. Delegation
8. Preventative
9. Critical Infrastructure
10. Vulnerability
11. Whistleblowing
12. Predictive

Section 11 Safety

1. Competent Person
2. Decibel
3. Lower Explosive Limit
4. Olfactory Fatigue
5. Oxygen Enrichment
6. Acute, Chronic
7. IDLH
8. Oxygen Deficiency
9. Sewer gas
10. Spoil
11. Confined Space
12. Carcinogen
13. Non-sparking tool
14. Engulfment
15. Permit-required
16. Non-permit
17. Septic
18. Mercaptans

Section 14
Handouts

Section 15
Notes