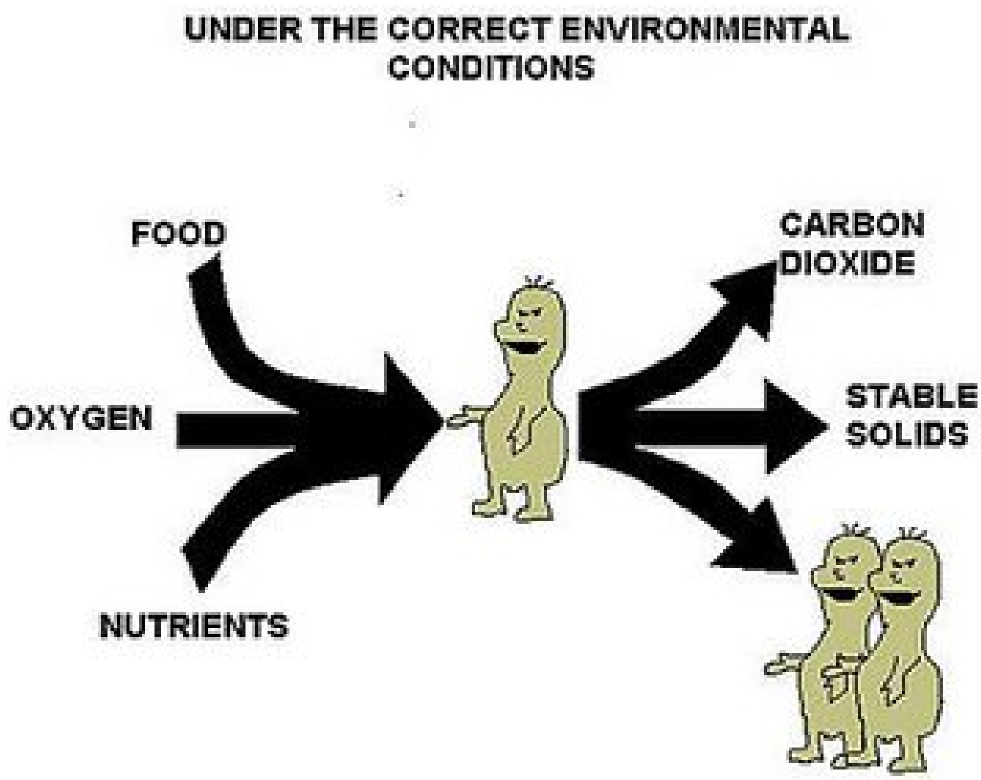
Wastewater Treatment
Grade 3 – 4

Week 2
Course #2201



Fleming Training Center

February 25 – March 1, 2012

http://tn.gov/environment/fleming/

Wastewater Treatment

State of Tennessee

GRADE 3 & 4
COURSE #2201
FEBRUARY 25— MARCH 1, 2013

Monday, February 25:

8:30	Review Exam # 1	Shannon
9:30	Tour	
12:00	LUNCH	
1:00	Maintenance	Shannon
2:30	Cross Connection Control	Dennis Conger

Tuesday, February 26:

8:30	Activated Sludge Math	Shannon
12:00	LUNCH	
1:00	Sampling/Laboratory Analyses	Shannon

Wednesday, February 27:

8:30	Trickling Filters	Shannon
10:45	Rotating Biological Contactors	Shannon
12:00	LUNCH	
1:00	Microscopic Exam	Shannon

Thursday, February 28:

8:30	Sludge Digestion and Solids Handling	Shannon
12:00	LUNCH	
1:00	Effluent Disposal	Shannon

Friday, March 1:

8:30	Math Review	Shannon
11:00	LUNCH	
12:00	Exam # 2 (Comprehensive)	Shannon

State of Tennessee

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Fleming Training Center

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Wastewater Treatment Grade 3 – 4

Week 2

Section 1

Activated Sludge Math

Applied Math for Wastewater Treatment
Activated Sludge

BOD or COD Loading, lbs/day

- This is the food part of the F/M ratio
- COD is sometimes used if there is a good correlation between it and BOD
- Loading guidelines for the 3 operational modes of Activated Sludge are:
    - High Rate
        - COD: greater than 1 lb COD/day/lb MLVSS under aeration
        - BOD: greater than 0.5 lb BOD/day/lb MLVSS under aeration
    - Conventional
        - COD: 0.5 to 1 lb COD/day/lb MLVSS under aeration
        - BOD: 0.25 to 0.5 lb BOD/day/lb MLVSS under aeration
    - Extended Aeration
        - COD: less than 0.2 lb COD/day/lb MLVSS under aeration
        - BOD: less than 0.1 lb BOD/day/lb MLVSS under aeration
- For untreated domestic wastewater, BOD = (0.4 to 0.8)(COD)

Solids Inventory in the Aeration Tank, lbs. MLSS or lbs. MLVSS

- In an activated sludge system, the solids under aeration must be controlled
- The SS in aeration tank are the MLSS
- MLVSS is an estimate of the microorganism population in the aeration tank.
- The MLVSS is typically 70% of the MLSS, the remaining 30% are fixed (or inorganic) solids

Food to Microorganism Ratio

- In order for an Activated Sludge system to operate properly, there must be a balance between the food (BOD or COD) and bugs in the aeration tank (MLVSS).
- The F/M ratio is a process control calculation used in many activated sludge plants
- Best F/M depends on the type of activated sludge system and the wastewater characteristics
- The F/M ratio is calculated from the amount of BOD or COD applied each day and from the solids inventory in the aeration tank.
- Typical ranges for F/M (using BOD):
    - Conventional ranges are 0.2-0.4
    - Extended Aeration ranges are 0.05-0.15

Mean Cell Residence Time (MCRT), days

- Also called SRT, Solids Retention Time
- Approach used for solids control, adjust WAS to maintain MCRT
- Most desirable MCRT for a plant is determined experimentally
- Typical ranges are:
    - Conventional plants MCRT is 5-15 days
    - Extended aeration MCRT is 20-30 days
- MCRT based on suspended solids leaving the system and includes the aeration tank and final clarifier
- Also can determine the type of bugs that predominate and therefore the degree of nitrification that may occur
    - From AWT Table 2.6: MCRT needed to produce nitrified effluent as related to temp
        - 10ºC – 30 days
        - 15ºC – 20 days
        - 20ºC – 15 days
        - 25ºC – 10 days
        - 30ºC – 7 days

Wasting Rates

- The amount of activated sludge wasted may vary from 1-20% of total incoming flow
- Expressed in lbs or gallons/day
- Wasting is the diverting of flow to primary clarifier, thickener, gravity belt thickener or aerobic or anaerobic digester

Applied Math for Wastewater Treatment
Activated Sludge

BOD or COD Loading, lbs/day

1. The flow to an aeration tank is 850,000 gpd. If the BOD content of the wastewater entering the aeration tank is 225 mg/L, how many pounds of BOD are applied to the aeration tank daily?

2. The flow to an aeration tank is 1200 gpm. If the COD concentration of the wastewater is 155 mg/L, what is the COD loading rate in lbs/day?

Solids Inventory in the Aeration Tank, lbs. MLSS or lbs. MLVSS

3. An aeration basin is 120 ft long, 45 ft wide and holds wastewater to a depth of 12 ft. If the aeration basin has an MLSS concentration of 2150 mg/L, how many pounds of MLSS are under aeration?

4. The aeration tank of a conventional activated sludge plant has an MLSS concentration of 2300 mg/L with a volatile solids content of 72%. If the volume of the aeration tank is 200,000 gallons, how many pounds of volatile solids are under aeration?

Food to Microorganism Ratio

5. An activated sludge aeration tank receives a primary effluent flow of 1.6 MGD with a BOD concentration of 180 mg/L. The mixed liquor volatile suspended solids is 2200 mg/L and the aeration tank volume is 420,000 gallons. What is the current F/M ratio?

6. The flow to a 195,000 gallon oxidation ditch is 365,000 gpd. The BOD concentration of the wastewater is 170 mg/L. If the MLSS concentration is 2550 mg/L with a volatile content of 70%, what is the F/M ratio?

7. The desired F/M ratio of an extended aeration activated sludge plant is 0.5 lbs COD/lb. MLVSS. If the 3.0 MGD primary effluent flow has a COD of 172 mg/L, how many lbs of MLVSS should be maintained in the aeration tank?

Mean Cell Residence Time (MCRT), days

8. An activated sludge system has a total of 28,500 lbs of mixed liquor suspended solids. The suspended solids leaving the final clarifier in the effluent is 400 lbs/day. The pounds suspended solids wasted from the final clarifier is 2910 lbs/day. What is the solids retention time (MCRT), days?

9. Determine MCRT given the following information:

Aeration Tank = 1,400,000 gal	MLSS = 2650 mg/L
Final Clarifier = 105,000 gal	S.E. SS = 22 mg/L
Flow = 3,000,000 gpd	CCSS = 1890 mg/L
WAS Pump Rate = 68,000 gpd	WAS = 6050 mg/L

Wasting Rates

10. Using Constant F/M Ratio: The desired F/M ratio for an activated sludge system is 0.6 lbs BOD/lb MLVSS. It has been calculated that 3300 lbs of BOD enter the aeration basin daily. If the volatile solids content of the MLSS is 68%, how many lbs MLSS are desired in the aeration basin?

11. Using Constant MCRT: The desired MCRT for an activated sludge plant is 8.5 days. The secondary effluent flow is 3.16 MGD with a suspended solids content of 22 mg/L. There is a total of 32,100 lbs SS in the system. How many lbs/day WAS SS must be wasted to maintain the desired MCRT?

Answers:

1. 1595 lbs BOD/day
2. 2234 lbs COD/day
3. 8691 lbs MLSS
4. 2762 lbs MLVSS
5. 0.31
6. 0.18
7. 8607 lbs MLVSS
8. 8.6 days
9. 8.2 days
10. 8088 lbs MLSS desired
11. 3197 lbs to waste

Applied Math for Wastewater Treatment
Activated Sludge

BOD or COD Loading, lbs/day pg. 10 in formula book

1. The flow to an aeration tank is 850,000 gpd. If the BOD content of the wastewater entering the aeration tank is 225 mg/L, how many pounds of BOD are applied to the aeration tank daily?

$$\text{lbs BOD/day} = (\text{BOD, mg/L})(\text{Flow, MGD})(8.34)$$
$$= (225\ \text{mg/L})(0.85\ \text{MG})(8.34)$$
$$= \boxed{1595\ \text{lbs/d}}$$

2. The flow to an aeration tank is 1200 gpm. If the COD concentration of the wastewater is 155 mg/L, what is the COD loading rate in lbs/day?

$$\frac{(1200\ \text{gpm})(1440)}{1{,}000{,}000} = 1.728\ \text{MGD}$$

$$\text{lbs COD/day} = (\text{COD, mg/L})(\text{Flow, MGD})(8.34)$$
$$= (155\ \text{mg/L})(1.728\ \text{MGD})(8.34)$$
$$= \boxed{2234\ \text{lbs/d}}$$

Solids Inventory in the Aeration Tank, lbs. MLSS or lbs. MLVSS

3. An aeration basin is 120 ft long, 45 ft wide and holds wastewater to a depth of 12 ft. If the aeration basin has an MLSS concentration of 2150 mg/L, how many pounds of MLSS are under aeration?

$$\text{aerator volume, gal} = (120\ \text{ft})(45\ \text{ft})(12\ \text{ft})(7.48) = 484{,}704\ \text{gal}$$

$$\text{MLSS, lbs} = (\text{MLSS, mg/L})(\text{Aer. Vol, MG})(8.34)$$
$$= (2150\ \text{mg/L})(0.484704\ \text{MG})(8.34)$$
$$= \boxed{8691\ \text{lbs MLSS}}$$

4. The aeration tank of a conventional activated sludge plant has an MLSS concentration of 2300 mg/L with a volatile solids content of 72%. If the volume of the aeration tank is 200,000 gallons, how many pounds of volatile solids are under aeration?

$$\text{MLVSS, lbs} = (\text{MLSS, mg/L})(\text{Aer. Vol., MG})(8.34)(\%\text{VS})$$
$$= (2300\text{ mg/L})(0.2\text{ MG})(8.34)(0.72)$$
$$= \boxed{2762\text{ lbs MLVSS}}$$

Food to Microorganism Ratio

5. An activated sludge aeration tank receives a primary effluent flow of 1.6 MGD with a BOD concentration of 180 mg/L. The mixed liquor volatile suspended solids is 2200 mg/L and the aeration tank volume is 420,000 gallons. What is the current F/M ratio?

$$F/M = \frac{(\text{BOD or COD, mg/L})(\text{Flow, MGD})(8.34)}{(\text{MLVSS, mg/L})(\text{Aer. Vol., MG})(8.34)}$$
$$= \frac{(180\text{ mg/L})(1.6\text{ MGD})(8.34)}{(2200\text{ mg/L})(0.42\text{ MG})(8.34)} = \frac{2401.92}{7706.16} = \boxed{0.31}$$

6. The flow to a 195,000 gallon oxidation ditch is 365,000 gpd. The BOD concentration of the wastewater is 170 mg/L. If the MLSS concentration is 2550 mg/L with a volatile content of 70%, what is the F/M ratio?

$$F/M = \frac{(170\text{ mg/L})(0.365\text{ MGD})(8.34)}{(2550\text{ mg/L})(0.195\text{ MG})(8.34)(0.70)}$$
$$= \frac{517.497}{2902.9455} = \boxed{0.18}$$

7. The desired F/M ratio of an extended aeration activated sludge plant is 0.5 lbs COD/lb. MLVSS. If the 3.0 MGD primary effluent flow has a COD of 172 mg/L, how many lbs of MLVSS should be maintained in the aeration tank?

$$\text{Desired MLVSS, lbs} = \frac{\text{BOD or COD, lbs}}{\text{Desired F/M ratio}}$$
$$= \frac{(172\text{ mg/L})(3.0\text{ MGD})(8.34)}{0.5}$$
$$= \boxed{8607\text{ lbs}}$$

Mean Cell Residence Time (MCRT), days pg. 11 formula book

8. An activated sludge system has a total of 28,500 lbs of mixed liquor suspended solids. The suspended solids leaving the final clarifier in the effluent is 400 lbs/day. The pounds suspended solids wasted from the final clarifier is 2910 lbs/day. What is the solids retention time (MCRT), days?

$$MCRT = \frac{\text{SS in System, lbs}}{\text{WAS, lbs/d} + \text{SE SS lbs/d}} = \frac{28{,}500 \text{ lbs}}{2910 \text{ lbs/d} + 400 \text{ lbs/d}}$$

$$= \frac{28{,}500 \text{ lbs}}{3310 \text{ lbs/d}}$$

$$= \boxed{8.6 \text{ days}}$$

9. Determine MCRT given the following information:

Aeration Tank = 1,400,000 gal
Final Clarifier = 105,000 gal
Flow = 3,000,000 gpd
WAS Pump Rate = 68,000 gpd

MLSS = 2650 mg/L
S.E. SS = 22 mg/L
CCSS = 1890 mg/L
WAS = 6050 mg/L

$$\text{MCRT, days} = \frac{(\text{MLSS, mg/L})(\text{Aer. Vol, MG})(8.34) + (\text{CCSS, mg/L})(\text{Final Clar., Vol})(8.34)}{(\text{WAS, SS mg/L})(\text{WAS Flow MGD})(8.34) + (\text{SE SS mg/L})(\text{Plant Flow})(8.34)}$$

$$= \frac{(2650)(1.4)(8.34) + (1890)(0.105)(8.34)}{(6050)(0.068)(8.34) + (22)(3.0)(8.34)}$$

$$= \frac{30941.4 + 1655.073}{3431.076 + 550.44} = \frac{32596.473}{3981.516} = \boxed{8.2 \text{ days}}$$

Wasting Rates

10. Using Constant F/M Ratio: The desired F/M ratio for an activated sludge system is 0.6 lbs BOD/lb MLVSS. It has been calculated that 3300 lbs of BOD enter the aeration basin daily. If the volatile solids content of the MLSS is 68%, how many lbs MLSS are desired in the aeration basin?

$$\text{Desired MLVSS, lbs} = \frac{3300 \text{ lbs BOD}}{0.6} = 5500 \text{ lbs}$$

$$\text{Desired MLSS, lbs} = \frac{5500 \text{ lbs MLVSS}}{0.68} = \boxed{8088 \text{ lbs}}$$

11. Using Constant MCRT: The desired MCRT for an activated sludge plant is 8.5 days. The secondary effluent flow is 3.16 MGD with a suspended solids content of 22 mg/L. There is a total of 32,100 lbs SS in the system. How many lbs/day WAS SS must be wasted to maintain the desired MCRT?

$$\text{WAS, lbs/d} = \frac{(\text{MLSS, mg/L})(\text{Aer. Vol, MG})(8.34)}{\text{MCRT, days}} - (\text{SE SS, mg/L})(\text{Plant Q})(8.34)$$

$$= \frac{32{,}100 \text{ lbs}}{8.5 \text{ days}} - (22 \text{ mg/L})(3.16 \text{ MGD})(8.34)$$

$$= 3776.4706 \text{ lbs/d} - 579.7968 \text{ lbs/d}$$

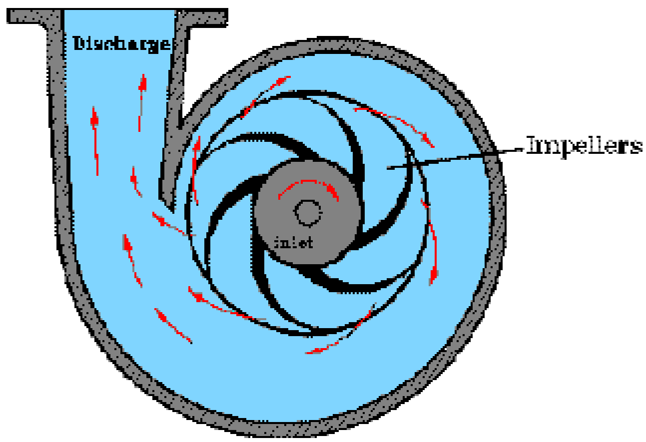
$$= \boxed{3197 \text{ lbs/d}}$$

Answers:

1. 1595 lbs BOD/day
2. 2234 lbs COD/day
3. 8691 lbs MLSS
4. 2762 lbs MLVSS
5. 0.31
6. 0.18
7. 8607 lbs MLVSS
8. 8.6 days
9. 8.2 days
10. 8088 lbs MLSS desired
11. 3197 lbs to waste

Section 2

Pumps and Equipment Maintenance



Wastewater Pumps and Equipment Maintenance

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

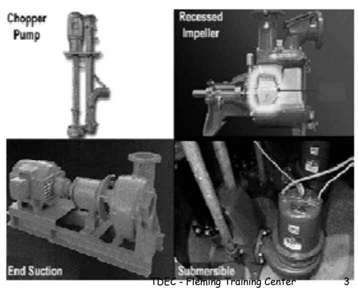
Wastewater Pumps

Raw wastewater pumps, Ames, IA

South Truckee Meadows, Reno, NV

Types of Pumps

- Classified by character of material handled:
  - Raw wastewater
  - Grit
  - Sludge
  - Effluent



Types of Pumps

- Velocity Pumps
- Positive-Displacement Pumps

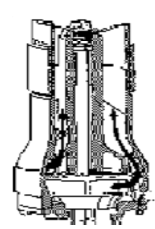
Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)

Volute

Velocity Pumps

- High velocity, low pressure water is converted to low velocity, high pressure water



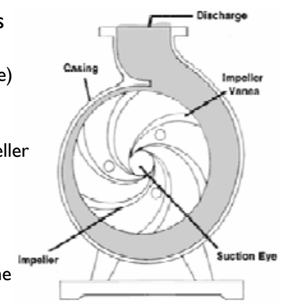
Diffuser

Velocity Pump Design Characteristics

- Axial - flow designs
  - Propeller shaped impeller adds head by lifting action on vanes
  - Water moves parallel to pump instead of being thrown outward
  - High volume, but limited head
  - Not self-priming

Velocity Pump Design Characteristics

- Radial flow designs
  - Water comes in through center (eye) of impeller
  - Water thrown outward from impeller to diffusers that convert velocity to pressure
  - The discharge is perpendicular to the pump shaft



Velocity Pump Design Characteristics

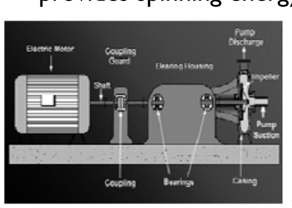
- Mixed - flow designs
  - Has features of axial and radial flow
  - Works well for water with solids

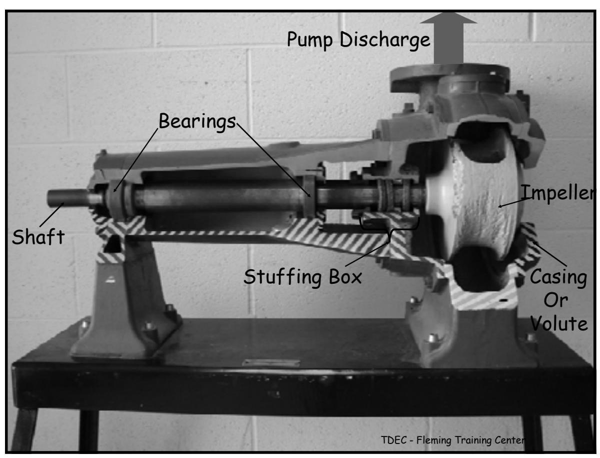
Types of Velocity Pumps

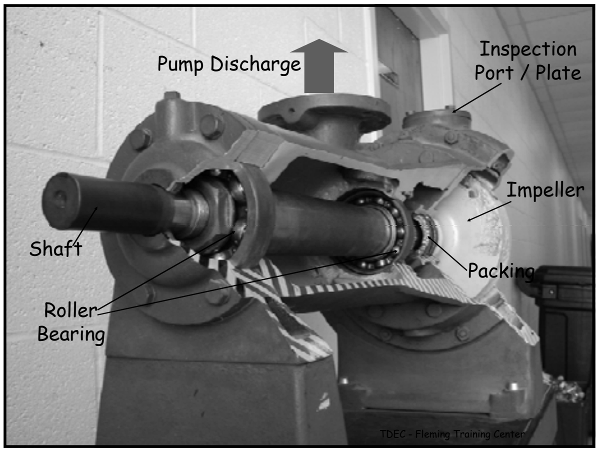
- Centrifugal pumps- most common type in wastewater lift stations
- Turbine pumps

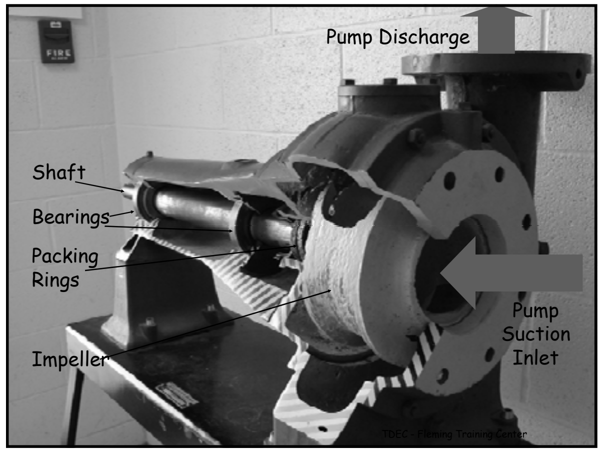
Submersible lift stations are designed to blend readily with natural surroundings, since there is no pump house and there is a minimum of above-ground equipment. Other advantages to below-ground installations are noise reductions and less safety-hazard concerns.

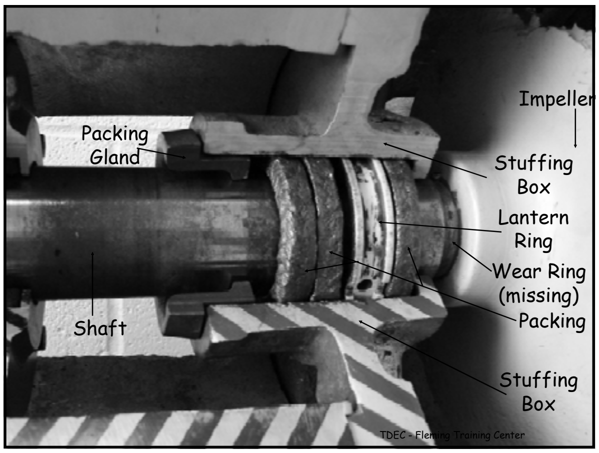
- Impeller rotates in sealed casing
- Impeller connected to motor which provides spinning energy





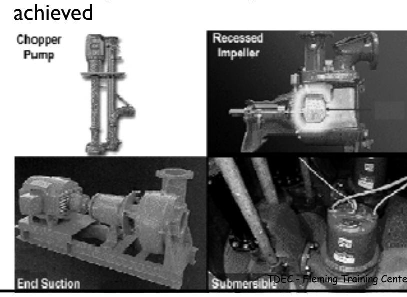






Centrifugal Pumps

- By varying size, shape, and width of impeller
- Wide range of flows and pressures can be achieved



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Self-Priming Pump Basics – Part 1

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Self-Priming Pump Basics – Part 2

GORMAN-RUPP PUMPS

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Vertical Turbine Pumps

- Impeller rotates in a channel of constant cross-sectional area
- Mixed or radial flow
- Create highest head available from velocity pumps

Vertical Turbine Pumps

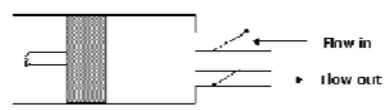
- Backflow limited
- Efficiencies up to 95% possible
- Water must be very clean

Positive-Displacement Pumps

- Sludge & chemical feed pumps
- Less efficient than centrifugal pumps
- Cannot operate against a closed discharge valve

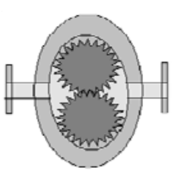
Positive-Displacement Pumps

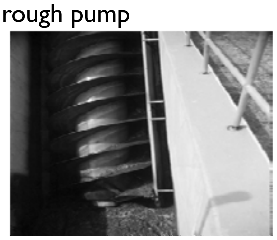
- Reciprocating (piston) pump - piston moves back and forth in cylinder, liquid enters and leaves through check valves



Positive-Displacement Pumps

- Rotary pump - Use lobes or gears to move liquid through pump





Incline screw pumps handle large solids without plugging

Screw Pumps

- Screw pumps are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge point

General Considerations

- Centrifugal pumps: wastewater
- Piston or diaphragm pumps: heavy solids
- Gear and piston pumps: high pressures
- Turbine or propeller pumps: mixing air or chemicals

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Centrifugal Pump Operation

- Pump Starting and Stopping -
  - Impeller must be submerged for a pump to start
  - Foot valve helps hold prime
  - Discharge valve should open slowly to control water hammer
  - In small pumps, a check valve closes immediately when pump stops to prevent flow reversal
  - In large pumps, discharge valve may close before pump stops

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Flow Control

- Flow usually controlled by starting and stopping pumps
- Throttling flow should be avoided - wastes energy
- Variable speed drives or motor are best way to vary flow

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Monitoring Operational Variables

- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

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Monitoring Operational Variables

- Suction and Discharge Heads
  - Pressure gauges
- Bearing and Motor Temperature
  - Temp indicators can shut down pump if temp gets too high
  - Check temp of motor by feel

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Monitoring Operational Variables

- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds

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Monitoring Operational Variables

- Likely causes of vibration
  - Bad bearings or bearing failure
  - Imbalance of rotating elements, damage to impeller
  - Misalignment from shifts in underlying foundation

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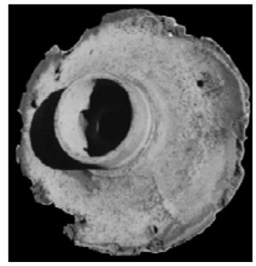
Monitoring Operational Variables



- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

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Monitoring Operational Variables

- Cavitation is a noise coming from a centrifugal pump that sounds like marbles trapped in the volute
- A condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound

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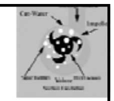
Suction Cavitation



- Suction Cavitation occurs when the pump suction is under a low pressure/high vacuum condition where the liquid turns into a vapor at the eye of the pump impeller.
- This vapor is carried over to the discharge side of the pump where it no longer sees vacuum and is compressed back into a liquid by the discharge pressure.
- This imploding action occurs violently and attacks the face of the impeller.
- An impeller that has been operating under a suction cavitation condition has large chunks of material removed from its face causing premature failure of the pump.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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Discharge Cavitation

- Discharge Cavitation occurs when the pump discharge is extremely high.
- It normally occurs in a pump that is running at less than 10% of its best efficiency point.
- The high discharge pressure causes the majority of the fluid to circulate inside the pump instead of being allowed to flow out the discharge.
- As the liquid flows around the impeller it must pass through the small clearance between the impeller and the pump cutwater at extremely high velocity.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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Discharge Cavitation

- This velocity causes a vacuum to develop at the cutwater similar to what occurs in a venturi and turns the liquid into a vapor.
- A pump that has been operating under these conditions shows premature wear of the impeller vane tips and the pump cutwater.
- In addition due to the high pressure condition premature failure of the pump mechanical seal and bearings can be expected and under extreme conditions will break the impeller shaft.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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Monitoring Operational Variables

- If a pump has packing glands, water should drip slowly
- If it has a mechanical seal, no leakage should occur

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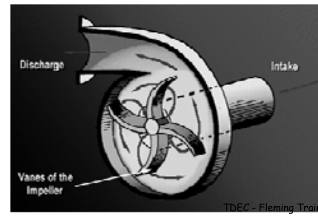
Mechanical Details of Centrifugal Pumps

- Casing
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape



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Mechanical Details of Centrifugal Pumps

- Impeller
  - Bronze or stainless steel
  - Closed; some single-suction have semi-open; open designs
  - Inspect regularly

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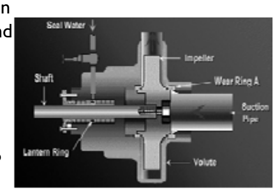
Mechanical Details of Centrifugal Pumps

- Wear rings
  - Restrict flow between impeller discharge and suction
  - Internal leakage is prevented by wear rings
    - Leakage reduces pump efficiency
  - Inspect regularly



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Mechanical Details of Centrifugal Pumps

- Shaft
  - Connects impeller to pump; steel or stainless steel
  - Should be repaired/replaced if grooves or scores appear on the shaft
- Shaft Sleeves
  - Protect shaft from wear from packing rings

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Mechanical Details of Centrifugal Pumps

- Packing Rings
  - Asbestos or metal ring lubricated with Teflon or graphite
  - Provides a seal where the shaft passes through the pump casing in order to keep air form being drawn or sucked into the pump and/or the water being pumped from coming out

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Mechanical Details of Centrifugal Pumps

- Packing Rings
  - If new packing leaks, stop the motor and repack the pump
  - Pumps need new packing when the gland or follower is pulled all the way down
  - The packing around the shaft should be tightened slowly, over a period of several hours to just enough to allow an occasional drop of liquid (20-60 drops per minute is desired)
    - Leakage acts as a lubricant
  - Joints of packing should be staggered at least 90^0

Mechanical Details of Centrifugal Pumps

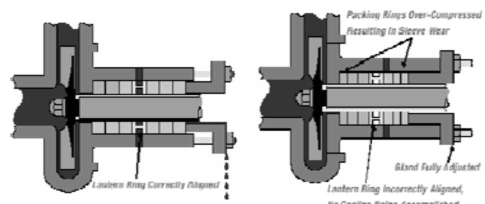
- Packing Rings
  - If packing is not maintained properly, the following troubles can arise:
    - Loss of suction due to air being allowed to enter pump
    - Shaft or shaft sleeve damage
    - Water or wastewater contaminating bearings
    - Flooding of pump station
    - Rust corrosion and unsightliness of pump and area

Packing Rings

- Advantages
  - Less expensive, short term
  - Can accommodate some looseness
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement

Mechanical Details of Centrifugal Pumps

- Lantern Rings
  - Perforated ring placed in stuffing box
  - Forms seal around shaft, helps keep air from entering the pump and lubricates packing

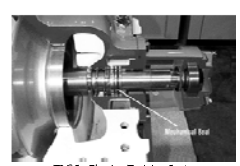


Mechanical Details of Centrifugal Pumps

- Mechanical Seals
  - Located in stuffing box
  - Prevents water from leaking along shaft; keeps air out of pump
  - Should not leak
  - Consists of a rotating ring and stationary element
  - The operating temperature on a mechanical seal should never exceed 160°F (71°C)

Mechanical Seal

- Advantages
  - Maintenance free
  - No wastewater leakage
  - Less wear on shaft and shaft sleeve
  - Should last for years
- Disadvantages
  - High initial cost
  - Great skill and care needed to replace



Mechanical Details of Centrifugal Pumps

- Bearings
  - Anti-friction devices for supporting and guiding pump and motor shafts
  - Get noisy as they wear out
  - If pump bearings are over lubricated, the bearings will overheat and can be damaged or fail
  - Types: ball, roller, sleeve

Mechanical Details of Centrifugal Pumps

- Couplings
  - Connect pump and motor shafts
  - Lubricated require greasing at 6 month intervals
  - Dry has rubber or elastomeric membrane

  - Calipers and thickness gauges can be used to check alignment on flexible couplings

Inspection and Maintenance

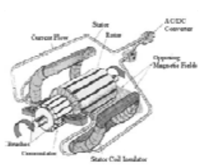
- Inspection and maintenance prolongs life of pumps
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

Inspection: Impellers

- Cavitation marks
- Chips, broken tips, corrosion, unusual wear
- Tightness on shaft
- Clearances
- Tears or bubbles (if rubber coated)


This impeller was damaged by cavitation

Pump Won't Start?



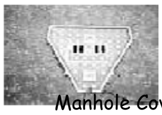
- Incorrect power supply
- No power supply
- Incorrectly connected
- Fuse out, loose or open connection
- Rotating parts of motor jammed mechanically
- Internal circuitry open

Pump Safety

- Machinery should always be turned off and locked out/tagged out before any work is performed on it
- Make sure all moving parts are free to move and all guards in place before restarting

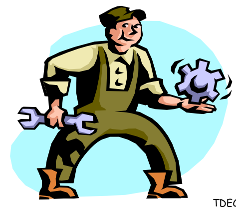
Pump Safety: Wet Wells

- Confined spaces
- Corrosion of ladder rungs
- Explosive atmospheres
- Hydrogen sulfide accumulation
- Slippery surfaces



Manhole Cover, London

Equipment Maintenance



Beware of Electricity

- Be careful around electrical panels, circuits, wiring, & equipment
  - Serious injury
  - Damage costly equipment
- Basic working knowledge is key

Tools, Meters & Testers

- Ammeter: records the current or amps in circuit

- Megger: checks insulation resistance on motors, feeders, grounds, and branch circuit wiring

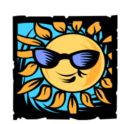
Tools, Meters & Testers

- **Ohmmeter**: measures resistance in a circuit. Tests fuses, relays, resistors and switches.

- **Voltage tester**: determines if circuit is energized, measures voltage, tests for blown fuses, single phasing of motors, and grounds

Need for Maintenance

- Performance and life of pumps and other equipment affected by:
  - Water
  - Dust
  - Humidity
  - Heat and cold
  - Vibration
  - Corrosive atmosphere

Need for Maintenance

- Inspect & maintain electrical equipment annually.
- Inspection should include:
  - Thorough examination
  - Replacement of worn & expendable parts
  - Operational checks & tests

Electrical Protective Devices: Fuses

- Protect control panel from excess voltage or amperage
- Fusible metal strip melts and breaks circuit
- One-time use devices

Electrical Protective Devices: Circuit Breaker

- Protect electrical systems from short circuiting
- Switch opens when current or voltage out of range
- Unlike fuse, can be reset

Transformer

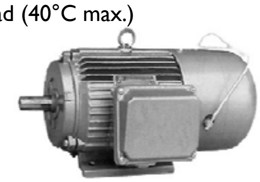
- Transformers are used to convert high voltage to low voltage
- High voltage is 440 volts or higher
- Standby engines should be run weekly to ensure that it is working properly
- Relays are used to protect electric motors

D.C. versus A.C.

- Direct current (D.C.) is flowing in one direction only an dis essentially free from pulsation
  - DC is seldom used in lift stations and wastewater treatment plants except in motor-generated sets, some control components of pump drives and standby lighting
  - DC is used exclusively in automotive equipment, certain types of welding equipment, and a variety of portable equipment
  - All batteries are DC
- Alternating current (A.C.) is periodic current that has alternating positive and negative values
  - AC are classified as:
    - Single phase
    - Two phase
    - Three phase or polyphase

A.C. Induction Motor

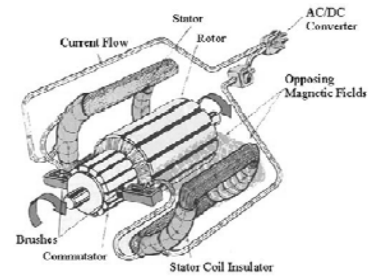
- Most common pump driver in wastewater pump stations
- Motors pull the most current on start up.
- Malfunction due to:
  - Thermal overload (40°C max.)
  - Contaminants
  - Single phasing
  - Old age
  - Rotor failure



Single-phase vs Three-phase

- Single-phase power is found in lighting systems, small pump motors, variable portable tools and throughout our homes.
  - It is usually 120 volts or 240 volts
  - Single phase means only one phase of power is supplied to the main electrical panel at 240 volts and the power supply has three wires or leads
    - 2 of these leads have 120 volts each, the other lead is neutral and usually coded white, which is grounded
- Three-phase power is generally used with motors and transformers found in lift stations and wastewater treatment plants
  - Generally all motors above 2 horsepower are three-phase

Motor Components



Motors

- In order to prevent damage, turn the circuit off immediately if the fuse on one of the legs of a three-phase circuit blows.
- An electric motor changes electrical energy into mechanical energy
- Power factors can be improved by:
  - Changing motor loading
  - Changing the motor type
  - Using capacitors

Motors

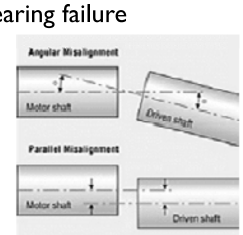
- Routine cleaning of pump motors includes:
  - Checking alignment and balance
  - Checking brushes
  - Removing dirt and moisture
  - Removal of obstructions that prevent air circulation
- Cool air extends the useful life of motors
- A motor (electrical or internal combustion) used to drive a pump is called a prime mover
- The speed at which the magnetic field rotates is called the motor synchronous speed and is expressed in rpm

Motors

- If a variable speed belt drive is not used for 30 days or more, shift the unit to minimum speed setting
- Emory cloth should not be used on electric motor components because it is electronically conductive and may contaminate parts
- Ohmmeters used to test a fuse in a motor starter circuit
- The most likely cause of a three-phase

Misalignment of Pump & Motor

- Excessive bearing loading
- Shaft bending
- Premature bearing failure
- Shaft damage



Compressors

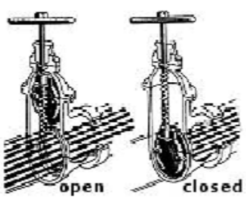
- Increase the pressure of air or gas
- Common uses:
  - Wastewater ejectors
  - Pump control systems (bubblers)
  - Water pressure systems
  - Portable pneumatic tools

Compressors

- Inspect suction filter at least monthly
- Lubrication
  - Oil bearings
  - Oil cup, grease fittings, crankcase reservoir
  - Change oil every 3 months (unless otherwise specified)
- Inspect belt tension
- Clean dirt, oil & grease at least monthly
- Drain condensate daily using valve on air receiver
- Examine operating controls

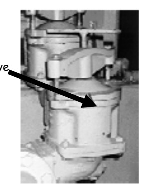
Valves

- Controlling device in piping systems to stop, regulate, check, or divert flow of liquids or gases
- Gate valve:
  - Open valve fully; reverse & close one-half turn
  - Operate all large valves at least yearly
  - Inspect valve stem packing for leaks; tighten if needed
  - Close valves slowly in pressure lines to prevent water hammer



Valves

- Check valves: discharge of pump to provide positive shut off from force main pressure & prevent force main from draining back into wet well



Valves

- Butterfly valves: often clog on sewer lines when installed to carry stormwater or wastewat

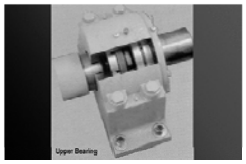
- Plug valves: less susceptible to plugging; sludge

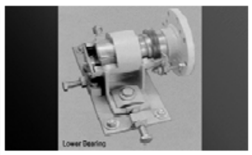
Lubrication

- Purposes:
  - Reduce friction between two surfaces
  - Remove heat due to friction
- Oils in service becomes acidic & may cause corrosion, deposits, sludging, etc.
- Oils & greases:
  - Can create fire hazard
  - Clean up spills immediately
  - Don't contaminate

Bearings

- Screw pumps are supported by 2 bearings, a ball or roller bearing above the flights & a sleeve bearing in the WW





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Bearings

- Usually last for years if serviced properly
- Failures:
  - Fatigue – excessive load
  - Contamination
  - Brinelling – improper mounting
  - Electric arching – leakage; short circuiting
  - Misalignment
  - Cam failure
  - Lubrication failure – dirty; too much; not enough; wrong kind

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Building Maintenance

- Keep facility clean, store tools in proper place
- Type of maintenance needed influenced by age, type & use of building
- Maintenance program includes:
  - Floors & roofs
  - Heating, cooling & ventilation
  - Lighting
  - Plumbing
  - Windows

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Pump Vocabulary

1. Axial-Flow Pump – a pump in which a propeller-like impeller forces water out in the direction parallel to the shaft. Also called a propeller pump.
2. Bearing – anti-friction device used to support and guide a pump and motor shafts.
3. Casing – the enclosure surrounding a pump impeller, into which the suction and discharge ports are machined.
4. Cavitation – a condition that can occur when pumps are run too fast or water is forced to change direction quickly. A partial vacuum forms near the pipe wall or impeller blade causing potentially rapid pitting of the metal.
5. Centrifugal Pumps – a pump consisting of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at high velocity, and the casing shape converts this velocity to pressure.
6. Closed-Coupled Pump – a pump assembly where the impeller is mounted on the shaft of the motor that drives the pump.
7. Diffuser Vanes – vanes installed within a pump casing on diffuser centrifugal pumps to change velocity head to pressure head.
8. Double-Suction Pump – a centrifugal pump in which the water enters from both sides of the impeller. Also called a split-case pump.
9. Foot Valve – a check valve placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe but closes to prevent water from passing out of it at the bottom end. Keeps prime.
10. Frame-Mounted Pump – a centrifugal pump in which the pump shaft is connected to the motor shaft with a coupling.
11. Impeller – the rotating set of vanes that forces water through the pump.
12. Jet Pump – a device that pumps fluid by converting the energy of a high-pressure fluid into that of a high-velocity fluid.
13. Lantern Ring – a perforated ring placed around the pump shaft in the stuffing box. Water from the pump discharge is piped to this ring. The water forms a liquid seal around the shaft and lubricates the packing.
14. Mechanical Seal – a seal placed on the pump shaft to prevent water from leaking from the pump along the shaft; the seal also prevents air from entering the pump.
15. Mixed-Flow Pump – a pump that imparts both radial and axial flow to the water.
16. Packing – rings of graphite-impregnated cotton, flax, or synthetic materials, used to control leakage along a valve stem or a pump shaft.
17. Packing Gland – a follower ring that compressed the packing in the stuffing box.
18. Positive Displacement Pump – a pump that delivers a precise volume of liquid for each stroke of the piston or rotation of the shaft.

19. Prime Mover – a source of power, such as an internal combustion engine or an electric motor, designed to supply force and motion to drive machinery, such as a pump.
20. Radial-Flow Pump – a pump that moves water by centrifugal force, spinning the water radially outward from the center of the impeller.
21. Reciprocating Pump – a type of positive-displacement pump consisting of a closed cylinder containing a piston or plunger to draw liquid into the cylinder through an inlet valve and forces it out through an outlet valve.
22. Rotary Pump – a type of positive-displacement pump consisting of elements resembling gears that rotate in a close-fitting pump case. The rotation of these elements alternately draws in and discharges the water being pumped.
23. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.
24. Stuffing Box – a portion of the pump casing through which the shaft extends and in which packing or a mechanical seal is placed to prevent leakage.
25. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.
26. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.
27. Velocity Pump – the general class of pumps that use a rapidly turning impeller to impart kinetic energy or velocity to fluids. The pump casing then converts this velocity head, in part, to pressure head. Also known as kinetic pumps.
28. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.
29. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head..
30. Water Hammer – the potentially damaging slam that occurs in a pipe when a sudden change in water velocity (usually as a result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.
31. Wear Rings – rings made of brass or bronze placed on the impeller and/or casing of a centrifugal pump to control the amount of water that is allowed to leak from the discharge to the suction side of the pump.

