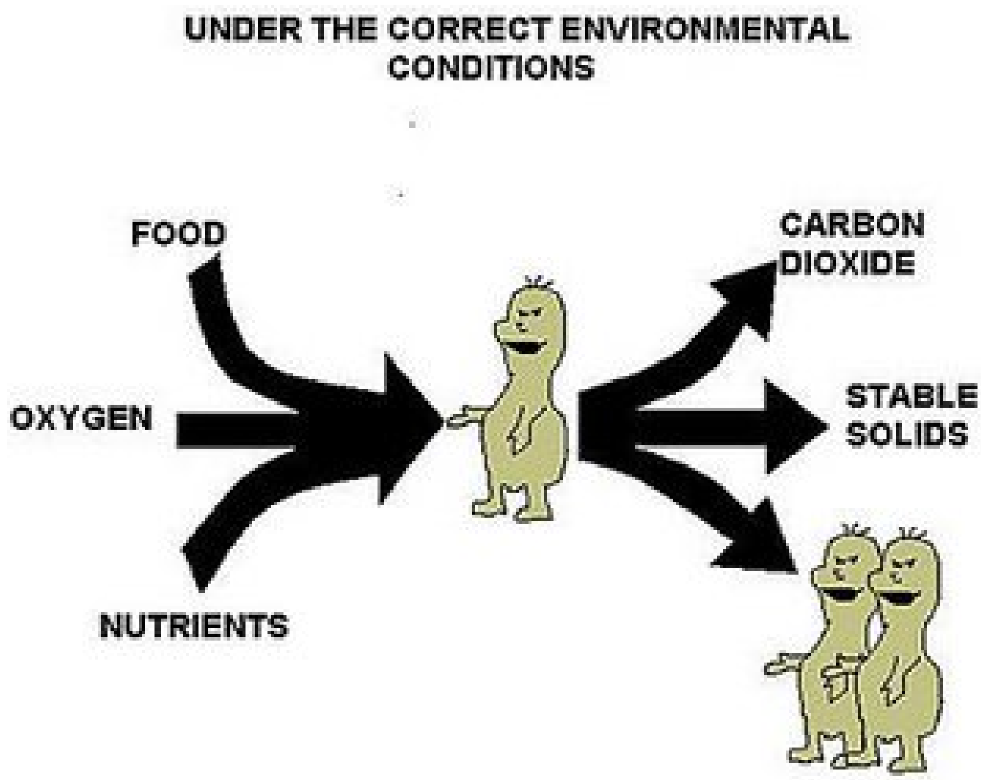
Wastewater Treatment
Grade 3 – 4

Week 2
Course #2201



Fleming Training Center
February 6-10, 2017

Introduction to Wastewater Treatment

State of Tennessee

GRADE 3 & 4 WEEK 2
COURSE #2201
FEBRUARY 6-10, 2017

Monday, February 6:

8:30	Review Exam # 1	**Carlton Boleyjack**
9:30	Effluent Disposal	Metro Water Services
11:00	LUNCH	carlton.boleyjack@nashville.gov
12:00	Sludge Digestion and Solids Handling	

Tuesday, February 7:

8:30	Sampling/Laboratory Analyses	**Barbara Loudermilk**
12:00	LUNCH	Div. of Water Resources
1:00	Tour—Sinking Creek WWTP	barbara.loudermilk@tn.gov

Wednesday, February 8:

8:30	Dosage and Feed Rate Math	**Amanda Carter**
12:00	LUNCH	Fleming Training Center
1:00	Maintenance	amanda.carter@tn.gov
2:30	Cross Connection Control	

Thursday, February 9:

8:30	Trickling Filters	**Amy Warren**
10:45	Rotating Biological Contactors	Div. of Water Resources
12:00	LUNCH	amy.warren@tn.gov
1:00	Microscopic Exam	**To Be Determined**

Friday, February 10:

8:30	Review	**Amanda Carter**
11:00	LUNCH	
12:00	Exam # 2 (Comprehensive)	

State of Tennessee

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Fleming Training Center
Your Partner in Clean Water