Equipment Maintenance Vocabulary

______1. Amperage
______2. Brinelling
______3. Cavitation
______4. Circuit
______5. Circuit Breaker
______6. Current
______7. Fuse
______8. Jogging
______9. Mandrel
______10. Megger
______11. Resistance
______12. Voltage

A. A safety device in an electric circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.
B. Tiny indentations (dents) high on the shoulder of the bearing race or bearing. A type of bearing failure.
C. A special tool used to push bearing in or to pull sleeves out. Also can be a gage used to measure for excessive deflection in a flexible conduit.
D. A protective device having a strip or wire of fusible metal that, when placed in a circuit, will melt and break the electric circuit if heated too much. High temperatures will develop in the fuse when a current flows through the fuse in excess of that which the circuit will carry safely.
E. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. This is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.
F. The electrical pressure available to cause a flow of current (amperage) when an electric circuit is closed.
G. The frequent starting and stopping of an electric motor.
H. A movement or flow of electricity.
I. An instrument used for checking the insulation resistance on motors, feeders, bus bar systems, grounds and branch circuit wiring.
J. The strength of an electric current measured in amperes. The amount of electric current flow, similar to the flow of water in gallons per minute.
K. That property of a conductor or wire that opposes the passage of a current, thus causing electrical energy to be transformed into heat.
L. The complete path of en electric current, including the generating apparatus or other source; or, a specific segment or section of the complete path.

Equipment Maintenance Questions

1. What are some of the uses of a voltage tester?

2. How often should motors and wirings be megged?

3. An ohmmeter is used to check the ohms of resistance in what control circuit components?

4. What are the <u>two</u> types of safety devices found in main electrical panels or control units?

5. What is the <u>most common pump driver</u> used in lift stations?

6. Why should inexperienced, unqualified or unauthorized persons and even qualified and authorized persons be extremely careful around electrical panels, circuits, wiring and equipment?

7. Under what conditions would you recommend the installation of a screw pump?

8. What are the <u>advantages</u> of a pneumatic ejector?

9. What is the <u>purpose</u> of packing?

10. What is the <u>purpose</u> of the lantern ring?

11. How often should impellers be inspected for wear?

12. What is the purpose of wear rings?

13. What causes cavitation?

14. How often should the suction filter of a compressor be cleaned?

15. How often should the condensate from the air receiver be drained?

16. What is the purpose of lubrication?

17. What precautions must be taken before oiling or greasing equipment?

18. If an ammeter reads higher than expected, the high current could produce
    a. “Freezing” of motor windings
    b. Irregular meter readings
    c. Lower than expected output horsepower
    d. Overheating and damage equipment

19. The <u>greatest cause</u> of electric motor failures is
    a. Bearing failures
    b. Contaminants
    c. Overload (thermal)
    d. Single phasing

20. Flexible shafting is used where the pump and driver are
    a. Coupled with belts
    b. Difficult to keep properly aligned
    c. Located relatively far apart
    d. Required to be coupled with universal joints

21. Never operate a compressor without the suction filter because dirt and foreign materials will cause
    a. Deterioration of lubricants
    b. Effluent contamination
    c. Excessive water
    d. Plugging of the rotors, pistons or blades

Answers to Vocabulary and Questions

Vocabulary:

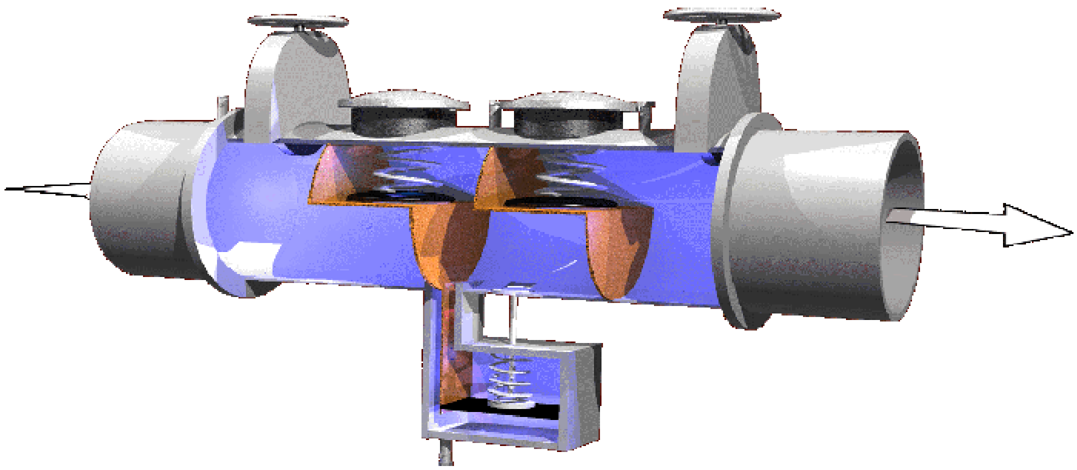
1. J	5. A	9. C
2. B	6. H	10. I
3. E	7. D	11. K
4. L	8. G	12. F

Questions:
1. A voltage tester can be used to test for voltage, open circuits, blown fuses, single phasing of motors and grounds.
2. At least once a year and twice a year if possible
3. Coils, fuses, relays, resistors and switches
4. Fuses and circuit breakers
5. A.C. induction motor
6. You can seriously injure yourself or damage costly equipment.
7. To pump fluctuating flows with large solids and rags.
8. They can handle limited flows with relatively large solids. Maintenance is not as complicated as the maintenance on most pumps; however, maintenance must be performed when scheduled.
9. To keep air from leaking in and water leaking out where the shaft passes through the casing

10. To allow outside water or grease to enter the packing for lubrication, flushing, and cooling and to prevent air from being sucked or drawn into the pump
11. Every 6 months or annually, depending on pumping conditions; if grit, sand or other abrasive material is being pumped, inspections should be more frequent
12. They protect the impeller and pump body from damage due to excessive wear.
13. Cavitation can be caused by a pump operating under different conditions than what it was designed for, such as off the design curve, poor suction conditions, high speed, air leaks into suction end and water hammer conditions.
14. The frequency of cleaning a suction filter on a compressor depends on the use of a compressor and the atmosphere around it. The filter should be inspected at least monthly and cleaned or replaced every three to six months. More frequent inspections, cleanings and replacements are required under dusty conditions such as operating a jackhammer on a street.
15. Daily
16. To reduce friction between two surfaces and to remove heat caused by friction
17. Shut it off, lock it out and tag it so it can't be started unexpectedly and injure you
18. D
19. C
20. C
21. C

Section 3

Cross Connection Control



Cross Connection Control

1

Authority

2

- Who has responsibility for the water served to the customer?
- Who has the responsibility to protect the water from Cross Connections?
- What can happen if the water supplier does NOT act responsibly in the area of cross connection control?

Authority

3

- Where does authority for the cross connection control program come from?
- What can the water provider do to protect their system from contamination? Ultimately?

Basics of Cross Connection Control

4

CROSS CONNECTION CONTROL MANUAL
EPA 816-R-03-002
WWW.EPA.GOV/SAFEWATER/CROSSCONNECTION.HTML

Flow of Water

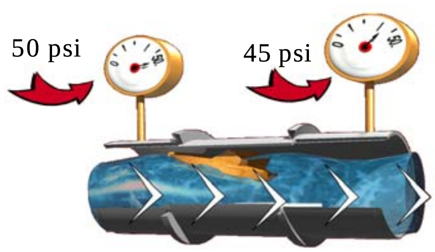
5

- Water pressure naturally tends to equalize

- Therefore, water flows from high pressure regions to low pressure regions

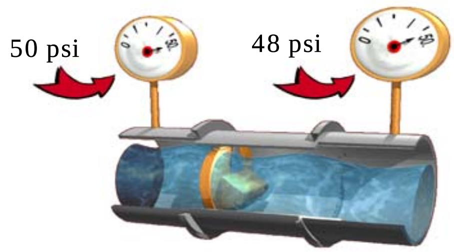
Normal Flow

6



No Flow

7



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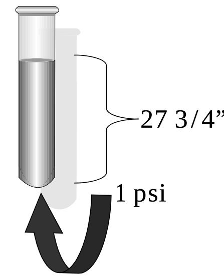
27 ¾” = 2.31 Feet of Head

8



- 27 3/4” of water generates a pressure of one pound per square inch (psi)

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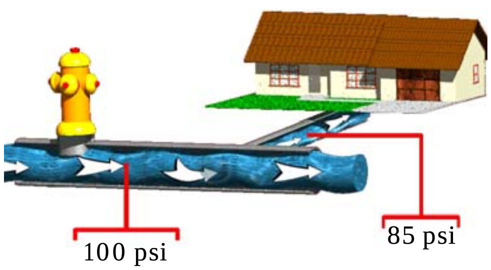
Normal Flow

9



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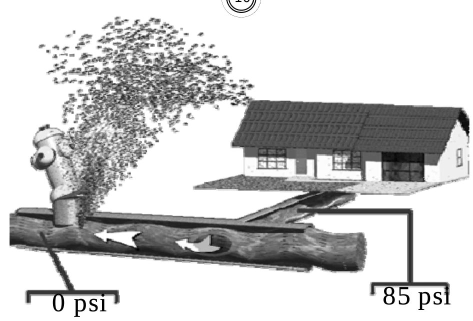
Reverse Flow

10



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Backflow

11

- The undesirable reversal of flow of water or other substances into the potable water distribution supply
- Occurs due to:
  - Backpressure
  - Backsiphonage

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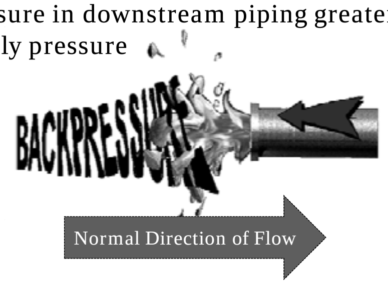
Backpressure

12

- Pressure in downstream piping greater than supply pressure



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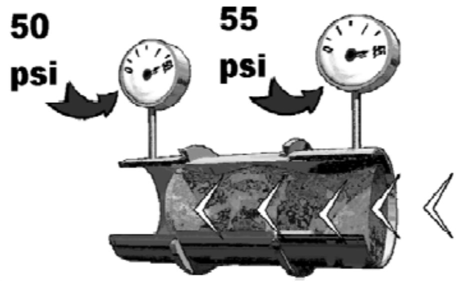
Backpressure

13



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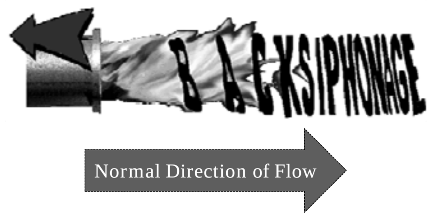
Backsiphonage

14

- Sub-atmospheric pressure in the water system



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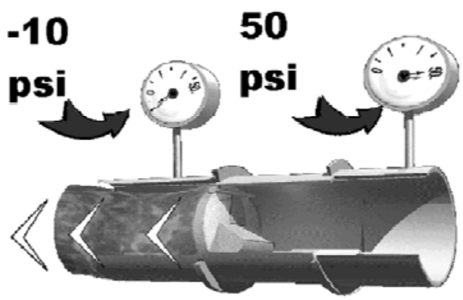
Backsiphonage

15



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Cross Connection

16

- An actual or potential connection between a potable water supply and any non-potable substance or source
- Cross connection types:
  - Direct
  - Indirect

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Direct Cross Connection

17

- A direct cross connection is subject to backpressure or backsiphonage

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Indirect Cross Connection

18

- An indirect cross connection is subject to backsiphonage only.

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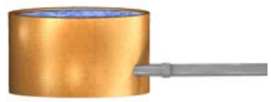
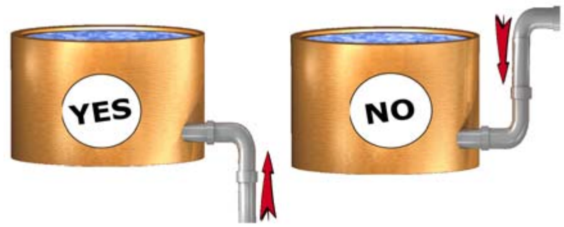
Indirect Cross Connection

19

Submerged Inlet	Low Inlet
	

Low Inlet

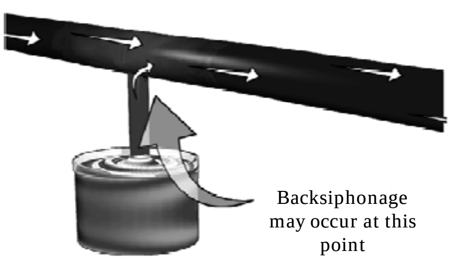
20



Direct Cross Connection?

Aspirator Effect

21



Degree of Hazard

22

- Non-Health Hazard
  - Low hazard
  - Will not cause illness or death
  - Pollutant
- Health Hazard
  - High hazard
  - Causes illness or death
  - Contaminant

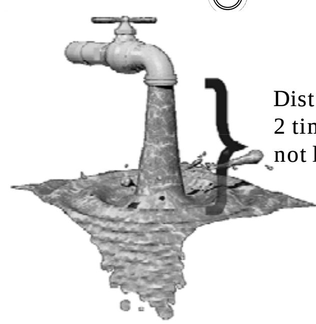
Five Means of Preventing Backflow

23

- Air Gap Separation
- Reduced Pressure Principle Assembly
- Double Check Valve Assembly
- Pressure Vacuum Breaker/ Spill-Resistant Vacuum Breaker
- Atmospheric Vacuum Breaker

Air Gap

24



Distance:
2 times the diameter,
not less than 1 inch

Approved Air Gap Separation

25

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	**Air Gap**	**Air Gap**	**Air Gap**
Non – Health Hazard	**Air Gap**	**Air Gap**	**Air Gap**

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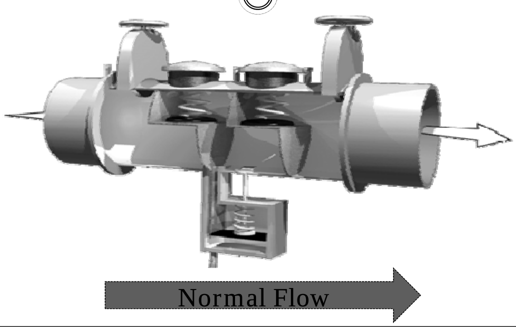
Reduced Pressure Principle Assembly

27



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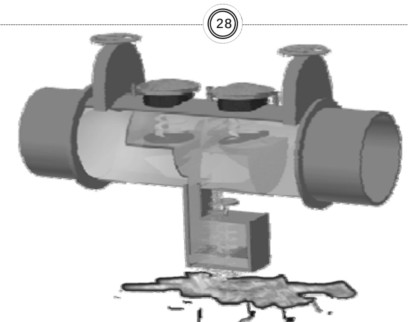
RP

28



Fouled Second Check with Backpressure

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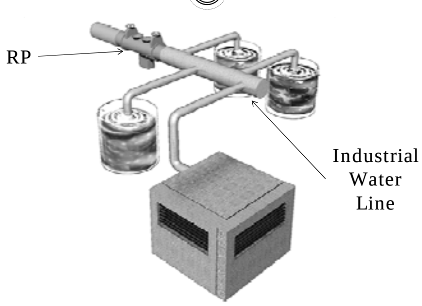
Where To Put an RP

29



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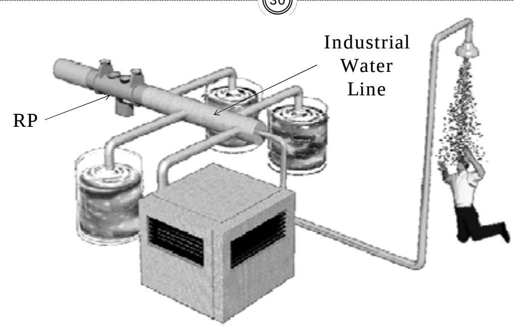
Where To Put an RP – Don't

30



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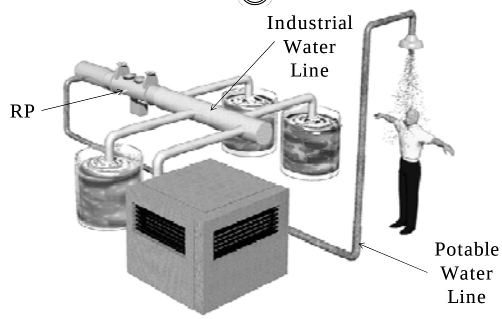
Where To Put an RP – Do

31



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RP

32

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	**RP**	**RP**
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	**RP**	**RP**

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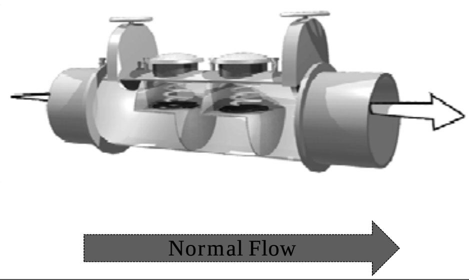
Double Check Valve Assembly (DC)

34



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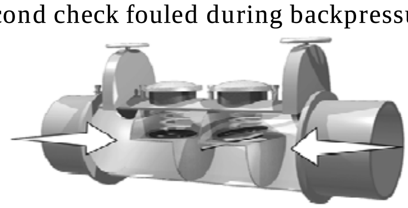
Double Check Valve Assembly (DC)

35

- Second check fouled during backpressure



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Double Check Valve Assembly (DC)

36

- Backsiphonage
- Backpressure
- Pollutant <u>only</u>

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	**DC**	**DC**

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Proper Installation for DC and RP

38

- USC Recommendations:
  - Minimum 12” above grade
  - Maximum 36” above grade
  - Accessibility for testing and repair
  - Weather/vandalism protection (if needed) with adequate drainage

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Proper Installation for DC and RP

39

- Backflow Preventers should only be installed vertically, if they have been specifically approved for vertical orientation

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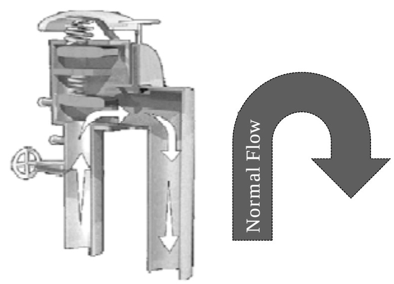
Pressure Vacuum Breaker (PVB)

40



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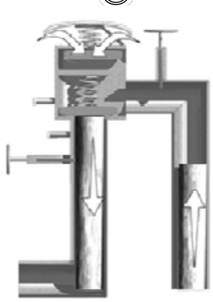
PVB Backsiphonage Condition

41



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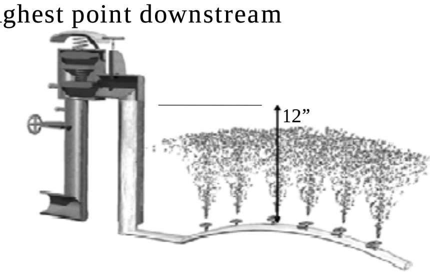
Installation of PVB

42

- Needs to be installed 12 inches above the highest point downstream



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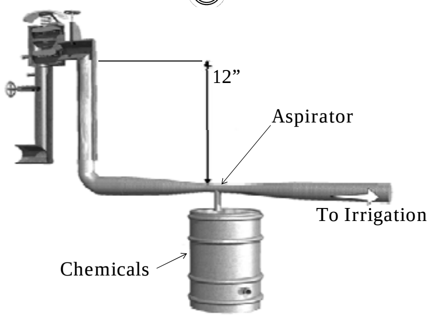
Pressure Vacuum Breaker

43



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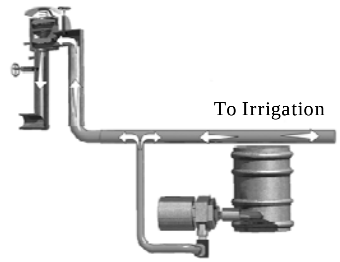
Pressure Vacuum Breaker

44

- Improper installation subject to backpressure



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Pressure Vacuum Breaker

45

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 12”

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	PVB	**PVB**	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	**PVB**	

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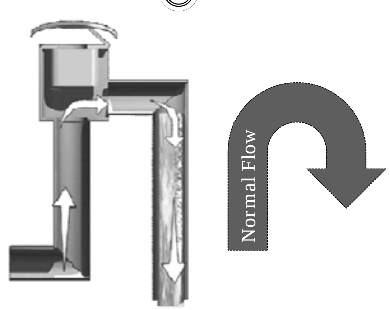
Atmospheric Vacuum Breaker (AVB)

47



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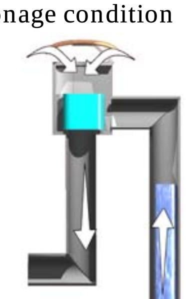
Atmospheric Vacuum Breaker (AVB)

48

- Backsiphonage condition



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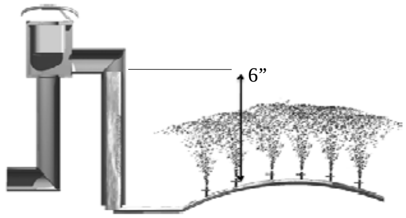
Installation of AVB

49

- Needs to be installed 6 inches above the highest point downstream



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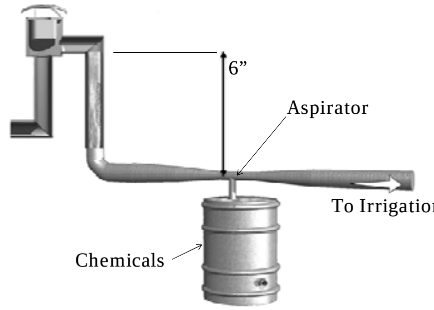
Atmospheric Vacuum Breaker

50



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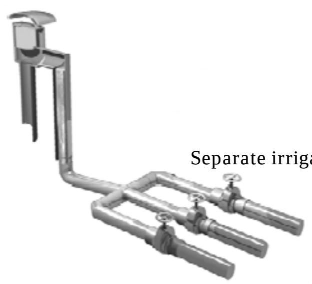
Atmospheric Vacuum Breaker

51

- Improper installation: downstream shutoff valves



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Atmospheric Vacuum Breaker

52

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 6”
- Non-Continuous Use

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	PVB	PVB	
		AVB	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	PVB	
		AVB	

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Testing of Assemblies

54

- Annual testing required
- Must be conducted by certified personnel

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Method/Device Review

55

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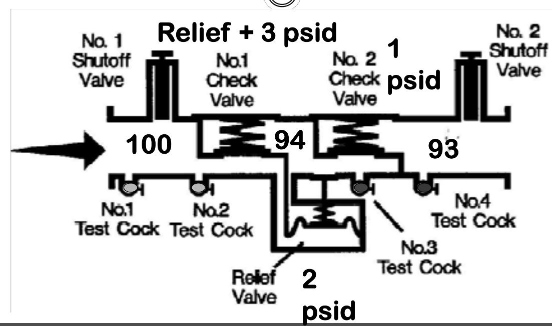
RP

56



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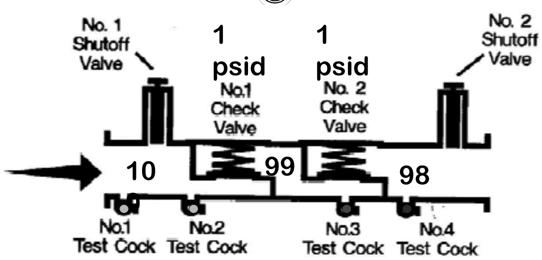
DC

57



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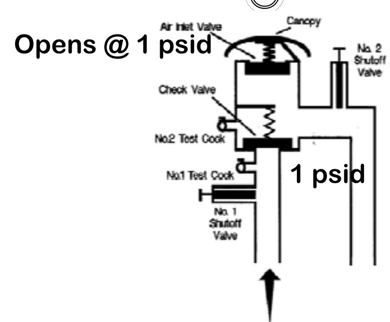
PVB

58



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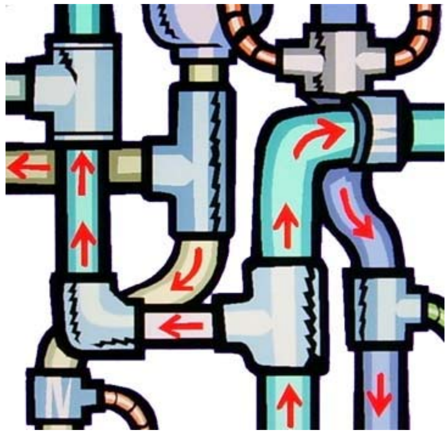


Vocabulary

Absolute Pressure – The total pressure; gauge pressure plus atmospheric pressure. Absolute pressure is generally measured in pounds per square inch (psi).

Air Gap – The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other device, and the flood-level rim of the receptacle. This is the most effective method for preventing backflow.

Atmospheric Pressure – The pressure exerted by the weight of the atmosphere (14.7 psi at sea level). As the elevation above sea increases, the atmospheric pressure decreases.

Backflow – The reversed flow of contaminated water, other liquids or gases into the distribution system of a potable water supply.

Backflow Prevention Device (Backflow Preventer) – Any device, method or construction used to prevent the backward flow of liquids into a potable distribution system.

Back Pressure (Superior Pressure) – (1) A condition in which the pressure in a nonpotable system is greater than the pressure in the potable distribution system. Superior pressure will cause nonpotable liquids to flow into the distribution system through unprotected cross connections. (2) A condition in which a substance is forced into a water systems because that substance is under higher pressure than the system pressure.

Backsiphonage – (1) Reversed flow of liquid cause by a partial vacuum in the potable distribution system. (2) A condition in which backflow occurs because the pressure in the distribution system is less than atmospheric pressure.

Bypass – Any arrangement of pipes, plumbing or hoses designed to divert the flow around an installed device through which the flow normally passes.

Chemical – A substance obtained by a chemical process or used for producing a chemical reaction.

Containment (Policy) – To confine potential contamination within the facility where it arises by installing a backflow prevention device at the meter or curbstop.

Contamination – The introduction into water of any substance that degrades the quality of the water, making it unfit for its intended use.

Continuous Pressure – A condition in which upstream pressure is applied continuously (more than 12 hours) to a device or fixture. Continuous pressure can cause mechanical parts within a device to freeze.

Cross Connection – (1) Any arrangement of pipes, fittings or devices that connects a nonpotable system to a potable system. (2) Any physical arrangement whereby a public water system is connected, either directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture or other waste or liquid of unknown or unsafe quality.

Cross Connection Control – The use of devices, methods and procedures to prevent contamination of a potable water supply through cross connections.

Degree of Hazard – The danger posed by a particular substance or set of circumstances. Generally, a low degree of hazard is one that does not affect health, but may be aesthetically objectionable. A high degree of hazard is one that could cause serious illness or death.

Direct Connection – Any arrangement of pipes, fixtures or devices connecting a potable water supply directly to a nonpotable source; for example, a boiler feed line.

Distribution System – All pipes, fitting and fixtures used to convey liquid from one point to another.

Double Check-Valve System Assembly – A device consisting of two check valves, test cocks and shutoff valves designed to prevent backflow.

Gauge Pressure – Pounds per square inch (psi) that are registered on a gauge. Gauge pressure measures only the amount of pressure above (or below) atmospheric pressure.

Indirect Connection – Any arrangement of pipes, fixtures or devices that indirectly connects a potable water supply to a nonpotable source; for example, submerged inlet to a tank.

Isolation (policy) – To confine a potential source of contamination to the nonpotable system being served; for example, to install a backflow prevention device on a laboratory faucet.

Liability – Obligated by law.

Negative Pressure – Pressure that is less than atmospheric; negative pressure in a pipe can induce a partial vacuum that can siphon nonpotable liquids into the potable distribution system.

Nonpotable – Any liquid that is not considered safe for human consumption.

Nontoxic – Not poisonous; a substance that will not cause illness or discomfort if consumed.

Physical Disconnection (Separation) – Removal of pipes, fittings or fixtures that connect a potable water supply to a nonpotable system or one of questionable quality.

Plumbing – Any arrangement of pipes, fittings, fixtures or other devices for the purpose of moving liquids from one point to another, generally within a single structure.

Poison – A substance that can kill, injure or impair a living organism.

Pollution – Contamination, generally with man-made waste.

Potable – Water (or other liquids) that are safe for human consumption.

Pressure – The weight (of air, water, etc.) exerted on a surface, generally expressed as pounds per square inch (psi).

Pressure Vacuum Breaker – A device consisting of one or two independently operating, spring-loaded check valves and an independently operating, spring-loaded air-inlet valve designed to prevent backsiphonage.

Reduced-Pressure-Principle or Reduced-Pressure-Zone Device (RP or RPZ) – A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the checks designed to protect against both backpressure and backsiphonage.

Refusal of Service (Shutoff Policy) – A formal policy adopted by a governing board to enable a utility to refuse or discontinue service where a known hazard exists and corrective measures are not undertaken.

Regulating Agency – Any local, state or federal authority given the power to issue rules or regulations having the force of law for the purpose of providing uniformity in details and procedures.

Relief Valve – A device designed to release air from a pipeline, or introduce air into a line if the internal pressure drops below atmospheric pressure.

Submerged Inlet – An arrangement of pipes, fittings or devices that introduces water into a nonpotable system below the flood-level rim of a receptacle.

Superior Pressure – See backpressure.

Test Cock – An appurtenance on a device or valve used for testing the device.

Toxic – Poisonous; a substance capable of causing injury or death.

Vacuum (Partial Vacuum) – A condition induced by negative (sub atmospheric) pressure that causes backsiphonage to occur.

Venturi Principle – As the velocity of water increases, the pressure decreases. The Venturi principle can induce a vacuum in a distribution system.

Waterborne Disease – Any disease that is capable of being transmitted through water.

Water Supplier (Purveyor) – An organization that is engaged in producing and/or distributing potable water for domestic use.

Some Cross-Connections and Potential Hazards

Connected System	Hazard Level
Sewage pumps	High
Boilers	High
Cooling towers	High
Flush valve toilets	High
Garden hose (sil cocks)	Low to high
Auxiliary water supply	Low to high
Aspirators	High
Dishwashers	Moderate
Car wash	Moderate to high
Photographic developers	Moderate to high
Commercial food processors	Low to moderate
Sinks	High
Chlorinators	High
Solar energy systems	Low to high
Sterilizers	High
Sprinkler systems	High
Water systems	Low to high
Swimming pools	Moderate
Plating vats	High
Laboratory glassware or washing equipment	High
Pump primers	Moderate to high
Baptismal founts	Moderate
Access hole flush	High
Agricultural pesticide mixing tanks	High
Irrigation systems	Low to high
Watering troughs	Moderate
Autopsy tables	High

Cross Connection Vocabulary

______1. Air Gap
______2. Atmospheric Vacuum Breaker
______3. Auxiliary Supply
______4. Backflow
______5. Back Pressure
______6. Backsiphonage
______7. Check Valve
______8. Cross Connection
______9. Feed Water
______10. Hose Bibb
______11. Overflow Rim
______12. Pressure Vacuum Breaker
______13. Reduced Pressure Zone Backflow Preventer
______14. RPBP

A. A valve designed to open in the direction of normal flow and close with the reversal of flow.
B. A hydraulic condition, caused by a difference in pressures, in which non-potable water or other fluids flow into a potable water system.
C. Reduced pressure backflow preventer.
D. In plumbing, the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other container, and the overflow rim of that container.
E. A backflow condition in which the pressure in the distribution system is less than atmospheric pressure.
F. A faucet to which a hose may be attached.
G. A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the check valves.
H. Any water source or system, other than potable water supply, that may be available in the building or premises.
I. Water that is added to a commercial or industrial system and subsequently used by the system, such as water that is fed to a boiler to produce steam.
J. A device designed to prevent backsiphonage, consisting of one or two independently operating spring-loaded check valves and an independently operating spring –loaded air-inlet valve.
K. A backflow condition in which a pump, elevated tank, boiler or other means results in a pressure greater than the supply pressure.
L. Any arrangement of pipes, fittings, fixtures or devices that connects a nonpotable water system.
M. The top edge of an open receptacle over which water will flow.
N. A mechanical device consisting of a float check valve and an air-inlet port designed to prevent backsiphonage.

Cross-Connections Review Questions

1. Define a cross-connection.

2. Explain what is meant by backsiphonage and backpressure.

3. List four situations that can cause negative pressure in a potable water supply.
    -
    -
    -
    -

4. List six waterborne diseases that are known to have occurred as a result of cross-connections.
    -
    -
    -
    -
    -
    -

5. What is the most reliable backflow-prevention method?

6. Is a single check valve position protection against backflow? Why or why not?

7. How often should a reduced-pressure-zone backflow preventer be tested?

8. In what position should an atmospheric vacuum breaker be installed relative to a shutoff valve? Why?

9. How does a vacuum breaker prevent backsiphonage?

10. List seven elements that are essential to implement and operate a cross-connection control program successfully?
    -
    -
    -
    -
    -
    -
    -

Vocabulary Answers:

1. D
2. N
3. H
4. B
5. K
6. E
7. A
8. L
9. I
10. F
11. M
12. J
13. G
14. C

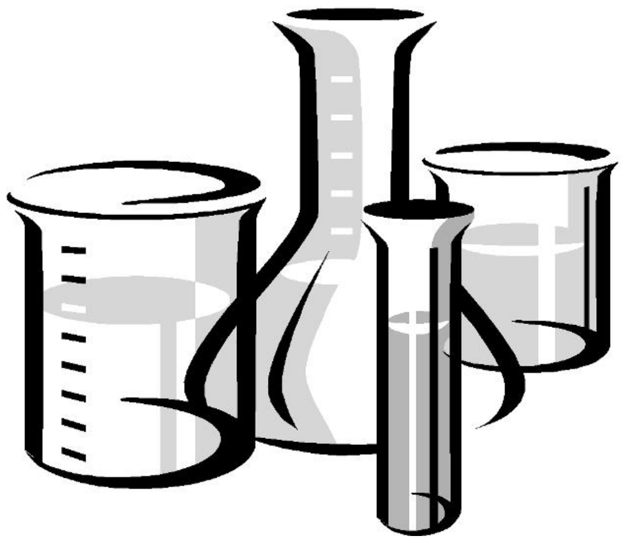
Review Question Answers:

1. A cross-connection is any connection or structural arrangement between a potable water system and a nonpotable system through which backflow can occur.

2. Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In more common terms, there is a partial vacuum on the potable system.
   Backpressure is a condition in which a substance is forced into a water system because that substance is under a higher pressure than system pressure.
3.
   - fire demand
   - a broken water main or exceptionally heavy water use at a lower elevation than the cross-connection
   - a booster pump used on a system
   - undersized piping
4.
   - typhoid fever
   - dysentery and gastroenteritis
   - salmonellosis
   - polio
   - hepatitis
   - brucellosis
5. The most reliable backflow prevention method is an air gap.
6. A single check valve is not considered positive protection against backflow. A check valve can easily be held partially open by debris, corrosion products or scale deposits.
7. Reduced-pressure-zone backflow preventers should be tested at least annually.
8. An atmospheric vacuum breaker must be installed downstream from the last shutoff valve. If it is placed where there will be continuing backpressure, the valve will be forced to remain open, even under backflow conditions.
9. When water stops flowing forward, a check valve drops, closing the water inlet and opening an atmospheric vent. This lets water in the breaker body drain out, breaking the partial vacuum in that part of the system.
10.
   - an adequate cross-connection control ordinance
   - an adequate organization with authority
   - a systematic surveillance program
   - follow-up procedures for compliance
   - provisions for backflow-prevention device approvals, inspection and maintenance
   - public awareness and information programs

Section 4

Lab



Wastewater Laboratory

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NPDES Permit

Effluent Characteristics	Effluent Limitations						Monitoring Requirements		
	Monthly Average Conc (mg/l)	Monthly Average Amount (lb/day)	Weekly Average Conc (mg/l)	Weekly Average Amount (lb/day)	Daily Maximum Conc (mg/l)	Daily Minimum Percent Removal	Measurement Frequency	Sample Type	Sampling Point
$CBOD_5$	5	83	7.5	125	10	40	3/week	composite	effluent
(May 1 - Oct. 31)	Report	—	—	—	Report	—	3/week	composite	influent
$CBOD_5$	15	250	20	333	25	40	3/week	composite	effluent
(Nov. 1 - April 30)	Report	—	—	—	Report	—	3/week	composite	influent
Ammonia as N (May 1 - Oct. 31)	1.2	20	1.0	30	2.4	—	3/week	composite	effluent
Ammonia as N (Nov. 1 - April 30)	2.8	47	4.2	70	5.6	—	3/week	composite	effluent
Total Nitrogen* (May 1 - Oct. 31)	Report	—	—	—	Report	—	2/month	composite	effluent
Total Phosphorous* (May 1 - Oct. 31)	Report	—	—	—	Report	—	2/month	composite	effluent
Suspended Solids	30	500	40	667	45	40	3/week	composite	effluent
(May 1 - Oct. 31)	Report	—	—	—	Report	—	3/week	composite	influent
Suspended Solids							3/week	composite	effluent
(Nov. 1 - April 30)	Report	—	—	—	Report	—	3/week	composite	influent
Sanitary Sewer Overflows, Total Occurrences	Report						continuous	visual	NA
Dry Weather Overflows, Total Occurrences	Report						continuous	visual	NA
Bypass of Treatment, Total Occurrences	Report						continuous	visual	NA

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- Sampling and data collection also help in managing the activated sludge process.

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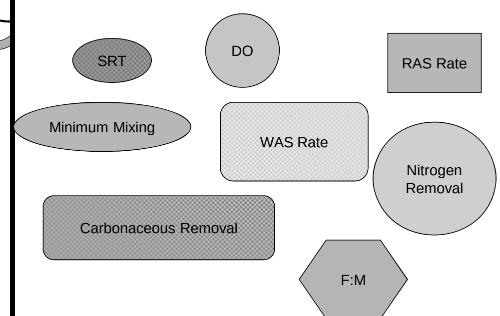
Common Wastewater Parameters



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Reliable sampling data are obtained by collecting samples:

- At the right location
- In the correct manner
- At the right time

Operator with Improvised Sampling Device

Automated Samplers

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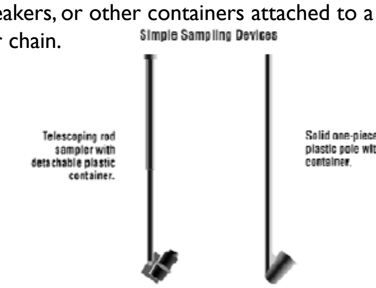
Samplers

- Sampling devices may include weighted buckets, beakers, or other containers attached to a rod or chain.



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Sample Types

- The two types of samples typically taken for an activated sludge process are:
  - Grab
  - Composite

Grab Samples

- Single volume of water
- Representative of water quality at exact time and place of sampling
- Grab samples are used to test for unstable parameters that could change if the sample were allowed to stand for any length of time
  - DO
  - pH
  - Chlorine residual
  - Temperature
  - E. coli and/or fecal coliform

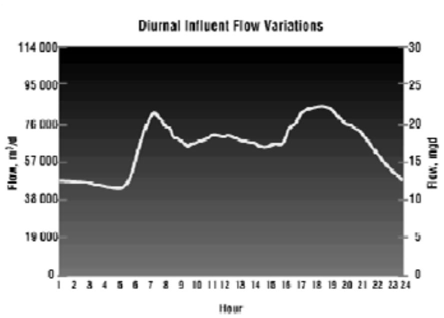
Composite Sample

- Representative of average water quality of location over a period of time
- Series of grab samples mixed together
- Determines average concentration
- Not suitable for all tests

Composite Sample

- Fixed volume or time composite; and
- Flow proportioned.

Flow Variations



Example of Flow-Proportioned Sample Collection

Time	Flow	Sample Volume
10:00 am	18 MGD	180 mL
10:00 pm	12 MGD	120 mL

Composite Sample

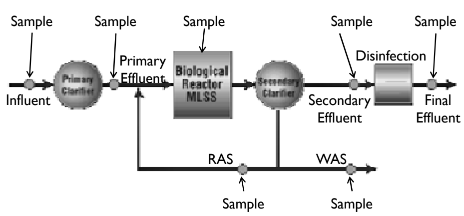
- Composite sampling is used when:
  - This is required by the permit
  - Plant removal efficiencies are calculated
  - Average data are needed to make process adjustments

Sample Volume and Storage

- Volume depends on test requirements
- Use proper sampling container
- Follow recommended holding times and preservation methods
  - If bottle already has preservative or dechlorinator in it, don't over fill or rinse out

✓ If you have questions regarding volume, container or holding times, check *40 CFR 136 Table II* or contact the lab if you have an outside lab do your analysis

Sample Points



Process Monitoring and Control Tests

- $cBOD_5$
- MLSS
- MLVSS
- Centrifuge (spin) Test
- Microscopic Examination
- SOUR
- Temp
- Depth of Blanket
- Thirty-minute settleometer
- SVI
- pH
- DO
- Nitrogen
  - Ammonia
  - Nitrate
  - Nitrite
  - Total Kjeldalh (TKN)

Analysis

- When you are ready to perform tests, refer to specific methods in *Standard Methods for the Examination of Water and Wastewater*

Suggested sampling locations, typical analyses performed, sampling frequencies, and type of sample required for wastewater treatment unit processes (continued)

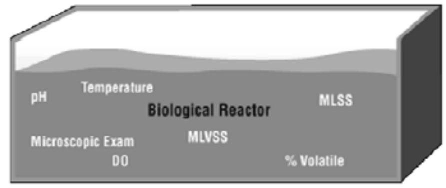
Unit processes	Sampling location	Anaylsis	Use [a]	Sample Frequency [a]	Sample Type [a]
Activated sludge	Primary effluent	BOD	PP	D[b]	C
		TSS	PP	D[b]	C
		pH	PC	D[b]	G
	Mixed liquor	DO	PC	D	G
		Temperature	PC	D	G
		TSS	PC	D[b]	C
		VSS	PC	D[b]	C
		NO_3	PC	W	G
	Return sludge	TSS	PC	D[b]	C
	Final settling tank effluent	BOD	PP	D[b]	C
		TSS	PP	D[b]	C
		DO	PP	D	G
		Fecal coliform	PP	D[b]	G
		Chlorine residual	PP	D	G
		pH	PP	D	G
		TKN	PP	W	G
		NH_3	PP	W	G
		NO_2	PP	W	G
		NO_3	PP	W	G

[a] *D= daily W= weekly C= composite sample G= grab sample PC= process control and PP= plant performance.*

[b] *Frequency could be reduced if the discharge permit allowed and/or process upsets were infrequent.*

Parameter No./name	Container [1]	Preservation [2,3]	Maximum holding time
Table IA—Bacterial Tests:			
1–5. Coliform, total, fecal, and *E. coli*	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	6 hours.[22,23]
6. Fecal streptococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	6 hours.[22]
7. Enterococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	6 hours.[22]
8. Salmonella	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	6 hours.[22]
Table IA—Aquatic Toxicity Tests:			
9–11. Toxicity, acute and chronic	P, FP, G	Cool, ≤6 °C[16]	36 hours.
Table IB—Inorganic Tests:			
1. Acidity	P, FP, G	Cool, ≤6 °C[18]	14 days.
2. Alkalinity	P, FP, G	Cool, ≤6 °C[18]	14 days.
4. Ammonia	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.
9. Biochemical oxygen demand	P, FP, G	Cool, ≤6 °C[18]	48 hours.
10. Boron	P, FP, or Quartz	HNO_3 to pH<2	6 months.
11. Bromide	P, FP, G	None required	28 days.
14. Biochemical oxygen demand, carbonaceous.	P, FP G	Cool, ≤6 °C[18]	48 hours.
15. Chemical oxygen demand	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.
16. Chloride	P, FP, G	None required	28 days.
17. Chlorine, total residual	P, G	None required	Analyze within 15 minutes.
21. Color	P, FP, G	Cool, ≤6 °C[18]	48 hours.
23–24. Cyanide, total or available (or CATC)	P, FP, G	Cool, ≤6 °C[18], NaOH to pH>12[6], reducing agent[5].	14 days.
25. Fluoride	P	None required	28 days.
27. Hardness	P, FP, G	HNO_3 or H_2SO_4 to pH<2	6 months.
28. Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes.
31, 43. Kjeldahl and organic N	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.

Analysis

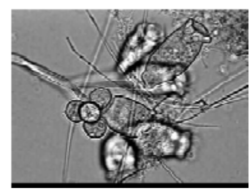


Sampling

- "Bomb" samplers can be useful when foam is present.

Microscopic Examination

- Microscopic examinations should be performed immediately after sample collection.



Biochemical Oxygen Demand

- The BOD test is used to measure the sample's organic strength.
- Measures the amount of oxygen required by a sample during the five days of incubation

Incubated at 20 ± 1° C for 5 days in the dark

Biochemical Oxygen Demand

- The total BOD includes both carbonaceous BOD and nitrogenous components.
- If your permit requires CBOD only, you must add nitrification inhibitor
  - This prevents the oxidation of nitrogen compounds

Biochemical Oxygen Demand

- In the US and Canada, the BOD of domestic wastewater typically ranges from 100 to 250 mg/L.
- Industrial wastewater can have much higher levels of BOD.

History of BOD

- A standard temperature at which BOD testing should be carried out was first proposed by the Royal Commission on Sewage Disposal in its eighth report in 1912:
  - "(c) An effluent in order to comply with the general standard must not contain as discharged more than 3 parts per 100,000 of suspended matter, and with its suspended matters included must not take up at 65° F (18-3° C.) more than 2.0 parts per 100,000 of dissolved oxygen in 5 days. This general standard should be prescribed either by Statute or by order of the Central Authority, and should be subject to modifications by that Authority after an interval of not less than ten years."

Information from http://en.wikipedia.org/wiki/Biochemical_oxygen_demand

History of BOD

History of BOD

- This was later standardized at 68° F and then 20° C.
- Although the Royal Commission on Sewage Disposal proposed 5 days as an adequate test period for rivers of the United Kingdom of Great Britain and Ireland, longer periods were investigated for North American rivers.
- Incubation periods of 1, 2, 5, 10 and 20 days were being used into the mid-20th century.
- Keeping dissolved oxygen available at their chosen temperature, investigators found up to 99 percent of total BOD was exerted within 20 days, 90 percent within 10 days, and approximately 68 percent within 5 days.

Information from http://en.wikipedia.org/wiki/Biochemical_oxygen_demand

History of BOD

- Variable microbial population shifts to nitrifying bacteria limit test reproducibility for periods greater than 5 days.
- The 5-day test protocol with acceptably reproducible results emphasizing carbonaceous BOD has been endorsed by the US EPA.
- This 5-day BOD test result may be described as the amount of oxygen required for aquatic microorganisms to stabilize decomposable organic matter under aerobic conditions.
- Stabilization, in this context, may be perceived in general terms as the conversion of food to living aquatic fauna.
- Although these fauna will continue to exert biochemical oxygen demand as they die, that tends to occur within a more stable evolved ecosystem.

Information from http://en.wikipedia.org/wiki/Biochemical_oxygen_demand

History of BOD

- A 5-day duration for BOD determination has no theoretical grounding but is based on historical convention.
- Tchobanoglous and Schroeder (1985) provide the following background:
  - "In a report prepared by the Royal Commission on Sewage Disposal in the United Kingdom at the beginning of the century, it was recommended that a 5-day, 18.3°C, BOD value be used as a reference in Great Britain.
  - These values were selected because British rivers do not have a flow time to the open sea greater than 5 days and average long-term summer temperatures do not exceed 18.3°C.

Information from: http://water.usgs.gov/owq/FieldManual/Chapter7/NFMChap7_2_BOD.pdf

Biochemical Oxygen Demand

- Requirements for valid BOD results:
  - Blank depletion must be ≤ 0.2 mg/L DO
  - Initial DO must be ≤ 9.0 mg/L
  - Samples must deplete at least 2.0 mg/L DO
  - Samples must have at least 1.0 mg/L DO remaining at the end of the incubation period

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Biochemical Oxygen Demand

- Typically a composite sample
- Not useful for process control
- Need minimum of 3 dilutions and run a duplicate every 10th sample

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BOD Calculation

- Initial DO = 8.2 mg/L
- Final DO = 4.5 mg/L
- Sample Volume = 6 mL
- BOD_5, mg/L = $\frac{D_1 - D_2}{P}$
- Where P = % sample
  - 6/300 = 0.02
- BOD_5, mg/L = $\frac{8.2 - 4.5}{0.02}$ = 185 mg/L

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BOD Calculation

- Use the following data to determine the BOD for this sample
  - Initial DO = 8.1 mg/L
  - Final DO = 4.0 mg/L
  - Sample Volume = 12 mL

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BOD Calculation

- P = 12/300 = 0.04
- BOD_5, mg/L = $\frac{8.1 - 4.0}{0.04}$ = 102.5 mg/L

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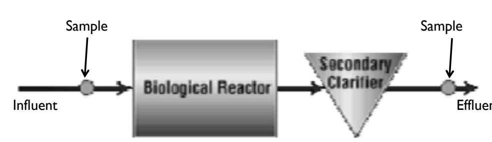
BOD Sampling Locations



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Chemical Oxygen Demand

- The COD test is used for more rapid assessment of organic strength.


Chemical Oxygen Demand

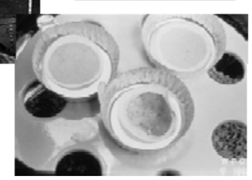
- The COD test measures oxidizable organic matter.
- Can be useful for process control:
  - Test yields data in 2 to 4 hours
  - BOD typically lower than COD (typical ratio is 0.5 to 1 for raw wastewater)
  - Ratio must be established for a specific plant.

Suspended Solids

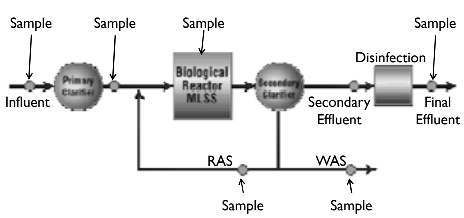
- To control activated sludge processes and account for solids inventories, we need to know the suspended solids at various stages through the process
- The SS test measures the amount of solids in suspension that can be removed by filtration
  - The sample is filtered through a pre-weighed filter paper and dried in an oven at 103-105°C

Suspended Solids

Technician Performing SS Test

Suspended Solids Sample Points



MLSS Calculation

- Use the following data to determine the MLSS for this sample.
  - Weight of filter and dry solids = 0.5955 g
  - Weight of filter = 0.4021 g
  - Sample volume = 50 mL
- SS, mg/L = $\frac{(A - B)(1{,}000{,}000)}{\text{sample, mL}}$
  - Where A = final weight of pan, filter and residue in grams
  - B = weight of prepared filter and pan, in grams

MLSS Calculation

- Weight of filter and dry solids = 0.5955 g
- Weight of filter = 0.4021 g
- Sample volume = 50 mL

- SS, mg/L = $\frac{(A - B)(1{,}000{,}000)}{\text{sample, mL}}$

  $= \frac{(0.5955 - 0.4021)(1{,}000{,}000)}{50 \text{ mL}}$

  $= \frac{(0.1934)(1{,}000{,}000)}{50 \text{ mL}}$

  $= 3868$ mg/L

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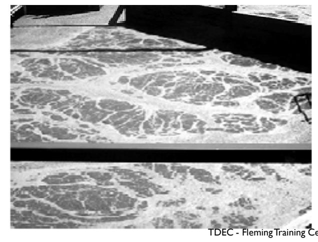
Suspended Solids

- Results of SS tests are used to determine secondary process removal efficiencies, SRT, F:M, and solids loading.



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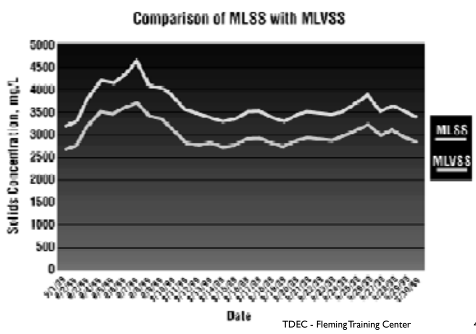
MLSS vs. MLVSS



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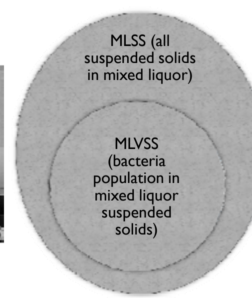
MLVSS

Technician Removing MLVSS Sample from Muffle Furnace



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MLVSS

- VSS is typically performed immediately following the SS test
- The filter paper and solids from the SS test are burned at 550°C in a muffle furnace
- Indicates the microorganism's portion in biomass
  - Usually 80-85% of MLSS

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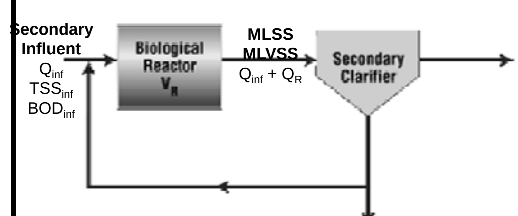
F:M Ratio

- F:M = $\frac{(BOD_{inf}, \text{mg/L})(Q_{inf}, \text{MGD})(8.34 \text{ lbs/gal})}{(\text{MLVSS, mg/L})(\text{Aerator Vol, MG})(8.34 \text{ lbs/gal})}$



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F:M Ratio

- Target F:M values
  - Conventional = 0.2 – 0.5
  - Nitrifying less than or equal to 0.10
- F:M based on BOD measurements does not give immediate process control feedback
- Running averages of F:M provide useful monitoring input
- F:M can be based on COD measurements when immediate process feedback is required
  - Target F:MCOD = $\frac{\text{Target F:M}_{BOD}}{\text{BOD:COD}}$

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F:M Example

BOD_{inf}	145 mg/L
Q_{inf}	15 MGD
MLVSS	2500 mg/L
Aerator Volume	2 MG

- F:M = $\frac{(\text{BODinf, mg/L})(\text{Qinf, MGD})(8.34 \text{ lbs/gal})}{(\text{MLVSS, mg/L})(\text{Aerator Vol, MG})(8.34 \text{ lbs/gal})}$
- F:M = $\frac{(145 \text{ mg/L})(15 \text{ MGD})(8.34 \text{ lbs/gal})}{(2500 \text{ mg/L})(2 \text{ MG})(8.34 \text{ lbs/gal})} = 0.44$

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F:M Ratio

Calculated F:M	Result	Action
Less than target F:M	Too many microorganisms in process	Increase wasting rate
Greater than target F:M	Not enough microorganisms in process	Reduce wasting rate

- Excess sludge to waste:
  - Excess M to waste (Microorganisms) = $\frac{\text{Current M – F (Food)}}{\text{F:M Target}}$

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F:M Ratio

- Excess sludge to waste:
  - Excess M to waste (Microorganisms) = $\frac{\text{Current M – F (Food)}}{\text{F:M Target}}$
- Wastewater formula book, pg. 11 has this as three different formulas:
  - Desired MLVSS, lbs = $\frac{\text{BOD or COD, lbs}}{\text{Desired F:M ratio}}$
  - Desired MLSS, lbs = $\frac{\text{Desired MLVSS, lbs}}{\text{\% Vol. Solids, as decimal}}$
  - SS, lbs to waste = Actual MLSS, lbs – Desired MLSS, lbs

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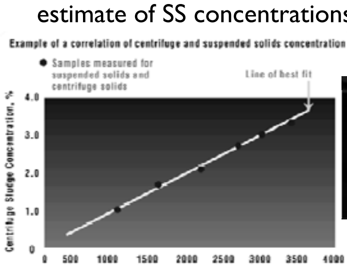
Centrifuge Spin Test

- The spin test can be used to get a quick estimate of SS concentrations.



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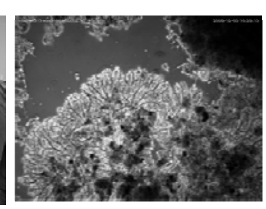
Microscopic Examination

- Microscopic examination of the mixed liquor provides valuable information.



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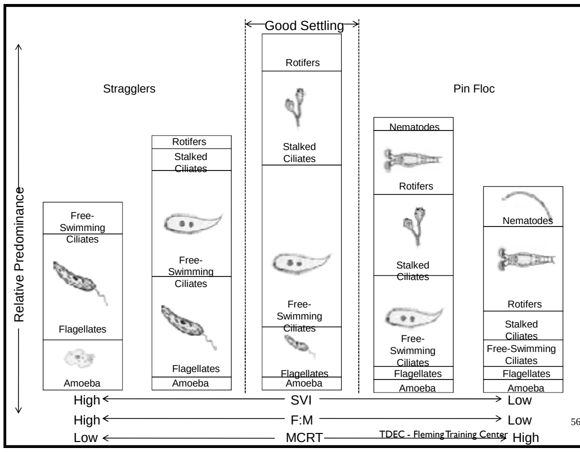
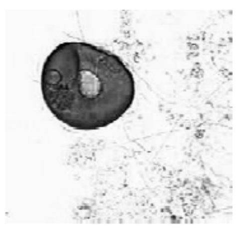
Microscopic Examination

- Provides information on the biological characteristics and health of the activated sludge process and gives warning of process problems, such as poor settling or the presence of a toxic or inhibitory material
  - To do the test, first place a drop of mixed liquor on a slide
  - Place a cover slide on top
  - A healthy activated sludge will have a tight floc structure and many organisms present



Sludge Age Indicator

- Amoebas indicate young sludge
- They usually predominate at plant start ups
- Environmental conditions:
  - Lots of food (BOD)
  - Insufficient biomass



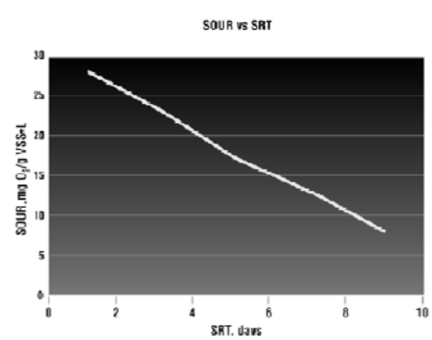
Sludge Age Indicator

- Predominance of ciliates and rotifers indicates the process is operating well
- Predominance of rotifers and worms indicates that sludge is old.

OUR

- The oxygen uptake rate (OUR) quickly indicates biological activity.

OUR



OUR

- Testing for OUR:
  - Collect grab sample
  - Measure DO at regular intervals

OUR

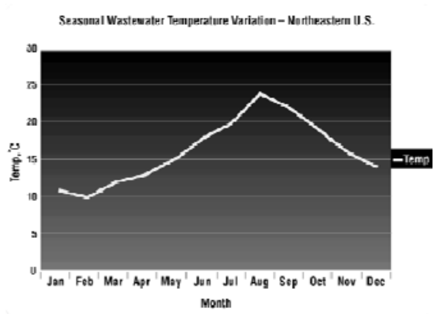
- Example:
  - Initial DO = 6.1 mg/L
  - Final DO = 1.4 mg/L
    Time = 4.5 min

- $\text{OUR, mg/L/hr} = \frac{\text{(Initial DO, mg/L – Final DO, mg/L)}}{\text{elapsed time, min}} \times 60 \text{ min/hr}$

  $= \frac{(6.1 - 1.4)}{4.5 \text{ min}} \times 60 \text{ min/hr}$

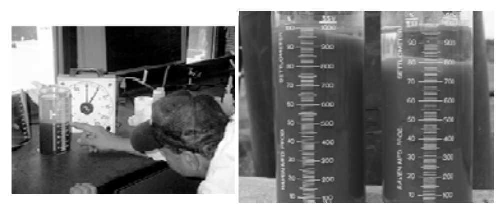
  $= 62.7 \text{ mg/L/hr}$

Temperature

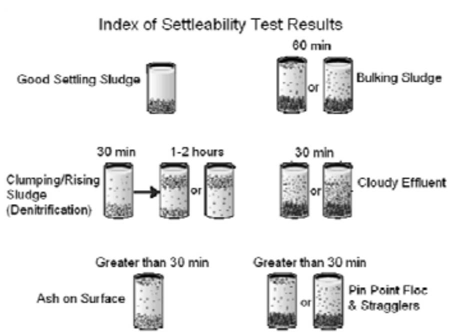


Thirty-Minute Settleometer

- The thirty-minute settleometer test indicates how well the mixed liquor will settle in the clarifiers.



Thirty-Minute Settleometer

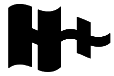


Sludge Volume Index

- Sludge Volume Index (SVI) **-** The ratio of the volume (in milliliters) of sludge settled from a 1000-mL sample in 30 minutes to the concentration of mixed liquor (in milligrams per liter [mg/L]) multiplied by 1000.

- $\text{SVI, mL/g} = \frac{\text{(Settled Sludge Vol, mL/L)(1,000)}}{\text{MLSS, mg/L}}$

pH



- Power of hydrogen
  - Measurement of the hydrogen ion concentration
  - Each decrease in pH unit equals a 10x increase in acid
- Indicates the intensity of its acidity or basicity
- Scale runs from 0 to 14, with 7 being neutral
- Probe measures millivolts, then converts into pH units
  - Temperature affects millivolts generated, therefore you need a temperature probe as well for corrections
- If the pH of the mixed liquor varies too far from neutral (pH=7.0), microorganisms may become inhibited or may start to die.

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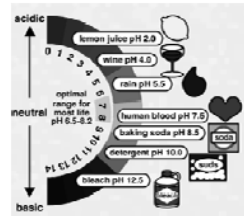
pH

- Calibrate daily with fresh buffers
  - Use at least two buffers
- Store probe in slightly acidic solution
- Replace probes yearly



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Dissolved Oxygen

- We must know the oxygen concentration in the aeration tanks to control it for optimum performance
  - Both BOD and nitrification are aerobic processes
- Two options for testing DO
  - DO probe and meter
  - Winkler method

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Nitrogen

- If your plant is required to nitrify (convert ammonia-nitrogen to nitrate-nitrogen), you must also include ammonia-nitrogen, nitrate-nitrogen and nitrite-nitrogen in your sampling
- By measuring these parameters, you can determine the efficiency of your plant and therefore make adjustments to your process

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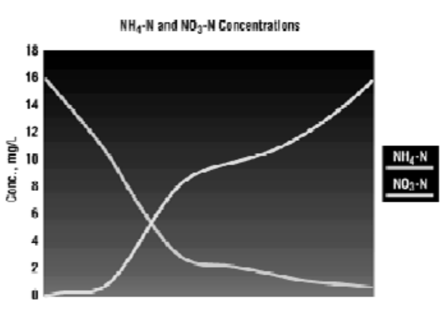
Nitrogen



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Chlorine Residual

- Two most common tests:
  - Amperometric titration
    - Less interferences such as color and/or turbidity
  - DPD (N,N-diethyl-p-phenylenediamine)
- Analysis should be performed ASAP
- Exposure to sunlight or agitation of the sample will cause a reduction in the chlorine residual

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Chlorine Residual

- Approved Methods:
  - Amperometric titration
  - Iodmetric titration – starch endpoint
  - Back titration
  - DPD - FAS
  - Spectrophotometric, DPD
  - Electrode
- NOTE: DPD color comparator is NOT an approved method

Chlorine Residual

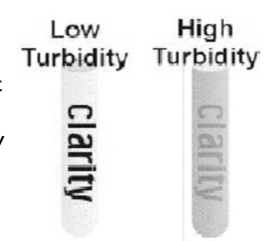
- DPD colorimetric method most commonly used
  - Match color of sample to a standard
  - ***Swirl sample for 20 seconds*** to mix
  - Wait ***three minutes***
  - Place it into colorimeter and take reading

Alkalinity

- Capacity of water to neutralize acids
- Due to presence of hydroxides, carbonates and bicarbonates
- Many chemicals (alum, chlorine, lime) alters water alkalinity
  - Alum and chlorine destroy
  - Lime adds
  - Nitrification and denitrification also affect alkalinity
- Titration using H_2SO_4 to pH endpoint
- Expressed as mg/L $CaCO_3$

Turbidity

- Turbidity is a quick (less than 30 minutes) control test that can be used to determine the quality of the treatment plant effluent.



Bacteriological Analysis

Coliform Bacteria

- MPN of coliform bacteria are estimated to indicate the presence of bacteria originating from the intestines of warm-blooded animals
- Coliform bacteria are generally considered harmless
  - But their presence may indicate the presence of pathogenic organisms

Coliform Bacteria

- Comprises all the aerobic and facultative anaerobic gram negative, nonspore-forming, rod-shaped bacteria that ferment lactose within 48 hours ~ 35°C
- Coliform bacteria can be split into fecal and non-fecal groups
- The fecal group can grow at higher temperatures (45 °C) than the non-fecal coliforms

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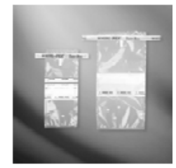
Sampling

- Clean, sterilized borosilicate glass or plastic bottles or sterile plastic bags.
- Leave ample air space for mixing.
- Collect samples representative of wastewater tested.
- Use aseptic techniques; avoid sample contamination.
- Test samples as soon as possible.



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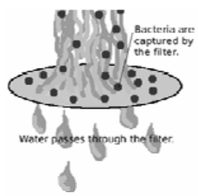
Approved Methods

- Coliform (fecal)
  - Number per 100 mL
    - Membrane filtration
- E. coli
  - Number per 100 mL
    - Multiple tub/multiple well (Colilert®)
    - Membrane filtration
      - m-ColiBlue24®
      - Modified mTEC agar



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Membrane Filtration

Simultaneous Total Coliform and E.coli Screening Method 10029

1. Use sterilized forceps to place a sterile, absorbent pad in a sterile petri dish. Replace the lid on the dish.
   Note: Do not touch the pad or the inside of the petri dish.
   Note: To sterilize the forceps, dip them in alcohol and flame in an alcohol or Bunsen burner. Let the forceps cool before use.
2. Invert ampules two or three times to mix broth. Break open an ampule of m-ColiBlue24 Broth using an ampule breaker. Pour the contents evenly over the absorbent pad. Replace the petri dish lid.
3. Set up the Membrane Filter Apparatus. With sterile forceps, place a membrane filter, grid side up, into the assembly.
4. Shake the sample vigorously to mix. Pour 100 mL of sample or diluted sample into the funnel. Apply vacuum and filter the sample. Rinse the funnel walls three times with 20 to 30 mL of sterile buffered dilution water.

M-ColiBlue24® Membrane Filtration Method, Hach Company, www.Hach.com

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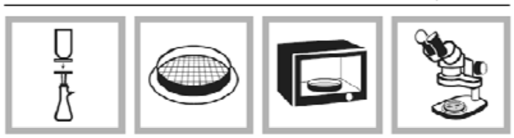
Membrane Filtration

Bacteria, Coliform



5. Turn off the vacuum and lift off the funnel top. Using sterile forceps, transfer the filter to the previously prepared petri dish.
6. With a slight rolling motion, place the filter, grid side up, on the absorbent pad. Check for trapped air under the filter and make sure the filter touches the entire pad. Replace the petri dish lid.
7. Invert the petri dish and incubate at 35 ±0.5 °C for 24 hours.
8. Remove the petri dish from the incubator and examine the filters for colony growth. Colonies are typically readily visible; however, a stereoscopic microscope or other 10–15X magnifier may be useful. Red and blue colonies indicate total coliforms and blue colonies specifically indicate *E. coli.*

M-ColiBlue24® Membrane Filtration Method, Hach Company, www.Hach.com

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Membrane Filtration Equipment

- Water bath or air incubator operating at appropriate temperature
- Vacuum pump
- UV sterilizer or boiling water bath
- 10-15 X dissecting microscope; should have fluorescent illuminator
- Alcohol burner

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Membrane Filtration Supplies and Glassware

- Sterile graduated cylinder
- Sterile pipets
- Sterile MF filtration flask
- Sterile dilution water
- Sterile sample vessels
- Samples containing chlorine must be treated with 3% sodium thiosulfate solution
- mFC Broth

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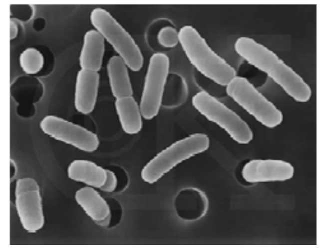
Fecal Coliform



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Fecal Coliform

- A 100 mL volume of sample is filtered through a 47-mm membrane filter using standard techniques.
- Filter is transferred to a 50-mm petri plate containing an absorbent pad saturated with mFC Broth.
- Invert filter and incubate at 44.5±0.2°C for 24 hrs.
- Count blue colonies.
- Interferences
  - None, but excess particulates may cause colonies to grow together on a crowded filter or slow the sample filtration process.

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Fecal Coliform

- Maximum hold time is 6 hrs at < 10°C
- Ideal sample volume yields 20-60 colonies
- Samples <20 mL, add 10 mL sterile dilution water to filter funnel before applying vacuum.
- Sanitize funnel between samples.

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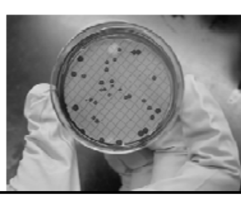
Fecal Data Analysis

- Visually determine colony counts on membrane filters.
- Verify using 10-15 X binocular wide-field microscope.
- Fecal coliforms appear blue.



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Fecal Data Interpretation

- Incubation time is 24 ± 2 hrs.
- Fecal coliform density reported as number of colonies per 100 mL of sample.
- NPDES permit limit: monthly average of 200/100 mL; daily maximum of 1000/100 mL.

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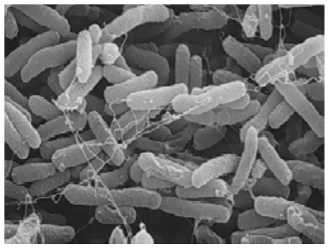
Escherichia coli (E.coli)

Colilert



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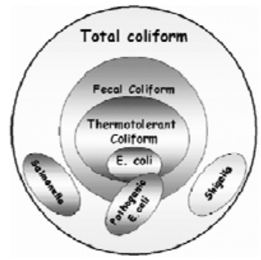
Family Portrait

- Indicators of water contamination



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Techniques for Measuring

- Most Probable Number (MPN)
- Membrane Filter

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Colilert® & Colilert-18®

MPN Method

- Add substrate to a 100 mL sample
- If making dilutions, use sterile DI water, not sterile buffered water.

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Colilert® & Colilert-18®

- Shake sample vigorously. Wait for bubbles to dissipate.
- Pour into QuantiTray.

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Colilert® & Colilert-18®

- Seal sample in Quanti-Tray
- Incubate at 35±0.5°C for 18 hrs (Colilert-18) OR 24 hrs (Colilert)

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Colilert® & Colilert-18®

- Examine tray for appropriate color change
- Yellow is an indicator of total coliforms

Left: The 97 well QuantiTray 2000 will count up to 2419 cfu without dilution.
Right: The 51 well QuantiTray will count up to 200 cfu without dilution.

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Colilert® & Colilert-18®

- Examine positive total coliform for fluorescence using a UV light in a dark environment
- Fluorescence is a positive indicator for E. coli
- Calculate MPN value according to the table provided with the QuantiTray

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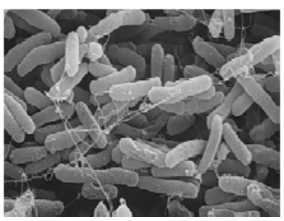
Escherichia coli (E.coli)

Modified mTEC Agar with Membrane Filtration



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EPA Method 1603

- Membrane Filter – modified mTEC agar
- Filter sample dilutions through a 47mm diameter sterile, white, grid marked filter (0.45µm pore size)
- Place sample in a petri dish with modified mTEC agar

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Method 1603

- Invert dish and incubate for 35± 0.5°C for 2 hours
  - Resuscitates injured or stressed bacteria
- Then incubate at 44.5± 0.2°C for 22 hours
- After incubation, remove the plate from the water bath or dry air incubator

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Method 1603

- Count and record the number of red or magenta colonies (verify with stereoscopic microscope)
- See the USEPA microbiology methods manual, Part II, Section C, 3.5, for general counting rules

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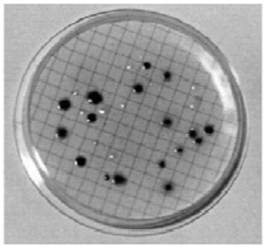
Method 1603

Modified mTEC



Count magenta colonies as *E. coli*. These are easily discerned from non-target colonies which are clear or beige.

Method 1603

- QC Tests:
  - Initial precision and recovery
  - Ongoing precision and recovery
  - Matrix spike
  - Negative control
  - Positive control
  - Filter sterility check
  - Method blank
  - Filtration blank
  - Media sterility check

Method 1603

- Initial precision and recovery
  - Should be performed by each lab before the method is used for monitoring field samples
- Ongoing precision and recovery
  - Run after every 20 field and matrix spike samples or one per week that samples are analyzed
- Matrix spike
  - Run 1 per 20 samples

Method 1603

- Negative control
  - Should be analyzed whenever a new batch of media or reagents is used
- Positive control
  - Should be analyzed whenever a new batch of media or reagents is used
- Filter sterility check
  - Place at least one membrane filter per lot of filters on a tryptic soy agar (TSA) plate and incubate for 24 ± 2 hours at 35^0C ± 0.5 ^{0}C .
  - Absence of growth indicates sterility of the filter.
  - Run daily.

Method 1603

- Method blank
  - Filter a 50-mL volume of sterile buffered dilution water and place on a modified mTEC agar plate and incubate.
  - Absence of growth indicates freedom of contamination from the target organism.
  - Run daily.
- Filtration blank
  - Filter a 50-mL volume of sterile buffered dilution water and place on a TSA plate and incubate at just at 35^0C ± 0.5 ^{0}C for 24 ± 2 hours .
  - Absence of growth indicates sterility of the buffer and filtration assembly.
  - Run daily.

Method 1603

- Media sterility check
  - The lab should test media sterility by incubating one unit (tube or plate) from each batch of medium (TSA, modified mTEC and verification media) as appropriate and observing for growth.
  - Absence of growth indicates media sterility.
  - Run daily.

Method 1603

- QC Tests:
  - Initial precision and recovery
  - Ongoing precision and recovery
  - Matrix spike
  - Negative control
  - Positive control
  - Filter sterility check
  - Method blank
  - Filtration blank
  - Media sterility check

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Method 1603

- QC Tests:
  - Initial precision and recovery
  - Ongoing precision and recovery
  - Matrix spike
  - Negative control
  - Positive control
  - Filter sterility check
  - Method blank
  - Filtration blank
  - Media sterility check

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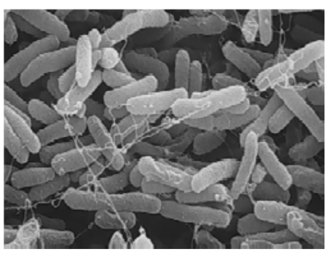
Escherichia coli (E.coli)

m-ColiBlue24® with Membrane Filtration



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E. coli m-ColiBlue24®

- Maximum hold time is 6 hrs at < 10°C
- Ideal sample volume yields 20-80 colonies
- Run a minimum of 3 dilutions
- Samples <20 mL, add 10 mL sterile dilution water to filter funnel before applying vacuum.
- Sanitize funnel between samples.
- Visually determine colony counts on membrane filters.
- Verify using 10-15 X binocular wide-field microscope.

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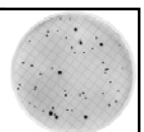
E. coli m-ColiBlue24®



- Incubation time is 24 ± 2 hrs.
- *E. coli* density reported as number of colonies per 100 mL of sample.
- *E. coli* appear blue
- NPDES permit limit: monthly average of 126/100 mL
- Samples and equipment known or suspected to have viable E. coli attached or contained must be sterilized prior to disposal.

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Expected Reactions of Various Microorganisms

- Total coliforms will produce a red colony
  - Enterobacter species
    - *E. cloacae*
    - *E. aerogenes*
  - Klebsiella species
    - *K. pneumoniae*
  - Citrobacter species
    - *C. freundii*

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Expected Reactions of Various Microorganisms

- *Escherichia coli* will produce a blue colony
  - *E. coli* O157:H7 will not produce a blue colony, but will grow as a red colony

Expected Reactions of Various Microorganisms

- Known negative reaction (no growth) after 24-25 hours
  - *Pseudomonas aeruginosa*
    - *Variable reaction may be positive for total coliform when incubated longer than 25 hours*
  - *Proteus vulgaris*
  - *Aeromonas hydrophila*

Expected Reactions of Various Microorganisms

- Some strains of the following microorganisms are known to produce a false-positive total coliform reaction (a red colony, but not a true total coliform)

- *Serratia species*
- *Hafnia alvei*
- *Vibrio fluvialis*
- *Aeromonas species*
- *Proteus vulgaris*
- *Providencia stuartii*
- *Yersinia enterocolitica*
- *Leclercia adecarboxylata*
- *Ewingella americana*
- *Staphylococcus species*
- *Proteus mirabilis*

M-ColiBlue24® Trouble-Shooting Guide, Hach Company, www.Hach.com

E. coli Information

- For Colilert ®: IDEXX Laboratories, www.idexx.com
- For mTEC Agar and mColiBlue-24® media: Hach Company, www.Hach.com
- EPA Method 1603: E.coli In Water By Membrane Filtration Using Modified-Thermotolerant Escherichia coli Agar (Modified mTEC), September 2002, EPA-821-R-02-023

All Bacteriological Checks

- Temperatures are documented daily
- Thermometers are certified at least annually against NIST thermometers
- Reagents for storage requirements and expiration dates

All Bacteriological Checks

- E. coli colonies identified correctly
- Calculations are correct
- Holding Times are met
  - Sample collection
  - Analysis start
  - End times

Geometric Mean

- You have run your E. coli samples for the month and need to figure your geometric mean.
- Your results are as follows:
  - 60 cfu
  - 100 cfu
  - 0 cfu
  - 0 cfu

$$\text{Geometric Mean} = (X_1)(X_2)(X_3)\ldots(X_n)^{1/n}$$

$$\text{Geometric Mean} = \sqrt[n]{(X_1)(X_2)(X_3)\ldots(X_n)}$$

Geometric Mean

- Geometric Mean – $(X_1)(X_2)(X_3)\ldots(X_n)^{1/n}$
- Step 1: 1/n → 1 divided the number of test results. For our example above, there are four test results.
  - 1 ÷ 4 = 0.25 (write this number down, you will use it in Step 3)
- Step 2: Multiply all of the test results together and punch the = button on the calculator. **Remember to count 0 as a 1**.
  - 60 x 100 x 1 x 1 = 6000 (Do Not clear out your calculator)
- Step 3: Punch the y^x button and then type in the number from Step 1, then punch =.
  - 6000 y^x 0.25 = 8.8011

Geometric Mean

- Geometric Mean – $(X_1)(X_2)(X_3)\ldots(X_n)^{1/n}$
- Step 1: 1/n → 1 divided the number of test results. For our example above, there are four test results.
  - 1 ÷ 4 = 0.25 (write this number down, you will use it in Step 3)
- Step 2: Multiply all of the test results together and punch the = button on the calculator. **Remember to count 0 as a 1**.
  - 60 x 100 x 1 x 1 = 6000 (Do Not clear out your calculator)
- Step 3: Punch the ^ button, then type in the number from Step 1, & then punch =.
  - 6000 y^x 0.25 = 8.8011

Geometric Mean

- Now, try one on your own:
- 20, 20, 210, 350
- Geometric Mean = 73.6

Geometric Mean

- ¼ = 0.25
- (20)(20)(210)(350) = 29,400,000
- $(29{,}400{,}000)^{0.25}$ = 73.6

Sampling and Analysis Plan

- Good sampling practices + Competent sample analysis = Quality data for process control

QA / QC Program

- A QA/QC program consists of procedures that ensure the precision and accuracy of tests performed on a daily basis
- Precision – repeatability; being able to get the same result time after time
  - Shooting at a target and hitting the same spot repeatedly
- Accuracy – closeness of test results to the correct (known) value
  - Shooting at a target and hitting the bull's eye

QA / QC Program

- Three phases:
  - Keeping records
  - Documenting that equipment is regularly calibrated and temperatures are correct
  - Perform QC tests to demonstrate precision and accuracy

Record Keeping

- Maintain a complete and accurate list of exact locations of all sampling sites
- Maintain a complete and accurate list of all test procedures used
  - Record method numbers on bench sheets
- Write in pen
- Initial your entries
- Use a notebook that has numbered pages

Quality Control Tests

- Duplicates
- Blanks
- Lab Standards
- Unknown Lab Standards
- Spikes

Duplicates

- Simplest form of QC test
- Run two tests on one sample
  - This shows how precise the analyst's procedure is
  - Sample results should yield very close results
    - goal is to have no difference
- General recommendation is to run a duplicate every 10 samples

Common source of errors for Dups.

- Sample size
  - Should be same size
- Insufficient mixing
- Dirty glassware
- Calculation errors
- Reagents
- Titration
  - Misreading burette
- Weighing
- Calibration
- Reagent water

Blanks

- Blanks can show test interference
- Blanks should be treated as a sample
  - Take through all procedures
  - Add all reagents or incubate along with other samples
- Target value for a blank is zero

Blanks

- Positive blanks show a problem
  - Bad reagents
  - Bad technique
  - Unclean glassware
  - Bad distilled water

Blanks

- Coliform tests
  - A blank should never be positive
  - Blanks should be run before you filter samples and when you are done filtering samples
    - If the pre-sample blank has colony growth, the equipment was not properly sterilized
    - If the post sample blank has colony growth, the equipment was not cleaned well enough between samples

Laboratory Standards

- Determines accuracy
- If the test value agrees with the true value, the test has been performed accurately
- Mix onsite or purchased from a supplier
  - Purchased standards should be the preference, because this can reduce the possibility of having mixing errors
  - They also come with a certificate of analysis
- Perform along with duplicates
  - One every 10 samples

Unknown Laboratory Samples

- EPA quality control unknowns
  - DMRQA samples
- Commercially available
- Gives confidence to analyst
- Can show deficiencies in the testing procedure

Spikes

- Determines accuracy
- A known amount of standard is added to a sample
- The results should equal the sample value plus the added known amount
- Goal is to have 100% recovery of spike and sample
- If you run Hach methods, most have directions on how to spike a sample

Spikes

- If your sample result was 100 mg/L and you added 50 mg/L into the spiked sample, you should yield 150 mg/L

Other Samples

- Some labs split samples with other labs to check the accuracy of the testing procedure
- If you are concerned that your contract lab is getting wrong values, send in a known standard as a sample
  - This does double your cost, but you can see how close they are to the known value
  - Don't tell the contracted lab that the second sample is a known

Sampling and Analysis Plan

- Tabulate each parameter and include
  - Sample site
  - Sample time
  - Sample type
  - Analytical technique
  - Analysis date
  - Name of analyst

Lab Safety

- Read MSDS for all chemicals used in lab
- Store chemicals properly
- Know where safety equipment is stored
- Never pour water into acid
- CPR and First Aid Training (TOSHA requirement)
- Clean chemical spills immediately
- Follow published lab procedures (Standard Methods)
- Read and become familiar with Safety SOP

MSDS

- Material Safety Data Sheets
- Keep on file for all chemicals purchased
  - According to the Americans with Disabilities Act of 1990, MSDS's should be kept for a minimum of 30 years
- Includes all information shown on chemical label and more

MSDS

- Must be readily available for employee review at all times you are in the work place
  - They can't be locked in an office or filling cabinet to which you don't have access to
  - If they are on a computer, everyone must know how to access them
- If you request to see an MSDS for a product you use at work, and your employer can't show it to you, after one working day you may refuse to work with that product until you are shown the correct MSDS

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MSDS

- Lists:
  - Common and chemical name
  - Manufacturer info
  - Hazardous ingredients
  - Health hazard data
  - Physical data
  - Fire and explosive data
  - Spill or leak procedures
  - PPE
  - Special precautions

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Chemical Label

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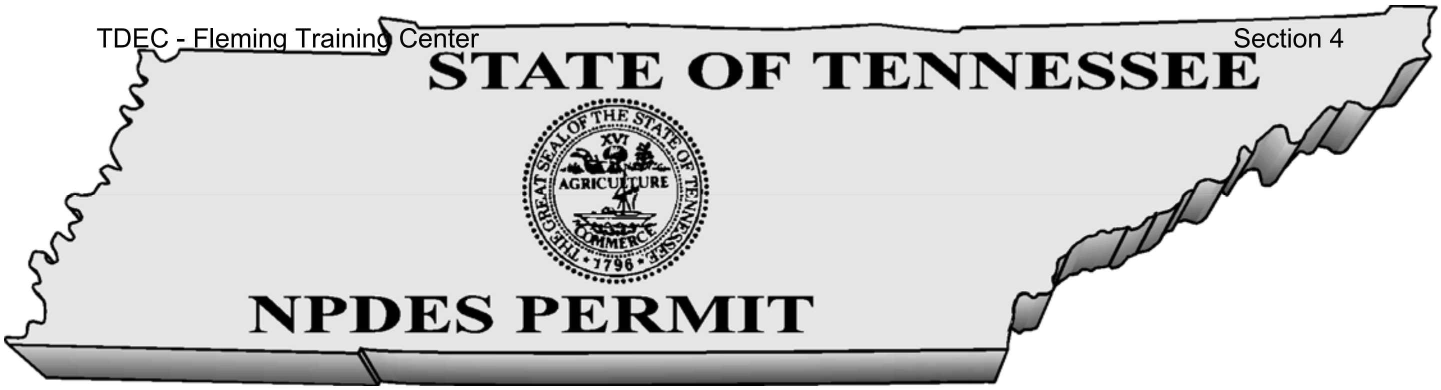

No. TN00-----

Authorization to discharge under the
National Pollutant Discharge Elimination System (NPDES)

Issued By

Tennessee Department of Environment and Conservation
Division of Water Pollution Control
401 Church Street
6th Floor, L & C Annex
Nashville, Tennessee 37243-1534

Under authority of the Tennessee Water Quality Control Act of 1977 (T.C.A. 69-3-101 et seq.) and the delegation of authority from the United States Environmental Protection Agency under the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977 (33 U.S.C. 1251, et seq.)

Discharger: **--- STP**

is authorized to discharge: **Treated municipal wastewater**

from a facility located: **in ---, --- County, Tennessee**

to receiving waters named: **Receiving stream Mile --**

in accordance with effluent limitations, monitoring requirements and other conditions set forth herein.

This permit shall become effective on:

This permit shall expire on:

Issuance date:

Paul E. Davis, Director
Division of Water Pollution Control

CN-0759
(Template Rev. 1-05)

RDAs 2352 and 2366

TABLE OF CONTENTS

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MTS
TN00-----PMT.DOC

1.0. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1.1. NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS

The City of --- is authorized to discharge Treated municipal wastewater to the Receiving stream Mile --. Discharge 001 consists of municipal wastewater from a treatment facility with a design capacity of 2 MGD. Discharge 001 shall be limited and monitored by the permittee as specified below:

Effluent Characteristics	**Effluent Limitations**						**Monitoring Requirements**		
	Monthly Average Conc. (mg/l)	Monthly Average Amount (lb/day)	Weekly Average Conc. (mg/l)	Weekly Average Amount (lb/day)	Daily Maximum Conc. (mg/l)	Daily Minimum Percent Removal	Measurement Frequency	Sample Type	Sampling Point
$CBOD_5$	5	83	7.5	125	10	40	3/week	composite	effluent
(May 1 - Oct. 31)	Report	—	—	—	Report	—	3/week	composite	influent
$CBOD_5$	15	250	20	333	25	40	3/week	composite	effluent
(Nov. 1 - April 30)	Report	—	—	—	Report	—	3/week	composite	influent
Ammonia as N	1.2	20	1.8	30	2.4	—	3/week	composite	effluent
(May 1 - Oct. 31)									
Ammonia as N	2.8	47	4.2	70	5.6	—	3/week	composite	effluent
(Nov. 1 - April 30)									
Total Nitrogen* (May 1 - Oct. 31)	Report	—	—	—	Report	—	2/month	composite	effluent
Total Phosphorous* (May 1 - Oct. 31)	Report	—	—	—	Report	—	2/month	composite	effluent
Suspended Solids	30	500	40	667	45	40	3/week	composite	effluent
(May 1 - Oct. 31)	Report	—	—	—	Report	—	3/week	composite	influent
Suspended Solids							3/week	composite	effluent
(Nov. 1 - April 30)	Report	—	—	—	Report	—	3/week	composite	influent
Sanitary Sewer Overflows, Total Occurrences	Report						continuous	visual	NA
Dry Weather Overflows, Total Occurrences	Report						continuous	visual	NA
Bypass of Treatment, Total Occurrences	Report						continuous	visual	NA

Note: The permittee shall achieve 85% removal of $CBOD_5$ and TSS on a monthly average basis. The permittee shall report all instances of overflow and/or bypasses. See Part 2.3.3.a for the definition of overflow and Part 1.3.5.1 for reporting requirements.

Note: Unless elsewhere specified, summer months are May through October; winter months are November through April.

Note: See Part 1.2.3 for test procedures.

Effluent Characteristics	**Effluent Limitations**			**Monitoring Requirements**		
	Monthly Average	Daily Minimum	Daily Maximum	Measurement Frequency	Sample Type	Sampling Point
*E. coli**	126/100 ml (see the following paragraphs)	—	487 or 941/100 ml	3/week	grab	effluent
Chlorine residual (Total)	—	—	0.02 mg/l instantaneous	5/week	grab	effluent
Settleable solids	—	—	1.0 ml/l	5/week	grab	effluent
Dissolved oxygen	—	6.0 mg/l instantaneous	—	5/week	grab	effluent
pH (Standard Units)	—	6.5.0	9.0	5/week	grab	effluent
Flow (MGD)	Report	—	Report	7/week	continuous	influent
	Report	—	Report	7/week	continuous	effluent
Mercury, Total	mg/l	— —	— —	1/month	grab	effluent
Cyanide, Total	mg/l	— —	— —	1/month	grab	effluent
48 hr LC_{50}	Survival in % effluent			1/quarter	grab	effluent
IC_{25}	Survival, reproduction and growth in 97% effluent			1/quarter	composite	effluent

Note: See Part 3.4 for biomonitoring test and reporting requirements. See next page for percent removal calculations.

Note: See Part 1.2.3 for test procedures.

* In the absence of a method in 40 CFR, Part 136 for measuring *E. coli* in effluent matrices, the permittee shall use methods proposed or added to Part 136 for measuring *E. coli* in ambient water.

Total residual chlorine (TRC) monitoring shall be applicable when chlorine, bromine, or any other oxidants are added. The acceptable methods for analysis of TRC are any methods specified in Title 40 CFR, Part 136 as amended. The method detection level (MDL) for TRC shall not exceed 0.05 mg/l unless the permittee demonstrates that its MDL is higher. The permittee shall retain the documentation that justifies the higher MDL and have it available for review upon request. In cases where the permit limit is less that the MDL, the reporting of TRC at less than the MDL shall be interpreted to constitute compliance with the permit.