Wastewater Treatment Grade 3 – 4

Week 2

Section 1

Feed Rate Math

Chemical Dosage

Chemical Feed, Mass, Mass Flux

Chemical Application

- Different chemicals are added to locations of wastewater treatment systems to maintain the system
- The amount of chemicals needed is determined by the dosage level desired and the purity of the chemicals used
  - If the purity of the chemical is not mentioned then it is assumed to be 100% available or 1.0 in decimal form for use in formulas

Chemical Application

- There are three possible formulas to calculate dosage rates:
  - Feed Rate, lbs/day
  - Mass, lbs
  - Mass Flux, lbs/day
- All three calculate pounds, but feed rate is the only one that factors in the percent purity of the chemical being applied

Chemical Application

- Chlorine application is achieved by applying one of two types of hypochlorite
  - Sodium hypochlorite
    - NaOCl
    - Bleach
    - 5-15% concentration
  - Calcium hypochlorite
    - $Ca(OCl)_2$
    - High test hypochlorite (HTH)
    - 65% concentration

Different percent purity

Feed Rate

- When dosing a volume of wastewater, a measured amount of chemical is required
- When a percent purity is given in a problem then the feed rate formula must be used

$$feed\ rate, \frac{lb}{day} = \frac{(dose)(flow)(8.34\ {}^{lb}/_{gal})}{\%\ purity}$$

Example 1

- A collections system wants to feed calcium hypochlorite with a purity of 65%. The required dose is 8 mg/L for a flow of 3 MGD. How many pounds per day of disinfectant must be fed?

$$feed\ rate, \frac{lb}{day} = \frac{(dose)(flow)(8.34\ {}^{lb}/_{gal})}{\%\ purity}$$

$$\frac{lb}{day} = \frac{(8\ {}^{mg}/_{L})(3\ MGD)(8.34\ {}^{lb}/_{gal})}{0.65}$$

$$\frac{lb}{day} = 307.94\ {}^{lb}/_{day}$$

Mass and Mass Flux

- Same as feed rate without the % purity
  - If percent purity of a chemical is not provided, it assumed to be 100% pure

$$mass, lbs = (volume, MG)(conc., \frac{mg}{L})\left(8.34\frac{lb}{gal}\right)$$

$$mass\ flux, \frac{lb}{day} = (flow, MGD)(conc., \frac{mg}{L})(8.34\frac{lb}{gal})$$

Dose

- To determine dose, we will need to rearrange the feed rate or mass formula

$$\frac{lb}{day} = \frac{(dose)(flow)(8.34)}{\%\ purity}$$

$$(\%\ purity)(\frac{lb}{day}) = (dose)(flow)(8.34)$$

$$\frac{(\%\ purity)(\frac{lb}{day})}{(flow)(8.34)} = dose$$

Example 2

- A collection system feeds 65 lb/day of 65% calcium hypochlorite. If the flow is 1.6 MGD, what dose, in mg/L, of disinfectant will result?

$$dose = \frac{(\%\ purity)(\frac{lb}{day})}{(flow)(8.34\ ^{lb}/_{gal})}$$

$$dose = \frac{(0.65)(65\ ^{lb}/_{day})}{(1.6\ MGD)(8.34\ ^{lb}/_{gal})}$$

$$dose = 3.17\ ^{mg}/_{L}$$

Two Normal equation

- $N = normality$
  - Can be replaced with concentration
- $V = volume\ or\ flow$

$$N_1 \times V_1 = N_2 \times V_2$$

OR

$$C_1 \times V_1 = C_2 \times V_2$$

Example 3

- An operator needs to make 10 gallons of a bleach dilution with a concentration 25 mg/L. The bleach on hand has a concentration of 100 mg/L. How many gallons of the concentrate must be used to achieve the dilution?

$$C_1 \times V_1 = C_2 \times V_2$$

$$(25\ mg/L)(10\ gal) = (100\ \ mg/L)(V)$$

$$\frac{(25\ \ mg/L)(10\ gal)}{100\ \ mg/L} = V$$

$$2.5\ gal = V$$

Applied Math for Wastewater Treatment
Chemical Dosage

- To convert between mg/L concentrations and % concentrations, use the conversion of 1% = 10,000 mg/L
- mg/L is "parts per million" concentration or ppm

Chemical Feed Rate (Full Strength), lbs/day

1. Determine the chlorinator setting (lbs/day) needed to treat a flow of 8.2 MGD with a chlorine dose of 4.5 mg/L.

2. The desired dosage for a dry polymer is 2.3 mg/L. If the flow to be treated is 4,236,800 gpd, how many lbs/day of polymer is required?