The wastewater discharge must be disinfected to the extent that viable coliform organisms are effectively eliminated. The concentration of the E. *coli* group after disinfection shall not exceed 126 cfu per 100 ml as the geometric mean calculated on the actual number of samples collected and tested for E. *coli* within the required reporting period. The permittee may collect more samples than specified as the monitoring frequency. Samples may not be collected at intervals of less than 12 hours. For the purpose of determining the geometric mean, individual samples having an *E. coli* group concentration of less than one (1) per 100 ml shall be considered as having a concentration of one (1) per 100 ml. In addition, the concentration of the *E. coli* group in any individual sample shall not exceed a specified maximum amount. A maximum daily limit of 487 colonies per 100 ml applies to lakes and Tier II waters. A maximum daily limit of 941 colonies per 100 ml applies to all other recreational waters.

There shall be no distinctly visible floating scum, oil or other matter contained in the wastewater discharge. The wastewater discharge must not cause an objectionable color contrast in the receiving stream.

The wastewater discharge shall not contain pollutants in quantities that will be hazardous or otherwise detrimental to humans, livestock, wildlife, plant life, or fish and aquatic life in the receiving stream.

Sludge or any other material removed by any treatment works must be disposed of in a manner that prevents its entrance into or pollution of any surface or subsurface waters. Additionally, the disposal of such sludge or other material must be in compliance with the Tennessee Solid Waste Disposal Act, TCA 68-31-101 et seq. and the Tennessee Hazardous Waste Management Act, TCA 68-46-101 et seq.

For the purpose of evaluating compliance with the permit limits established herein, where certain limits are below the State of Tennessee published required detection levels (RDLs) for any given effluent characteristics, the results of analyses below the RDL shall be reported as Below Detection Level (BDL), unless in specific cases other detection limits are demonstrated to be the best achievable because of the particular nature of the wastewater being analyzed.

For $CBOD_5$ and TSS, the treatment facility shall demonstrate a minimum of 85% removal efficiency on a monthly average basis. This is calculated by determining an average of all daily influent concentrations and comparing this to an average of all daily effluent concentrations. The formula for this calculation is as follows:

$$\left[1 - \frac{\text{average of daily effluent concentration}}{\text{average of daily influent concentration}} \right] \times 100\% \quad = \%\ \text{removal}$$

The treatment facility will also demonstrate 40% minimum removal of the $CBOD_5$ and TSS based upon each daily composite sample. The formula for this calculation is as follows:

$$\left[1 - \frac{\text{daily effluent concentration}}{\text{daily influent concentration}} \right] \times 100\% \quad = \% \text{ removal}$$

1.2. MONITORING PROCEDURES

1.2.1. Representative Sampling

Appropriate flow measurement devices and methods consistent with accepted scientific practices shall be selected and used to insure the accuracy and reliability of measurements of the volume of monitored discharges. The devices shall be installed, calibrated and maintained to insure that the accuracy of the measurements is consistent with accepted capability of that type of device. Devices selected shall be capable of measuring flows with a maximum deviation of less than plus or minus 10% from the true discharge rates throughout the range of expected discharge volumes.

Samples and measurements taken in compliance with the monitoring requirements specified above shall be representative of the volume and nature of the monitored discharge, and shall be taken at the following location(s):

Influent samples must be collected prior to mixing with any other wastewater being returned to the head of the plant, such as sludge return. Those systems with more than one influent line must collect samples from each and proportion the results by the flow from each line.

Effluent samples must be representative of the wastewater being discharged and collected prior to mixing with any other discharge or the receiving stream. This can be a different point for different parameters, but must be after all treatment for that parameter or all expected change:

a. $CBOD_5$ samples can be collected before disinfection to avoid having to seed the samples and dechlorinate if chlorine is used.

b. The chlorine residual must be measured after the chlorine contact chamber and any dechlorination. It may be to the advantage of the permittee to measure at the end of any long outfall lines.

c. Samples for *E. Coli* can be collected at any point between disinfection and the actual discharge.

d. The dissolved oxygen can drop in the outfall line; therefore, D.O. measurements are required at the discharge end of outfall lines greater than one mile long. Systems with outfall lines less than one mile may measure dissolved oxygen as the wastewater leaves the treatment facility. For systems with dechlorination, dissolved oxygen must be measured after this step and as close to the end of the outfall line as possible.

e. Total suspended solids and settleable solids can be collected at any point after the final clarifier.

f. Biomonitoring tests (if required) shall be conducted on final effluent.

1.2.2. Sampling Frequency

Where the permit requires sampling and monitoring of a particular effluent characteristic(s) at a frequency of less than once per day or daily, the permittee is precluded from marking the “No Discharge” block on the Discharge Monitoring Report if there has been any discharge from that particular outfall during the period which coincides with the required monitoring frequency; i.e. if the required monitoring frequency is once per month or 1/month, the monitoring period is one month, and if the discharge occurs during only one day in that period then the permittee must sample on that day and report the results of analyses accordingly.

1.2.3. Test Procedures

a. Test procedures for the analysis of pollutants shall conform to regulations published pursuant to Section 304 (h) of the Clean Water Act (the "Act"), as amended, under which such procedures may be required.

b. Unless otherwise noted in the permit, all pollutant parameters shall be determined according to methods prescribed in Title 40, CFR, Part 136, as amended, promulgated pursuant to Section 304 (h) of the Act.

c. In the absence of a method in 40 CFR, Part 136 for measuring *E. coli* in effluent matrices, the permittee shall use methods proposed or added to Part 136 for measuring *E. coli* in ambient water. The Division does recognize the use of EPA Method 1604: Total Coliforms and *Escherichia coli* in Water by Membrane Filtration Using a Simultaneous Detection Technique (MI Medium) for monitoring and reporting as required in the permit limits table(s).

d. Composite samples must be proportioned by flow at time of sampling. Aliquots may be collected manually or automatically. The sample aliquots must be maintained at 4 degrees Celsius during the compositing period.

1.2.4. Recording of Results

For each measurement or sample taken pursuant to the requirements of this permit, the permittee shall record the following information:

a. The exact place, date and time of sampling;

b. The exact person(s) collecting samples;

c. The dates and times the analyses were performed;

d. The person(s) or laboratory who performed the analyses;

e. The analytical techniques or methods used, and;

f. The results of all required analyses.

1.2.5. Records Retention

All records and information resulting from the monitoring activities required by this permit including all records of analyses performed and calibration and maintenance of instrumentation shall be retained for a minimum of three (3) years, or longer, if requested by the Division of Water Pollution Control.

1.3. REPORTING

1.3.1. Monitoring Results

Monitoring results shall be recorded monthly and submitted monthly using Discharge Monitoring Report (DMR) forms or an electronic program supplied by the Division of Water Pollution Control. Submittals shall be postmarked or sent electronically no later than 15 days after the completion of the reporting period. The top two copies of each report are to be submitted. A copy should be retained for the permittee's files. DMRs and any communication regarding compliance with the conditions of this permit must be sent to:

TENNESSEE DEPT. OF ENVIRONMENT & CONSERVATION
DIVISION OF WATER POLLUTION CONTROL
COMPLIANCE REVIEW SECTION
401 CHURCH STREET
L & C ANNEX 6TH FLOOR
NASHVILLE TN 37243-1534

The first DMR is due on the 15^{th} of the month following permit effectiveness.

DMRs and any other report or information submitted to the division must be signed and certified by a responsible corporate officer as defined in 40 CFR 122.22, a general partner or proprietor, or a principal municipal executive officer or ranking elected official, or his duly authorized representative. Such authorization must be submitted in writing and must explain the duties and responsibilities of the authorized representative.

The electronic submission of DMRs will be accepted only if approved in writing by the division. For purposes of determining compliance with this permit, data submitted in electronic format is legally equivalent to data submitted on signed and certified DMR forms.

1.3.2. Additional Monitoring by Permittee

If the permittee monitors any pollutant specifically limited by this permit more frequently than required at the location(s) designated, using approved analytical methods as specified herein, the results of such monitoring shall be included in the calculation and reporting of the values required in the DMR form. Such increased frequency shall also be indicated on the form.

1.3.3. Falsifying Results and/or Reports

Knowingly making any false statement on any report required by this permit or falsifying any result may result in the imposition of criminal penalties as provided for in Section 309 of the Federal Water Pollution Control Act, as amended, and in Section 69-3-115 of the Tennessee Water Quality Control Act.

1.3.4. Monthly Report of Operation

Monthly operational reports shall be submitted on standard forms to the appropriate Division of Water Pollution Control Environmental Field Office in Jackson, Nashville, Chattanooga, Columbia, Cookeville, Memphis, Johnson City, or Knoxville. Reports shall be submitted by the 15th day of the month following data collection.

1.3.5. Bypass and Overflow Reporting

1.3.5.1. Report Requirements

A summary report of known or suspected instances of overflows in the collection system or bypass of wastewater treatment facilities shall accompany the Discharge Monitoring Report. The report must contain the date and duration of the instances of overflow and/or bypassing and the estimated quantity of wastewater released and/or bypassed.

The report must also detail activities undertaken during the reporting period to (1) determine if overflow is occurring in the collection system, (2) correct those known or suspected overflow points and (3) prevent future or possible overflows and any resulting bypassing at the treatment facility.

On the DMR, the permittee must report the number of sanitary sewer overflows, dry-weather overflows and in-plant bypasses separately. Three lines must be used on the DMR form, one for sanitary sewer overflows, one for dry-weather overflows and one for in-plant bypasses.

1.3.5.2. Anticipated Bypass Notification

If, because of unavoidable maintenance or construction, the permittee has need to create an in-plant bypass which would cause an effluent violation, the permittee must notify the division as soon as possible, but in any case, no later than 10 days prior to the date of the bypass.

1.3.6. Reporting Less Than Detection

A permit limit may be less than the accepted detection level. If the samples are below the detection level, then report “BDL” or “NODI =B” on the DMRs. The permittee must use the correct detection levels in all analytical testing required in the permit. The required detection levels are listed in the Rules of the Department of

Environment and Conservation, Division of Water Pollution Control, Chapter 1200-4-3-.05(8).

For example, if the limit is 0.02 mg/l with a detection level of 0.05 mg/l and detection is shown; 0.05 mg/l must be reported. In contrast, if nothing is detected reporting "BDL" or "NODI =B" is acceptable.

1.4. COMPLIANCE WITH SECTION 208

The limits and conditions in this permit shall require compliance with an area-wide waste treatment plan (208 Water Quality Management Plan) where such approved plan is applicable.

1.5. REOPENER CLAUSE

This permit shall be modified, or alternatively revoked and reissued, to comply with any applicable effluent standard or limitation issued or approved under Sections 301(b)(2)(C) and (D), 307(a)(2) and 405(d)(2)(D) of the Clean Water Act, as amended, if the effluent standard, limitation or sludge disposal requirement so issued or approved:

a. Contains different conditions or is otherwise more stringent than any condition in the permit; or

b. Controls any pollutant or disposal method not addressed in the permit.

The permit as modified or reissued under this paragraph shall also contain any other requirements of the Act then applicable.

2.0. GENERAL PERMIT REQUIREMENTS

2.1. GENERAL PROVISIONS

2.1.1. Duty to Reapply

Permittee is not authorized to discharge after the expiration date of this permit. In order to receive authorization to discharge beyond the expiration date, the permittee shall submit such information and forms as are required to the Director of Water Pollution Control (the "director") no later than 180 days prior to the expiration date. Such forms shall be properly signed and certified.

2.1.2. Right of Entry

The permittee shall allow the director, the Regional Administrator of the U.S. Environmental Protection Agency, or their authorized representatives, upon the presentation of credentials:

a. To enter upon the permittee's premises where an effluent source is located or where records are required to be kept under the terms and conditions of this permit, and at reasonable times to copy these records;

b. To inspect at reasonable times any monitoring equipment or method or any collection, treatment, pollution management, or discharge facilities required under this permit; and

c. To sample at reasonable times any discharge of pollutants.

2.1.3. Availability of Reports

Except for data determined to be confidential under Section 308 of the Federal Water Pollution Control Act, as amended, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the Division of Water Pollution Control. As required by the Federal Act, effluent data shall not be considered confidential.

2.1.4. Proper Operation and Maintenance

a. The permittee shall at all times properly operate and maintain all facilities and systems (and related appurtenances) for collection and treatment which are installed or used by the permittee to achieve compliance with the terms and conditions of this permit. Proper operation and maintenance also includes adequate laboratory and process controls and appropriate quality assurance procedures. This provision requires the operation of backup or auxiliary facilities or similar systems, which are installed by a permittee only when the operation is necessary to achieve compliance with the conditions of the permit. Backup continuous pH and flow monitoring equipment are not required.

b. Dilution water shall not be added to comply with effluent requirements to achieve BCT, BPT, BAT and or other technology based effluent limitations such as those in State of Tennessee Rule 1200-4-5-.03.

2.1.5. Treatment Facility Failure (Industrial Sources)

The permittee, in order to maintain compliance with this permit, shall control production, all discharges, or both, upon reduction, loss, or failure of the treatment facility, until the facility is restored or an alternative method of treatment is provided. This requirement applies in such situations as the reduction, loss, or failure of the primary source of power.

2.1.6. Property Rights

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of federal, state, or local laws or regulations.

2.1.7. Severability

The provisions of this permit are severable. If any provision of this permit due to any circumstance, is held invalid, then the application of such provision to other circumstances and to the remainder of this permit shall not be affected thereby.

2.1.8. Other Information

If the permittee becomes aware of failure to submit any relevant facts in a permit application, or of submission of incorrect information in a permit application or in any report to the director, then the permittee shall promptly submit such facts or information.

2.2. CHANGES AFFECTING THE PERMIT

2.2.1. Planned Changes

The permittee shall give notice to the director as soon as possible of any planned physical alterations or additions to the permitted facility. Notice is required only when:

a. The alteration or addition to a permitted facility may meet one of the criteria for determining whether a facility is a new source in 40 CFR 122.29(b); or

b. The alteration or addition could significantly change the nature or increase the quantity of pollutants discharged. This notification applies to pollutants, which are subject neither to effluent limitations in the permit, nor to notification requirements under 40 CFR 122.42(a)(1).

2.2.2. Permit Modification, Revocation, or Termination

a. This permit may be modified, revoked and reissued, or terminated for cause as described in 40 CFR 122.62 and 122.64, Federal Register, Volume 49, No. 188 (Wednesday, September 26, 1984), as amended.

b. The permittee shall furnish to the director, within a reasonable time, any information which the director may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The permittee shall also furnish to the director, upon request, copies of records required to be kept by this permit.

c. If any applicable effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established for any toxic pollutant under Section 307(a) of the Federal Water Pollution Control Act, as amended, the director shall modify or revoke and reissue the permit to conform to the prohibition or to the effluent standard, providing that the effluent standard is more stringent than the limitation in the permit on the toxic pollutant. The permittee shall comply with these effluent standards or prohibitions within the time provided in the regulations that establish these standards or prohibitions, even if the permit has not yet been modified or revoked and reissued to incorporate the requirement.

d. The filing of a request by the permittee for a modification, revocation, reissuance, termination, or notification of planned changes or anticipated noncompliance does not halt any permit condition.

2.2.3. Change of Ownership

This permit may be transferred to another party (provided there are neither modifications to the facility or its operations, nor any other changes which might affect the permit limits and conditions contained in the permit) by the permittee if:

a. The permittee notifies the director of the proposed transfer at least 30 days in advance of the proposed transfer date;

b. The notice includes a written agreement between the existing and new permittees containing a specified date for transfer of permit responsibility, coverage, and liability between them; and

c. The director, within 30 days, does not notify the current permittee and the new permittee of his intent to modify, revoke or reissue, or terminate the permit and to require that a new application be filed rather than agreeing to the transfer of the permit.

Pursuant to the requirements of 40 CFR 122.61, concerning transfer of ownership, the permittee must provide the following information to the division in their formal notice of intent to transfer ownership: 1) the NPDES permit number of the subject permit; 2) the effective date of the proposed transfer; 3) the name and address of the transferor; 4) the name and address of the transferee; 5) the names of the responsible parties for both the transferor and transferee; 6) a statement that the transferee assumes responsibility for the subject NPDES permit; 7) a statement that the transferor relinquishes responsibility for the subject NPDES permit; 8) the signatures of the responsible parties for both the transferor and transferee pursuant to the requirements of 40 CFR 122.22(a), "Signatories to permit applications"; and, 9) a statement regarding any proposed modifications to the facility, its operations, or any other changes which might affect the permit limits and conditions contained in the permit.

2.2.4. Change of Mailing Address

The permittee shall promptly provide to the director written notice of any change of mailing address. In the absence of such notice the original address of the permittee will be assumed to be correct.

2.3. NONCOMPLIANCE

2.3.1. Effect of Noncompliance

All discharges shall be consistent with the terms and conditions of this permit. Any permit noncompliance constitutes a violation of applicable state and federal laws and is grounds for enforcement action, permit termination, permit modification, or denial of permit reissuance.

2.3.2. Reporting of Noncompliance

a. 24-Hour Reporting

In the case of any noncompliance which could cause a threat to public drinking supplies, or any other discharge which could constitute a threat to human health or the environment, the required notice of non-compliance shall be provided to the Division of Water Pollution Control in the appropriate Environmental Field Office within 24-hours from the time the permittee becomes aware of the circumstances. (The Environmental Field Office should be contacted for names and phone numbers of environmental response team).

A written submission must be provided within five days of the time the permittee becomes aware of the circumstances unless the director on a case-by-case basis waives this requirement. The permittee shall provide the director with the following information:

i. A description of the discharge and cause of noncompliance;

ii. The period of noncompliance, including exact dates and times or, if not corrected, the anticipated time the noncompliance is expected to continue; and

iii. The steps being taken to reduce, eliminate, and prevent recurrence of the noncomplying discharge.

b. Scheduled Reporting

For instances of noncompliance which are not reported under subparagraph 2.3.2.a above, the permittee shall report the noncompliance on the Discharge Monitoring Report. The report shall contain all information concerning the steps taken, or planned, to reduce, eliminate, and prevent recurrence of the violation and the anticipated time the violation is expected to continue.

2.3.3. Overflow

a. "**Overflow**" means any release of sewage from any portion of the collection, transmission, or treatment system other than through permitted outfalls.

b. Overflows are prohibited.

c. The permittee shall operate the collection system so as to avoid overflows. No new or additional flows shall be added upstream of any point in the collection system, which experiences chronic overflows (greater than 5 events per year) or would otherwise overload any portion of the system.

d. Unless there is specific enforcement action to the contrary, the permittee is relieved of this requirement after: 1) an authorized representative of the Commissioner of the Department of Environment and Conservation has approved an engineering report and construction plans and specifications prepared in accordance with accepted engineering practices for correction of the problem; 2) the correction work is underway; and 3) the cumulative, peak-design, flows potentially added from new connections and line extensions upstream of any chronic overflow point are less than or proportional to the amount of inflow and infiltration removal documented upstream of that point. The inflow and infiltration reduction must be measured by the permittee using practices that are customary in the environmental engineering field and reported in an attachment to a Monthly Operating Report submitted to the local TDEC Environmental Field Office. The data measurement period shall be sufficient to account for seasonal rainfall patterns and seasonal groundwater table elevations.

e. In the event that more than 5 overflows have occurred from a single point in the collection system for reasons that may not warrant the self-imposed moratorium or completion of the actions identified in this paragraph, the permittee may request a meeting with the Division of Water Pollution Control EFO staff to petition for a waiver based on mitigating evidence.

2.3.4. Upset

a. "***Upset***" means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

b. An upset shall constitute an affirmative defense to an action brought for noncompliance with such technology-based permit effluent limitations if the permittee demonstrates, through properly signed, contemporaneous operating logs, or other relevant evidence that:

   i. An upset occurred and that the permittee can identify the cause(s) of the upset;

   ii. The permitted facility was at the time being operated in a prudent and workman-like manner and in compliance with proper operation and maintenance procedures;

   iii. The permittee submitted information required under "Reporting of Noncompliance" within 24-hours of becoming aware of the upset (if this information is provided orally, a written submission must be provided within five days); and

   iv. The permittee complied with any remedial measures required under "Adverse Impact."

2.3.5. Adverse Impact

The permittee shall take all reasonable steps to minimize any adverse impact to the waters of Tennessee resulting from noncompliance with this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge. It shall not be a defense for the permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

2.3.6. Bypass

a. "***Bypass***" is the intentional diversion of wastewater away from any portion of a treatment facility. "Severe property damage" means substantial physical damage to property, damage to the treatment facilities which would cause them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

b. Bypasses are prohibited unless all of the following 3 conditions are met:

i. The bypass is unavoidable to prevent loss of life, personal injury, or severe property damage;

ii. There are no feasible alternatives to bypass, such as the construction and use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass, which occurred during normal periods of equipment downtime or preventative maintenance;

iii. The permittee submits notice of an unanticipated bypass to the Division of Water Pollution Control in the appropriate Environmental Field Office within 24 hours of becoming aware of the bypass (if this information is provided orally, a written submission must be provided within five days). When the need for the bypass is foreseeable, prior notification shall be submitted to the director, if possible, at least 10 days before the date of the bypass.

c. Bypasses not exceeding permit limitations are allowed **only** if the bypass is necessary for essential maintenance to assure efficient operation. All other bypasses are prohibited. Allowable bypasses not exceeding limitations are not subject to the reporting requirements of 2.3.6.b.iii, above.

2.3.7. Washout

a. 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 decrease due to solids wasting to the sludge disposal system. A washout can be caused by improper operation or from peak flows due to infiltration and inflow.

b. A washout is prohibited. If a washout occurs the permittee must report the incident to the Division of Water Pollution Control in the appropriate Environmental Field Office within 24 hours by telephone. A written submission must be provided within five days. The washout must be noted on the discharge monitoring report. Each day of a washout is a separate violation.

2.4. LIABILITIES

2.4.1. Civil and Criminal Liability

Except as provided in permit conditions for "***Bypassing***," "***Overflow,***" and "***Upset***," nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for noncompliance. Notwithstanding this permit, the permittee shall remain liable for any damages sustained by the State of Tennessee, including but not limited to fish kills and losses of aquatic life and/or wildlife, as a result of the discharge of wastewater to any surface or subsurface waters. Additionally, notwithstanding this Permit, it shall be the responsibility of the permittee to conduct its wastewater treatment and/or discharge activities in a manner such that public or private nuisances or health hazards will not be created.

2.4.2. Liability Under State Law

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable state law or the Federal Water Pollution Control Act, as amended.

3.0. PERMIT SPECIFIC REQUIREMENTS

3.1. CERTIFIED OPERATOR

The waste treatment facilities shall be operated under the supervision of a Grade 3 certified wastewater treatment operator and the collection system operated under the supervision of a Grade 1 Collection System certified operator in accordance with the Water Environmental Health Act of 1984.

Paragraph 1a-c applies if the STP does NOT have an approved pretreatment program:
Paragraph 2a-c applies if the pretreatment program is inactive:
Paragraph 3a-d applies if the STP has an approved or developing pretreatment program:

3.2. POTW PRETREATMENT PROGRAM GENERAL PROVISIONS

As an update of information previously submitted to the division, the permittee will undertake the following activity.

(If developing, replace the above sentence with the one below, and delete the 120-day IWS submission requirement in 1c.h.)

Requirements of Section III.B. shall apply after the division director or pretreatment coordinator has approved the pretreatment program by letter.

1a. The permittee shall submit the results of an Industrial Waste Survey (IWS) in accordance with 40 CFR 403.8(f)(2)(i), including any industrial users (IU) covered under Section 301(i)(2) of the Act. As much information as possible must be obtained relative to the character and volume of pollutants contributed to the POTW by the IUs. This information will be submitted to the Division of Water Pollution Control, Pretreatment Section within one hundred twenty (120) days of the effective date of this permit. Development of a pretreatment program may be required after completion of the industrial user review. All requirements and conditions of the pretreatment program are enforceable through the NPDES permit.

2a. The current pretreatment program is in the inactive stage. The program will remain inactive as long as no significant industries discharge into the collection system. Should a significant industrial user request permission to discharge into the --- system, then the City must request that the division reactivate the pretreatment program. This must be done prior to the industrial discharge taking place.

The permittee shall submit the results of an Industrial Waste Survey (IWS) in accordance with 40 CFR 403.8(f)(2)(i), including any industrial users (IU) covered under Section 301(i)(2) of the Act. As much information as possible must be obtained relative to the character and volume of pollutants contributed to the

POTW by the IUs. This information will be submitted to the Division of Water Pollution Control, Pretreatment Section within one hundred twenty (120) days of the effective date of this permit. Development of a pretreatment program may be required after completion of the industrial user review. All requirements and conditions of the pretreatment program are enforceable through the NPDES permit.

3a. The permittee has been delegated the primary responsibility and therefore becomes the "control authority" for enforcing the 40 CFR 403 General Pretreatment Regulations. Where multiple plants are concerned the permittee is responsible for the Pretreatment Program for all plants within its jurisdiction. The permittee shall implement and enforce the Industrial Pretreatment Program in accordance with Section 403(b)(8) of the Clean Water Act, the Federal Pretreatment Regulations 40 CFR 403, Tennessee Water Quality Control Act Part 63-3-123 through 63-3-128, and the legal authorities, policies, procedures, and financial provisions contained in its approved Pretreatment Program, except to the extent this permit imposed stricter requirements. Such implementation shall require but not limit the permittee to do the following:

i. Carry out inspection, surveillance, and monitoring procedures which will determine, independent of information supplied by the industrial user (IU), whether the IU is in compliance with the pretreatment standards;

ii. Require development, as necessary, of compliance schedules for each IU for the installation of control technologies to meet applicable pretreatment standards;

iii. Require all industrial users to comply with all applicable monitoring and reporting requirements outlined in the approved pretreatment program and IU permit;

iv. Maintain and update, as necessary, records identifying the nature and character of industrial user discharges, and retain such records for a minimum of three (3) years;

v. Obtain appropriate remedies for noncompliance by an IU with any pretreatment standard and/or requirement;

vi. Publish annually, pursuant to 40 CFR 403.8 (f)(2)(vii), a list of industrial users that have significantly violated pretreatment requirements and standards during the previous twelve-month period.

vii. Maintain an adequate revenue structure for continued operation of the pretreatment program.

viii. Update its Industrial Waste Survey at least once every five years. Results of this update shall be submitted to the Division of Water Pollution Control, Pretreatment Section within 120 days of the effective date of this permit.

ix. Submit a written technical evaluation of the need to revise local limits within 120 days of the effective date of this permit to the state pretreatment program coordinator. The evaluation shall include the most recent pass-through limits proposed by the division. The technical evaluation shall be based on practical and specialized knowledge of the local program and not be limited by a specified written format.

b. The permittee shall enforce 40 CFR 403.5, "prohibited discharges". Pollutants introduced into the POTW by a non-domestic source shall not cause pass through or interference as defined in 40 CFR Part 403.3. These general prohibitions and the specific prohibitions in this section apply to all non-domestic sources introducing pollutants into the POTW whether the source is subject to other National Pretreatment Standards or any state or local pretreatment requirements.

   Specific prohibitions. Under no circumstances shall the permittee allow introduction of the following wastes in the waste treatment system:

   i. Pollutants which create a fire or explosion hazard in the POTW;

   ii. Pollutants which will cause corrosive structural damage to the treatment works, but in no case discharges with pH less than 5.0 unless the system is specifically designed to accept such discharges.

   iii. Solid or viscous pollutants in amounts which will cause obstruction to the flow in the treatment system resulting in interference.

   iv. Any pollutant, including oxygen-demanding pollutants (BOD, etc.) released in a discharge at a flow rate and/or pollutant concentration which will cause interference with the treatment works.

   v. Heat in amounts which will inhibit biological activity in the treatment works resulting in interference, but in no case heat in such quantities that the temperature at the treatment works exceeds 40°C (104°F) unless the works are designed to accommodate such heat.

   vi. Any priority pollutant in amounts that will contaminate the treatment works sludge.

   vii. Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;

   viii. Pollutants which result in the presence of toxic gases, vapors or fumes within the POTW in a quantity that may cause acute worker health and safety problems;

   ix. Any trucked or hauled pollutants except at discharge points designated by the POTW.

c. The permittee shall notify the Tennessee Division of Water Pollution Control of any of the following changes in user discharge to the system no later than 30 days prior to change of discharge:

   i. New introductions into such works of pollutants from any source which would be a new source as defined in Section 306 of the Act if such source were discharging pollutants.

   ii. New introductions of pollutants into such works from a source which would be subject to Section 301 of the "Federal Water Quality Act as Amended" if it were discharging such pollutants.

   iii. A substantial change in volume or character of pollutants being introduced into such works by a source already discharging pollutants into such works at the time the permit is issued.

   This notice will include information on the quantity and quality of the wastewater introduced by the new source into the publicly owned treatment works, and on any anticipated impact on the effluent discharged from such works. If this discharge necessitates a revision of the current NPDES permit or pass-through guidelines, discharge by this source is prohibited until the Tennessee Division of Water Pollution Control gives final authorization.

d. Reporting Requirements

   The permittee shall provide a semiannual report briefly describing the permittee's pretreatment program activities over the previous six-month period. Reporting periods shall end on the last day of the months of March and September. The report shall be submitted to the Division of Water Pollution Control, Central Office and a copy to the appropriate Environmental Field Office no later than the 28th day of the month following each reporting period. For control authorities with multiple STPs, one report should be submitted with a separate Form 1 for each STP. Each report shall conform to the format set forth in the State POTW Pretreatment Semiannual Report Package which contains information regarding:

   i. An updated listing of the permittee's industrial users.

   ii. Results of sampling of the influent and effluent of the wastewater treatment plant. At least once each reporting period, the permittee shall analyze the wastewater treatment plant influent and effluent for the following pollutants, using the prescribed sampling procedures:

(approved and developing programs)

Pollutant	**Sample Type**
chromium	24-hour composite
copper	24-hour composite
lead	24-hour composite
nickel	24-hour composite
zinc	24-hour composite
cadmium	24-hour composite
mercury	24-hour composite
silver	24-hour composite
total phenols	grab
cyanide	grab

If any particular pollutant is analyzed more frequently than is required, the permittee shall report the maximum and average values on the semiannual report. All upsets, interferences, and pass-through violations must also be reported on the semiannual report, the actions that were taken to determine the causes of the incidents and the steps that have been taken to prevent the incidents from recurring.

At least once during the term of this permit, the permittee shall analyze the effluent from the STP (and report the results in the next regularly scheduled report) for the following pollutants:

<table>
<tr><td>chromium, total</td><td>silver</td><td rowspan="5">phthalates, sum of the following:
bis (2-ethylhexyl) phthalate
butyl benzylphthalate
di-n-butylphthalate
diethyl phthalate</td></tr>
<tr><td>copper</td><td>benzene</td></tr>
<tr><td>lead</td><td>carbon tetrachloride</td></tr>
<tr><td>nickel</td><td>chloroform</td></tr>
<tr><td>zinc</td><td>ethylbenzene</td></tr>
<tr><td>cadmium</td><td>methylene chloride</td><td>tetrachloroethylene</td></tr>
<tr><td>mercury</td><td>naphthalene</td><td>toluene</td></tr>
<tr><td>phenols, total</td><td>1,1,1 trichloroethane</td><td>trichloroethylene</td></tr>
<tr><td>cyanide</td><td>1,2 trans-dichloroethylene</td><td></td></tr>
</table>

iii. Compliance with categorical and local standards, and review of industrial compliance, which includes a summary of the compliance status for all permitted industries. Also included is information on the number and type of major violations of pretreatment regulations, and the actions taken by the POTW to obtain compliance. The effluent from all significant industrial users must be analyzed for the appropriate pollutants at least once per reporting period.

iv. A list of industries in significant non-compliance as published in local newspapers in accordance with the requirements set forth in 40 CFR 403.8(f)(2)(vii).

v. A description of all substantive changes made to the permittee's pretreatment program. Any such changes shall receive prior approval. Substantive changes include, but are not limited to, any change in any ordinance, major modification in the program's administrative structure, local limits, or a change in the method of funding the program.

vi. Summary of permittee's industrial user inspections, which includes information on the number and type of industry inspected. All significant industrial users must be inspected at least once per year.

3.3. SLUDGE MANAGEMENT PRACTICES

a. The permittee must comply with 40 CFR 503 et seq. Sludge shall be sampled and analyzed at a frequency dependant both on the amount of sludge generated annually and on the disposal practice utilized. Whenever sampling and analysis are required by 40 CFR 503, the permittee shall report to the division the quantitative data for the following parameters:

1)	Arsenic	7)	Nickel
2)	Cadmium	8)	Selenium
3)	Copper	9)	Zinc
4)	Lead	10)	Nitrite plus Nitrate, NO_2, + NO_3 as N
5)	Mercury	11)	Total Kjeldahl Nitrogen, as N
6)	Molybdenum	12)	Ammonia, NH_3, as N

This sludge analysis must be submitted by February 19th of each calendar year. This information shall be submitted to the Division of Water Pollution Control, Central Office, 401 Church Street, 6th Floor Annex, Nashville TN 37243-1534, Attention: Sludge Coordinator, Municipal Facilities Section.

b. Land application of sludge shall halt immediately if any of the following concentrations are exceeded:

POLLUTANT	CONCENTRATION (mg/kg[1])
Arsenic	75
Cadmium	85
Zinc	7500
Copper	4300
Lead	840

POLLUTANT	CONCENTRATION (mg/kg[1])
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100

1 Dry Weight Basis

Monthly average pollutant concentrations shall not exceed Table 3 of 40 CFR §503.13. If they are exceeded cumulative pollutant loading rates are to be calculated and recorded and shall not exceed Table 2 of 40 CFR §503.13 for the life of the land application site.

c. If land application is the final disposition of the wasted sludge, the permittee shall provide pathogen reduction, sludge stabilization and comply with land and crop usage controls as listed in 40 CFR Part 503, as authorized by the Clean Water Act. Records must be maintained by the permittee that indicate compliance or non-compliance with this rule. If the permittee is required to report to EPA, copies of all reports should be sent to the division, at the address listed in paragraph 1 of this section.

d. Before land applying municipal sludge the permittee must obtain approvals for each site(s) in writing from the division using the latest revision of Guidelines for Land Application or Surface Disposal of Biosolids, unless the sludge being land applied meets the pollutant concentrations of 40 CFR 503.13(b)(3), the Class A pathogen requirements in 40 CFR 503.32(a), and one of the vector attraction reduction requirements in 40 CFR 503.33 (b)(1) through (b)(8).

e. Reopener: If an applicable "acceptable management practice" or numerical limitation for pollutants in sewage sludge promulgated under Section 405(d)(2) of the Clean Water Act, as amended by the Water Quality Act of 1987, is more stringent than the sludge pollutant limit or acceptable management practice in this permit, or controls a pollutant not limited in this permit, this permit shall be promptly modified or revoked and reissued to conform to the requirements promulgated under Section 405(d)(2). The permittee shall comply with the limitations by no later than the compliance deadline specified in the applicable regulations as required by Section 405(d)(2) of the Clean Water Act.

f. Notice of change in sludge disposal practice: The permittee shall give prior notice to the director of any change planned in the permittee's sludge disposal practice. If land application activities are suspended permanently and sludge disposal moves to a municipal solid waste landfill, the permittee shall contact the local Division of Solid Waste Management office address for other permitting and approvals (see table below):

Division of Solid Waste Management			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	540 McCallie Avenue, Suite 550	37402-2013	(423) 634-5745
Jackson	362 Carriage House Drive	38305-2222	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 432-4015
Columbia	2484 Park Plus Drive	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	2700 Middlebrook Pike, Suite 220	37921	(865) 594-6035
Memphis	2510 Mt. Moriah Road, Suite E-645	38115-1511	(901) 368-7939
Nashville	711 R.S. Gass Boulevard	37243-1550	(615) 687-7000

If sludge disposal is to a municipal solid waste landfill:

The current method of sludge disposal is to a municipal solid waste landfill (or co - composting facility). This method of disposal is controlled by the rules of the Tennessee Division of Solid Waste Management (DSWM) and Federal Regulations at 40 CFR 258. If the permittee anticipates changing its disposal practices to either land application or surface disposal, the Division of Water Pollution Control shall be notified prior to the change. A copy of the results of pollutant analyses required by the Tennessee Division of Solid Waste Management (DSWM) and / or 40 CFR 258 shall be submitted to the Division of Water Pollution Control.

Sludge language for lagoon systems:

a. The permittee shall give prior notice to the director of any change planned in the permittee's sludge disposal practice. In the event the --- STP removes any sludge from any lagoon the permittee must comply with 40 CFR 503 et seq.

b. Before land applying municipal sludge the permittee must obtain approvals for each site(s) in writing from the division using the latest revision of Guidelines for Land Application or Surface Disposal of Biosolids, unless the sludge being land applied meets the pollutant concentrations of 40 CFR 503.13(b)(3), the Class A pathogen requirements in 40 CFR 503.32(a), and one of the vector attraction reduction requirements in 40 CFR 503.33 (b)(1) through (b)(8).

c. If sludge disposal moves to a municipal solid waste landfill, the permittee shall contact the local Division of Solid Waste Management office address for other permitting and approvals (see table below):

Division of Solid Waste Management			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	540 McCallie Avenue, Suite 550	37402-2013	(423) 634-5745
Jackson	362 Carriage House Drive	38305-2222	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 432-4015
Columbia	2484 Park Plus Drive	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	2700 Middlebrook Pike, Suite 220	37921	(865) 594-6035
Memphis	2510 Mt. Moriah Road, Suite E-645	38115-1511	(901) 368-7939
Nashville	711 R.S. Gass Boulevard	37243-1550	(615) 687-7000

3.4. BIOMONITORING REQUIREMENTS, CHRONIC

The permittee shall conduct a 3-Brood *Ceriodaphnia dubia* Survival and Reproduction Test and a 7-Day Fathead Minnow *(Pimephales promelas)* Larval Survival and Growth Test on samples of final effluent from Outfall 001.

The measured endpoint for toxicity will be the inhibition concentration causing 25% reduction in survival, reproduction and growth (IC_{25}) of the test organisms. The IC_{25} shall be determined based on a 25% reduction as compared to the controls, and as derived from linear interpolation. The average reproduction and growth responses will be determined based on the number of *Ceriodaphnia dubia* or *Pimephales promelas* larvae used to initiate the test.

If the permit limit is 100%, use this table:

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
Permit Limit (PL)	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**0.0625 X PL**	**Control**
% effluent					
100	**50**	**25**	**12.5**	**6.25**	**0**

If the permit limit is at or above 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**Control**
% effluent					
100	**xx**	**0.0**	**0.0**	**0.0**	**0**

If the permit limit is above 25%, but below 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**(100+PL)/2**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
100	**50**	**xx**	**0.0**	**0.0**	**0**

If the permit limit is at or below 25%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
4 X PL	**2 X PL**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
0	**0**	**xx**	**0.0**	**0.0**	**0**

The dilution/control water used will be moderately hard water as described in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013 (or the most current edition). A chronic standard reference toxicant quality assurance test shall be conducted with each species used in the toxicity tests and the results submitted with the discharge monitoring report. Additionally, the analysis of this multi-concentration test shall include review of the concentration-response relationship to ensure that calculated test results are interpreted appropriately.

Toxicity will be demonstrated if the IC_{25} is less than or equal to the permit limit indicated for each outfall in the above table(s). Toxicity demonstrated by the tests specified herein constitutes a violation of this permit.

All tests will be conducted using a minimum of three 24-hour flow-proportionate composite samples of final effluent collected on days 1, 3 and 5. If, in any control more than 20% of the test organisms die in 7 days, the test (control and effluent) is considered invalid and the test shall be repeated within two (2) weeks. Furthermore, if the results do not meet the acceptability criteria in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013 (or the most current edition), or if the required concentration-response review fails to yield a valid relationship per guidance contained in Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing, EPA-821-B-00-004 (or the most current edition), that test shall be repeated. Any test initiated but terminated before completion must also be reported along with a complete explanation for the termination.

USE THIS LANGUAGE WHEN DILUTION RATIO IS GREATER THAN 500 TO 1:

The toxicity tests specified herein shall be conducted yearly (1/yr) for Outfall 001 and begin no later than 90 days from the effective date of this permit. Monitoring frequency will be 1/quarter when a non-categorical Significant Industrial User (SIU) or a Categorical Industrial User (CIU) discharges to the treatment works.

The toxicity tests specified herein shall be conducted quarterly (1/Quarter) for Outfall 001 and begin no later than 90 days from the effective date of this permit.

In the event of a test failure, the permittee must start a follow-up test within 2 weeks and submit results from a follow-up test within 30 days from obtaining initial WET testing results. The follow-up test must be conducted using the same serial dilutions as presented in the corresponding table(s) above. **The follow-up test will not negate an initial failed test. In addition, the failure of a follow-up test will constitute a separate permit violation.**

In the event of 2 consecutive test failures or 3 test failures within a 12-month period for the same outfall, the permittee must initiate a Toxicity Identification Evaluation/Toxicity Reduction Evaluation (TIE/TRE) study within 30 days and so notify the division by letter. This notification shall include a schedule of activities for the initial investigation of that outfall. **During the term of the TIE/TRE study, the frequency of biomonitoring shall be once every three months.** Additionally, the permittee shall submit progress reports once every three months throughout the term of the TIE/TRE study. The toxicity must be reduced to allowable limits for that outfall within 2 years of initiation of the TIE/TRE study. Subsequent to the results obtained from the TIE/TRE studies, the permittee may request an extension of the TIE/TRE study period if necessary to conduct further analyses. The final determination of any extension period will be made at the discretion of the division.

The TIE/TRE study may be terminated at any time upon the completion and submission of 2 consecutive tests (for the same outfall) demonstrating compliance. Following the completion of TIE/TRE study, the frequency of monitoring will return to a regular schedule, as defined previously in this section as well in Part I of the permit. **During the course of the TIE/TRE study, the permittee will continue to conduct toxicity testing of the outfall being investigated at the frequency of once every three months but will not be required to perform follow-up tests for that outfall during the period of TIE/TRE study.**

Test procedures, quality assurance practices, determinations of effluent survival/reproduction and survival/growth values, and report formats will be made in accordance with Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013, or the most current edition.

Results of all tests, reference toxicant information, copies of raw data sheets, statistical analysis and chemical analyses shall be compiled in a report. The report will be written in accordance with Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013, or the most current edition.

Two copies of biomonitoring reports (including follow-up reports) shall be submitted to the division. One copy of the report shall be submitted along with the discharge monitoring report (DMR). The second copy shall be submitted to the local Division of Water Pollution Control office address (see table below):

Division of Water Pollution Control			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	540 McCallie Avenue, Suite 550	37402-2013	(423) 634-5745
Jackson	362 Carriage House Drive	38305-2222	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 432-4015
Columbia	2484 Park Plus Drive	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	2700 Middlebrook Pike, Suite 220	37921	(865) 594-6035
Memphis	2510 Mt. Moriah Road, Suite E-645	38115-1511	(901) 368-7939
Nashville	711 R.S. Gass Boulevard	37243-1550	(615) 687-7000

3.5. BIOMONITORING REQUIREMENTS, ACUTE

The permittee shall conduct a 48-hour static acute toxicity test on two test species on samples of final effluent from Outfall 001. The test species to be used are Water Fleas (Ceriodaphnia dubia) and Fathead Minnows (Pimephales promelas).

The measured endpoint for toxicity will be the concentration causing 50% lethality (LC50) of the test organisms. The LC50 shall be determined based on a 50% lethality as compared to the controls, and as derived from linear interpolation.

If the permit limit is 100%, use this table:

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
Permit Limit (PL)	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**0.0625 X PL**	**Control**
% effluent					
100	**50**	**25**	**12.5**	**6.25**	**0**

If the permit limit is at or above 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**Control**
% effluent					
100	**xx**	**0.0**	**0.0**	**0.0**	**0**

If the permit limit is above 25%, but below 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**(100+PL)/2**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
100	**50**	**xx**	**0.0**	**0.0**	**0**

If the permit limit is at or below 25%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
4 X PL	**2 X PL**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
0	**0**	**xx**	**0.0**	**0.0**	**0**

The dilution/control water used will be moderately hard water as described in Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012 (or the most current edition). An acute standard reference toxicant quality assurance test shall be conducted with each species used in the toxicity tests and the results submitted with the discharge monitoring report. Additionally, the analysis of this multi-concentration test shall include review of the concentration-response relationship to ensure that calculated test results are interpreted appropriately.

Toxicity will be demonstrated if the LC50 is less than or equal to the permit limit indicated for each outfall in the above table(s). Toxicity demonstrated by the tests specified herein constitutes a violation of this permit.

All tests will be conducted using four separate grab samples of final effluent, to be used in four separate tests, and shall be collected at evenly spaced (6-hour) intervals over a 24-hour period. If in any control, more than 10% of the test organisms die in 48 hours, the test (control and effluent) is considered invalid and the test shall be repeated within two (2) weeks. Furthermore, if the results do not meet the acceptability criteria in Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012 (or the most current edition), if the required concentration-response review fails to yield a valid relationship per guidance contained in Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing, EPA-821-B-00-004 (or the most current edition), that test shall be repeated. Any test initiated but terminated before completion must also be reported along with a complete explanation for the termination.

The toxicity tests specified herein shall be conducted quarterly (1/Quarter) for Outfall 001 and begin no later than 90 days from the effective date of this permit.