Chemical Feed Rate (Less than Full Strength), lbs/day

3. A total chlorine dose of 6.8 mg/L is required to treat a particular wastewater. If the flow is 1.3 MGD and the calcium hypochlorite has 65% available chlorine, calculate the lbs/day of hypochlorite required.

4. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite (65% available chlorine). The recommended dose is 15 mg/L chlorine. If your flow is 69 gpm, how much calcium hypochlorite is required, lbs/day?

Chlorine Dose, Demand and Residual, mg/L

Demand = Dose – Residual
Dose = Demand + Residual
Residual = Dose – Demand

5. A secondary wastewater effluent is tested and found to have a chlorine demand of 3.2 mg/L. If the desired chlorine residual is 0.5 mg/L, what is the desired chlorine dose, mg/L?

6. What should the chlorinator setting be (lbs/day) to treat a flow of 4.2 MGD if the chlorine demand is 6 mg/L and a chlorine residual of 1.0 mg/L is desired?

Chemical Dosage, mg/L

7. A wastewater plant has a flow of 1,180 gpm. If the chlorinator is feeding 76 pounds per day, what is the dose in mg/L?

8. The chlorinator is set to feed 26.5 lbs of chlorine per 24 hours for a plant flow of 1.2 MGD. Calculate the chlorine residual for a chlorine demand of 1.85 mg/L.

Hypochlorination

9. How many pounds of HTH (65% available chlorine) will it take to make a 5% solution when dissolved in enough water to make 25 gallons of hypochlorite?

10. How many pounds of 65% HTH are used to make 10 gallon of 5% solution?

Answers:

1. 308 lbs/day
2. 81.3 lbs/day
3. 113 lbs/day
4. 19.1 lbs/day
5. 3.7 mg/L
6. 245 lbs/day
7. 5.36 mg/L
8. 0.8 mg/L
9. 16 lbs
10. 6.4 lbs

Applied Math for Wastewater Treatment
Chemical Dosage

Chemical Feed Rate (Full Strength), lbs/day

1. Determine the chlorinator setting (lbs/day) needed to treat a flow of 4.4 MGD with a chlorine dose of 3.2 mg/L.

2. The desired dosage for a dry polymer is 1.1 mg/L. If the flow to be treated is 1,660,000 gpd, how many lbs/day of polymer is required?

3. To neutralize a sour digester, one pound of lime is added for every pound of volatile acids in the digester sludge. If the digester contains 195,000 gallons of sludge with a volatile acid level of 2,100 mg/L, how many pounds of lime should be added?

4. To control hydrogen sulfide (H_2S) and odors in an 8-inch sewer, the chlorine dose must be 10 mg/L when the flow is 0.37 MGD. Determine the chlorine feed rate in lbs/day.

5. A wastewater flow of 3.8 cfs requires a chlorine dose of 15 mg/L. What is the desired chlorine feed rate in lbs/day?

6. A company contends a new product effectively controls roots in sewer pipes at a concentration of 150 mg/L if the contact time is 60 minutes. How many pounds of chemical are required, assuming perfect mixing, if 450 feet of 6-inch sewer were to be treated?

Chemical Feed Rate (Less than Full Strength), lbs/day

7. A total chlorine dose of 10.8 mg/L is required to treat a particular wastewater. If the flow is 2.77 MGD and the calcium hypochlorite has 65% available chlorine, calculate the lbs/day of hypochlorite required.

8. The desired dose of a polymer is 4 mg/L. The polymer literature provided indicates the compound is 60% active polymer. If a flow of 4.2 MGD is to be treated, how many lbs/day of polymer compound must be fed?