In the event of a test failure, the permittee must start a follow-up test within 2 weeks and submit results from a follow-up test within 30 days from obtaining initial WET testing results. The follow-up test must be conducted using the same serial dilutions as presented in the corresponding table(s) above. The follow-up test will not negate an initial failed test. In addition, the failure of a follow-up test will constitute a separate permit violation.

In the event of 2 consecutive test failures or 3 test failures within a 12-month period for the same outfall, the permittee must initiate a Toxicity Identification Evaluation/Toxicity Reduction Evaluation (TIE/TRE) study within 30 days and so notify the division by letter. This notification shall include a schedule of activities for the initial investigation of that outfall. During the term of the TIE/TRE study, the frequency of biomonitoring shall be once every three months. Additionally, the permittee shall submit progress reports once every three months throughout the term of the TIE/TRE study. The toxicity must be reduced to allowable limits for that outfall within 2 years of initiation of the TIE/TRE study. Subsequent to the results obtained from the TIE/TRE studies, the permittee may request an extension of the TIE/TRE study period if necessary to conduct further analyses. The final determination of any extension period will be made at the discretion of the division.

The TIE/TRE study may be terminated at any time upon the completion and submission of 2 consecutive tests (for the same outfall) demonstrating compliance. Following the completion of TIE/TRE study, the frequency of monitoring will return to a regular schedule, as defined previously in this section as well in Part I of the permit. During the course of the TIE/TRE study, the permittee will continue to conduct toxicity testing of the outfall being investigated at the frequency of once every three months but will not be required to perform follow-up tests for that outfall during the period of TIE/TRE study.

Test procedures, quality assurance practices and determination of effluent lethality values will be made in accordance with Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012, or the most current edition.

Results of all tests, reference toxicant information, copies of raw data sheets, statistical analysis and chemical analysis shall be compiled in a report. The report shall be written in accordance with Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012, or the most current edition.

Two copies of biomonitoring reports (including follow-up reports) shall be submitted to the division. One copy of the report shall be submitted along with the discharge monitoring report (DMR). The second copy shall be submitted to the local Division of Water Pollution Control office address (see table below):

Division of Water Pollution Control			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	540 McCallie Avenue, Suite 550	37402-2013	(423) 634-5745
Jackson	362 Carriage House Drive	38305-2222	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 432-4015
Columbia	2484 Park Plus Drive	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	2700 Middlebrook Pike, Suite 220	37921	(865) 594-6035
Memphis	2510 Mt. Moriah Road, Suite E-645	38115-1511	(901) 368-7939
Nashville	711 R.S. Gass Boulevard	37243-1550	(615) 687-7000

3.6. PLACEMENT OF SIGNS

Within sixty (60) days of the effective date of this permit, the permittee shall place and maintain a sign(s) at each outfall and any bypass/overflow point in the collection system. For the purposes of this requirement, any bypass/overflow point that has discharged five (5) or more times in the last year must be so posted. The sign(s) should be clearly visible to the public from the bank and the receiving stream. The minimum sign size should be two feet by two feet (2' x 2') with one-inch (1") letters. The sign should be made of durable material and have a white background with black letters.

The sign(s) are to provide notice to the public as to the nature of the discharge and, in the case of the permitted outfalls, that the discharge is regulated by the Tennessee Department of Environment and Conservation, Division of Water Pollution Control. The following is given as an example of the minimal amount of information that must be included on the sign:

Permitted CSO or unpermitted bypass/overflow point:

UNTREATED WASTEWATER DISCHARGE POINT
--- STP
contact phone number
NPDES Permit NO. TN00-----
TENNESSEE DIVISION OF WATER POLLUTION CONTROL
1-888-891-8332 ENVIRONMENTAL FIELD OFFICE - Columbia

NPDES Permitted Municipal/Sanitary Outfall:

TREATED MUNICIPAL/SANITARY WASTEWATER
--- STP
contact phone number
NPDES Permit NO. TN00-----
TENNESSEE DIVISION OF WATER POLLUTION CONTROL
1-888-891-8332 ENVIRONMENTAL FIELD OFFICE - Columbia

No later than sixty (60) days from the effective date of this permit, the permittee shall have the above sign(s) on display in the location specified.

3.7. ANTIDEGRADATION

Pursuant to the Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-3-.06, titled “Tennessee Antidegradation Statement,” and in consideration of the department’s directive in attaining the greatest degree of effluent reduction achievable in municipal, industrial, and other wastes, the permittee shall further be required, pursuant to the terms and conditions of this permit, to comply with the effluent limitations and schedules of compliance required to implement applicable water quality standards, to comply with a State Water Quality Plan or other state or federal laws or regulations, or where practicable, to comply with a standard permitting no discharge of pollutants.

The pump/lift station inspection language is for permittees in Johnson City:

3.8. PUMP/LIFT STATION INSPECTION

All pump/lift stations > or = 100 gpm must be inspected five (5) days a week. In populated areas, all stations < 300 gpm may alternately be equipped with alarms, lights and or horns. In populated areas, all stations > or = 300 gpm may alternately be equipped with true remote sensing telemetry systems. All stations < 100 gpm must be inspected as necessary to ensure proper operation. The inspector shall note the date, time and inspector initials in a bound log notebook.

4.0. DEFINITIONS AND ACRONYMS

4.1. DEFINITIONS

A "***bypass***" is defined as the intentional diversion of waste streams from any portion of a treatment facility.

A “***calendar day***” is defined as the 24-hour period from midnight to midnight or any other 24-hour period that reasonably approximates the midnight to midnight time period.

A "***composite sample***" is a combination of not less than 8 influent or effluent portions, of at least 100 ml, collected over a 24-hour period. Under certain circumstances a lesser time period may be allowed, but in no case, less than 8 hours.

The "***daily maximum concentration***" is a limitation on the average concentration in units of mass per volume (e.g. milligrams per liter), of the discharge during any calendar day. When a proportional-to-flow composite sampling device is used, the daily concentration is the concentration of that 24-hour composite; when other sampling means are used, the daily concentration is the arithmetic mean of the concentrations of equal volume samples collected during any calendar day or sampling period.

“***Degradation***” means the alteration of the properties of waters by the addition of pollutants or removal of habitat. Alterations not resulting in the condition of pollution that are of a temporary nature or those alterations having de minimus impact (not measurable or less than 5 percent loss of assimilative capacity) will not be considered degradation. Degradation will not be considered de minimus if a substantial loss (more than 50 percent) of assimilative capacity has already occurred.

“***Discharge***” or “discharge of a pollutant” refers to the addition of pollutants to waters from a source.

A “***dry weather overflow***” is a type of sanitary sewer overflow and is defined as one day or any portion of a day in which unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall occurs and is not directly related to a rainfall event. Discharges from more than one point within a 24-hour period shall be counted as separate overflows.

An “***ecoregion***” is a relatively homogeneous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

The "***geometric mean***" of any set of values is the n^{th} root of the product of the individual values where "n" is equal to the number of individual values. The geometric mean is equivalent to the antilog of the arithmetic mean of the logarithms of the individual values. For the purposes of calculating the geometric mean, values of zero (0) shall be considered to be one (1).

A "***grab sample***" is a single influent or effluent sample collected at a particular time.

The "***instantaneous maximum concentration***" is a limitation on the concentration, in milligrams per liter, of any pollutant contained in the wastewater discharge determined from a grab sample taken from the discharge at any point in time.

The "***instantaneous minimum concentration***" is the minimum allowable concentration, in milligrams per liter, of a pollutant parameter contained in the wastewater discharge determined from a grab sample taken from the discharge at any point in time.

The "***monthly average amount***", shall be determined by the summation of all the measured daily discharges by weight divided by the number of days during the calendar month when the measurements were made.

The "***monthly average concentration***", other than for *E. Coli* bacteria, is the arithmetic mean of all the composite or grab samples collected in a one-calendar month period.

A "***one week period***" (or "***calendar-week***") is defined as the period from Sunday through Saturday. For reporting purposes, a calendar week that contains a change of month shall be considered part of the latter month.

"***Pollutant***" means sewage, industrial wastes, or other wastes.

A "***quarter***" is defined as any one of the following three-month periods: January 1 through March 31, April 1 through June 30, July 1 through September 30, and/or October 1 through December 31.

A "***rainfall event***" is defined as any occurrence of rain, preceded by 10 hours without precipitation that results in an accumulation of 0.01 inches or more. Instances of rainfall occurring within 10 hours of each other will be considered a single rainfall event.

A "***rationale***" (or "fact sheet") is a document that is prepared when drafting an NPDES permit or permit action. It provides the technical, regulatory and administrative basis for an agency's permit decision.

A "***reference site***" means least impacted waters within an ecoregion that have been monitored to establish a baseline to which alterations of other waters can be compared.

A "***reference condition***" is a parameter-specific set of data from regional reference sites that establish the statistical range of values for that particular substance at least-impacted streams.

A **"*sanitary sewer overflow (SSO*)"** is defined as an unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall.

"***Sewage***" means water-carried waste or discharges from human beings or animals, from residences, public or private buildings, or industrial establishments, or boats, together with such other wastes and ground, surface, storm, or other water as may be present.

"***Severe property damage***" when used to consider the allowance of a bypass or SSO means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass or SSO. Severe property damage does not mean economic loss caused by delays in production.

"***Sewerage system***" means the conduits, sewers, and all devices and appurtenances by means of which sewage and other waste is collected, pumped, treated, or disposed.

A "***subecoregion***" is a smaller, more homogenous area that has been delineated within an ecoregion.

"***Upset***" means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

The term, "***washout***" is applicable to activated sludge plants and is defined as loss of mixed liquor suspended solids (MLSS) of 30.00% or more from the aeration basin(s).

"***Waters***" means any and all water, public or private, on or beneath the surface of the ground, which are contained within, flow through, or border upon Tennessee or any portion thereof except those bodies of water confined to and retained within the limits of private property in single ownership which do not combine or effect a junction with natural surface or underground waters.

The "***weekly average amount***", shall be determined by the summation of all the measured daily discharges by weight divided by the number of days during the calendar week when the measurements were made.

The "***weekly average concentration***", is the arithmetic mean of all the composite samples collected in a one-week period. The permittee must report the highest weekly average in the one-month period.

4.2. ACRONYMNS AND ABBREVIATIONS

1Q10 – 1-day minimum, 10-year recurrence interval

30Q20 – 30-day minimum, 20-year recurrence interval

7Q10 – 7-day minimum, 10-year recurrence interval

BAT – best available technology economically achievable

BCT – best conventional pollutant control technology

BDL – below detection level

BOD_5 – five day biochemical oxygen demand

BPT – best practicable control technology currently available

$CBOD_5$ – five day carbonaceous biochemical oxygen demand

CFR – code of federal regulations

CFS – cubic feet per second

CFU – colony forming units

CIU – categorical industrial user

CSO – combined sewer overflow

DMR – discharge monitoring report

D.O. – dissolved oxygen

E. coli – *Escherichia coli*

EFO – environmental field office

LB(lb) - pound

IC_{25} – inhibition concentration causing 25% reduction in survival, reproduction and growth of the test organisms

IU – industrial user

IWS – industrial waste survey

LC_{50} – acute test causing 50% lethality

MDL – method detection level

MGD – million gallons per day

MG/L(mg/l) – milligrams per liter

ML – minimum level of quantification

ml – milliliter

MLSS – mixed liquor suspended solids

NODI – no discharge

NOEC – no observed effect concentration

NPDES – national pollutant discharge elimination system

PL – permit limit

POTW – publicly owned treatment works

RDL – required detection limit

SIU – significant industrial user

SSO – sanitary sewer overflow

STP – sewage treatment plant

TCA – Tennessee code annotated

TDEC – Tennessee Department of Environment and Conservation

TIE/TRE – toxicity identification evaluation/toxicity reduction evaluation

TMDL – total maximum daily load

TRC – total residual chlorine

TSS – total suspended solids

WQBEL – water quality based effluent limit

RATIONALE

--- STP
NPDES PERMIT No. TN00-----
DATE: 4/7/06
Permit Writer: Maybelle T. Sparks

1. FACILITY INFORMATION

--- STP
Contact person - title
---, --- County, Tennessee
Contact phone number
Treatment Plant Average Design Flow: 2 MGD
Percentage Industrial Flow: 0%
Treatment Description: Activated sludge plant with chlorination and dechlorination

2. RECEIVING STREAM INFORMATION

Receiving stream Mile --
Watershed Group: Duck-Lower
Hydrocode: 6040003
Low Flow: 7Q10 = 0.052 MGD (0.08 CFS)
Low Flow Reference:
USGS Water-Resource Investigation Report 95-4293
Station #03532200
Tier Designation: Not evaluated at this time.
Stream Classification Categories:

Domestic Wtr Supply	Industrial	Fish & Aquatic	Recreation
		X	X
Livestock Wtr & Wlife	Irrigation	Navigation	
X	X		

3. CURRENT PERMIT STATUS

Permit Type:	Municipal
Classification:	Major/Minor
Issuance Date:	3/31/2004
Expiration Date:	3/31/2008
Effective Date:	5/1/2004

The EPA Administrator, Lisa P. Jackson, signed the following final rule on April 17, 2012 and EPA is submitting it for publication in the *Federal Register* (FR). While we have taken steps to ensure the accuracy of this Internet version of the rule, it is not the official version of the rule. Please refer to the official version in a forthcoming FR publication, which will appear on the Government Printing Office's FDsys website (http://www.gpo.gov/fdsys/search/home.action) and on Regulations.gov (http://www.regulations.gov) in Docket No. EPA-HQ-OW-2010-0192. Once the official version of this document is published in the FR, this version will be removed from the Internet and replaced with a link to the official version.

Table IA–List of Approved Biological Methods for Wastewater and Sewage Sludge

Parameter and units	Method[1]	EPA	Standard Methods	AOAC, ASTM, USGS	Other
Bacteria:					
1. Coliform (fecal), number per 100 mL or number per gram dry weight	Most Probable Number (MPN),5 tube, 3 dilution, or	p. 132[3] 1680[11,15] 1681[11,20]	9221 C E–2006		
	Membrane filter (MF)[2], single step	p. 124[3]	9222 D–1997	B–0050–85[4]	
2. Coliform (fecal) in presence of chlorine, number per 100 mL	MPN, 5 tube, 3 dilution, or	p. 132[3]	9221 C E–2006		
	MF[2], single step[5]	p. 124[3]	9222 D–1997		
3. Coliform (total), number per 100 mL	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221 B–2006		
	MF[2], single step or two step	p. 108[3]	9222 B–1997	B–0025–85[4]	
4. Coliform (total), in presence of chlorine, number per 100 mL	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221 B–2006		
	MF[2] with enrichment[5]	p. 111[3]	9222 (B+B.5c)−1997		
5. E. coli, number per 100 mL[21]	MPN[6,8,16] multiple tube, or		9221B.1-2006/9221F-2006[12,14]		
	multiple tube/multiple well, or		9223 B–2004[13]	991.15[10]	Colilert®[13,18] Colilert-18®[13,17, 18]
	MF[2,6,7,8] single step	1603[22]			mColiBlue-24®[19]
6. Fecal streptococci, number per 100 mL	MPN, 5 tube 3 dilution, or	p. 139[3]	9230 B–2007		
	MF[2], or	p. 136[3]	9230 C–2007	B–0055–85[4]	
	Plate count	p. 143[3]			
7. Enterococci, number per 100 mL[22]	MPN[6,8], multiple tube/multiple well, or			D6503–99[9]	Enterolert®[13,24]
	MF[2,6,7,8]single step or	1600[25]	9230 C-2007		
	Plate count	p. 143[3]			
8. Salmonella, number per gram dry weight[11]	MPN multiple tube	1682[23]			
Aquatic Toxicity:					
9. Toxicity, acute, fresh water organisms, LC_{50}, percent effluent	Ceriodaphnia dubia acute	2002.0[26]			
	Daphnia puplex and Daphnia magna acute	2021.0[26]			
	Fathead Minnow, Pimephales promelas, and Bannerfin shiner, Cyprinella leedsi, acute	2000.0[26]			

Parameter and units	Method[1]	EPA	Standard Methods	AOAC, ASTM, USGS	Other
	Rainbow Trout, Oncorhynchus mykiss, and brook trout, Salvelinus fontinalis, acute	2019.0[26]			
10. Toxicity, acute, estuarine and marine organisms of the Atlantic Ocean and Gulf of Mexico, LC_{50}, percent effluent	Mysid, Mysidopsis bahia, acute	2007.0[26]			
	Sheepshead Minnow, Cyprinodon *variegatus*, acute	2004.0[26]			
	Silverside, Menidia beryllina, Menidia menidia, and Menidia peninsulae, acute	2006.0[26]			
11. Toxicity, chronic, fresh water organisms, NOEC or IC_{25}, percent effluent	Fathead minnow, Pimephales promelas, larval survival and growth	1000.0[27]			
	Fathead minnow, Pimephales promelas, embryo-larval survival and teratogenicity	1001.0[27]			
	Daphnia, Ceriodaphnia dubia, survival and reproduction	1002.0[27]			
	Green alga, Selenastrum capricornutum, growth	1003.0[27]			
12. Toxicity, chronic, estuarine and marine organisms of the Atlantic Ocean and Gulf of Mexico, NOEC or IC_{25}, percent effluent	Sheepshead minnow, Cyprinodon variegatus, larval survival and growth	1004.0[28]			
	Sheepshead minnow, Cyprinodon variegatus, embryo-larval survival and teratogenicity	1005.0[28]			
	Inland silverside, Menidia beryllina, larval survival and growth	1006.0[28]			
	Mysid, Mysidopsis bahia, survival, growth, and fecundity	1007.0[28]			
	Sea urchin, Arbacia punctulata, fertilization	1008.0[28]			

[1] The method must be specified when results are reported.

[2] A 0.45-µm membrane filter (MF) or other pore size certified by the manufacturer to fully retain organisms to be cultivated and to be free of extractables which could interfere with their growth.

[3] Microbiological Methods for Monitoring the Environment, Water, and Wastes, EPA/600/8–78/017. 1978. US EPA.

[4] U.S. Geological Survey Techniques of Water-Resource Investigations, Book 5, Laboratory Analysis, Chapter A4, Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples. 1989. USGS..

[5] Because the MF technique usually yields low and variable recovery from chlorinated wastewaters, the Most Probable Number method will be required to resolve any controversies.

[6] Tests must be conducted to provide organism enumeration (density). Select the appropriate configuration of tubes/filtrations and dilutions/volumes to account for the quality, character, consistency, and anticipated organism density of the water sample.

[7] When the MF method has been used previously to test waters with high turbidity, large numbers of noncoliform bacteria, or samples that may contain organisms stressed by chlorine, a parallel test should be conducted with a multiple-tube technique to demonstrate applicability and comparability of results.

[8] To assess the comparability of results obtained with individual methods, it is suggested that side-by-side tests be conducted across seasons of the year with the water samples routinely tested in accordance with the most current Standard Methods for the Examination of Water and Wastewater or EPA alternate test procedure (ATP) guidelines.

[9] Annual Book of ASTM Standards–Water and Environmental Technology, Section 11.02. 2000, 1999, 1996. ASTM International.

[10] Official Methods of Analysis of AOAC International. 16th Edition, 4th Revision, 1998. AOAC International

[11] Recommended for enumeration of target organism in sewage sludge.

[12] The multiple-tube fermentation test is used in 9221B.1-2006. Lactose broth may be used in lieu of lauryl tryptose broth (LTB), if at least 25 parallel tests are conducted between this broth and LTB using the water samples normally tested, and this comparison demonstrates that the false-positive rate and false-negative rate for total coliform using lactose broth is less than 10 percent. No requirement exists to run the completed phase on 10 percent of all total coliform-positive tubes on a seasonal basis.

[13] These tests are collectively known as defined enzyme substrate tests, where, for example, a substrate is used to detect the enzyme β-glucuronidase produced by E. coli.

[14] After prior enrichment in a presumptive medium for total coliform using 9221B.1-2006, all presumptive tubes or bottles showing any amount of gas, growth or acidity within 48 h ± 3 h of incubation shall be submitted to 9221F-2006. Commercially available EC-MUG media or EC media supplemented in the laboratory with 50 µg/mL of MUG may be used.

[15] Method 1680: Fecal Coliforms in Sewage Sludge (Biosolids) by Multiple-Tube Fermentation Using Lauryl-Tryptose Broth (LTB) and EC Medium, EPA–821–R–10–003. April 2010. US EPA.

[16] Samples shall be enumerated by the multiple-tube or multiple-well procedure. Using multiple-tube procedures, employ an appropriate tube and dilution configuration of the sample as needed and report the Most Probable Number (MPN). Samples tested with Colilert® may be enumerated with the multiple-well procedures, Quanti-Tray®, Quanti-Tray®/2000, and the MPN calculated from the table provided by the manufacturer.

[17] Colilert-18® is an optimized formulation of the Colilert® for the determination of total coliforms and E. coli that provides results within 18 h of incubation at 35°C rather than the 24 h required for the Colilert® test and is recommended for marine water samples.

[18] Descriptions of the Colilert®, Colilert-18®, Quanti-Tray®, and Quanti-Tray®/2000 may be obtained from IDEXX Laboratories, Inc.

[19] A description of the mColiBlue24® test, is available from Hach Company.

[20] Method 1681: Fecal Coliforms in Sewage Sludge (Biosolids) by Multiple-Tube Fermentation using A–1 Medium, EPA–821–R–06–013. July 2006. US EPA.

[21] Recommended for enumeration of target organism in wastewater effluent.

[22] Method 1603: Escherichia coli (E. coli) in Water by Membrane Filtration Using Modified membrane-Thermotolerant Escherichia coli Agar (modified mTEC), EPA–821–R–09–007. December 2009. US EPA.

[23] Method 1682: Salmonella in Sewage Sludge (Biosolids) by Modified Semisolid Rappaport-Vassiliadis (MSRV) Medium, EPA–821–R–06–014. July 2006. US EPA.

[24] A description of the Enterolert® test may be obtained from IDEXX Laboratories Inc.

[25] Method 1600: Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI), EPA–821–R–09–016. December 2009. US EPA.

[26] Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. EPA-821-R-02-012. Fifth Edition, October 2002. US EPA.

[27] Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. EPA-821-R-02-013. Fourth Edition, October 2002. US EPA.

[28] Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms. EPA-821-R-02-014. Third Edition, October 2002. US EPA.

TABLE IB – LIST OF APPROVED INORGANIC TEST PROCEDURES

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
1. Acidity, as $CaCO_3$, mg/L	Electrometric endpoint or phenolphthalein endpoint		2310 B-1997	D1067–06	I–1020–85[2]
2. Alkalinity, as $CaCO_3$, mg/L	Electrometric or Colorimetric titration to pH 4.5, Manual		2320 B-1997	D1067–06	973.43[3], I–1030–85[2]
	Automatic	310.2 (Rev. 1974)[1]			I–2030–85[2]
3. Aluminum–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 D-1999 or 3111 E-1999		I–3051–85[2]
	AA furnace		3113 B-2004		
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	Direct Current Plasma (DCP)[36]			D4190–08	See footnote[34]
	Colorimetric (Eriochrome cyanine R)		3500–Al B-2001		
4. Ammonia (as N), mg/L	Manual distillation[6] or gas diffusion (pH > 11), followed by any of the following:	350.1, Rev. 2.0 (1993)	4500–NH_3 B-1997		973.49[3]
	Nesslerization			D1426–08 (A)	973.49[3], I–3520–85[2]
	Titration		4500–NH_3 C-1997		
	Electrode		4500–NH_3 D-1997 or E-1997	D1426–08 (B)	
	Manual phenate, salicylate, or other substituted phenols in Berthelot reaction based methods		4500–NH_3 F-1997		See footnote [60]
	Automated phenate, salicylate, or other substituted phenols in Berthelot reaction based methods	350.1[30], Rev. 2.0 (1993)	4500–NH_3 G-1997 4500-NH_3 H-1997		I–4523–85[2]
	Automated electrode				See footnote [7]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	Ion Chromatography			D6919–09	
5. Antimony–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 B-1999		
	AA furnace		3113 B-2004		
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
6. Arsenic–Total,[4] mg/L	Digestion[4], followed by any of the following:	206.5 (Issued 1978)[1]			
	AA gaseous hydride		3114 B-2009 or 3114 C-2009	D2972–08 (B)	I–3062–85[2]
	AA furnace		3113 B-2004	D2972–08 (C)	I–4063–98[49]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4020–05[70]
	Colorimetric (SDDC)		3500–As B-1997	D2972–08 (A)	I–3060–85[2]
7. Barium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 D-1999		I–3084–85[2]
	AA furnace		3113 B-2004	D4382–02(07)	
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999		I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	DCP[36]				See footnote[34]
8. Beryllium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 D-1999 or 3111 E-1999	D3645–08 (A)	I–3095–85[2]
	AA furnace		3113 B-2004	D3645–08 (B)	

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	DCP			D4190–08	See footnote[34]
	Colorimetric (aluminon)		See footnote[61]		
9. Biochemical oxygen demand (BOD5), mg/L	Dissolved Oxygen Depletion		5210 B-2001		973.44,[3] p. 17.[9], I–1578–78[8], See footnote[10, 63]
10. Boron–Total,[37] mg/L	Colorimetric (curcumin)		4500–B B - 2000		I–3112–85[2]
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	DCP			D4190–08	See footnote [34]
11. Bromide, mg/L	Electrode			D1246–05	I–1125–85[2]
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1-1, Rev 1.0 (1997)	4110 B-2000, C-2000, D-2000	D4327–03	993.30[3]
	CIE/UV		4140 B-1997	D6508–00(05)	D6508, Rev. 2[54]
12. Cadmium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 B -1999 or 3111 C-1999	D3557–02(07) (A or B)	974.27,[3] p. 37.[9], I–3135–85[2] or I–3136–85[2]
	AA furnace		3113 B -2004	D3557–02(07) (D)	I–4138–89[51]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–1472–85[2] or I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	DCP[36]			D4190–08	See footnote[34]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	Voltametry[11]			D3557–02(07) (C)	
	Colorimetric (Dithizone)		3500-Cd-D-1990		
13. Calcium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 B-1999	D511–08(B)	I–3152–85[2]
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999		I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
	DCP				See footnote[34]
	Titrimetric (EDTA)		3500–Ca B-1997	D511–08 (A)	
	Ion Chromatography			D6919–09	
14. Carbonaceous biochemical oxygen demand ($CBOD_5$), mg/L[12]	Dissolved Oxygen Depletion with nitrification inhibitor		5210 B-2001		See footnote[35, 63]
15. Chemical oxygen demand (COD), mg/L	Titrimetric	410.3 (Rev. 1978)[1]	5220 B-1997 or C-1997	D1252–06 (A)	973.46[3], p. 17[9,] I–3560–85[2]
	Spectrophotometric, manual or automatic	410.4, Rev. 2.0 (1993)	5220 D-1997	D1252–06 (B)	See footnotes[13, 14]. I–3561–85[2]
16. Chloride, mg/L	Titrimetric: (silver nitrate)		4500–Cl^- B-1997	D512–04 (B)	I–1183–85[2]
	(Mercuric nitrate)		4500–Cl^- C-1997	D512–04 (A)	973.51[3], I–1184–85[2]
	Colorimetric: manual				I–1187–85[2]
	Automated (Ferricyanide)		4500–Cl^- E-1997		I–2187–85[2]
	Potentiometric Titration		4500–Cl^- D-1997		
	Ion Selective Electrode			D512–04 (C)	
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1-1, Rev 1.0 (1997)	4110 B-2000 or 4110 C-2000	D4327–03	993.30[3] , I–2057–90[51]
	CIE/UV		4140 B-1997	D6508–00(05)	D6508, Rev. 2[54]
17. Chlorine–Total residual, mg/L	Amperometric direct		4500–Cl D-2000	D1253–08	
	Amperometric direct (low level)		4500–Cl E-2000		

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	Iodometric direct		4500–Cl B-2000		
	Back titration ether end–point[15]		4500–Cl C-2000		
	DPD–FAS		4500–Cl F-2000		
	Spectrophotometric, DPD		4500–Cl G-2000		
	Electrode				See footnote[16]
17A. Chlorine–Free Available, mg/L	Amperometric direct		4500–Cl D-2000	D1253–08	
	Amperometric direct (low level)		4500–Cl E-2000		
	DPD–FAS		4500–Cl F-2000		
	Spectrophotometric, DPD		4500–Cl G-2000		
18. Chromium VI dissolved, mg/L	0.45-micron Filtration followed by any of the following:				
	AA chelation–extraction		3111 C-1999		I–1232–85[2]
	Ion Chromatography	218.6, Rev. 3.3 (1994)	3500–Cr C-2009	D5257–03	993.23
	Colorimetric (Diphenyl–carbazide)		3500–Cr B-2009	D1687–02(07) (A)	I–1230–85[2]
19. Chromium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 B-1999	D1687–02(07) (B)	974.27[3], I–3236–85[2]
	AA chelation–extraction		3111 C-1999		
	AA furnace		3113 B-2004	D1687–02(07) (C)	I–3233–93[46]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4020–05[70]
	DCP[36]			D4190–08	See footnote[34]
	Colorimetric (Diphenyl–carbazide)		3500–Cr B-2009		
20. Cobalt–Total,[4] mg/L	Digestion[4], followed by any of the following:				

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	AA direct aspiration		3111 B-1999 or 3111 C-1999	D3558–08 (A or B)	p. 37[9], I–3239–85[2]
	AA furnace		3113 B-2004	D3558–08 (C)	I–4243–89[51]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4020–05[70]
	DCP			D4190–08	See footnote[34]
21. Color, platinum cobalt units or dominant wavelength, hue, luminance purity	Colorimetric (ADMI)				See footnote[18]
	(Platinum cobalt)		2120 B-2001		I–1250–85[2]
	Spectrophotometric				
22. Copper–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 B-1999 or 3111 C-1999	D1688–07 (A or B)	974.27[3] p. 37[9,] I–3270–85[2] or I–3271–85[2]
	AA furnace		3113 B-2004	D1688–07 (C)	I–4274–89[51]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4020–05[70]
	DCP[36]			D4190–08	See footnote[34]
	Colorimetric (Neocuproine)		3500–Cu B-1999		
	(Bathocuproine)		3500–Cu C-1999		See footnote[19]
23. Cyanide–Total, mg/L	Automated UV digestion /distillation and Colorimetry				Kelada–01[55]
	Segmented Flow Injection, In-Line Ultraviolet Digestion, followed by gas diffusion amperometry			D7511-09	
	Manual distillation with $MgCl_2$, followed by any of the following:	335.4, Rev. 1.0 (1993)[57]	4500–CN^- B-1999 or C-1999	D2036–09(A), D7284-08	10–204–00–1–X[56]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	Flow Injection, gas diffusion amperometry			D2036-09(A) D7284-08	
	Titrimetric		4500–CN^- D-1999	D2036-09(A)	p. 22[9]
	Spectrophotometric, manual		4500–CN^- E-1999	D2036–09(A)	I–3300–85[2]
	Semi-Automated[20]	335.4, Rev. 1.0 (1993)[57]			10–204–00–1–X[56], I–4302–85[2]
	Ion Chromatography			D2036-09(A)	
	Ion Selective Electrode		4500–CN^- F-1999	D2036–09(A)	
24. Cyanide–Available, mg/L	Cyanide Amenable to Chlorination (CATC); Manual distillation with $MgCl_2$, followed by Titrimetric or Spectrophotometric		4500–CN^- G-1999	D2036–09(B)	
	Flow injection and ligand exchange, followed by gas diffusion amperometry[59]			D6888–09	OIA–1677-09[44]
	Automated Distillation and Colorimetry (no UV digestion)				Kelada–01[55]
24.A Cyanide-Free, mg/L	Flow Injection, followed by gas diffusion amperometry			D7237-10	OIA–1677-09[44]
	Manual micro-diffusion and colorimetry			D4282-02	
25. Fluoride–Total, mg/L	Manual distillation[6], followed by any of the following:		4500–F^- B-1997		
	Electrode, manual		4500–F^- C-1997	D1179–04 (B)	
	Electrode, automated				I–4327–85[2]
	Colorimetric, (SPADNS)		4500–F^- D-1997	D1179–04 (A)	
	Automated complexone		4500–F^- E-1997		
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1-1, Rev 1.0 (1997)	4110 B-2000 or C-2000	D4327–03	993.30[3]
	CIE/UV		4140 B-1997	D6508–00(05)	D6508, Rev. 2[54]
26. Gold–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 B-1999		

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	AA furnace	231.2 (Issued1978)[1]	3113 B-2004		
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
	DCP				See footnote[34]
27. Hardness–Total, as $CaCO_3$, mg/L	Automated colorimetric	130.1 (Issued 1971)[1]			
	Titrimetric (EDTA)		2340 C-1997	D1126–02(07)	973.52B[3], I–1338–85[2]
	Ca plus Mg as their carbonates, by inductively coupled plasma or AA direct aspiration. (See Parameters 13 and 33).		2340 B-1997		
28. Hydrogen ion (pH), pH units	Electrometric measurement		4500–H^+ B-2000	D1293–99 (A or B)	973.41[3], I–1586–85[2]
	Automated electrode	150.2 (Dec. 1982)[1]			See footnote[21], I–2587–85[2]
29. Iridium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 B-1999		
	AA furnace	235.2 (Issued 1978)[1]			
	ICP/MS		3125 B-2009		
30. Iron–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 B-1999 or 3111 C-1999	D1068–05 (A or B)	974.27[3], I–3381–85[2]
	AA furnace		3113 B-2004	D1068–05 (C)	
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
	DCP[36]			D4190–08	See footnote[34]
	Colorimetric (Phenanthroline)		3500–Fe-1997	D1068–05 (D)	See footnote[22]
31. Kjeldahl Nitrogen[5]–Total, (as N), mg/L	Manual digestion[20] and distillation or gas diffusion, followed by any of the following:		4500–N_{org} B-1997 or C-1997 and 4500–NH_3 B-1997	D3590–02(06) (A)	I–4515–91[45]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	Titration		4500–NH_3 C-1997		973.48[3]
	Nesslerization			D1426–08 (A)	
	Electrode		4500–NH_3 D-1997 or E-1997	D1426–08 (B)	
	Semi-automated phenate	350.1 Rev 2.0 1993	4500–NH_3 G-1997 4500–NH_3 H-1997		
	Manual phenate, salicylate, or other substituted phenols in Berthelot reaction based methods		4500–NH_3 F-1997		See footnote[60]
	Automated Methods for TKN that do not require manual distillation				
	Automated phenate, salicylate, or other substituted phenols in Berthelot reaction based methods colorimetric (auto digestion and distillation)	351.1 (Rev. 1978)[1]			I–4551–78[8]
	Semi-automated block digestor colorimetric (distillation not required)	351.2, Rev. 2.0 (1993)	4500–N_{org} D-1997	D3590–02(06) (B)	I–4515–91[45]
	Block digester, followed by Auto distillation and Titration				See footnote[39]
	Block digester, followed by Auto distillation and Nesslerization				See footnote[40]
	Block Digester, followed by Flow injection gas diffusion (distillation not required)				See footnote[41]
32. Lead–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 B-1999 or 3111 C-1999	D3559–08 (A or B)	974.27[3], I–3399–85[2]
	AA furnace		3113 B-2004	D3559–08 (D)	I–4403–89[51]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	DCP[36]			D4190–08	See footnote[34]
	Voltametry[11]			D3559–08 (C)	
	Colorimetric (Dithizone)		3500–Pb B-1997		
33. Magnesium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 B-1999	D511–08 (B)	974.27[3], I–3447–85[2]
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
	DCP				See footnote[34]
	Gravimetric				
	Ion Chromatography			D6919–09	
34. Manganese–Total,[4] mg/L	Digestion[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-1999	D858–07 (A or B)	974.27[3], I–3454–85[2]
	AA furnace		3113 B-2004	D858–07 (C)	
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	DCP[36]			D4190–08	See footnote[34]
	Colorimetric (Persulfate)		3500–Mn B-1999		920.203[3]
	(Periodate)				See footnote[23]
35. Mercury–Total[4], mg/L	Cold vapor, Manual	245.1, Rev. 3.0 (1994)	3112 B-2009	D3223–02(07)	977.22[3], I–3462–85[2]
	Cold vapor, Automated	245.2 (Issued 1974)[1]			
	Cold vapor atomic fluorescence spectrometry (CVAFS)	245.7 Rev. 2.0 (2005)[17]			I-4464-01[71]
	Purge and Trap CVAFS	1631E[43]			
36. Molybdenum–Total[4], mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 D-1999		I–3490–85[2]
	AA furnace		3113 B-2004		I–3492–96[47]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	DCP				See footnote[34]
37. Nickel–Total,[4] mg/L	Digestion[4] followed by any of the following:				
	AA direct aspiration[36]		3111 B-1999 or 3111 C-1999	D1886–08 (A or B)	I–3499–85[2]
	AA furnace		3113 B-2004	D1886–08 (C)	I–4503–89[51]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4020–05[70]
	DCP[36]			D4190–08	See footnote[34]
38. Nitrate (as N), mg/L	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1-1, Rev 1.0 (1997)	4110 B-2000 or C-2000	D4327–03	993.30[3]
	CIE/UV		4140 B-1997	D6508–00(05)	D6508, Rev. 2[54]
	Ion Selective Electrode		4500–NO_3^- D-2000		
	Colorimetric (Brucine sulfate)	352.1 (Issued 1971)[1]			973.50[3], 419D[1,7], p. 28[9]
	Nitrate-nitrite N minus Nitrite N (See parameters 39 and 40).				See footnote[62]
39. Nitrate-nitrite (as N), mg/L	Cadmium reduction, Manual		4500–NO_3^- E-2000	D3867–04 (B)	
	Cadmium reduction, Automated	353.2, Rev. 2.0 (1993)	4500–NO_3^- F-2000	D3867–04 (A)	I–2545–90[51]
	Automated hydrazine		4500–NO_3^- H-2000		
	Reduction/Colorimetric				See footnote[62]
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1-1, Rev 1.0 (1997)	4110 B-2000 or C-2000	D4327–03	993.30[3]
	CIE/UV		4140 B-1997	D6508–00(05)	D6508, Rev. 2[54]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
40. Nitrite (as N), mg/L	Spectrophotometric: Manual		4500–NO_2^- B-2000		See footnote[25]
	Automated (Diazotization)				I–4540–85[2], See footnote[62]
	Automated (*bypass cadmium reduction)	353.2, Rev. 2.0 (1993)	4500–NO_3^- F-2000	D3867–04 (A)	I–4545–85[2]
	Manual (*bypass cadmium reduction)		4500–NO_3^- E-2000	D3867–04 (B)	
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1-1, Rev 1.0 (1997)	4110 B-2000 or C-2000	D4327–03	993.30[3]
	CIE/UV		4140 B-1997	D6508–00(05)	D6508, Rev.2[54]
41. Oil and grease–Total recoverable, mg/L	Hexane extractable material (HEM): n–Hexane extraction and gravimetry	1664 Rev. A; 1664 Rev. B[42]	5520 B-2001[38]		
	Silica gel treated HEM (SGT–HEM): Silica gel treatment and gravimetry.	1664 Rev. A; 1664 Rev. B[42]	5520 B-2001[38] and 5520 F-2001[38]		
42. Organic carbon–Total (TOC), mg/L	Combustion		5310 B-2000	D7573–09	973.47[3], p. 14[24]
	Heated persulfate or UV persulfate oxidation		5310 C 2000 5310 D 2000	D4839–03	973.47[3,], p. 14[24]
43. Organic nitrogen (as N), mg/L	Total Kjeldahl N (Parameter 31) minus ammonia N (Parameter 4)				
44. Ortho-phosphate (as P), mg/L	Ascorbic acid method:				
	Automated	365.1, Rev. 2.0 (1993)	4500-P F-1999 or G-1999		973.56[3], I–4601–85[2]
	Manual single reagent		4500-P E-1999	D515–88(A)	973.55[3]
	Manual two reagent	365.3 (Issued 1978)[1]			
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1-1, Rev 1.0 (1997)	4110 B-2000 or C-2000	D4327–03	993.30[3]
	CIE/UV		4140 B-1997	D6508–00(05)	D6508, Rev. 2[54]
45. Osmium–Total[4], mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration,		3111 D-1999		
	AA furnace	252.2 (Issued 1978)[1]			

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
46. Oxygen, dissolved, mg/L	Winkler (Azide modification)		4500–O B-2001, C-2001, D-2001, E-2001, F-2001	D888–09 (A)	973.45B[3], I–1575–78[8]
	Electrode		4500–O G-2001	D888–09 (B)	I–1576–78[8]
	Luminescence Based Sensor			D888–09 (C)	See footnote[63] See footnote[64]
47. Palladium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 B-1999		
	AA furnace	253.2[1](Issued 1978)			
	ICP/MS		3125 B-2009		
	DCP				See footnote[34]
48. Phenols, mg/L	Manual distillation[26], followed by any of the following:	420.1[1](Rev. 1978)	5530 B-2005	D1783–01	
	Colorimetric (4AAP) manual	420.1[1](Rev. 1978)	5530 D-2005[27]	D1783–01 (A or B)	
	Automated colorimetric (4AAP)	420.4 Rev. 1.0 (1993)			
49. Phosphorus (elemental), mg/L	Gas–liquid chromatography				See footnote[28]
50. Phosphorus–Total, mg/L	Digestion[20], followed by any of the following:		4500-P B(5)-1999		973.55[3]
	Manual	365.3[1](Issued 1978)	4500-P E-1999	D515–88 (A)	
	Automated ascorbic acid reduction	365.1 Rev. 2.0 (1993)	4500-P F-1999, G-1999, H-1999		973.56[3], I–4600–85[2]
	ICP/AES[4, 36]	200.7, Rev. 4.4 (1994)	3120 B-1999		I–4471–97[50]
	Semi–automated block digestor (TKP digestion)	365.4[1] (Issued 1974)		D515–88 (B)	I–4610–91[48]
51. Platinum–Total,[4] mg/L	Digestion[4] followed by any of the following:				
	AA direct aspiration		3111 B-1999		
	AA furnace	255.2 (Issued 1978)[1]			
	ICP/MS		3125 B-2009		
	DCP				See footnote[34]
52. Potassium–Total,[4] mg/L	Digestion[4], followed by any of the following:				

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	AA direct aspiration		3111 B-1999		973.53[3], I–3630–85[2]
	ICP/AES	200.7, Rev. 4.4 (1994)	3120 B-1999		
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
	Flame photometric		3500–K B-1997		
	Electrode		3500-K C-1997		
	Ion Chromatography			D6919–09	
53. Residue–Total, mg/L	Gravimetric, 103–105°		2540 B-1997		I–3750–85[2]
54. Residue–filterable, mg/L	Gravimetric, 180°		2540 C-1997	D5907–03	I–1750–85[2]
55. Residue–non–filterable (TSS), mg/L	Gravimetric, 103–105° post washing of residue		2540 D-1997	D5907–03	I–3765–85[2]
56. Residue–settleable, mg/L	Volumetric, (Imhoff cone), or gravimetric		2540 F-1997		
57. Residue–Volatile, mg/L	Gravimetric, 550°	160.4 (Issued 1971)[1]	2540-E-1997		I–3753–85[2]
58. Rhodium–Total,[4] mg/L	Digestion[4] followed by any of the following:				
	AA direct aspiration, or		3111 B-1999		
	AA furnace	265.2 (Issued 1978)[1]			
	ICP/MS		3125 B-2009		
59. Ruthenium–Total,[4] mg/L	Digestion[4] followed by any of the following:				
	AA direct aspiration, or		3111 B-1999		
	AA furnace	267.2[1]			
	ICP/MS		3125 B-2009		
60. Selenium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA furnace		3113 B-2004	D3859–08 (B)	I–4668–98[49]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4020–05[70]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	AA gaseous hydride		3114 B-2009,or 3111 C-2009	D3859–08 (A)	I–3667–85[2]
61. Silica–Dissolved,[37] mg/L	0.45-micron filtration followed by any of the following:				
	Colorimetric, Manual		4500–SiO_2 C-1997	D859–05	I–1700–85[2]
	Automated (Molybdosilicate)		4500–SiO_2 E-1997 or F-1997		I–2700–85[2]
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999		I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
62. Silver–Total,[4, 31] mg/L	Digestion[4, 29], followed by any of the following:				
	AA direct aspiration		3111 B-1999 or 3111 C-1999		974.27[3], p. 37[9], I–3720–85[2]
	AA furnace		3113 B -2004		I–4724–89[51]
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
	DCP				See footnote[34]
63. Sodium–Total,[4] mg/L	Digestion[4,], followed by any of the following:				
	AA direct aspiration		3111 B-1999		973.54[3], I–3735–85[2]
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999		I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
	DCP				See footnote[34]
	Flame photometric		3500–Na B-1997		
	Ion Chromatography			D6919–09	
64. Specific conductance, micromhos/cm at 25°C	Wheatstone bridge	120.1[1](Rev. 1982)	2510 B-1997	D1125–95(99) (A)	973.40[3], I–2781–85[2]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
65. Sulfate (as SO_4), mg/L	Automated colorimetric	375.2, Rev. 2.0 (1993)	4500-SO_4^{2-} F-1997 or G-1997		
	Gravimetric		4500-SO_4^{2-} C-1997 or D-1997		925.54[3]
	Turbidimetric		4500-SO_4^{2-} E-1997	D516–07	
	Ion Chromatography	300.0, Rev 2.1 (1993) and 300.1-1, Rev 1.0 (1997)	4110 B-2000 or C-2000	D4327–03	993.30[3], I–4020–05[70]
	CIE/UV		4140 B-1997	D6508–00(05)	D6508, Rev. 2[54]
66. Sulfide (as S), mg/L	Sample Pretreatment		4500–S^{2-} B, C-2000		
	Titrimetric (iodine)		4500–S^{2-}F-2000		I–3840–85[2]
	Colorimetric (methylene blue)		4500–S^{2-}D-2000		
	Ion Selective Electrode		4500–S^{2-}G-2000	D4658–08	
67. Sulfite (as SO_3), mg/L	Titrimetric (iodine-iodate)		4500–SO_3^{2-} B-2000		
68. Surfactants, mg/L	Colorimetric (methylene blue)		5540 C-2000	D2330–02	
69. Temperature, °C	Thermometric		2550 B-2000		See footnote[32]
70. Thallium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 B-1999		
	AA furnace	279.2[1](Issued 1978)	3113 B-2004		
	STGFAA	200.9, Rev. 2.2 (1994)			
	ICP/AES	200.7, Rev. 4.4 (1994);); 200.5 Rev. 4.2 (2003)[68]	3120 B-1999	D1976–07	
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4471–97[50]
71. Tin–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 B-1999		I–3850–78[8]
	AA furnace		3113 B-2004		
	STGFAA	200.9, Rev. 2.2 (1994)			

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)			
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
72. Titanium–Total,[4] mg/L	Digestion[4] followed by any of the following:				
	AA direct aspiration		3111 D-1999		
	AA furnace	283.2[1](Issued 1978)			
	ICP/AES	200.7, Rev. 4.4 (1994)			
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3]
	DCP				See footnote[34]
73. Turbidity, NTU[53]	Nephelometric	180.1, Rev. 2.0 (1993)	2130 B-2001	D1889–00	I–3860–85[2] See footnote[65] See footnote[66] See footnote[67]
74. Vanadium–Total,[4] mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration		3111 D-1999		
	AA furnace		3113 B-2004	D3373–03(07)	
	ICP/AES	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4020–05[70]
	DCP			D4190–08	See footnote[34]
	Colorimetric (Gallic Acid)		3500–V B-1997		
75. Zinc–Total[4], mg/L	Digestion[4], followed by any of the following:				
	AA direct aspiration[36]		3111 B-1999 or 3111 C-1999	D1691–02(07) (A or B)	974.27[3], p. 37[9], I–3900–85[2]
	AA furnace	289.2[1](Issued 1978)			
	ICP/AES[36]	200.5, Rev 4.2 (2003)[68]; 200.7, Rev. 4.4 (1994)	3120 B-1999	D1976–07	I–4471–97[50]
	ICP/MS	200.8, Rev. 5.4 (1994)	3125 B-2009	D5673–05	993.14[3], I–4020–05[70]
	DCP[36]			D4190–08	See footnote[34]
	Colorimetric (Zincon)		3500 Zn B-1997		See footnote[33]

Parameter	Methodology[58]	EPA[52]	Standard Methods	ASTM	USGS/AOAC/Other
76. Acid Mine Drainage		1627[69]			

Table IB Notes:

[1] Methods for Chemical Analysis of Water and Wastes,EPA–600/4–79–020. Revised March 1983 and 1979, where applicable. US EPA.

[2] Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Book 5, Chapter A1., unless otherwise stated. 1989. USGS.

[3] Official Methods of Analysis of the Association of Official Analytical Chemists, Methods Manual, Sixteenth Edition, 4th Revision, 1998. AOAC International.

[4] For the determination of total metals (which are equivalent to total recoverable metals) the sample is not filtered before processing. A digestion procedure is required to solubilize analytes in suspended material and to break down organic-metal complexes (to convert the analyte to a detectable form for colorimetric analysis). For non–platform graphite furnace atomic absorption determinations a digestion using nitric acid (as specified in Section 4.1.3 of Methods for the Chemical Analysis of Water and Wastes) is required prior to analysis. The procedure used should subject the sample to gentle, acid refluxing and at no time should the sample be taken to dryness. For direct aspiration flame atomic absorption determinations (FLAA) a combination acid (nitric and hydrochloric acids) digestion is preferred prior to analysis. The approved total recoverable digestion is described as Method 200.2 in Supplement I of "Methods for the Determination of Metals in Environmental Samples" EPA/600R–94/111, May, 1994, and is reproduced in EPA Methods 200.7, 200.8, and 200.9 from the same Supplement. However, when using the gaseous hydride technique or for the determination of certain elements such as antimony, arsenic, selenium, silver, and tin by non–EPA graphite furnace atomic absorption methods, mercury by cold vapor atomic absorption, the noble metals and titanium by FLAA, a specific or modified sample digestion procedure may be required and in all cases the referenced method write–up should be consulted for specific instruction and/or cautions. For analyses using inductively coupled plasma-atomic emission spectrometry (ICP–AES), the direct current plasma (DCP) technique or the EPA spectrochemical techniques (platform furnace AA, ICP–AES, and ICP–MS) use EPA Method 200.2 or an approved alternate procedure (e.g., CEM microwave digestion, which may be used with certain analytes as indicated in Table IB); the total recoverable digestion procedures in EPA Methods 200.7, 200.8, and 200.9 may be used for those respective methods. Regardless of the digestion procedure, the results of the analysis after digestion procedure are reported as "total" metals.

[5] Copper sulfate or other catalysts that have been found suitable may be used in place of mercuric sulfate.

[6] Manual distillation is not required if comparability data on representative effluent samples are on file to show that this preliminary distillation step is not necessary: however, manual distillation will be required to resolve any controversies. In general, the analytical method should be consulted regarding the need for distillation. If the method is not clear, the laboratory may compare a minimum of 9 different sample matrices to evaluate the need for distillation. For each matrix, a matrix spike and matrix spike duplicate are analyzed both with and without the distillation step. (A total of 36 samples, assuming 9 matrices). If results are comparable, the laboratory may dispense with the distillation step for future analysis. Comparable is defined as < 20% RPD for all tested matrices). Alternatively the two populations of spike recovery percentages may be compared using a recognized statistical test.

[7] Industrial Method Number 379–75 WE Ammonia, Automated Electrode Method, Technicon Auto Analyzer II. February 19, 1976. Bran & Luebbe Analyzing Technologies Inc.

[8] The approved method is that cited in Methods for Determination of Inorganic Substances in Water and Fluvial Sediments, Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 5, Chapter A1. 1979. USGS.

[9] American National Standard on Photographic Processing Effluents. April 2, 1975. .American National Standards Institute.

[10] In-Situ Method 1003-8-2009, Biochemical Oxygen Demand (BOD) Measurement by Optical Probe. 2009. In-Situ Incorporated.

[11]The use of normal and differential pulse voltage ramps to increase sensitivity and resolution is acceptable.

Table II - Required Containers, Preservation Techniques, and Holding Times

Parameter Number/Name	Container [1]	Preservation [2, 3]	Maximum Holding Time [4]
Table IA - Bacterial Tests:			
1-5. Coliform, total, fecal, and E. coli	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	8 hours[22,23]
6. Fecal streptococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	8 hours[22]
7. Enterococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	8 hours[22]
8. Salmonella	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	8 hours[22]
Table IA - Aquatic Toxicity Tests:			
9-12. Toxicity, acute and chronic	P, FP, G	Cool, ≤6 °C [16]	36 hours
Table IB - Inorganic Tests:			
1. Acidity	P, FP, G	Cool, ≤6 °C[18]	14 days
2. Alkalinity	P, FP, G	Cool, ≤6 °C[18]	14 days
4. Ammonia	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
9. Biochemical oxygen demand	P, FP, G	Cool, ≤6 °C[18]	48 hours
10. Boron	P, FP, or Quartz	HNO_3 to pH<2	6 months
11. Bromide	P, FP, G	None required	28 days
14. Biochemical oxygen demand, carbonaceous	P, FP G	Cool, ≤6 °C[18]	48 hours
15. Chemical oxygen demand	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
16. Chloride	P, FP, G	None required	28 days
17. Chlorine, total residual	P, G	None required	Analyze within 15 minutes
21. Color	P, FP, G	Cool, ≤6 °C[18]	48 hours
23-24. Cyanide, total or available (or CATC) and free	P, FP, G	Cool, ≤6 °C[18], NaOH to pH>10[5, 6], reducing agent if oxidizer present	14 days
25. Fluoride	P	None required	28 days
27. Hardness	P, FP, G	HNO_3 or H_2SO_4 to pH<2	6 months
28. Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes
31, 43. Kjeldahl and organic N	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
Table IB - Metals: [7]			
18. Chromium VI	P, FP, G	Cool, ≤6 °C[18], pH = 9.3 - 9.7 [20]	28 days
35. Mercury (CVAA)	P, FP, G	HNO_3 to pH<2	28 days
35. Mercury (CVAFS)	FP, G; and FP-lined cap [17]	5 mL/L 12N HCl or 5 mL/L BrCl [17]	90 days [17]
3, 5-8, 12, 13, 19, 20, 22, 26, 29, 30, 32-34, 36, 37, 45, 47, 51, 52, 58-60, 62, 63, 70-72, 74, 75. Metals, except boron, chromium VI, and mercury	P, FP, G	HNO_3 to pH<2, or at least 24 hours prior to analysis [19]	6 months
38. Nitrate	P, FP, G	Cool, ≤6 °C[18]	48 hours

Parameter Number/Name	Container [1]	Preservation [2, 3]	Maximum Holding Time [4]
39. Nitrate-nitrite	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
40. Nitrite	P, FP, G	Cool, ≤6 °C[18]	48 hours
41. Oil and grease	G	Cool to ≤6 °C[18], HCl or H_2SO_4 to pH<2	28 days
42. Organic Carbon	P, FP, G	Cool to ≤6 °C[18], HCl, H_2SO_4, or H_3PO_4 to pH<2	28 days
44. Orthophosphate	P, FP, G	Cool, to ≤6 °C[18,24]	Filter within 15 minutes; Analyze within 48 hours
46. Oxygen, Dissolved Probe	G, Bottle and top	None required	Analyze within 15 minutes
47. Winkler	G, Bottle and top	Fix on site and store in dark	8 hours
48. Phenols	G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
49. Phosphorous (elemental)	G	Cool, ≤6 °C[18]	48 hours
50. Phosphorous, total	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
53. Residue, total	P, FP, G	Cool, ≤6 °C [18]	7 days
54. Residue, Filterable	P, FP, G	Cool, ≤6 °C [18]	7 days
55. Residue, Nonfilterable (TSS)	P, FP, G	Cool, ≤6 °C [18]	7 days
56. Residue, Settleable	P, FP, G	Cool, ≤6 °C [18]	48 hours
57. Residue, Volatile	P, FP, G	Cool, ≤6 °C [18]	7 days
61. Silica	P or Quartz	Cool, ≤6 °C [18]	28 days
64. Specific conductance	P, FP, G	Cool, ≤6 °C [18]	28 days
65. Sulfate	P, FP, G	Cool, ≤6 °C [18]	28 days
66. Sulfide	P, FP, G	Cool, ≤6 °C [18], add zinc acetate plus sodium hydroxide to pH>9	7 days
67. Sulfite	P, FP, G	None required	Analyze within 15 minutes
68. Surfactants	P, FP, G	Cool, ≤6 °C [18]	48 hours
69. Temperature	P, FP, G	None required	Analyze
73. Turbidity	P, FP, G	Cool, ≤6 °C [18]	48 hours
Table IC - Organic Tests [8]			
13, 18-20, 22, 24-28, 34-37, 39-43, 45-47, 56, 76, 104, 105, 108-111, 113. Purgeable Halocarbons	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5]	14 days
6, 57, 106. Purgeable aromatic hydrocarbons	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5], HCl to pH 2 [9]	14 days [9]
3, 4. Acrolein and acrylonitrile	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$, pH to 4-5[10]	14 days [10]
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols [11]	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$	7 days until extraction,40 days after extraction
7, 38. Benzidines [11, 12]	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5]	7 days until extraction [13]

Parameter Number/Name	Container [1]	Preservation [2, 3]	Maximum Holding Time [4]
14, 17, 48, 50-52. Phthalate esters [11]	G, FP-lined cap	Cool, ≤6 ºC [18]	7 days until extraction, 40 days after extraction
82-84. Nitrosamines [11, 14]	G, FP-lined cap	Cool, ≤6 ºC [18], store in dark, 0.008% $Na_2S_2O_3$ [5]	7 days until extraction, 40 days after extraction
88-94. PCBs [11]	G, FP-lined cap	Cool, ≤6 ºC [18]	1 year until extraction, 1 year after extraction
54, 55, 75, 79. Nitroaromatics and isophorone [11]	G, FP-lined cap	Cool, ≤6 ºC [18], store in dark, 0.008% $Na_2S_2O_3$ [5]	7 days until extraction, 40 days after extraction
1, 2, 5, 8-12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons [11]	G, FP-lined cap	Cool, ≤6 ºC [18], store in dark, 0.008% $Na_2S_2O_3$ [5]	7 days until extraction, 40 days after extraction
15, 16, 21, 31, 87. Haloethers [11]	G, FP-lined cap	Cool, ≤6 ºC [18], 0.008% $Na_2S_2O_3$ [5]	7 days until extraction, 40 days after extraction
29, 35-37, 63-65, 107. Chlorinated hydrocarbons [11]	G, FP-lined cap	Cool, ≤6 ºC [18]	7 days until extraction, 40 days after extraction
60-62, 66-72, 85, 86, 95-97, 102, 103. CDDs/CDFs [11]			
Aqueous Samples: Field and Lab Preservation	G	Cool, ≤6 ºC [18], 0.008% $Na_2S_2O_3$ [5], pH<9	1 year
Solids and Mixed-Phase Samples: Field Preservation	G	Cool, ≤6 ºC [18]	7 days
Tissue Samples: Field Preservation	G	Cool, ≤6 ºC [18]	24 hours
Solids, Mixed-Phase, and Tissue Samples: Lab Preservation	G	Freeze, ≤ -10 ºC	1 year
114 -118. Alkylated phenols	G	Cool, < 6 ºC, H_2SO_4 to pH < 2	28 days until extraction, 40 days after extraction
119. Adsorbable Organic Halides (AOX)	G	Cool, < 6 ºC, 0.008% $Na_2S_2O_3$ HNO_3 to pH < 2	Hold *at least* 3 days, but not more than 6 months
120. Chlorinated Phenolics		Cool, < 6 ºC, 0.008% $Na_2S_2O_3$ H_2SO_4 to pH < 2	30 days until acetylation, 30 days after acetylation
Table ID - Pesticides Tests:			
1-70. Pesticides [11]	G, FP-lined cap	Cool, ≤6 ºC [18], pH 5-9 [15]	7 days until extraction, 40 days after extraction
Table IE - Radiological Tests:			
1-5. Alpha, beta, and radium	P, FP, G	HNO_3 to pH<2	6 months
Table IH - Bacterial Tests:			
1. E. coli	PA, G	Cool, <10 ºC, 0.0008% $Na_2S_2O_3$ [5]	8 hours[22]

Parameter Number/Name	Container [1]	Preservation [2, 3]	Maximum Holding Time [4]
2. Enterococci	PA, G	Cool, <10 ºC, 0.0008% $Na_2S_2O_3$ [5]	8 hours[22]
Table IH - Protozoan Tests:			
8. Cryptosporidium	LDPE; field filtration	1 - 10 ºC	96 hours [21]
9. Giardia	LDPE; field filtration	1 - 10 ºC	96 hours [21]

[1] ''P'' is for polyethylene; ''FP'' is fluoropolymer (polytetrafluoroethylene (PTFE); Teflon®), or other fluoropolymer, unless stated otherwise in this Table II; ''G'' is glass; ''PA'' is any plastic that is made of a sterilizable material (polypropylene or other autoclavable plastic); ''LDPE'' is low density polyethylene.

[2] Except where noted in this Table II and the method for the parameter, preserve each grab sample within 15 minutes of collection. For a composite sample collected with an automated sample (e.g., using a 24-hour composite sample; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), refrigerate the sample at ≤ 6 °C during collection unless specified otherwise in this Table II or in the method(s). For a composite sample to be split into separate aliquots for preservation and/or analysis, maintain the sample at ≤ 6 °C, unless specified otherwise in this Table II or in the method(s), until collection, splitting, and preservation is completed. Add the preservative to the sample container prior to sample collection when the preservative will not compromise the integrity of a grab sample, a composite sample, or aliquot split from a composite sample within 15 minutes of collection. If a composite measurement is required but a composite sample would compromise sample integrity, individual grab samples must be collected at prescribed time intervals (e.g., 4 samples over the course of a day, at 6-hour intervals). Grab samples must be analyzed separately and the concentrations averaged. Alternatively, grab samples may be collected in the field and composited in the laboratory if the compositing procedure produces results equivalent to results produced by arithmetic averaging of results of analysis of individual grab samples. For examples of laboratory compositing procedures, see EPA Method 1664 Rev. A (oil and grease) and the procedures at 40 CFR 141.34(f)(14)(iv) and (v) (volatile organics).

[3] When any sample is to be shipped by common carrier or sent via the U.S. Postal Service, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirement of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater; Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4] Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before the start of analysis and still be considered valid. Samples may be held for longer periods only if the permittee or monitoring laboratory has data on file to show that, for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under Sec. 136.3(e). For a grab sample, the holding time begins at the time of collection. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR part 403, Appendix E), the holding time begins at the time of the end of collection of the composite sample. For a set of grab samples composited in the field or laboratory, the holding time begins at the time of collection of the last grab sample in the set. Some samples may not be stable for the maximum time period given in

CHAPTER 13

Plant Flow Measurement and Sampling

13.1 Purpose

13.2 Flow Measurement

- 13.2.1 General Considerations
- 13.2.2 Parshall Flumes
- 13.2.3 Sharp Crested Weirs
- 13.2.4 Venturi and Modified Flow Tube Meters
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- 13.2.6 Hydrograph Controlled Release (HCR) Systems

13.3 Sampling

- 13.3.1 Automatic Sampling Equipment
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- 13.3.3 Long Outfall Lines
- 13.3.4 Sampling Schedules

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

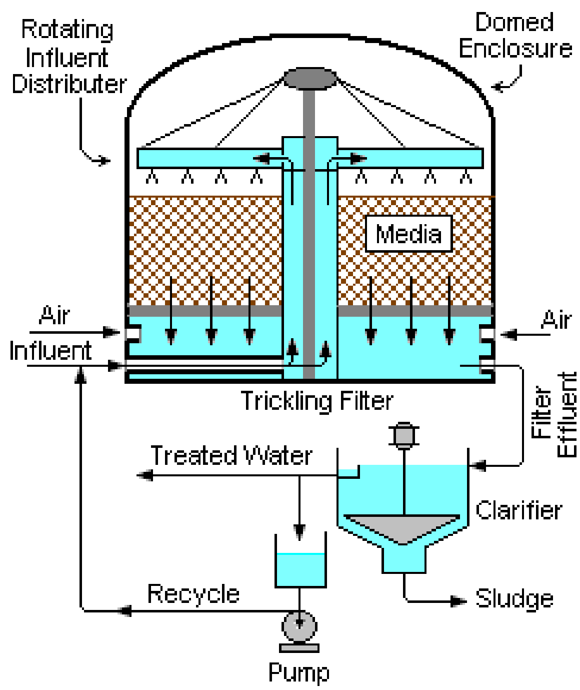
Many wastewater systems are constructing long outfall lines to take advantage of secondary or equivalent permit limits. Due to possible changes in effluent quality between the treatment facility and the outfall, a remote sampling station will be required at or near the confluence of the outfall line 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.

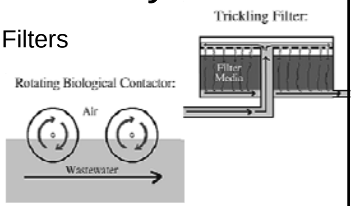
Section 5

Attached Growth



Attached Growth Wastewater Treatment Systems

Trickling Filters
RBCs
MBBR
IFAS



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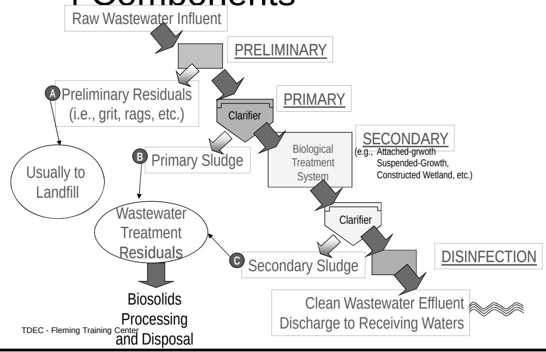
General Overview of Plant Components



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Biological Wastewater (WW) Treatment

- To remove the suspended solids & the dissolved organic load from the WW by using microbial populations.
- The microorganisms are responsible for:
  - degradation of the organic matter
  - they can be classified into
    - aerobic (require oxygen for their metabolism)
    - anaerobic (grow in absence of oxygen)
    - facultative (proliferate either with or without oxygen)

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Biological Wastewater (WW) Treatment

- If the microorganisms are suspended in the WW during biological operation
  - Recycling of settled biomass is required
- While the microorganisms that are attached to a surface over which they grow
  - Biomass attached to media (rock, plastic,etc.)
  - Recycling of settled biomass is not required.

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Attached Growth Process

- What can this process do?
  - Remove nutrients
  - Removed dissolved organic solids
  - Remove suspended organic solids

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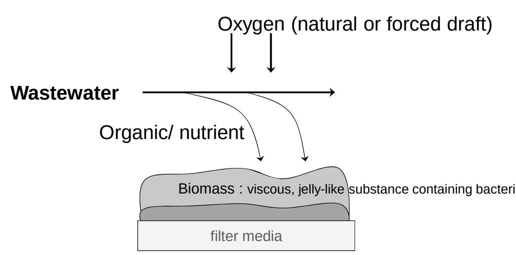
Cross-section of Attached Growth Biomass Film



Biomass = "zoogleal mass" or "Biofilm"
Filter media = rock, slag, coal, bricks, redwood blocks or molded plastic

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Attached Growth Systems: Advantages

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

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Trickling Filter (TF)

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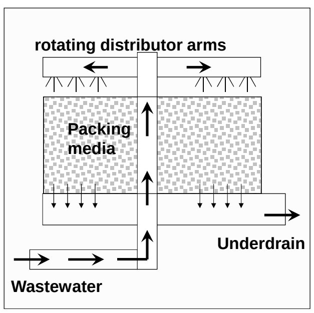
Trickling Filter (TF)- Side View



- TF consists of:
  - A rotating arm that 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

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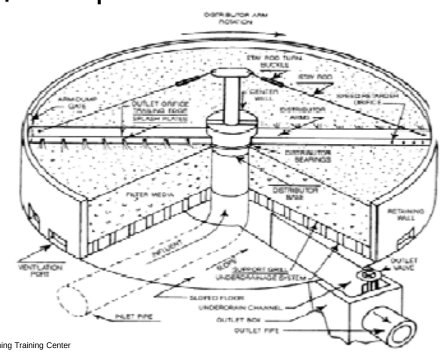
Components



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Components

- 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

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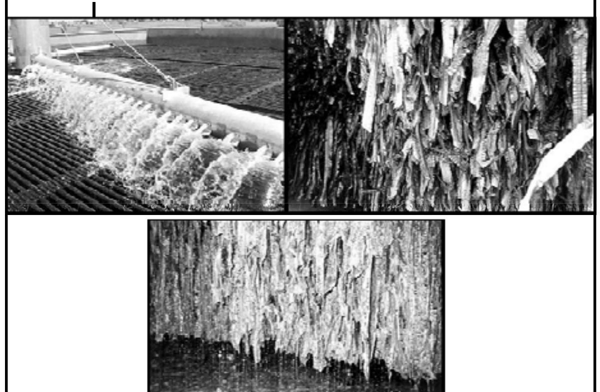

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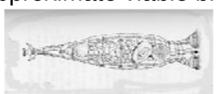
What is Zoogleal Film (Biomass)?

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

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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)

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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

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Preliminary and Primary Treatment Processes

- Trickling filters shall be preceded by primary clarifiers equipped with scum and grease collecting devices or other suitable primary treatment facilities. (TN Design Criteria)
- If fine screening is provided, the screen size shall have from 0.03 to 0.06 inch openings.
- Bar screens are not suitable as the sole means of preliminary/primary treatment.

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Primary Clarification Poor Settling

- Media plugging and ponding
- Poor oxygen transfer to biofilm
- Heavy, uncontrolled sloughing
- High solids in TF effluent
- Poor secondary clarifier performance

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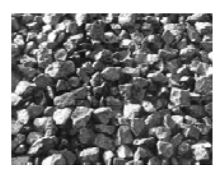
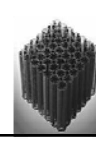
Filter Media



- Crushed rock
  - Durable & insoluble
  - Locally available
  - But, reduce the void spaces for passage of air
  - Less surface area per volume for biological growth
- Plastic media
  - Random packing media
  - Modular packing media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Design Considerations - Filter Media

- 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

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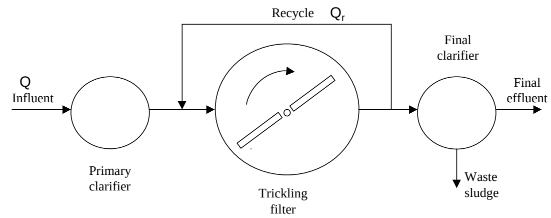
Flow & Recirculation Rates

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



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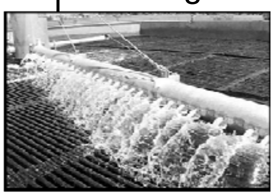
Trickling Filter Process



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Design Considerations - Recirculation

- Why is recirculation required?
  - maintain constant wetting rate
  - dilute toxic wastes
  - increase air flow
  - recirculation flow dilutes the strength of raw wastewater & allows untreated wastewater to be passes through the filter more than once.

- A common range for recirculation ratio
  - 0.5~3.0
  - Use the lowest recirculation rate that will produce good effluent but not cause ponding

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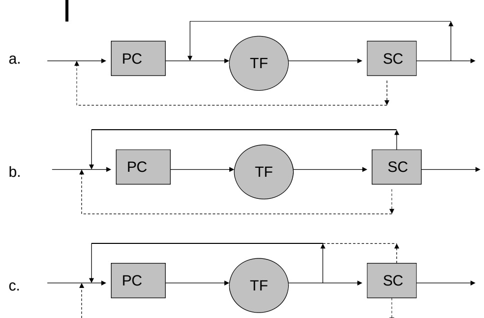
Single stage



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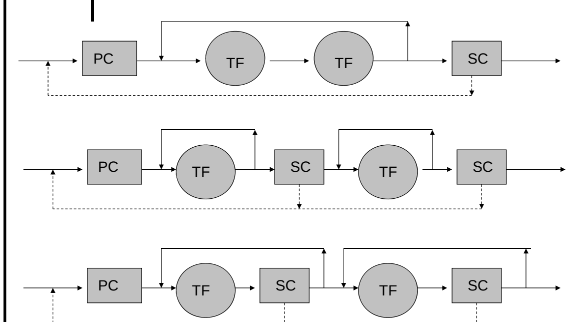
Two Stage



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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 settle in the clarifier
  - Risk is to hydraulically overload the clarifier

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Underdrainage and Ventilation Systems

- Two purposes:
  - to carry the filtered wastewater and the biomass lump (sloughed solids) from the filter to the final clarification process
  - 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.

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Ventilation System

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

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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.

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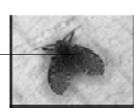
Abnormal Conditions

- Ponding-filter plugging



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

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Odors

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

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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

- 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 provides more oxygen and increases 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

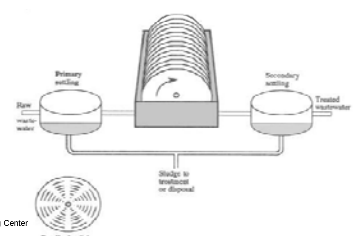
Control of Insects, Snails & Algae

- Flies (Psychoda):
  - 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
  - Keep grass cut
    - Shrubbery, weeds and tall grasses provide a natural sanctuary for filter flies.
  - Maintain hydraulic load of at least 200 gpd/ft^2

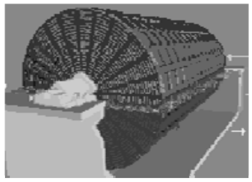
Typical Loading Rates

	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)



RBC Features



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

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RBC Features

- 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

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Rotating Biological Contactor

- 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

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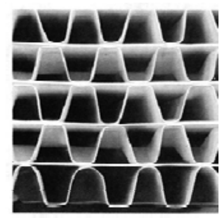
Media



- 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.

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Rotating Biological Contactor - Stages

- 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

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Rotating Biological Contactor - Stages

- 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

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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.

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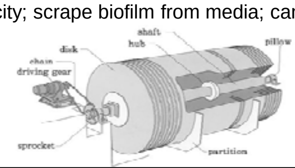
Motor with Chain Drive Unit

- 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.



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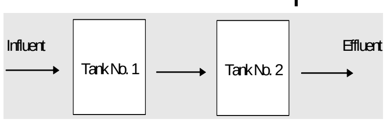
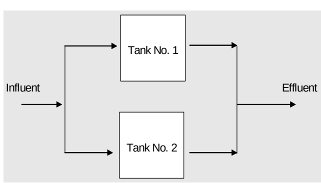
Series vs. Parallel Operation





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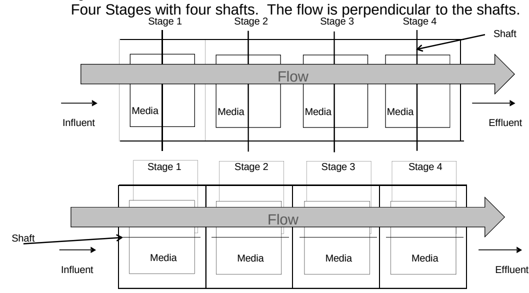
Flow

Four Stages with four shafts. The flow is perpendicular to the shafts.



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

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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

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Daily Inspection: 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

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Daily Inspection: 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, this needs to be removed by draining basin, washing out sludge and returning to service

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Daily Inspection: Biomass

- Snails are not a problem in RBC's used to remove CBOD, snails are a problem mainly on nitrifying systems
  - Bacteria removing CBOD has high growth and the microbial slime consumed by snails is quickly replaced by new growth
  - Snails remove slow-growing nitrifying bacteria and interfere with nitrification.

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Daily Inspection: 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.

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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

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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 (ventilation, lights, humidity control)

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Monitoring the Process

- 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

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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

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Moving Bed Biofilm Reactor

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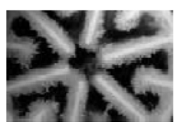
MBBR

- 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
- MBBR video



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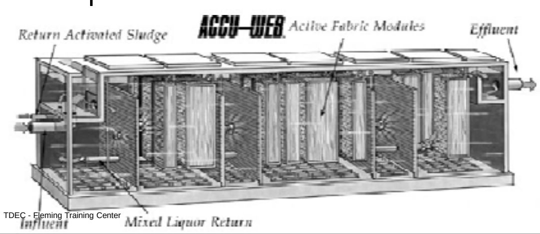
Integrated Fixed-film Activated Sludge



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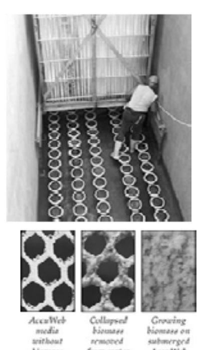
IFAS

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



Brentwood Industries

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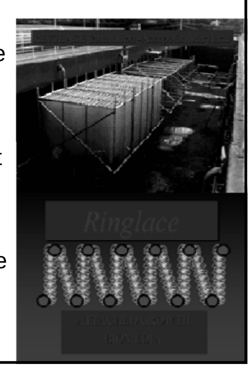
IFAS

- 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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CHAPTER 6

Fixed Film Reactors

6.1 Trickling Filters

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6.1.2 Pretreatment
6.1.3 Types of Processes
6.1.4 Consideration For Design
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6.2 Rotating Biological Contactors

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6.2.3 Design Loadings
6.2.4 Special Details

6.3 Activated Biofilter

6.3.1 General
6.3.2 ABF Media
6.3.3 Design
6.3.4 Special Details

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	1-4	4-10	10-40	15-90	60-180*
gpd/sq ft	25-90	90-230	230-900	350-2000*	1400-4200*
Organic Loading:					
lb BOD/acre-ft/day	200-1000	700-1400	1000-12000		
lb BOD/1000 cu ft/day	5-25	10-40	25-300	up to 300	100+
Depth (ft)	5-10	4-8	3-6	3-8	15-40
BOD Removal (%)	80-85	50-70	65-80	65-85	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.

Trickling Filter Math

1. A standard rate filter, 90 feet in diameter, treats a primary effluent flow of 540,000 gpd. If the recirculated flow to the trickling filter is 120,000 gpd, what is the hydraulic loading rate on the filter in gpd/sq.ft.?

2. A trickling filter, 75 feet in diameter, treats a primary effluent flow of 640,000 gpd. If the recirculated flow to the trickling filter is 110,000 gpd, what is the hydraulic loading rate in gpd/sq.ft. on the trickling filter?

3. A trickling filter, 85 feet in diameter with a media depth of 5 feet, receives a flow of 1,200,000 gpd. If the BOD concentration of the primary effluent is 160 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 cu.ft.?

4. A trickling filter, 80 feet in diameter with a media depth of 6 feet, receives a flow of 3,240,000 gpd. If the BOD concentration of the primary effluent is 110 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 cu.ft.?

5. If a trickling filter removes 113 mg/L suspended solids, how many lbs/day suspended solids are removed when the flow is 2,668,000 gpd?

6. If a trickling filter removes 177 mg/L BOD when the flow is 2,840,000 gpd, how many lbs/day BOD are removed?

7. The suspended solids concentration entering a trickling filter is 210 mg/L. If the suspended solids concentration in the trickling filter effluent is 67 mg/L, what is the suspended solids removal efficiency of the trickling filter?

8. The influent to a primary clarifier has a BOD content of 252 mg/L. The trickling filter effluent BOD is 20 mg/L. What is the BOD removal efficiency of the treatment plant?

Answers:

1. 103.8 gpd/sq.ft.
2. 169.9 gpd/sq.ft.
3. 56.5 lbs/day/1000 cu.ft.
4. 98.6 lbs/day/1000 cu.ft.
5. 2514.4 lbs/day
6. 4192.4 lbs/day
7. 68.1%
8. 92.1%

Formulas - pg. 9

Trickling Filter Math

1. A standard rate filter, 90 feet in diameter, treats a primary effluent flow of 540,000 gpd. If the recirculated flow to the trickling filter is 120,000 gpd, what is the hydraulic loading rate on the filter in gpd/sq.ft.?

$$HLR, gpd/sq.ft = \frac{\text{Prim. Eff, gpd} + \text{Recirc., gpd}}{\text{Area, sq.ft.}}$$

$$= \frac{540{,}000\ gpd + 120{,}000\ gpd}{(0.785)(90\ ft)(90\ ft)} = \boxed{103.8\ gpd/ft^2}$$

2. A trickling filter, 75 feet in diameter, treats a primary effluent flow of 640,000 gpd. If the recirculated flow to the trickling filter is 110,000 gpd, what is the hydraulic loading rate in gpd/sq.ft. on the trickling filter?

$$HLR, gpd/ft^2 = \frac{640{,}000\ gpd + 110{,}000\ gpd}{(0.785)(75\ ft)(75\ ft)}$$

$$= \boxed{169.9\ gpd/ft^2}$$

3. A trickling filter, 85 feet in diameter with a media depth of 5 feet, receives a flow of 1,200,000 gpd. If the BOD concentration of the primary effluent is 160 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 cu.ft.?

$$OLR, lbs/day/1000\ ft^3 = \frac{(BOD\ mg/L)(Flow, MGD)(8.34\ lbs/gal)}{\left(\frac{(0.785)(Diam, ft)^2(depth, ft)}{1000}\right)}$$

$$= \frac{(160\ mg/L)(1.2\ MGD)(8.34)}{\underbrace{\left(\frac{(0.785)(85\ ft)^2(5\ ft)}{1000}\right)}_{28.3581}} = \boxed{56.5\ lbs/day/1000\ ft^3}$$

4. A trickling filter, 80 feet in diameter with a media depth of 6 feet, receives a flow of 3,240,000 gpd. If the BOD concentration of the primary effluent is 110 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 cu.ft.?

$$OLR, lbs/day/1000\ ft^3 = \frac{(110\ mg/L)(3.24\ MGD)(8.34)}{\underbrace{\left(\frac{(0.785)(80\ ft)^2(6\ ft)}{1000}\right)}_{30.144}} = \boxed{98.6\ lbs/day/1000\ ft^3}$$

5. If a trickling filter removes 113 mg/L suspended solids, how many lbs/day suspended solids are removed when the flow is 2,668,000 gpd?

$$\text{lbs/day removed} = (\text{removed, mg/L})(Q, \text{MGD})(8.34\ \text{lbs/gal})$$
$$= (113\ \text{mg/L})(2.668\ \text{MGD})(8.34)$$
$$= \boxed{2514.4\ \text{lbs/d}}$$

6. If a trickling filter removes 177 mg/L BOD when the flow is 2,840,000 gpd, how many lbs/day BOD are removed?

$$\text{lbs/day removed} = (177\ \text{mg/L})(2.84\ \text{MGD})(8.34)$$
$$= \boxed{4192.4\ \text{lbs/d}}$$

7. The suspended solids concentration entering a trickling filter is 210 mg/L. If the suspended solids concentration in the trickling filter effluent is 67 mg/L, what is the suspended solids removal efficiency of the trickling filter?

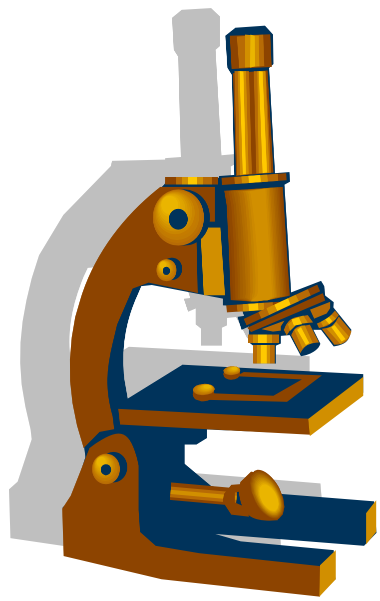
$$\text{Efficiency, \%} = \left(\frac{\text{in} - \text{out}}{\text{in}}\right)(100)$$
$$= \left(\frac{210 - 67}{210}\right)(100) = \boxed{68.1\%}$$

8. The influent to a primary clarifier has a BOD content of 252 mg/L. The trickling filter effluent BOD is 20 mg/L. What is the BOD removal efficiency of the treatment plant?

$$\text{Efficiency, \%} = \left(\frac{252 - 20}{252}\right)(100)$$
$$= \boxed{92.1\%}$$

Section 6

Microscopic Exam



Microscopic Exam

Wastewater

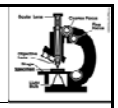
1

The First Light Microscopes

- Around 1590 Zaccharias and Hans Janssen experimented with lenses in a tube, leading to the forerunner of the microscope and the telescope
- In the late 1600's, Anton van Leeuwenhoek was the first to see bacteria, yeast, and many other microbes using a microscope

2

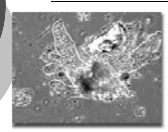
How Light Microscopes Work



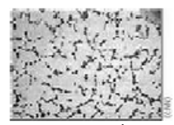
- First, the objective lens gathers light from the specimen and magnifies the image
  - Most microscopes have several objective lenses that can be rotated into position to provide different levels of magnification (4X, 10X, 40X)
- The ocular lens in the eyepiece magnifies and transmits the image to your eye
  - The magnification of the ocular lens is 10X
- To find the total magnification of the microscope you are using, multiply the magnification of the objective lens by the magnification of the ocular lens.
  - For example: 40X (objective lens) x 10X (ocular lens) = 400X magnification

3

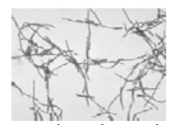
Images Produced by Light Microscopes



Amoeba



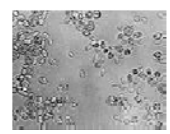
Streptococcus bacteria



Anthrax bacteria

Human cheek cells

Plant cells



Yeast cells

4

Beyond Light Microscopes

- Light microscopes are limited by their resolution.
  - Light microscopes cannot produce clear images of objects smaller than 0.2 micrometers
- The electron microscope was invented in the 1930's by Max Knott and Ernst Ruska
  - Electron microscopes use beams of electrons, rather than light, to produce images
  - Electron microscopes can view objects as small as the diameter of an atom

5

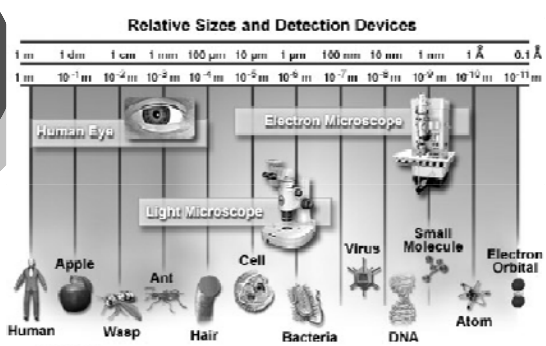


Figure 1

6

Types of Electron Microscopes

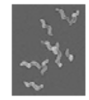
- Transmission electron microscopes (TEMs) pass a beam of electron through a thin specimen
- Scanning electron microscopes (SEMs) scan a beam of electrons over the surface of a specimen
- Specimens from electron microscopy must be preserved and dehydrated, so living cells cannot be viewed

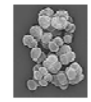
7

Images Produced by Electron Microscopes


Cyanobacteria (TEM)


Lactobacillus (SEM)

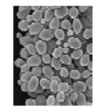

Campylobacter (SEM)


Deinococcus (SEM)


House ant


Avian influenza virus

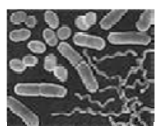

Human eyelash


Yeast

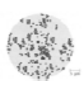
8

Using Microscopes to Visualize the Three Shapes of Bacteria

- Cocci (round)
- Bacilli (rod)
- Spirilla (spiral)


Three shapes of bacteria taken with an SEM

Light microscope:


Cocci


Bacilli


Spirilla

9

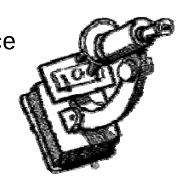
Microscope Care

- Always carry with 2 hands
- Only use lens paper for cleaning
- Do not force knobs
- Always store covered
- Keep objects clear of desk and cords

10

Using the Microscope

- Place the slide on the microscope
- Use stage clips
- Click nosepiece to the lowest (shortest) setting
- Look into the eyepiece
- Use the coarse focus



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Using High Power

- Follow steps to focus using low power
- Click the nosepiece to the longest objective
- Do NOT use the coarse focusing Knob
- Use the fine focus knob to bring the slide

What can you find on your slide?

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Vocabulary

- Compound Microscope - Used for very small objects, up to 1000x magnification possible.
- Brightfield Microscopy - Light aimed toward lens beneath the condenser, through specimen.
- Darkfield Microscopy - Images of light and dark are reversed, field appears almost black, specimen light.
- Phase Contrast Microscopes - Fine detail revealed through specimens that have little contrast. Works well with protozoa's and bacteria.

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Data From Microscope?

- Organism type(s)
- Floc particle examination
- Organism(s) volume
- General health
- Motility

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Types of Microscopes

- Stereo
- Compound

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Stereo Microscope Uses

- Low power applications
- Bacterial colony counting etc.

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Compound Microscope

- Magnifies very small objects
- Thin specimens to transmit light
- Specimens mounted on cover slides
- High quality specimen selection & preparation important
- Correct selection of magnification and lighting crucial
- Available options: Phase Contrast, adjustable condensers, Dark-field

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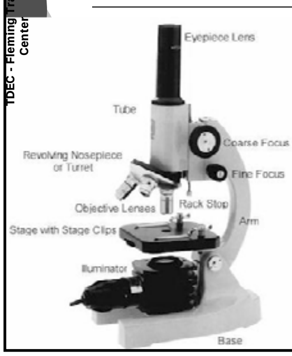
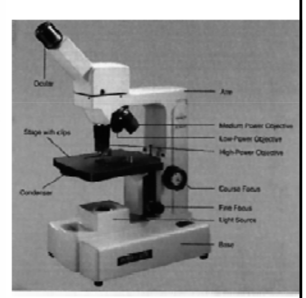
Compound Scope Parts





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Focusing Specimens – Step 1

- Always start with the scanning objective.
- Odds are, you will be able to see something on this setting.
- Use the coarse knob to focus, image may be small at this magnification, but you won't be able to find it on the higher powers without this first step.
- Do not use stage clips, try moving the slide around until you find something.

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Note

- If you wear glasses, take them off; if you see only your eyelashes, move closer.
- Be sure to close, or cover your other eye!!

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Focusing Specimens – Step 2

- Once you've focused on scanning, switch to low power.
- Use the coarse knob to refocus.
- Again, if you haven't focused on this level, you will not be able to move to the next level.