9. The effluent from a wastewater lagoon requires a chlorine dose of 18 mg/L. If the average daily flow is 1,095,000 gpd and sodium hypochlorite (15% available chlorine) is to be used to disinfect the wastewater, how many lbs/day of hypochlorite are required?

10. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite (65% available chlorine). The recommended dose is 15 mg/L chlorine. If your flow is 75 gpm, how much calcium hypochlorite is required, lbs/day?

11. If sodium hypochlorite (15% available chlorine) is used instead in #10, how many gallons must be fed daily? (Assume 1 gallon of solution weighs 8.34 lbs.)

12. To inactivate and control slime in the collection system, 40% sodium hydroxide (NaOH) can be fed at about 8,000 mg/L over one hour. If the NaOH solution is used to treat a section of 12-inch sewer 800 ft long, calculate the volume in gallons of NaOH solution required. (Assume 1 gallon solution weighs 8.34 lbs)

Chlorine Dose, Demand and Residual, mg/L

13. A secondary wastewater effluent is tested and found to have a chlorine demand of 4.8 mg/L. If the desired chlorine residual is 0.9 mg/L, what is the desired chlorine dose, mg/L?

14. The chlorine dose for a secondary effluent is 8.4 mg/L. If the chlorine residual after a 30 minute contact time is found to be 0.8 mg/L, what is the chlorine demand, mg/L?

15. What should the chlorinator setting be (lbs/day) to treat a flow of 3.9 MGD if the chlorine demand is 8 mg/L and a chlorine residual of 1.5 mg/L is desired?

16. A secondary effluent is tested and found to have a chlorine demand of 4.9 mg/L. If the desired residual is 0.8 mg/L, what is the desired chlorine dose (mg/L)?

17. The chlorine dosage for a secondary effluent is 8.8 mg/L. If the chlorine residual after 30 minutes of contact time is found to be 0.9 mg/L, what is the chlorine demand in mg/L?

18. The chlorine demand of a secondary effluent is 7.9 mg/L. If the chlorine residual of 0.6 mg/L is desired, what is the desired chlorine dosage in mg/L?

Chemical Dosage, mg/L

19. The chlorinator is set to feed 31.5 lbs of chlorine per 24 hours for a plant flow of 1.6 MGD. Calculate the chlorine residual for a chlorine demand of 1.85 mg/L.

20. A wastewater plant has a flow of 2,570 gpm. If the chlorinator is feeding 93 pounds per day, what is the dose in mg/L?

21. What should the chlorinator setting be in lbs/day to treat a flow of 4.0 MGD if the chlorinator demand is 9 mg/L and a chlorine residual of 1.7 mg/L is desired?

Hypochlorination

22. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

23. How many pounds of 65% HTH are used to make 1 gallon of 3% solution?

24. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

Use the following information for problems 25 – 28:

At 8:00 a.m. on Monday morning a chlorine cylinder weighs 83 pounds. At 8:00 a.m. on Tuesday morning the same cylinder weighs 69 pounds.

25. What is the chlorinator feed rate in pounds per day?

26. Estimate the chlorine dose in mg/L for the chlorinator. The flow totalizer reads 12,982,083 gallons at 8:00AM on Monday morning and 13,528,924 at 8:00AM on Tuesday morning. (Note: This totalizer does not zero out each morning.)

27. If the setting on the chlorinator does not change, how many pounds of chlorine will be left in the cylinder on Friday morning at 8:00 a.m.?

28. How many 150-lb chlorine cylinders will this water plant need in a month (with 30 days) if the chlorinator setting remains the same?

Use the following information for problems 29 – 31:
At 8:00 a.m. on Friday morning a chlorine cylinder weighs 298 pounds. That afternoon at 4:00 p.m. the same cylinder weighs 216 pounds.

29. What is the chlorinator feed rate in pounds per day?

30. How many pounds of chlorine will be in the cylinder at 8:00 a.m. on Saturday morning if the feed rate does not change?