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Focusing Specimens – Step 3

- Now switch to High Power.
  - If you have a thick slide, or a slide without a cover, do NOT use the high power objective.
- At this point, ONLY use the fine adjustment knob to focus specimens.

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Focusing Specimens – Step 4

- If the specimen is too light or too dark, try adjusting the diaphragm.

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Focusing Specimens – Step 5

- If you see a line in your viewing field, try twisting the eyepiece, the line should move.
- That's because its a pointer, and is useful for pointing out things to your lab partner or teacher.

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Bright Field Microscopes

- Optical range from 100X to up to 1000X
- Ideal for larger populations
- Large filamentous counting
- Large rod-shaped bacteria populations
- May miss smallest protozoa's & bacteria

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Use of Bright Field Microscopes

- Best suited pigmented specimen w/ contrast
- Useless on colorless bacteria, tissue, single organisms
- Stained bacteria, grouped colonies
- Living organisms
- Magnifications 40X, 100X, 400X, 1000X

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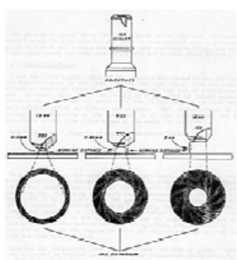
Magnification

- Two-lens system
  - Ocular (Closest the eye)
  - Objective(Closest the specimen)
- Total Magnification =
  - Ocular rating X Objective Rating



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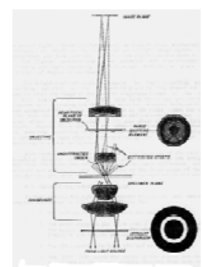
Phase Contrast Microscopes

- Light bends to greater angles, away from center of lens where intensity is needed
- Results-too little visual detail in living cells
- Preferred in 400X to 1000X magnification to see cell detail.
- Ideal for smallest Protozoa's
- Rod-shaped bacteria
- Certain algae



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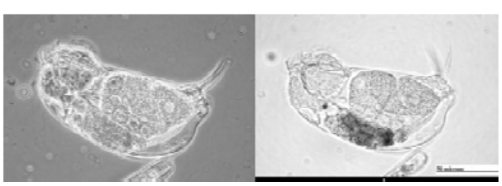
Phase Contrast / Bright Field



Phase Contrast Bright Field

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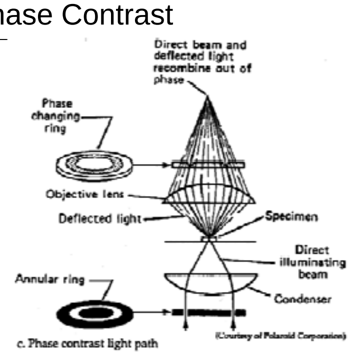
Phase Contrast



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Phase Contrast v/s Staining

- Improves organism cell structure viewing
- Aids in Identification
- Staining kills the organism
- Phase microscopy does not
- More organism information

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Dark Field Microscopy

- Opaque disk added under condenser
- Only light that is scattered reaches the eye
- Use in low magnification-100X
- Ideal initial investigation of Mixed Liquor
- Determine motile/nonmotile bacteria
- Algae
- Protozoan scans

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Oil Immersion Microscopy

- Different refractive indexes for water/air.
- Light bends, loss of resolution, distortion
- Special oil-immersion lens used
- Drop of oil to cover slip
- Dry lens focus first
- Oil immersion lens next
- Lens nearly touches cover slip when focusing
- Use w/ very thin specimens

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Sample Collection

- Potential sampling areas
  - Aeration Basin
  - Suspect problematic areas
  - Mixed Liquor
  - WAS
  - RAS

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Sample Collection

- 100 mL plastic bottles
- Select:
  - Mixed liquor from effluent side
  - Discharge from secondary clarifer center well
  - RAS pump discharge
- Foam samples if suspect
- Wastewater Inf/Eff samples

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Cover Slide Prep, Wet

- Clean slide & cover slip
- Shake sample bottle, transfer 50 mL to beaker
- Drop of sample to slide center
- Hold cover slip at 45° above sample
- Slide slip toward sample drop
- Allow sample to spread to cover slip edge

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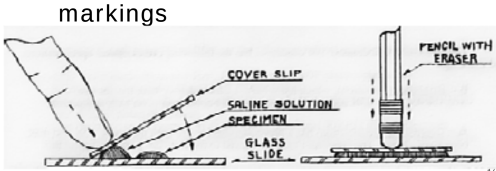
Cover Slide Prep, Wet

- Drop slip into place on sample
- Press slip w/ pencil eraser to spread
- Absorb excess sample with tissue
- ID the slide with appropriate markings



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Slide Staining

- Adds to organism visibility/contrast
- More organism detail
- May help low-featured microscope performance.
- Enhance Bright Microscopy and those microscopes w/o Phase Contrast.
- But......Staining kills organism
- Requires a smear slide preparation

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Slide Prep, Staining

- Clean slide & cover glass
- Drop of sample in center of slide
- Spread/smear sample w/ glass rod
- Air-dry(do not use a heat source....hair-dryer)
- Stain per Standard Methods, following protocol, or manufacturer instructions

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Staining Types

- Gram stain
- Neisser stain
- India Ink reverse stain
- Polyhydroxybutyrate stain
- Crystal Violet Sheath stain

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Gram Stains

- Available as kit from lab supply houses includes:
  - Gentian Violet solution
  - Crystal Violet solution
  - Gram's Iodine solution
  - Decolorizer
  - Safranin solution

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Gram Stains, How-To

- Prepare thin smear of sample-air dry
- Stain 1 minute w/ Gentian Violet - rinse 1 sec in water
- Stain 1 minute w/ Gram's Iodine solution, rinse well
- Add Decolorizing agent drop-by-drop for 25 seconds, Blot dry

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Gram Stains, How-To

- Stain w/ Safranin Solution for 1 minute
- Examine using 1000X mag under oil immersion
  - Blue-Violet is Positive
  - Pink-Red is Negative

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Neisser Stains, How-to

- Prepare as required via Standard Methods or purchase from supply house
- Prepare thin smear - air dry
- Stain 1 min w/ solution #1, rinse 1 sec in water
- Stain 1 min w/ solution #2, rinse well w/water, blot dry
- Examine @1000X Oil immersion: Blue-violet-Positive, Yell-Brn- Negative

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India Ink Reverse Stains, How-to

- Mix 1 drop India Ink w/ one drop Activated Sludge on slide
- Cover slide and view @ 1000X
- Normal: Ink particles penetrate floc completely, small clear center
- Abnormal: Large clear areas w/ low density cells

45

Polyhydroxbutyrate Stains, How-to

- Two solutions:
  - #1Sudan Blk, 0.3% w/v 60% ethanol
  - #2 Safranin 0, 0.5% (supply house)
- Thin smear on slide, air-dry
- Stain 10 min w/ solution # 1 avoid dry-out
- Rinse 1 minute in water
- Stain 10 seconds w/ solution #2, rinse, blot dry
- View @ 1000 Oil immersion, PHB Blu-Blk, Cytoplasm - Pink to clear

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Crystal Violet Stains, How-to

- Obtain from supply house
- Mix 1 drop of activated sludge w/ 1 drop of Crystal Violet Solution, cover and view @ 1000X.
- Cells stain deep violet
- Sheaths are clear-pink

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Photographic Cataloging

- Inventory known organisms
- Identify unknown organism
- Helps process control decision-making
- HOWEVER...... Expensive to buy hardware, and requires expertise to use and store data

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Permanent Slides

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- Catalogs known organisms in your plant
- Historical reference data for comparing future slides.
- Helps identify previously unknown creatures.
- Process control tool for decision-making.

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Permanent Slide Preparations

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- Label Slide
- Use select specimen
- Add drop of Cytoseal next specimen
- Move cover slip to touch Cytoseal.
- Keep edge of slip down
- Cytoseal will spread across specimen
- Allow to dry, store slide in cool dry location

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Microorganism Review

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Bacteria

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- Convert dissolved organic material
  - Phosphates
  - Sugars
  - Proteins
  - Starches
- Protozoa's present as well
- Poorly visible w/ bright field microscopy
- Filamentous visible here
- Requires phase contrast to view individual sizes and shapes

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Filaments

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- Some filaments OK for floc formation
- Excess?:
  - Check DO levels > 1 PPM
  - Nutrients(N, P, FE)
  - pH
- No Filaments?
  - Check F/M ratio
  - Check DO, reduce if > 3.0 PPM

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Protozoa

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- Abundant & diverse in activated sludge process
- Inactive?
  - Toxic shocks?
- No Protozoa?
  - F/M too high (Reduce wasting, incr. return)
  - Low to normal F/M (Incr. DO, toxic shock)
- Healthy protozoa, dispersed floc?
  - Reduce mixing, reduce aeration

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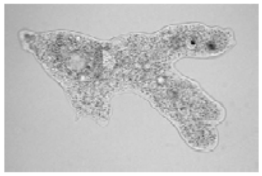
Amoebae



- Earliest organism that show-up in activated sludge process
- Associated with "young sludge"
- Feed by pseudopodia(false feet)
- Engulf small of organic matter.
- Extremely difficult to see w/ bright field microscope

55

Flagellates

- Tail-like structure which whips back & forth for mobility.
- Engulf organic particles & bacteria
- Activated sludge activator
- Can be seen in bright field microscope with care magnification and cell staining.

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Free & Stalked Ciliates

- Highly prized in wastewater's
- Associated w/ good settleability
- Low suspended solids
- Organism in sweeping motion
- Sweeping effect by ciliates gather small particles to form floc
- Settle rapidly
- Requires good bright microscopy to see these organisms.
- Phase contrast may offer better visibility

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Free & Stalked Ciliates

Free Swimming Ciliates

Stalked Ciliates

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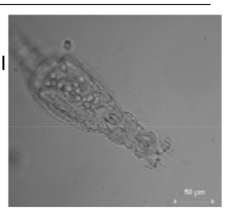
Rotifers



- Rotary sweeping organism that pull small particles into mouth.
- Constant movement.
- Wastewater's may numbers in activated sludge process.
- Better settling.
- Some wastewater's, higher numbers mean old sludge and more wasting needs.
- Best viewed with bright microscopy at 300X to 400X power

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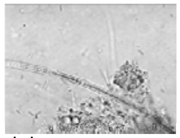
Nematodes

- Roundworms that feed on organic matter and bacteria.
- Associated with old sludge.
- Substantial numbers usually a sign to increase wasting rates.
- Some are predators feeding upon protozoa, rotifers.
- Best viewed upon Bright Microscopy @ 300X

60

Algae/Fungi



- Lagoon or pond type organisms
- Contribute to SS
- Add oxygen in sunlight,
- Control or harvest is essential.
- Best viewed with bright microscopy @ <400X power.
- Phase contrast helps identify species.

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Scope Care & Maintenance

- Never touch lens
- Never leave slide on stage when not in use
- Always remove oil from objective
- Stage should be clean
- Do not tilt microscope when using oil
- Keep microscope covered when not in use
- Store in cabinet when not in use
- Regular professional service

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Tips & Tools

- Never force the scope, adjustments should work freely
- Never allow lens to touch slide
- Never use coarse adjustments for viewing
- Never interchange different mfr. lens

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Troubleshooting

- Image is too dark!
- *Adjust the diaphragm, make sure your light is on.*
- Only half of my viewing field is lit, it looks like there's a half-moon in there!
- *You probably don't have your objective fully clicked into place*

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Troubleshooting – continued

- There's a spot in my viewing field, even when I move the slide the spot stays in the same place!
- *Your lens is dirty.*
  - *Use lens paper, and only lens paper to carefully clean the objective and ocular lens.*
  - *The ocular lens can be removed to clean the inside.*

65

Troubleshooting – continued

- I can't see anything under high power!
- *Remember the steps, if you can't focus under scanning and then low power, you won't be able to focus anything under high power.*

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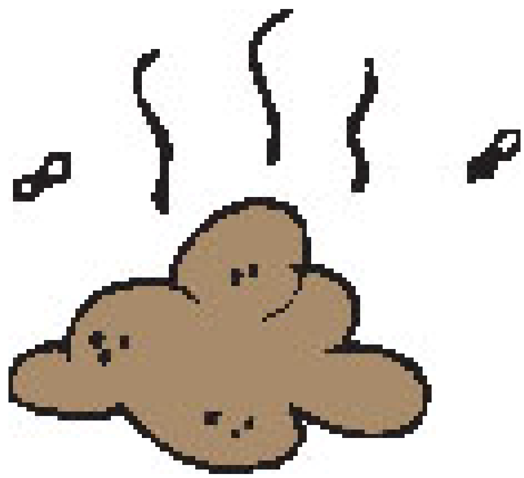
Section 7

Sludge Thickening, Digestion and Dewatering



Sludge Thickening, Digestion, and Dewatering

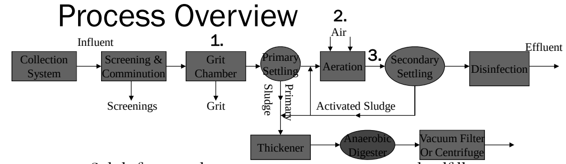
- or -

Now What Do We Do With It?

Sludge Thickening, Digestion, and Dewatering

- Thickening
  - Gravity
  - Floatation
  - Gravity belt
- Stabilization
  - Anaerobic digestion
  - Aerobic digestion
- Dewatering
  - Centrifuge
  - Plate and frame
  - Belt filter press
  - Vacuum filter
  - Drying beds

Process Overview



1. Solids from preliminary treatment are sent to landfill
   - Screenings (coarse solids), grit, scum
2. Primary and secondary solids are most often treated onsite
   - Primary sludge usually is grey and slimy with an offensive odor
   - Sludge from activated sludge and trickling filter has brown, flocculant appearance, both digest readily
3. Sludge from chemical precipitation with metal salts
   - Usually dark in color and may be gelatinous
   - Decomposes slowly and may give off large amounts of gases

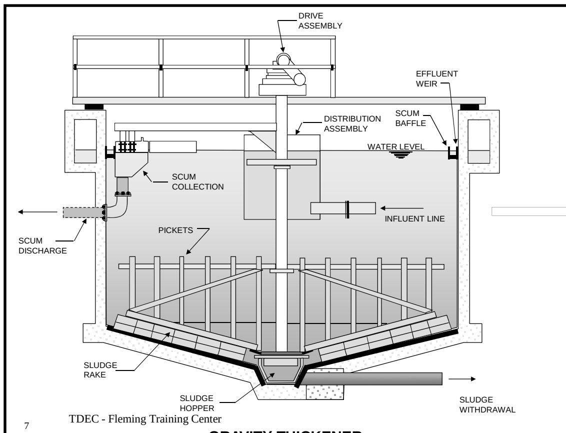
Sludge Thickening

Main component of sludge is water

~90% or more before treatment

Gravity Thickening

- Most effective on primary sludge
- Detention time is around 24 hours
- Thickening tank looks like a primary circular clarifier
- Monitored for blanket depth and sludge concentration
- Affected by temperature of sludge
  - Increased temperature will increase biological activity and gas production
- Separates solids into three zones
  - Clear supernatant
  - Sedimentation zone
  - Thickening zone



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GRAVITY THICKENER

Gravity Thickening

- Dilute sludge is fed into center well
- Supernatant is returned to primary clarifier or plant headworks
- Thickened sludge is pumped to digester or dewatered

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Flotation Thickener

- Treats waste activated sludge
  - Often with added polymers
- Dissolved-air flotation (DAF)
- Small amount of recycled water is aerated under pressure
- Air bubbles attach to the solids and carry them to the surface
- The "Float Cake" is skimmed off the surface
- Cake is 2 – 4% solids without polymer fed, or 3 – 5% solids with polymer fed

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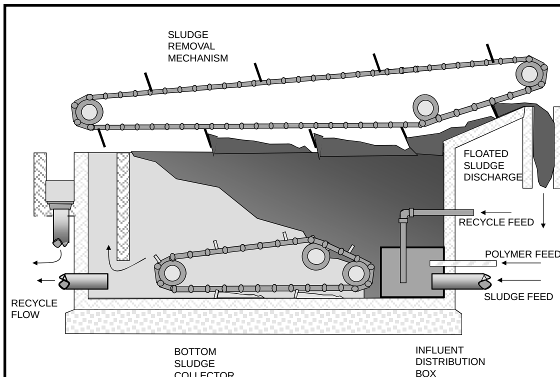

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Gravity Belt Thickener

- Concentrates solids on a porous horizontal belt
- Sludge usually preconditioned with polymer
- Water drawn by gravity through the belt
- Can thicken secondary sludge to 4 –7% solids

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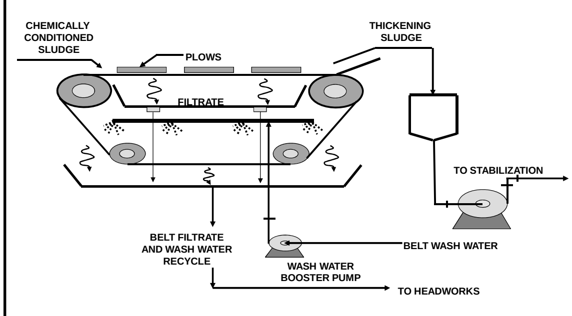

Gravity Belt Filter Thickener

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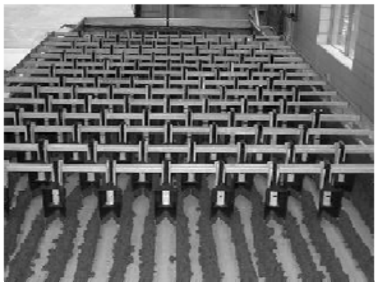

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Biosolids Stabilization (Digestion)

Reduce volume

Stabilize organic matter

Eliminate pathogenic organisms

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Stabilization

- Helps to avoid odor problems
- Prevents breeding of insects
- Reduces the number of pathogenic organisms

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General Overview

Before digestion of 100 pounds of sludge: 75% Volatile, 25% Fixed Solids	After a 65% reduction in Volatile Solids there is less sludge remaining to process
	50 Lbs of CH_4, CO_2, H_2O
75 Lbs VS	25 Lbs VS
25 Lbs Fixed	25 Lbs Fixed

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Biosolids Stabilization

Anaerobic Digestion

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Anaerobic Digestion

- Removes 50-65% VS and 85-99% of pathogens
- Wastewater solids and water are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen.
- The purpose of sludge digestion is to decrease the bulk of sludge to facilitate handling, to decompose enough of the organic matter to avoid creating a nuisance and to separate the liquid from the solids to facilitate drying.
- At least two general groups of bacteria act in balance: Saprophytic Bacteria and Methane Producers break down the acids to methane, carbon dioxide, and water.

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Anaerobic Digestion

- Anaerobic Digestion reduces wastewater solids from a sticky, smelly mixture to a mixture that is relatively odor free, dewaterable and capable of being disposed of without causing a nuisance.
- In this process organic solids in the sludge are liquefied, the solids volume is reduced, and valuable methane gas is produced in the digester by the action of two different groups of bacteria living together in the same environment.
  - One group consists of SAPROPHYTIC ORGANISMS, commonly referred to as "acid formers."
  - The second group, which uses the acid produced by the saprophytes, are the "methane producers"

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Anaerobic Digestion

- 2-phase process:
  - Acid formers - Facultative bacteria convert organic matter to volatile acids, CO_2, and H_2S
  - Methane producers - Anaerobic bacteria convert acids to CH_4 and CO_2
    - The methane producers are not as abundant in raw wastewater as are the acid formers.
    - The methane producers desire a pH range of 6.6 to 7.6 and will reproduce only in that range.
- 28-40% carbon dioxide, 60-72% methane
  - Minimum methane for reuse is 62%
- Sludge retention time is 30-60 days

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Temperature Ranges

- Heated units operate ~ 90-95°F
- An anaerobic digester may be operated in one of three temperature zones or ranges, each of which has its own particular type of bacteria.
  - Cold temperature - Psychrophilic bacteria
  - Medium temperature - Mesophilic bacteria
  - Hot temperature - Thermophilic bacteria

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Psychrophilic Bacteria

- The lowest range (in an unheated digester) utilizes Psychrophilic (cold temperature loving) bacteria.
  - The psychrophilic upper range is around 68°F (20°C).
  - Digestion in this range requires from 50 to 180 days, depending upon the degree of treatment or solids reduction required.

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Mesophilic Bacteria

- Organisms in the middle temperature range are called the Mesophilic (medium temperature loving) bacteria
  - Thrive between about 68°F (20°C) and 113°F (45°C).
  - The optimum temperature range is 85°F (30°C) to 100°F (38°C), with temperatures being maintained at about 95°F (35°C) in most anaerobic digesters.
  - Digestion at 95°F may take from 5 to 50 days or more (normally around 25 to 30 days), depending upon the required degree of volatile solids reduction and adequacy of mixing.

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Thermophilic Bacteria

- Organisms in the third temperature range are called Thermophilic (hot temperature loving) bacteria and they thrive above 113 °F (45°C).
- The optimum temperature range is considered 120 °F (49°C).
- The time required for digestion in this range falls between 5 and 12 days, depending upon operational conditions and degree of volatile solids reduction.
  - However, the problems of maintaining temperature, sensitivity of the organisms to temperature change, and some reported problems of poor solids - liquid separation are reasons why only a few plants have actually been operated in the thermophilic range.

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Changing Temperatures

- You can't change temperature and expect a quick change in bacteria population and therefore a shorter digestion time
- An excellent rule for digestion is never change the temperature more than one degree a day to allow the bacterial culture to become acclimated (adjust to the temperature changes).

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Anaerobic Digestion

- Several products end up in the digester that are not desirable because the bacteria can't effectively use or digest them, and they can't be readily removed by the normal process
  - Petroleum products and mineral oils
  - Rubber goods
  - Plastics (back sheets to diapers)
  - Filter tips from cigarettes
  - Hair
  - Grit (sand and other inorganics)

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Anaerobic Digestion

- When wastewater solids are first added to a new digester, naturally occurring bacteria attack the most easily digestible food available, such as sugar, starches, and soluble nitrogen.
- The anaerobic acid producers change these foods into organic acids, alcohols, and carbon dioxide, along with some hydrogen sulfide.
- The PH of the sludge drops from 7.0 to about 6.0 or lower.
- An acid regression stage then starts and lasts as long as six to eight weeks.

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Anaerobic Digestion

- During this time ammonia and bicarbonate compounds are formed, and the pH gradually increases to around 6.8 again, establishing an environment for the methane fermentation or alkaline fermentation phase.
- Organic acids are available to feed the methane fermenters.
- Larger quantities of methane gas are produced as well as carbon dioxide, and the pH increases to 7.0 to 7.2.
- Once alkaline fermentation is well established, strive to keep the digesting sludge in the 7.0 to 7.2 range.

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Feeding Anaerobic Digester

- Better operational performance occurs when the digester is fed several times a day, rather than once a day because you are avoiding temporary overloads on the digester and you are using your available space more effectively.
- Several pumpings a day not only helps the digestion process, but maintains better conditions in the clarifiers, permits thicker sludge pumping, and prevents coning in the primary clarifier hopper.
- Never pump thin sludge or water to a digester.
- A sludge is considered thin if it contains less than 5 percent solids (too much water).

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Feeding Anaerobic Digester

- Reasons, for not pumping a thin sludge include:
  - Excess water requires more to heat than may be available
  - Excess water reduces holding time of the sludge in digester, and
  - Excess water forces seed and alkalinity from the digester, jeopardizing the system due to insufficient buffer capacity for the acids produced by digestion of the raw sludge.
- Feeding the digester must be regulated an the basis of laboratory test results in order to insure that the volatile acid/alkalinity relationship does not start to increase and become too high.

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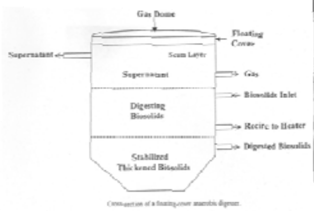
Anaerobic Digestion



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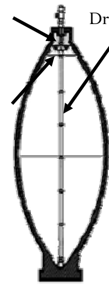
Cross-Section of an Egg-Shaped Digester

Gas Collection Area

Draft Tube

Maximum Fill for Sludge



Baltimore, Maryland

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Anaerobic Digestion – Normal Ranges

Parameter	Normal Ranges
Sludge retention time	30 – 60 days (Heated)
Operating Temperature	90 – 95 °F (Heated)
Volatile Solids Loading	0.04 – 0.1 lb VM/day/ft^3
% Methane in gas	60 – 72%
% Carbon Dioxide in gas	28 – 40%
pH	6.8 – 7.2
Volatile acids: alkalinity ratio	≤0.1
Volatile solids reduction	40 – 60%

* For every 1 lb. of VM destroyed, 12-18 ft^3 of gas is produced.

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Anaerobic Digestion

- Volatile Acids to Alkalinity Ratio

$$\text{Ratio} = \frac{\text{volatile acids concentration, mg/L}}{\text{alkalinity concentration, mg/L}}$$

  - Must monitor alkalinity
  - Can be used to control operation of anaerobic digester
  - Very sensitive indicator of process condition
  - One of the first indicators that the digester is going sour

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Acid-Alkalinity Relationship

Optimum	V.A./ALK = .05 - 0.1
Stress	V.A./ALK = 0.3 - 0.4
Deep Trouble	V.A./ALK = 0.5 - 0.7
Failure	V.A./ALK = 0.8 and above

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Anaerobic Digestion

- Mixing
  - Puts microorganisms in contact with food
  - Controls pH, distributes buffering alkalinity
  - Distributes heat throughout the tank
  - Mixing combined with heating speeds up the digestion rate

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Anaerobic Digestion

- Mechanical mixing is most common method
  - Shaft-driven propeller extended down into sludge
  - Susceptible to wear
  - Cleaning and replacement necessary
- Other methods
  - Propeller with draft tube
  - Bubble-gun type

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Anaerobic Digestion

Anaerobic Digestion – Sludge Parameters	
< 4% Solids	Loss of alkalinity Decreased Sludge retention time Increased heating requirements Decreased volatile acid/alkalinity ratio
4 – 8% Solids	Normal Operation
> 8% Solids	Poor mixing Organic overloading Decreased volatile acid/alkalinity ratio

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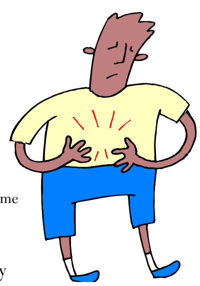
Anaerobic Digestion

- A digester can be compared with your own body.
  - Both require food; but if fed too much will become upset.
  - Excess acid will upset both.
- Sour digester?
  - Lime
    - Lime is added at a 1:1 ratio, 1 lb of lime for every 1 lb or volatile acid
  - Soda ash
  - Transfer alkalinity from secondary digester to primary



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Anaerobic Digestion

- Foaming
  - Problems: odors, excess pressure on cover, plugs gas piping system
  - Cause: Gas production at startup with insufficient solids separation
  - Prevention: Adequate mixing before foaming starts

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Neutralizing a Sour Digester

- The recovery of a sour digester can be accelerated by neutralizing the acids with a caustic material such as anhydrous ammonia, soda ash, or lime, by transferring alkalinity in the form of digested sludge from the secondary digester.
- Such neutralization reduces the volatile acid/alkalinity to a level suitable from growth of the methane fermenters and provides buffering material which will help maintain the required volatile acid/alkalinity relationship and pH.
- If digestion capacity and available recovery time are great enough, it is probably preferable to simply reduce loading while heating and mixing so that natural recovery occurs.

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Neutralizing a Sour Digester

- When neutralizing a digester, the prescribed dose must be carefully calculated.
  - Too little will be ineffective, and too much is both toxic and wasteful. In considering dosage with lime, the small plant without laboratory facilities could use a rough guide a dosage of about **one pound of lime added for every 1000 gallons of sludge** to be treated.
  - You must realize that neutralizing a sour digester will only bring the PH to a suitable level, it will not cure the cause of the upset.
- Stuck Digester - A stuck digester does not decompose organic matter properly.
  - The digester is characterized by low gas production, high VA/alk relationship, and poor liquid-solids separation.
  - A digester in a stuck condition is sometimes called a "sour" or "upset" digester.

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Gas Production

- When methane fermentation starts and the methane content reaches around 60%, the gas will be capable of burning.
- Methane production eventually should predominate, generating a gas with 65-70% methane and 30-35% carbon dioxide by volume.
- Digester gas will burn when it contains 56% methane, but is not usable as a fuel until the methane content approaches 62%.
- When the gas produced is burnable, it may be used to heat the digester as well as for powering engines and for providing building heating.

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Biosolids Stabilization

Aerobic Digestion

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Aerobic Digestion

- Extended aeration of wastewater
  - Wastes stabilized by long-term aeration of about 10-20 days
  - Check pH weekly and adjust if less than 6.5
  - Lower equipment costs than anaerobic (but higher energy costs)
  - Less noxious odors at DO ≥ 1 mg/L
  - Better on secondary sludge than primary sludge
  - Sludge has higher water content
  - By products: residual solids, CO_2, H_2O, SO_4^-, NO_3^-

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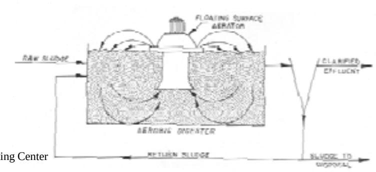
Aerobic Digestion

- Aerobic digesters are operated under the principle of extended aeration from the activated sludge process relying on the mode or region called endogenous respiration.
- Aerobic digestion consists of continuously aerating the sludge without the addition of new food, other than the sludge itself, so the sludge is always in the endogenous region.



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Comparison Between Anaerobic and Aerobic Digestion

Anaerobic Digestion	Aerobic Digestion
Does not use aeration	Aeration equipment—oxygenation, mixing
Fresh wastes	Partially stabilized solids
Putrefaction	Produces fewer odors
Concentrates sludge	Higher water content sludge
Produces solids, water, etc.	Produces residual solids, water, etc
Liquids that are difficult to treat	Liquids that are easier to treat

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Aerobic Digestion – Normal Ranges

Parameter	Normal Levels
Detention time (days)*	>20
Volatile Solids Loading (lb/ft^3/day)	0.1 – 0.3
DO (mg/L)	1.0 to 2.0
pH	5.9 – 7.7
Volatile Solids Reduction	40 – 50%

*To meet Class B standards for pathogen reduction, SRT ≥ 40 days at 20°C or ≥ 60 days at 15°C

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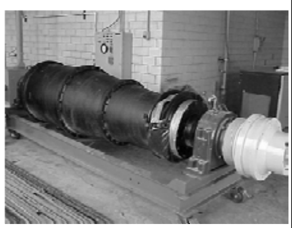
Sludge Dewatering

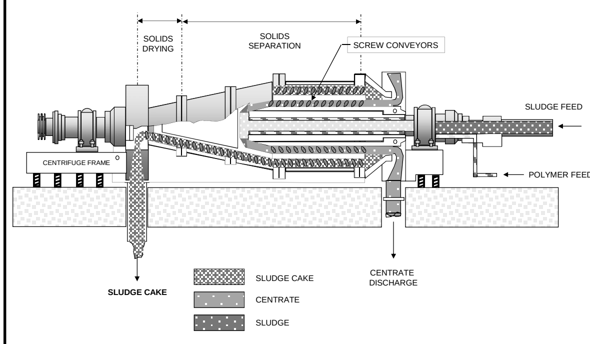
Sludge Dewatering

- Dewatering reduces sludge moisture and volume to allow for more economical disposal
- Types:
  - Centrifuge
  - Plate and Frame Press
  - Belt Press
  - Vacuum Filter
  - Drying Beds

Centrifuge

- Used to thicken or dewater secondary sludges
- Sludge fed at constant rate into rotating horizontal bowl
- Solids separated from liquid and compacted by centrifugal force (1000 – 2000 rpm)





SCROLL CENTRIFUGE

Plate-and-Frame

- Solids are pumped in batches into spaces between plates
- 200 – 250 psi pressure applied to squeeze out water
- At end of cycle (1.5 – 4 hours), plates are separated and solid drops out onto conveyor
- Pressure filtration that forces liquid through the filter media

Plate-and-Frame

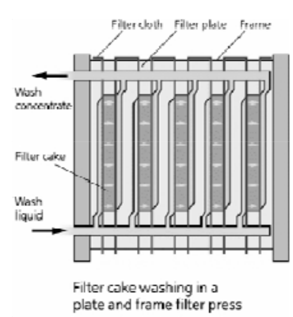


Plate-and-Frame

JVAP (US Filter) – Chattanooga
• Modified plate and frame that is vacuum assisted

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Belt Filter Press

- Low power use
- Reliable
- Continuous operation
- Two long belts that travel over a series of rollers
- Sludge applied to free water zone (much water will drain off here)
- Solids then squeezed between a series of rollers (and more water is removed)
- Remaining solids are scraped from the belt
- Belts are washed and the process repeats

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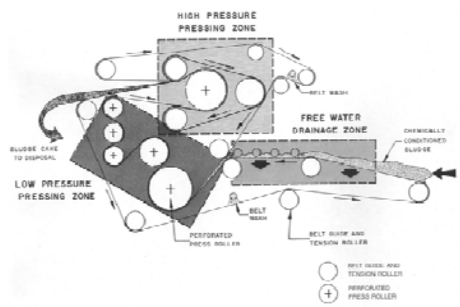
Belt Filter Press



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Vacuum Filter

- Sludge pumped into a tank around a partially submerged rotating drum
- Drum rotates, vacuum collects solids on surface
- Vacuum removes excess water
- Vacuum is then released and solids are removed

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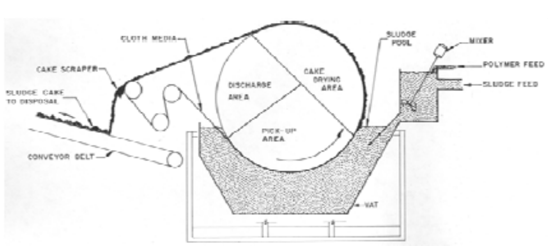
Vacuum Filter



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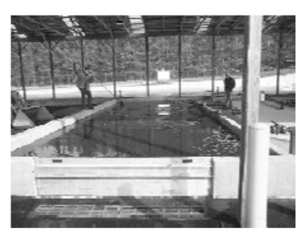
Drying Bed

- Simplest of all methods
- Sludge deposited in layer on sand bed or other surface with drain
- Dewatering occurs by drainage and evaporation
- Time required is affected by climate, depth of solids, and type of solids
- Sometimes drying beds are covered while others have vacuum assisted drainage



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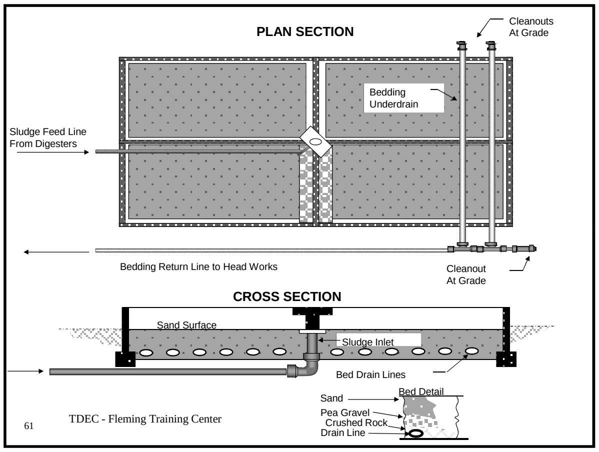

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503 Regs

- The 40 CFR part 503 Sludge Regulations was published in the Federal Register on February 19, 1993,and became effective on March 22, 1993.
- This regulation requires the generator of sludge to treat the sludge to a certain degree before land applying of the sludge.
- The 503 regulation requires the sludge to be monitored for certain pollutants (metals)- disease causing organisms called pathogens - and Vector Attraction Reduction, which is the reduction of Volatile organic solids to the degree where vectors (flies, mosquitoes, and other disease -carrying organisms) are not attracted to the sludge or biosolids once it is placed on the land.

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503 Regs

- Now that the 503 regulation is in effect, digesters will have to be efficiently operated to meet the parameters of the regulation.
- If the Sludge is prepared for land application or surface disposal, it must comply with applicable pathogen reduction requirements.
- The part 503 regulation allows nine pathogen reduction alternatives, which are divided into two distinct classes :
  - Class A
  - Class B

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503 Regs

- Class A alternatives produce a sludge that is virtually pathogen free.
- Class B alternatives significantly reduce the pathogen level in sludge.
- Both Class A and B alternatives specify maximum levels of fecal coliform allowed in the sludge.
- Monitoring frequency for the pollutants, pathogen reduction and vector reduction requirements are based on amount of (dry weight tons) disposal per year.
- Records of the results will be kept at the sludge wastewater plant.

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503 Regs

- If your wastewater plant has a design influent flow rate equal to or greater than 1 million gallons per day, or serves a population of 10,000 or more, or Class I Sludge management facilities (State of Tennessee Industrial Pretreatment Program) you must report annually to the permitting authority.
- Annual reports cover information and data collected during the calendar year (January 1 to December 31) and are due February 19, every year and submitted to the permitting authority, which is the EPA Regional IV Office for Tennessee.

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Metals Limits

- The sludge (Biosolids) applied to land must meet the ceiling concentrations for table section 503.13 pollutants at a minimum.
- The Table 3 section 503.13 pollutant concentration limits are the best limits to meet because they are considered exceptional quality required no loading rate limits to the land being applied to.

TABLE 3 OF §503.13—POLLUTANT CONCENTRATIONS

Pollutant	Monthly average concentration (milligrams per kilogram)[1]
Arsenic	41
Cadmium	39
Copper	1500
Lead	300
Mercury	17
Nickel	420
Selenium	100
Zinc	2800

[1] Dry weight basis.

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Pathogen Requirements

- Either Class A or Class B pathogen requirements and site restrictions must be met before the biosolids (sludge) can be land applied; the two classes differ depending on the level of pathogen reduction that has been obtained.
  - Aerobic digesters with adequate detention times (40-60 days), maintaining correct dissolved oxygen levels and feeding the digesters correctly will usually be able to have to the sludge tested for class B pathogens and meet it with satisfactory results (less than 2 million colony - forming units per gram of total solids - dry weight).

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Pathogen Requirements

- There are a total of 3 options to meet the Class B Reduction:
  - Fecal Coliform Count
  - Processes to Significantly Reduce Pathogens
  - Processes to Significantly Reduce Pathogens Equivalent

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Vector Attraction Reduction

- Vector attraction reduction is to reduce the attraction of vectors (flies, mosquitoes, and other potential disease - carrying organisms) to the biosolids or sludge.
- 1 of 10 options specified in part 503 to achieve vector attraction reduction must be met when biosolids are applied to land.

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Requirements in one of the following options must be met for vector attraction reduction

- Reduce the mass of volatile solids by a minimum of 38%
- Demonstrate vector attraction reduction with additional anaerobic digestion in a bench -scale unit.
- Meet a specific oxygen up take rate for aerobically treated biosolids.
- Use aerobic processes at greater than 40^{0}C (average temp. 45^{0}C) for 14 days or longer (during biosolids composting).
- Add alkaline materials to raise the PH under specified conditions.
- Reduce moisture content of biosolids that do not contain unstabilized solids from other than primary treatment to at least 75% solids.
- Reduce moisture content of biosolids with unstabilized solids to at least 90%.
- Inject biosolids beneath the soil surface within a specified time, depending on the level of pathogen treatment.
- Incorporate biosolids applied to or placed on the land surface within specified time periods after application to or placement on the land surface.

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CHAPTER 12

Sludge Processing and Disposal

12.1 General

12.1.1 Definition
12.1.2 Total Systems Approach To Design
12.1.3 Recycle Streams
12.1.4 Multiple Units
12.1.5 Sludge Pumps
12.1.6 Sludge Piping

12.2 Sludge Production

12.3 Thickening

12.3.1 General
12.3.2 Gravity Thickeners
12.3.3 Flotation Thickeners
12.3.4 Centrifugal Thickeners
12.3.5 Other Thickeners

12.4 Conditioning

12.4.1 General
12.4.2 Chemical

12.5 Digestion

12.5.1 Anaerobic Digestion
12.5.2 Aerobic Sludge Digestion

12.6 Composting

12.7 Sludge Dewatering

12.7.1 General
12.7.2 Sludge Drying Beds
12.7.3 Mechanical Dewatering

12.8 Sludge Storage Lagoons

12.9 Sludge Disposal

SLUDGE PROCESSING AND DISPOSAL

12.1 General

12.1.1 Definition

Sludge is a broad term used to describe the various aqueous suspensions of solids encountered during treatment of sewage. The nature and concentration of the solids control the processing characteristics of the sludge. Grit screenings and scum are not normally considered as sludge and therefore are not discussed in this section.

12.1.2 Total Systems Approach to Design

The most frequently encountered problem in wastewater treatment plant design is the tendancy to optimize a given subsystem, such as sludge dewatering, without considering the side effects of this optimization on the overall plant operation and treatment costs.

Sludge handling processes can be classified as thickening, conditioning, stabilization, dewatering, and disposal. Numerous process alternatives exist within each of these categories. Each unit process should be evaluated as part of the total system, keeping in mind that the objective is to use that group of processes that provides the most cost-effective method of sludge disposal.

The analysis should include a materials balance to identify the amounts of material which enter, leave, accumulate, or are depleted in the given process and the system as a whole. Energy requirements should also be provided to aid in determining capital and operating costs of the total system.

12.1.3 Recycle Streams

Recycle streams from the process alternatives, including thickener overflow, centrate, filtrate, and supernatant, should be returned to the sewage treatment process at appropriate points to maintain effluent quality within the limits established. Volume and strength of each recycle stream should be considered in the plant design. Sidestream treatment should be provided if the load is not included in the plant design or if the side stream will upset the treatment process. Equalization of side streams should be considered to reduce instantaneous loading on the treatment process.

12.1.4 Multiple Units

Multiple units and/or storage facilities should be provided so that individual units may be taken out of service without unduly interrupting plant operation.

12.1.5 Sludge Pumps

12.1.5.1 Capacity

Pump capacities should be adequate to maintain pipeline velocities of 3 feet per second. Provisions for varying pump capacity are desirable.

12.1.5.2 Duplicate Units

Duplicate units shall be provided where failure of one unit would seriously hamper plant operation.

12.1.5.3 Type

Plunger pumps, progressing cavity pumps, or other types of pumps with demonstrated solids handling capability should be provided for handling raw sludge.

12.1.5.4 Minimum Head

A minimum positive head of 24 inches (or the manufacturer's recommendation) should be provided at the suction side of centrifugal-type pumps and is desirable for all types of sludge pumps. Maximum suction lifts should not exceed 10 feet (or the manufacturer's recommendation) for plunger pumps.

12.1.5.5 Sampling Facilities

Unless sludge sampling facilities are otherwise provided, quick-closing sampling valves should be installed at the sludge pumps. The size of valve and piping should be at least 1-1/2 inches.

12.1.6 Sludge Piping

12.1.6.1 Size and Head

Sludge withdrawal piping shall have a minimum diameter of 8 inches for gravity withdrawal and 6 inches for pump suction and discharge lines. Where withdrawal is by gravity, the available head on the discharge pipe should be at least 2 feet and preferably more, with provisions to backflush the line.

12.1.6.2 Slope

Gravity piping shall be laid on uniform grade and alignment. Slope on gravity discharge piping should not be less than 3 percent.

12.1.6.3 Cleaning

Provision should be made for draining and flushing suction and discharge lines. Where sludge pumps are available, piping should be such that suction lines can be backflushed with pump discharge or rodded. Glass-lined or equivalent pipe should be considered for raw sludge piping and scum lines.

12.1.6.4 Corrosion Resistance

Special consideration shall be given to the corrosion resistance and continuing stability of pipes and supports located inside digestion tanks.

12.2 Sludge Production

The sludge production rates listed in the literature have often been shown to be underestimated. The sludge production rates (SPR) listed below in Table 12-1 have been determined from various studies and provide a more realistic basis for designing solids handling facilities. These values shall be used for design unless other acceptable data is submitted.

Table 12-1
Sludge Production Rates

Type of Treatment	SPR (lb sludge)/(lb BOD removed)
Conventional Activated Sludge	0.85
Extended Aeration	0.75
Contact Stabilization	1.00
Other Activated Sludge	0.85
Trickling Filter	0.75
Roughing Filters	1.00

12.3 Thickening

12.3.1 General

The cost-effectiveness of sludge thickening should be considered prior to treatment and/or disposal.

12.3.1.1 Capacity

Thickener design should provide adequate capacity to meet peak demands.

12.3.1.2 Septicity

Thickener design should provide means to prevent septicity during the thickening process. Odor consideration should be considered.

12.3.1.3 Continuous Return

Thickeners should be provided with a means of continuous return of supernatant for treatment. Provisions for side-stream treatment of supernatant may be required.

12.3.1.4 Chemical Addition

Consideration should be given to the use of chemicals or polymer to improve solids capture in the thickening process. This will not normally increase the solids level of the thickened sludge.

12.3.2 Gravity Thickeners

12.3.2.1 Stirring and skimming

Mechanical thickeners should employ pickets on rake arms for continuous gentle stirring of the sludge. Skimmers should be considered for use with biological sludges.

12.3.2.2 Depth and Freeboard

Tank depth shall be sufficient so that solids will be retained for a period of time needed to thicken the sludge to the required concentration and to provide storage for fluctuations in solids loading rates. The thickener should be operated to avoid denitrification.

At least two feet of freeboard shall be provided above the maximum water level.

12.3.2.3 Continuous Thickening

Variable-speed sludge draw-off pumps may be provided so that thickening can be continuous, or an adjustable on-off time clock control for pulse withdrawal may be used with constant-speed pumps to improve control over the thickening.

12.3.2.4 Solids and Surface Loading Rates

The engineer shall provide the design basis and calculations for the solids and surface loading rates and the support calculations upon request. Thickener solids loading rates vary with the type of sludge.
Some typical solids loading rates are given below in Table 12-2. These values shall be used for design unless other acceptable data are submitted. For loading rates of other type sludges, refer to Table 5.2 of the EPA Process Design Manual-Sludge Treatment and Disposal.

Table 12-2
Solids Loading Rate

Type of Sludge	Solids Loading Rate (lb/day/sq ft)
Primary	20-30
Activated sludge	5-6
Trickling filter	8-10
Primary and activated combined	6-10
Primary and trickling filter combined	10-12

Surface loading rates of 400 gallons per day per square foot (gpd/sq ft) or less will normally result in septic conditions. To prevent septic conditions, surface overflow rates should be maintained between 500 and 800 gpd/sq ft. For very thin mixtures or WAS only, hydraulic loading rates of 100-200 gpd/sq ft are appropriate. An oxygen-rich water source, such as secondary effluent, shall be available as a supplemental flow to the thickener to achieve the necessary overflow rates.

The diameter of a gravity thickener should not exceed 80 feet.

12.3.2.5 Bottom Slope

Bottom slopes shall be sufficient to keep the sludge moving toward the center well with the aid of a rake. Generally, the slope should be greater than conventional clarifiers. A floor slope of 2-3 inches per foot is recommended.

12.3.3 Flotation Thickeners

Flotation thickeners are normally used to concentrate waste activated sludge.

12.3.3.1 Air-Charged Water

The thickener underflow is generally used as a source of water for the air-charging units, although primary tank effluent or plant effluent may also be used.

12.3.3.2 Design Sizing

The engineer shall provide the design basis for sizing the units and for the support calculation. Design sizing should be based on rational calculations, including: total pounds of waste sludge anticipated, design solids and hydraulic loading of the unit, operating cycle in hours per day per week, removal efficiency, and quantity and type of chemical aids required. Flotation thickeners are normally sized by solids surface loadings. Typical design loadings range from 1.0 to 2.5 pounds per hour per square foot. (See Table 12-3, for typical solids loading rates to produce a minimum 4% solids concentration.)

12.3.3.3 Hydraulic Loading Rates

If polymers are used, hydraulic loading rates of 2.5 gpm/sq ft or less should be used. The hydraulic loading rates shall be lower if polymers are not used. Hydraulic loading rates shall be based on the total flow (influent plus recycle). The design of any thickened sludge pump from DAF units should be conservative. Frequently, polymer conditioned sludge will result in a solids concentration greater than 4%. Pumps shall be capable of handling a sludge of at least 5% thickness.

TABLE 12-3
TYPICAL DAF THICKENER SOLIDS LOADING RATES NECESSARY TO PRODUCE A MINIMUM 4 PERCENT SOLIDS CONCENTRATION

	Solids loading rate, lb/sq ft/hr	
Type of sludge	No chemical addition	Optimum chemical addition
Primary only	0.83 - 1.25	up to 2.5
Waste activated sludge (WAS)		
Air	0.42	up to 2.0
Oxygen	0.6 - 0.8	up to 2.2
Trickling filter	0.6 - 0.8	up to 2.0
Primary + WAS (air)	0.6 - 1.25	up to 2.0
Primary + trickling filter	0.83 - 1.25	up to 2.5

______12.3.4 Centrifugal Thickeners

12.3.4.1 Pretreatment

Any pretreatment required is in addition of that required for the main wastewater stream. For example, separate and independent grit removal may be needed for the centrifuge feed stream.

Disc nozzle centrifuges require pretreatment of the feed stream. Both screening and grit removal are required to reduce operation and maintenance requirements. Approximately 11% of the feed stream will be rejected in pretreatment, consideration should be given to the treatment of this flow. It is usually routed to the primary clarifier.

Basket centrifuges do not require pretreatment and are recommended in small plants (1.0-2.0 MGD) without primary clarification and grit removal.

Solid bowl decanter centrifuges require grit removal in the feed stream and are a potentially high maintenance item.

12.3.4.2 Chemical Coagulants

Provisions for the addition of coagulants to the sludge should be considered for improving dewatering and solids capture.

12.3.4.3 Design Data

The engineer shall provide the design basis for loading rates and support calculations. Both hydraulic and solids loading rate limitations should be addressed.

12.3.5 Other Thickeners

Other thickner designs will be evaluated on a case-by-case basis. Pilot plant data shall be provided by the design engineer upon request.

12.4 Conditioning

______12.4.1 General

Pretreatment of the sludge by chemical or thermal conditioning should be investigated to improve the thickening, dewatering, and/or stabilization characteristics of the sludge.

The effects of conditioning on downstream processes and subsequent side-stream treatment should be evaluated. Thermal conditioning will concentrate the BOD level of the side stream. Its treatment must be considered in calculating organic loadings of other units.

12.4.2 Chemical

Type of chemical, location of injection, and method of mixing should be carefully considered to ensure obtaining anticipated results. Pilot testing is often necessary to determine the best conditioning system for a given sludge.

12.5 Digestion

______12.5.1 Anaerobic Digestion

12.5.1.1 General

a. Operability

Anaerobic digestion is a feasible stabilizing method for wastewater sludges that have low concentrations of toxins and a volatile solids content above 50%. It should not be used where wide variations in sludge quantity and quality are common. Anaerobic digestion is a complex process requiring close operator control. The process is very susceptible to upsets as the microorganisms involved are extremely sensitive to changes of their environment. Frequent monitoring of the following parameters is required:

(i) pH (6.4 - 7.5 recommended)

(ii) volatile acids/alkalinity ratio (always 0.5 or greater)

(iii) toxics (volatile acids, heavy metals, light metal cations, oxygen, sulfides, and ammonia)

(iv) temperature (within 1° F of design temperature)

(v) recycle streams (BOD, SS, NH_3, phenols)

The importance of avoiding digester upsets cannot be overlooked. The methane-producer bacteria have a very slow growth rate and it will take two weeks or more to resume normal digester performance.

b. Multiple Units

Multiple units should be provided. Staged digestion design may be used, provided the units can be used in parallel as well as in series. Where multiple units are not provided, a lagoon or storage tanks should be provided for emergency use so that digestion tanks may be taken out of service without unduly interrupting plant operation. Means of returning sludge from the secondary digester unit to the primary digester should be provided. In large treatment plants where digesters are provided, separate digestion of primary sludges
should be considered.

c. Depth

The proportion of depth to diameter should provide for the formation of a supernatant liquor with a minimum depth of 6 feet. Sidewall depth is generally about one-half the diameter of the digester for diameters up to 60 feet, and decreases to about one-third the diameter for diameters approaching 100 feet.

d. Maintenance Provisions

To facilitate emptying, cleaning, and maintenance, the following features are required:

(i) Slope

The tank bottom shall slope to drain toward the withdrawal pipe. A slope of between 1 inch per foot and 3 inches per foot is recommended.

(ii) Access Manholes

At least two access manholes should be provided in the top of the tank, in addition to the gas dome. One opening should be large enough to permit the insertion of mechanical equipment to remove scum, grit, and sand. A separate side wall manhole should be provided at ground level.

(iii) Safety

Nonsparking tools, rubber-soled shoes, safety harness, gas detectors for flammable and toxic gasses and the hose type or self-contained type breathing apparatus shall be provided.

e. Pre-thickening of sludge may be advantageous, but the solids content shall be less than 8% to ease mixing problems.

12.5.1.2 Sludge Inlets and Outlets

Multiple sludge inlets and draw-offs and multiple recirculation suction and discharge points should be provided to facilitate flexible operation and effective mixing of the digester contents, unless adequate mixing facilities are provided within the digester. One inlet should discharge above the liquid level and be located at approximately the center of the tank to assist in scum breakup. Raw sludge inlet points should be located to minimize short-circuiting to the supernatant drawoff.

12.5.1.3 Tank Capacity

a. General

Two cultures of bacteria are primarily involved in anaerobic digestion: acid formers and methane formers. Capacity of the digester tank shall be based on the growth rate of the methane-formers, as they have extremely slow growth rates.

b. Solids Basis

Where the composition of the sewage has been established, tank capacity should be computed from the volume and character of sludge to be digested. The total digestion tank capacity should be determined by rational calculations based upon factors such as volume of sludge added, its percent solids and character, volatile solids loading, temperature to be maintained in the digesters, and the degree or extent of mixing to be obtained. These detailed calculations shall be submitted to justify the basis of design.

Where composition of the sewage has not been established, the minimum combined digestion tank capacity outlined below shall be provided. Such requirements assume that the raw sludge is derived from ordinary domestic wastewater, a digestion temperature is maintained in the range of 85° to 100° F, there is 40 to 50 percent volatile matter in the digested sludge, and that the digested sludge will be removed frequently from the process.

(i) Completely Mixed Systems

For heated digestion systems providing for intimate and effective mixing of the digester designed for a constant feed loading rate of 150 to 400 pounds 1,000 cubic feet of volume per day in the active digesting unit. The design average detention time in completely mixed systems shall have sufficient mixing capacity to provide for complete digester turnover every 30 minutes.

(ii) Moderately Mixed Systems

For digestion systems where mixing is accomplished only by circulating external heat exchanger, the system may be loaded up to 40 pounds of volatile solids per 1,000 cubic feet of volume per day in the active digestion units. This loading may be modified upward or downward, depending upon the degree of mixing provided. Where mixing is accomplished by other methods, loading rates will be determined on the basis of information furnished by the design engineer.

c. Population Basis

Where solids data are not available, the following unit capacities shown in Table 12-4 for conventional, heated tanks shall be used for plants treating domestic sewage. The capacities should be increased by allowing for the suspended solids population equivalent of any industrial wastes in the sewage. The capacities stated apply where digested sludge is dewatered on sand drying beds and may be reduced if the sludge is dewatered mechanically or otherwise frequently withdrawn.

Table 12-4
Cubic Feet Per Capita

Type of Plant	Moderately Mixed Systems	Completely Mixed Systems
Primary	2 to 3	1.3
Primary and Trickling Filter	4 to 5	2.7 to 3.3

Primary and Activated Sludge	4 to 6	2.7 to 4

For small installations (population 5,000 or less) the larger values should be used.

12.5.1.4 Gas Collection System

a. General

All portions of the gas system, including the space above the tank liquor, storage facilities, and piping shall be so designed that under all normal operating conditions, including sludge withdrawal, the gas will be maintained under positive pressure. All enclosed areas where any gas leakage might occur shall be adequately ventilated.

b. Safety Equipment

All necessary safety facilities shall be included where gas is produced. Pressure and vacuum relief valves and flame traps, together with automatic safety shutoff valves, are essential. Water-seal equipment shall not be installed on gas piping.

c. Gas Piping and Condensate

Gas piping shall be of adequate diameter and shall slope to condensation traps at low points. The use of float-controlled condensate traps is not permitted. Condensation traps shall be placed in accessible locations for daily servicing and draining. Cast iron, ductile iron, and/or stainless steel piping should be used.

d. Electrical Fixtures and Equipment

Electrical fixtures and equipment in enclosed places where gas may accumulate shall comply with the National Board of Fire Underwriters' specifications for hazardous conditions. Explosion-proof electrical equipment shall be provided in sludge-digestion tank galleries containing digested sludge piping or gas piping and shall be provided in any other hazardous location where gas or digested sludge leakage is possible.

e. Waste Gas

Waste gas burners shall be readily accessible and should be located at least 50 feet away from any plant structure, if placed near ground level, or may be located on the roof of the control building if sufficiently removed from the tank. Waste gas burners shall not be located on top of the digester. The waste gas burner should be sized and designed to ensure complete combustion to eliminate odors.

f. Ventilation and Cover

Any underground enclosures connecting with digestion tanks or containing sludge or gas piping or equipment shall be provided with forced ventilation. Tightly fitting, self-closing doors shall be provided at connecting passageways and tunnels to minimize the spread of gas. A floating cover should be provided instead of a fixed cover for increased operational flexibility and safety.

g. Metering

Gas meters with bypasses should be provided to meter total gas production and utilization.

h. Pressure Indication

Gas piping lines for anaerobic digesters should be equipped with closed-type pressure indicating gauges. These gauges should read directly in inches of water. Normally, three gauges should be provided, one to measure the main line pressure, a second to measure the pressure upstream of gas-utilization equipment, and the third to measure pressure to wasteburners. Gas-tight shutoff and vent cocks shall be provided. The vent piping shall be extended outside the building, and the opening shall be screened to prevent entrance by insects and turned downward to prevent entrance of rainwater. All piping shall be protected with safety equipment.

i. Gas Utilization Equipment

Gas-burning boilers, engines, and other gas utilization equipment should be located at or above ground level in well-ventilated rooms. Gas lines to these units shall be provided with suitable flame traps.

12.5.1.5 Heating

a. Insulation

Digestion tanks should be constructed above the water table and should be suitably insulated to minimize heat loss.

b. Heating Facilities

Sludge may be heated by circulating the sludge through external heaters or by units located inside the digestion tank.

(i) External Heating

Piping should be designed to provide for the preheating of feed sludge before introduction to the digesters. Provisions should be made in the layout of the piping and valving to facilitate cleaning of these lines.

Heat exchanger sludge piping should be sized for heat transfer requirements.

(ii) Internal Coils

Hot water coils for heating digestion tanks should be at least 2 inches in diameter and the coils, support brackets, and all fastenings should be of corrosion-resistant material. The use of dissimilar metals should be avoided to minimize galvanic action. The high point in the coils should be vented to avoid air lock.

(iii) Other Methods

Other types of heating facilities will be considered on their own merits.

c. Heating Capacity

Sufficient heating capacity shall be provided to consistently maintain the digesting sludge temperature to within 1°F (0.6°C) of the design temperature. An alternate source of fuel should be available and the boiler or other heat source should be capable of using the alternate fuel if digester gas is the primary fuel. Thermal shocks shall be avoided. Sludge storage may be required to accomplish this.

d. Hot Water Internal Heating Controls

(i) Mixing Valves

A suitable automatic mixing valve should be provided to temper the boiler water with return water so that the inlet water to the heat jacket or coils can be held to below a temperature (130° to 150°F) at which sludge caking will be accentuated. Manual control should also be provided by suitable bypass valves.

(ii) Boiler Controls

The boiler should be provided with suitable automatic controls to maintain the boiler temperature at approximately 180°F to minimize corrosion and to shut off the main fuel supply in the event of pilot burner or electrical failure, low boiler water level, or excessive temperature.

(iii) Thermometers

Thermometers shall be provided to show temperatures of the sludge, hot water feed, hot water return, and boiler water.

12.5.1.6 Mixing

Facilities for mixing the digester contents shall be provided where required for proper digestion by reason of loading rates, or other features of the system.

12.5.1.7 Supernatant Withdrawal

a. Piping Size

Supernatant piping should not be less than 6 inches in diameter, although 4-inch lines will be considered in special cases.

b. Withdrawal Arrangements

(i) Withdrawal Levels

Piping should be arranged so that withdrawal can be made from three or more levels in the tank. A positive unvalved vented overflow shall be provided.

(ii) Withdrawal Selection

On fixed-cover tanks the supernatant withdrawal level should preferably be selected by means of interchangeable extensions at the discharge end of the piping.

(iii) Supernatant Selector

If a moveable supernatant selector is provided, provision should be made for at least one other draw-off level located in the supernatant zone of the tank in addition to the unvalved emergency supernatant draw-off pipe. High-pressure backwash facilities should be provided.

c. Sampling

Provisions shall be made for sampling at each supernatant draw-off level. Sampling pipes should be at least 1-1/2 inches in diameter.

d. Supernatant Handling

Problems such as shock organic loads, pH, and high ammonia levels associated with digester supernatant shall be addressed in the plant design. Recycle streams should be bled continuously back to the treatment process.

12.5.2 Aerobic Sludge Digestion

12.5.2.1 Mixing and Aeration

Aerobic sludge digestion tanks shall be designed for effective mixing and aeration. Minimum mixing requirements of 20 cubic feet per minute per 1,000 cubic feet for air systems and 0.5 horsepower per 1,000 cubic feet for mechanical systems are recommended. Aeration requirements may be more or less than the mixing requirements, depending on system design and actual solids loading. Approximately 2.0 pounds of oxygen per pound volatile solids are needed for aeration. If diffusers are used, types should be provided to minimize clogging and designed to permit removal for inspection, maintenance, and replacement without dewatering the tanks, if only one digester is proposed.

12.5.2.2 Size and Number of Tanks

The size and number of aerobic sludge digestion tank or tanks should be determined by rational calculations based upon such factors as volume of sludge added, its percent solids and character, the degree of volatile solids reduction required and the size of installation with appropriate allowance for sludge and supernatant storage.

Generally, 40 to 50 percent volatile solids destruction is obtained during aerobic digestion. To ensure a stabilized sludge which will not emit odors, the volatile solids content should be less than 60 percent in the digested sludge. Calculations shall be submitted upon request to justify the basis of design. The following design parameter ranges should be considered the minimum in designing aerobic digestion facilities.

a. Hydraulic Detention Time

Hydraulic detention time at 20°C should be in the range of 15 to 25 days, depending upon the type of sludge being digested. Activated sludge alone requires the lower detention time and a combination of primary plus activated or trickling filter sludges requires the high detention time. Detention times should be adjusted for operating temperatures other than 20°C.

b. Volatile Solids

The volatile solids loading shall be in the range of 0.1 to 0.2 pound of volatile solids per cubic foot per day.

c. Dissolved Oxygen

Design dissolved oxygen concentration should be in the range of 1 to 2 mg/l. A minumum of 1.0 mg/l shall be maintained at all times.

d. Mixing Energy

Energy input requirements for mixing should be in the range of 0.5 to 1.5 horsepower per 1,000 cubic feet where mechanical aerators are used; 20 to 35 standard cubic feet of air per minute per 1,000 cubic feet of aeration tank where diffused air mixing is used on activated sludge alone; and greater than 60 cubic feet per minute per 1,000 cubic feet for primary sludge alone and primary plus activated sludge.

e. Storage

Detention time should be increased for temperatures below 20°C. If sludge cannot be withdrawn during certain periods, additional storage capacity should be provided. Plants smaller than 75,000 gpd should have storage capacity of 2 cubic foot per population equivalent served.

12.5.2.5 Supernatant Separation

Facilities should be provided for separation or decantation of supernatant. Provisions for sidestream treatment of supernatant should be considered.

12.6 Composting

Composting operations will be considered on a case-by-case basis, provided that the basis for design and a cost-effective analysis are submitted by the engineer.

12.7 Sludge Dewatering

12.7.1 General

Drainage from drying beds and centrate or filtrate from dewatering units should be returned to the sewage treatment process at appropriate points preceding the secondary process. The return flows shall be returned downstream of the influent sample and/or flow measuring point and a means shall be provided to sample return flows. These organic loads must be considered in plant design.

12.7.2 Sludge Drying Beds

12.7.2.1 Area

It is recommended that wastewater systems have a hybrid sludge disposal method because of the seasonal downtime associated with drying beds. The amount of rainfall
normal for our state makes the use of sludge drying beds insufficient at times.

Consideration shall be given to the location of drying beds to avoid areas where moisture in the air is higher than normal (i.e., adjacent to rivers where morning fog is common).

In determining the area for sludge drying beds, consideration shall be given to climatic conditions, the character and volume of the sludge to be dewatered, type of bed used, and methods of ultimate sludge disposal. Design calculations shall be submitted upon request to substantiate the area used.

Drying bed design should be based on square feet per capita or pounds of sludge solids per square foot per year. Table 12-5 presents the range of values that should be used, these values are for drying anaerobically digested sludges. Additional area is required for wetter sludges such as those resulting from aerobic digestion; therefore, use the higher number of the required range.

Table 12-5 DRYING BED DESIGN CRITERIA*

	Open Beds		Covered Beds
Type of Sludge	Per Capita (sq ft/capita)	Solids (lb/sq ft/yr)	Per Capita (sq ft/capita)
Primary	1.0 to 1.5	27.5	0.75 to 1.0

Attached Growth	1.25 to 1.75	22.0	1.0 to 1.25
Suspended Growth	2.50	15.0	2.00

*The design engineer should rely on his experience and the plant location.

These criteria are a minimum.

____________12.7.2.2. Percolation Type

a. Gravel

The lower course of gravel around the underdrains should be properly graded to range in size from 1/4-inch to 1-inch and should be 12 inches in depth, extending at least 6 inches above the top of the underdrains. It is desirable to place this in 2 or more layers. The top layer of at least 3 inches should consist of gravel 1/8 inch to 1/4 inch in size. The gravel shall be laid on an inpervious surface so that the filtrate will not escape to the soil.

b. Sand

The top course shall consist of at least nine inches of sand with a uniformity coefficient of less than 3.5. For trickling filter sludge, the effective size of the sand shall be between 0.8 to 3.0 millimeter. For waste activated sludge, the effective size of the sand shall be between 0.5 to 0.8 millimeter. For combinations, use the lower size range.

c. Underdrains

Underdrains should be clay pipe, concrete drain tile, or other underdrain acceptable material and shall be at least 4 inches in diameter and sloped not less than 1 percent to drain. Underdrains shall be spaced between 8 and 20 feet apart. The bottom of the bed shall slope towards the underdrains. Consideration should be given to placing the underdrain in a trench.

12.7.2.3 Impervious Types

Paved surface beds may be used if supporting data to justify such usage are acceptable to the Department. The use of paved beds for aerobically digested sludge is generally not recommended.

12.7.2.4 Walls

Walls should be watertight and extend 15 to 18 inches above the ground surface. Outer walls should be curbed to prevent soil from washing onto the beds.

12.7.2.5 Sludge Removal

Not less than two beds should be provided and they should be arranged to facilitate sludge removal. Concrete truck tracks should be provided for all percolation-type sludge beds with pairs of tracks for the beds on appropriate centers. If truck access is by way of an opening in the drying bed wall, the opening shall be designed so that no sludge will leak out during the filling process.

12.7.2.6 Sludge Influent

The sludge pipe to the beds should terminate at least 12 inches above the surface and be arranged so that it will drain. Concrete splash plates shall be provided at sludge discharge points.

12.7.3 Mechanical Dewatering

12.7.3.1 Methods and Applicability

The methods used to dewater sludge may include use of one or more of the following devices:

a. Rotary vacuum filters

b. Centrifuges, either solid bowl or basket type

c. Filter presses

d. Horizontal belt filters

e. Rotating gravity concentrators

f. Vacuum drying beds

g. Other "media type" drying beds

The technology and design of sludge dewatering devices are constantly under development; therefore, each type should be given careful consideration. The applicability of a given method should be determined on a case-by-case basis, with the specifics of any given situation being carefully evaluated, preferably in pilot tests. The engineer shall justify the method selected using pilot plant data or experience at a similar treatment plant.

12.7.3.2 Considerations

Considerations in selection should include:

a. Type and amount of sludge

b. Variations in flow rate and solids concentration

c. Capacity of the equipment

d. Chemicals required for conditioning

e. Degree of dewatering required for disposal

f. Experience and qualifications of plant staff

g. Reliability

h. Operation and maintenance cost

i. Space requirements

12.7.3.3 Storage

Adequate storage shall be provided for all systems.

12.8 Sludge Storage Lagoons

______Refer to Chapter 9, Ponds and Aerated Lagoons, for the requirements of sludge storage lagoons.

12.9 Sludge Disposal

______The ultimate disposal of sludge through various methods (i.e., landfilling, land application) is subject to the regulations and/or guidelines of the Tennessee Division of Water Pollution Control (DWPC). Approval by DWPC is required prior to initiation of the selected disposal alternative.

Anaerobic Digestion

2000 Communication Arts Multimedia, Inc.
28 minutes

1. Objectives of digestion:

   a. Inactivate __________ (maintaining a detention time of ≥ 15 days at 95°F).

   - Some organisms we are trying to destroy are:

     1. __________
     2. __________
     3. __________
     4. __________
     5. __________

   b. Reduce sludge volume by _____ % (through carbon dioxide and water production).

   c. Produce __________ gas.

   - 70% methane and __________ % carbon dioxide

   d. Obtain a residual of solids.

2. Food to the digester.

   a. Primary clarifier sludge is typically _____ to _____ % solids.

   b. Expect 3500 gallons of primary sludge / 1MG wastewater flow.

   c. Thickening in a DAF unit generates sludge at _____ to _____% solids.

   d. Ammonia, calcium, magnesium, potassium and sodium are analyzed for their effect on the digestion process.

   e. Industrial discharges may cause: poor digestion, __________ solids, pathogens, and poor __________ quality.

3. Calculations
   a. Digester loading: 0.05 lbs VS/day/ft^3 (expected).
   b. Volatile acids/Alkalinity ratio: 0.05-0.25.
   c. Gas production: 12-18 ft^3/lb volatile matter destroyed.
   d. Detention time, days.
   e. Volatile solids reduction, %.
4. Sludge physical characteristics:
   a. Good quality sludge is __________ in color and has a __________ - like odor.
   b. Poor quality sludge has an unpleasant odor and __________ or __________ colored streaks.
5. Digester gas:
   a. Usable fuel at _____ % methane.
   b. Good flame color has a __________ color.
6. Special Precautions:
   a. No smoking in the digester area.
   b. Confined space hazards: monitor for __________ and __________ gases and __________ deficiency.
   c. Dangerous microorganisms in the sludge.

Sludge Digestion Math

Volatile Solids to the Digester, lbs/day

1. If 8,250 lbs/day of solids with a volatile solids content of 68% are sent to the digester, how many lbs/day volatile solids are sent to the digester?

2. A total of 3600 gpd of sludge is pumped to a digester. If the sludge has 5.7% solids content with 71% volatile solids, how many lbs/day volatile solids are pumped to the digester.

Digester Loading Rate, lbs VS added / day / ft^3

3. What is the digester loading if a digester, 45 ft. diameter with a liquid level of 20 ft., receives 82,500 lbs/day of sludge with 5.8% solids and 69% volatile solids?

4. A digester, 40 ft. in diameter with a liquid level of 18 ft. receives 26,400 gpd of sludge with 5.7% solids and 71% volatile solids. What is the digester loading in lbs VS added/day/ft^3?

Volatile Acids / Alkalinity Ratio

5. The volatile acids concentration of the sludge in an anaerobic digester is 170 mg/L. If the measured alkalinity is 2150 mg/L, what is the VA/Alkalinity ratio?

6. What is the VA/Alkalinity ratio if the volatile acids concentration of the sludge in an anaerobic digester is 215 mg/L and the measured alkalinity is 1957 mg/L?

Percent Volatile Solids Reduction

7. The raw sludge to a digester has a volatile solids content of 69%. The digested sludge volatile solids content is 53%. What is the percent volatile solids reduction?

8. The raw sludge to a digester has a volatile solids content of 72%. The digested sludge volatile solids content is 51%. What is the percent volatile solids reduction?

Volatile Solids Destroyed, lbs VS / day / ft^3

9. A flow of 3750 gpd sludge is pumped to a 35,000 ft^3 digester. The solids concentration of the sludge is 6.3% with a volatile solids content of 68%. If the volatile solids reduction during digestion is 54%, how many lbs/day volatile solids are destroyed per ft^3 of digester capacity?

10. A flow of 2165 gpd sludge is pumped to a 22,500 ft^3 digester. The solids concentration of the sludge is 4.5% with a volatile solids content of 72%. If the volatile solids reduction during digestion is 45%, how many lbs/day volatile solids are destroyed per ft^3 of digester capacity?

Digester Gas Production, ft^3 Gas Produced / lb. VS destroyed

11. The anaerobic digester at a treatment plant receives a total of 10,500 gpd of raw sludge. This sludge has a solids content of 5.3% of which 64% is volatile. If the digester yields a volatile solids reduction of 61%, and the average digester gas production is 22,300 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

12. The anaerobic digester at a treatment plant receives a total of 11,400 gpd of raw sludge. This sludge has a solids content of 5.4% of which 62% is volatile. If the digester yields a volatile solids reduction of 58%, and the average digester gas production is 25,850 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

Digestion Time, days

13. An aerobic digester 40 ft. in diameter has a side water depth of 12 ft. The sludge flow to the digester is 8200 gpd. Calculate the hydraulic detention time in days.

14. A 50 ft. aerobic digester has a side water depth of 10 ft. The sludge flow to the digester is 9500 gpd. Calculate the detention time in days.

Oxygen Uptake Rate, mg/L/hr

15. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake, mg/L/hr.

Elapsed Time, Min	DO, mg/L
0	7.9
1	6.8
2	6.1
3	5.3
4	4.6
5	3.9

16. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake, mg/L/hr.

Elapsed Time, Min	DO, mg/L
0	6.9
1	5.8
2	5.0
3	4.3
4	3.7
5	2.9

Answers
1. 5610 VS lbs/day
2. 1215 lbs/day
3. 0.10 lbs VS added/day/ft^3
4. 0.39 lbs VS added/day/ft^3
5. 0.08
6. 0.11
7. 49%
8. 59.5%
9. 0.021 lbs VS/day/ft^3
10. 0.012 lbs VS/day/ft^3
11. 12.3 ft^3/lb VS destroyed
12. 14.0 ft^3/lb VS destroyed
13. 13.7 days
14. 15.5 days
15. 44 mg/L/hr
16. 42 mg/L/hr

Answers for Anaerobic Digestion

2000 Communication Arts Multimedia, Inc.
28 minutes

1.
   a. *pathogens*
      -
         1. *Typhoid*
         2. *Paratyphoid*
         3. *Cholera*
         4. *Polio*
         5. *Giardia*
   b. *50*
   c. *methane*
      - *30*
2.
   a. 4-7
   c. 6-7
   e. *Unstable*, *gas*
4.
   a. *black*, *tar*
   b. *green, grey*
5.
   a. *62*.
   b. *blue*
6.
   a.
   b. *Toxic, explosive, oxygen*

Sludge Digestion Math

Volatile Solids to the Digester, lbs/day

pg. 12

1. If 8,250 lbs/day of solids with a volatile solids content of 68% are sent to the digester, how many lbs/day volatile solids are sent to the digester?

$$V.S. = (\text{Total Solids, lbs/d})(\% \text{ VS})$$
$$= (8250 \text{ lbs/d})(0.68)$$
$$= \boxed{5610 \text{ VS lbs/d}}$$

2. A total of 3600 gpd of sludge is pumped to a digester. If the sludge has 5.7% solids content with 71% volatile solids, how many lbs/day volatile solids are pumped to the digester.

$$V.S. \text{ lbs/d} = \underbrace{(3600 \text{ gpd})(8.34)(0.057)}_{\text{solids, lbs}}(0.71)$$
$$= \boxed{1215 \text{ lbs/d}}$$

Digester Loading Rate, lbs VS added / day / ft³ * ~ 0.15 - 0.35 in a heated, mixed, high rate digester

3. What is the digester loading if a digester, 45 ft. diameter with a liquid level of 20 ft., receives 82,500 lbs/day of sludge with 5.8% solids and 69% volatile solids?

$$\text{Digester Loading} = \frac{(\text{sludge, lbs/d})(\% \text{ Solids})(\% \text{ VS})}{(0.785)(D, ft)^2(d, ft)}$$
$$= \frac{(82,500 \text{ lbs/d})(0.058)(0.69)}{(0.785)(45 ft)^2(20 ft)}$$
$$= \frac{3301.65}{31792.5} = \boxed{0.10 \text{ lbs VS added/day/ft}^3}$$

4. A digester, 40 ft. in diameter with a liquid level of 18 ft. receives 26,400 gpd of sludge with 5.7% solids and 71% volatile solids. What is the digester loading in lbs VS added/day/ft^3?

$$\text{Digester Loading} = \frac{(26,400 \text{ gpd})(8.34)(0.057)(0.71)}{(0.785)(40 ft)^2(18 ft)}$$
$$= \frac{8910.52}{22608} = \boxed{0.39 \text{ lbs VS added/day/ft}^3}$$

- VA/Alk ratio is an indicator of the progress of digestion and the balance between the 2 stage process of anaerobic digestion
- Normally <0.1

Volatile Acids / Alkalinity Ratio

5. The volatile acids concentration of the sludge in an anaerobic digester is 170 mg/L. If the measured alkalinity is 2150 mg/L, what is the VA/Alkalinity ratio?

$$\text{VA/Alk ratio} = \frac{\text{Volatile Acids, mg/L}}{\text{Alkalinity mg/L}}$$

$$= \frac{170 \text{ mg/L}}{2150 \text{ mg/L}} = \boxed{0.08}$$

- Increase indicates possible excess feeding of raw sludge to the digester or removal of too much digested sludge

6. What is the VA/Alkalinity ratio if the volatile acids concentration of the sludge in an anaerobic digester is 215 mg/L and the measured alkalinity is 1957 mg/L?

$$\text{VA/Alk ratio} = \frac{215 \text{ mg/L}}{1957 \text{ mg/L}} = \boxed{0.11}$$

Percent Volatile Solids Reduction

- One of the best indicators of the effectiveness of the digestion process

7. The raw sludge to a digester has a volatile solids content of 69%. The digested sludge volatile solids content is 53%. What is the percent volatile solids reduction?

$$\text{\% VS Reduction} = \frac{(\text{In} - \text{Out})}{(\text{In} - (\text{In})(\text{Out}))} \times 100$$

$$= \frac{0.69 - 0.53}{0.69 - (0.69)(0.53)} \times 100$$

$$= \frac{0.16}{0.69 - 0.3657} \times 100$$

$$\frac{0.16}{0.3243} \times 100$$

$$= \boxed{49\%}$$

8. The raw sludge to a digester has a volatile solids content of 72%. The digested sludge volatile solids content is 51%. What is the percent volatile solids reduction?

$$\text{\% VS Reduction} = \frac{0.72 - 0.51}{0.72 - (0.72)(0.51)} \times 100$$

$$= \frac{0.21}{0.72 - 0.3672} \times 100$$

$$= \frac{0.21}{0.3528} \times 100$$

$$\boxed{59.5\%}$$

Sludge Thickening, Digestion and Dewatering

Volatile Solids Destroyed, lbs VS / day / ft^3

9. A flow of 3750 gpd sludge is pumped to a 35,000 ft^3 digester. The solids concentration of the sludge is 6.3% with a volatile solids content of 68%. If the volatile solids reduction during digestion is 54%, how many lbs/day volatile solids are destroyed per ft^3 of digester capacity?

$$\text{VS destroyed, lbs VS/day/ft}^3 = \frac{(\text{Sludge, gpd})(8.34)(\%\text{ Solids})(\%\text{ VS})(\%\text{ VS reduc.})}{(0.785)(D,\text{ ft})^2(d,\text{ ft})}$$

$$= \frac{(3750\text{ gpd})(8.34)(0.063)(0.68)(0.54)}{35{,}000\text{ ft}^3}$$

$$= \boxed{0.021\text{ lbs VS/day/ft}^3}$$

10. A flow of 2165 gpd sludge is pumped to a 22,500 ft^3 digester. The solids concentration of the sludge is 4.5% with a volatile solids content of 72%. If the volatile solids reduction during digestion is 45%, how many lbs/day volatile solids are destroyed per ft^3 of digester capacity?

$$\text{VS destroyed, lbs VS/day/ft}^3 = \frac{(2165\text{ gpd})(8.34)(0.045)(0.72)(0.45)}{22{,}500\text{ ft}^3}$$

$$= \boxed{0.012\text{ lbs VS/day/ft}^3}$$

Digester Gas Production, ft^3 Gas Produced / lb. VS destroyed

11. The anaerobic digester at a treatment plant receives a total of 10,500 gpd of raw sludge. This sludge has a solids content of 5.3% of which 64% is volatile. If the digester yields a volatile solids reduction of 61%, and the average digester gas production is 22,300 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

$$\text{VS, lbs} = (10{,}500\text{ gpd})(8.34)(.053)(.64) = 2970.3744\text{ lbs/d VS}$$

$$\text{Digestor Gas Production, ft}^3\text{/lbs VS destroyed} = \frac{\text{gas produced, ft}^3\text{/d}}{(\text{VS to digester, lbs/d})(\%\text{ VS Reduc.})}$$

$$= \frac{22{,}300\text{ ft}^3}{(2970.3744\text{ lbs/d})(0.61)} = \boxed{12.3}$$

12. The anaerobic digester at a treatment plant receives a total of 11,400 gpd of raw sludge. This sludge has a solids content of 5.4% of which 62% is volatile. If the digester yields a volatile solids reduction of 58%, and the average digester gas production is 25,850 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

$$\text{Digestor Gas Production, ft}^3\text{/lbs VS destroyed} = \frac{25{,}850\text{ ft}^3}{(11{,}400\text{ gpd})(8.34)(0.054)(0.62)(0.58)}$$

$$= \boxed{14.0}$$

- Indicator of the progress of digestion
- Normal range is 12-18 ft^3 gas/lb VS destroyed
- lower indicates slowing of digestion + sludge removal may be overdone
- sharp increase indicates presence of high organic content of sludge

Sludge Thickening, Digestion and Dewatering

Section 7

Digestion Time, days • Flow through time in digester

13. An aerobic digester 40 ft. in diameter has a side water depth of 12 ft. The sludge flow to the digester is 8200 gpd. Calculate the hydraulic detention time in days.

$$\text{Digestion Time, days} = \frac{(0.785)(D, ft)^2(d, ft)(7.48)}{\text{Sludge Flow Rate, gpd}}$$

$$= \frac{(0.785)(40 ft)^2(12 ft)(7.48)}{8200 \text{ gpd}}$$

$$= \boxed{13.7 \text{ days}}$$

14. A 50 ft. aerobic digester has a side water depth of 10 ft. The sludge flow to the digester is 9500 gpd. Calculate the detention time in days.

$$\text{Digestion Time, days} = \frac{(0.785)(50 ft)^2(10 ft)(7.48)}{9500 \text{ gpd}}$$

$$= \boxed{15.5 \text{ days}}$$

(OUR)
Oxygen Uptake Rate, mg/L/hr
• Indicates biomass activity
• an increase means increase microorganism activity
• a decrease occurs when bugs are less active

pg. 116

15. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake, mg/L/hr.

Elapsed Time, Min	DO, mg/L
0	7.9
1	6.8
2	6.1
3	5.3
4	4.6
5	3.9

• DO on digested sample is measured at 1min. intervals for 5min total
• DO @ 2 & 5 min are used to calculate

$$\text{OUR, mg/L/hr} = \frac{\text{start DO} - \text{end DO}}{\text{elapsed time}} \times 60$$

$$= \frac{6.1 - 3.9}{3 \text{ min}} \times 60$$

$$= \boxed{44 \text{ mg/L/hr}}$$

16. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake, mg/L/hr.

Elapsed Time, Min	DO, mg/L
0	6.9
1	5.8
2	5.0
3	4.3
4	3.7
5	2.9

$$\text{OUR mg/L} = \frac{5.0 - 2.9}{3 \text{ min}} \times 60$$

$$= 42 \text{ mg/L/hr}$$

Section 8

Effluent Disposal

Effluent Disposal

Intro to Wastewater

1

Effluent Disposal

- Dilution
  - Lakes
  - Rivers
  - Streams
- Wastewater Reclamation
  - Land application
  - Underground disposal

2

Disposal by Dilution

- Treatment required prior to discharge:
  - Stabilize waste
  - Protect public health
  - Meet discharge requirements
- Site specific
- Most common method of effluent disposal

3

Disposal by Dilution

- Diffusers
- Cascading outfalls
  - Increase D.O.
  - Remove chlorine
  - Remove sulfur dioxide
- Surface discharge

4

Land Treatment of Wastewater Effluent

5

Land Treatment Systems

- When high-quality effluent or even zero-discharge is required, land treatment offers a means of reclamation or ultimate disposal

6

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

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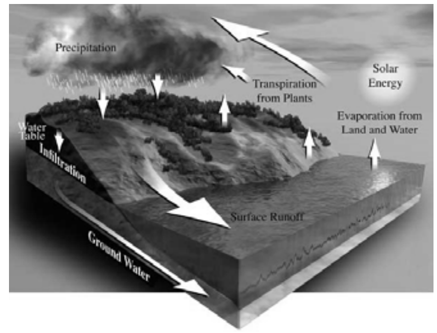
Hydrologic Cycle



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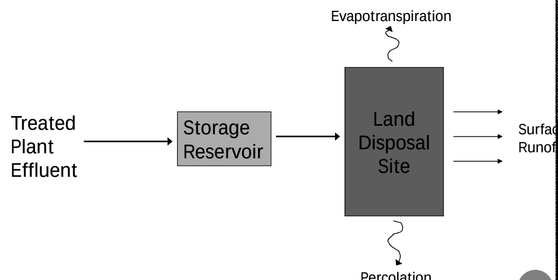
Land Application System

- Treatment prior to application
- Transmission to the land treatment site
- Storage
- Distribution over the site
- Runoff recovery system
- Crop systems

9

Land Application System



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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

11

Wastewater Reclamation: Land Application

- Irrigation most common:
  - Ridge and furrow
  - Sprinklers
  - Surface/drip systems
- Overland flow

Wastewater Treatment Plant & Poplar Tree Reuse System; Woodburn, Oregon

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IRRIGATION

- Method depends on crop grown
  - Silage / hay
  - Parks / golf courses
  - Horticulture / timber / turf grass
- Water & nutrients enhance plant growth for beneficial use.
- Water removed by:
  - Surface evaporation & plant transpiration
  - Deep percolation to subsoil

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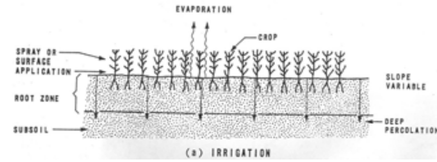
IRRIGATION



- 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

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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

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IRRIGATION - SPRAY SYSTEMS

- Fixed
  - Buried or on surface
  - Cultivated crops or woodlands
- Moving - center pivot
- Minimum slope 2 – 3%
  - Promotes lateral drainage and reduces ponding
- Maximum slope in TN:
  - Row crops 8%
  - Forage crops 15%
  - Forests 30 %

16

IRRIGATION - SPRAY SYSTEMS

Fixed spray irrigation on risers

Center pivot, moving spray irrigation

17

IRRIGATION – RIDGE & FURROW

- Wastewater flows through furrows between rows of crop
- Wastewater slowly percolates into soil
- Wastewater receives partial treatment before it is absorbed by plants

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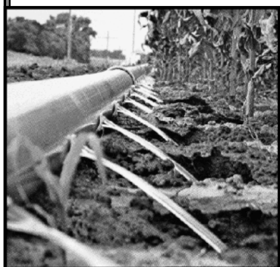
IRRIGATION – RIDGE & FURROW



Gated pipe applying flow to furrows

Irrigation ditch in foreground supplying water to furrows

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IRRIGATION – REMOVAL EFFICIENCIES

Parameter	% Removal
BOD	98
COD	80
Suspended Solids	98
Nitrogen	85
Phosphorus	95
Metals	95
Microorganisms	98

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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

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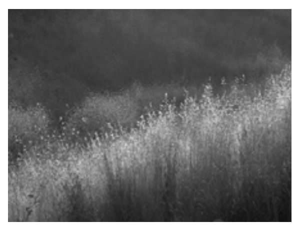
OVERLAND FLOW



- Spray or surface application
  - 6-12 hours/day
  - 5-7 days/week
- 2-4% slope
- Slow surface flow treats wastewater
- Water removed by evaporation & percolation
- Runoff collection

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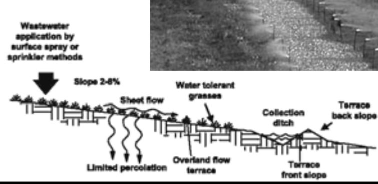
22

OVERLAND FLOW



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OVERLAND FLOW

- Wastewater is applied intermittently at top of terrace
- Runoff collected at bottom (for further treatment)
- Treatment occurs through direct contact with soil

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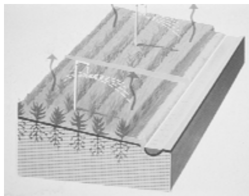
Overland Flow



- 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

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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

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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

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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

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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

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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

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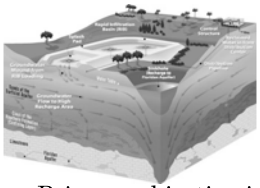
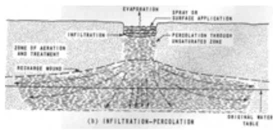
Rapid Infiltration





- 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

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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.

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Rapid Infiltration

- Effluent is discharged into a basin with a porous liner
- No plants needed or desired
- Primary objective is groundwater recharge
- 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

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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

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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

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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

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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

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Water Quality Indicators: Whole Effluent Toxicity

- Also known as WET test
- Effluent limits and monitoring requirements included in NPDES permit
- Evaluates toxic effects of effluent:
  - behavioral changes
  - reproductive malfunction
  - deformity/genetic damage
  - disease

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WET Testing

- Evaluates effects of effluent and dilutions of effluent on living organisms
  - Fathead minnow (vertebrate)
  - Water flea (invertebrate)
  - Green algae
- Acute tests (lethality)
- Chronic tests (fertilization, growth, reproduction

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