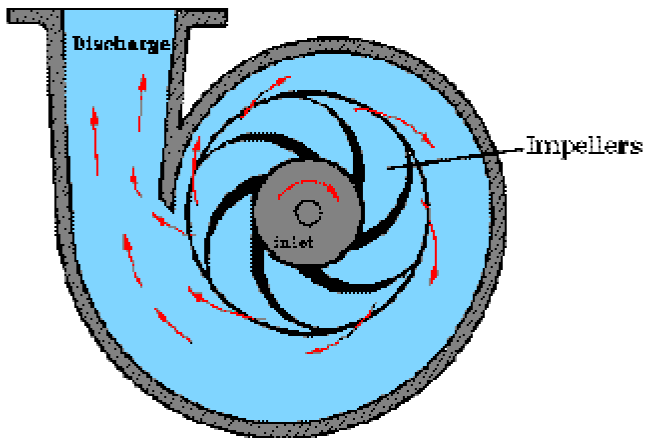
31. What is the minimum number of ton cylinders the operator will need in a month with 31 days (at this feed rate)?

Answers:

1. 117 lbs/day
2. 15.2 lbs/day
3. 3415 lbs
4. 30.9 lbs/day
5. 307 lbs/day
6. 0.83 lbs
7. 384 lbs/day
8. 234 lbs/day
9. 1096 lbs/day
10. 20.8 lbs/day
11. 10.8 gpd
12. 93.9 gpd
13. 5.7 mg/L
14. 7.6 mg/L
15. 309 lbs/day
16. 5.7 mg/L
17. 7.9 mg/L
18. 8.5 mg/L
19. 0.51 mg/L
20. 3.0 mg/L
21. 357 lbs/day
22. 3.8 lbs
23. 0.4 lbs
24. 11.5 lbs
25. 14 lbs/day
26. 3.1 mg/L
27. 27 lbs
28. 3 cylinders
29. 246 lbs/day
30. 52 lbs
31. 4 cylinders

Section 2

Pumps and Equipment Maintenance



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WASTEWATER PUMPS AND EQUIPMENT MAINTENANCE

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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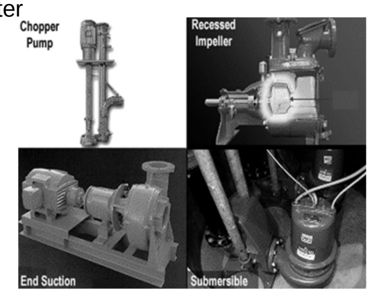
Types of Pumps

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



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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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Types of Pumps

- Positive-Displacement Pumps
  - Metering pumps – sometimes used to feed chemicals
  - Piston pump
  - Screw pump
- Velocity Pumps
  - Vertical turbine
  - Centrifugal
    - Most common type in wastewater lift stations

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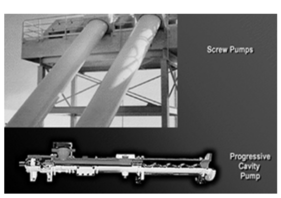
Positive-Displacement Pumps

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



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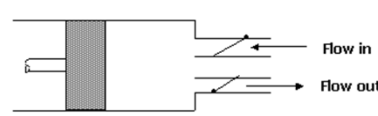
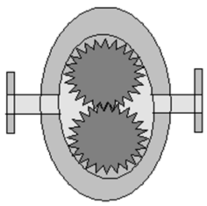
Positive-Displacement Pumps

- 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

Screw Pumps

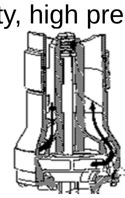
- Screw pumps are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge point

Incline screw pumps handle large solids without plugging

Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)
- High velocity, low pressure water is converted to low velocity, high pressure water

Volute



Diffuser

Vertical Wet Well Pumps

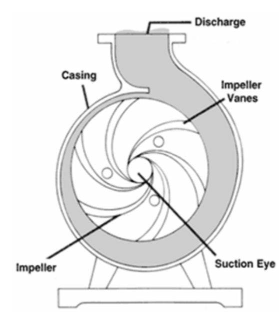
- Has a vertical shaft, diffuser-type centrifugal pump with the pumping element suspended from the discharge piping.
- The needs of a given installation determines the length of discharge column
- The pumping bowl assembly may connect directly to the discharge head for shallow sumps, or may be suspended several hundred feet for raising water from wells
- Vertical turbine pumps are used to pump water from deep wells and may be of the single-stage or multistage type

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

Centrifugal Pump

- Basically a very simple device: an impeller rotating in a casing
- The impeller is supported on a shaft, which in turn, is supported by bearings
- Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge

Most Common Centrifugal Pumps

- Horizontal non-clog type
- Vertical ball bearing type
- Propeller type

Advantages of Centrifugal Pumps

- Wide range of capacities
- Uniform flow at a constant speed and head
- Low cost
- Ability to be adapted to various types of drivers
- Moderate to high efficiency
- No need for internal lubrication

Disadvantages of Centrifugal Pumps

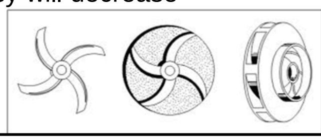
- Efficiency is limited to very narrow ranges of flow and head
- Flow capacity greatly depends on discharge pressure
- Generally no self-priming ability
- Can run backwards if check valve fails and sticks open
- Potential impeller damage if pumping abrasive water

Let's Build a Centrifugal Pump

- First we need a device to spin liquid at high speeds – an impeller
  - This is the heart of our pump
  - As the impeller spins, liquid between the blades is impelled outward by centrifugal force
  - As liquid in the impeller moves outward, it will suck more liquid behind it through this eye, provided it is not clogged.
    - If there is any danger that foreign material may be sucked into the pump, clogging or wearing of the impeller unduly, provide the intake end of the suction piping with a suitable screen

Impeller

- Bronze or stainless steel
- Closed; some single-suction have semi-open; open designs
- Inspect regularly
- As the impeller wears on a pump, the pump efficiency will decrease



Let's Build a Centrifugal Pump

- Now we need a shaft to support and turn the impeller
  - It must maintain the impeller in precisely the right place
  - But that ruggedness does not protect the shaft from the corrosive or abrasive effects of the liquid pumped, so we must protect it with sleeves slid on from either end.

Shaft and Sleeves

- 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
  - Generally they are bronze, but various other alloys, ceramics, glass or even rubber-coating are sometimes required.

Let's Build a Centrifugal Pump

- We mount the shaft on sleeve, ball or roller bearings
  - If bearings supporting the turning shaft and impeller are allowed to wear excessively and lower the turning units within a pump's closely fitted mechanism, the life and efficiency of that pump will be seriously threatened.
  - 2 types:
    - Oil-lubricated
    - Grease lubricated

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
  - Tiny indentations high on the shoulder of a bearing or race is called brinelling
  - When greasing a bearing on an electric motor, the relief plug should be removed and replaced after the motor has run for a few minutes. This prevents you from damaging the seals of the bearing.
- Types: ball, roller, sleeve

Bearings

- Inspect and lubricate bearings-grease
  - If possible, remove bearing cover and visually inspect grease.
  - When greasing, remove relief plug and cautiously add 5 or 6 strokes of the grease gun.
  - Afterward, check bearing temperature with thermometer.
    - If over 220°F (104°C), remove some grease.

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Let's Build a Centrifugal Pump

- To connect with the motor, we add a coupling flange
  - Our pump is driven by a separate motor, and we attach a flange to one end of the shaft through which bolts will connect with the motor flange
  - If shafts are met at an angle, every rotation throws tremendous extra load on bearings of both pump and the motor
    - Flexible couplings will not correct this condition if excessive

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Common Pump & Motor Connections

- Direct coupling
- Angle drive
- Belt or chain
- Flexible coupling
- Close-coupled

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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

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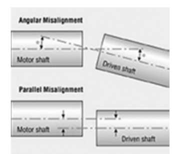
Misalignment of Pump & Motor

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



- Checking alignment should be a regular procedure in pump maintenance.
  - Foundations can settle unevenly
  - Piping can change pump position
  - Bolts can loosen
  - Misalignment is a major cause of pump and coupling wear.

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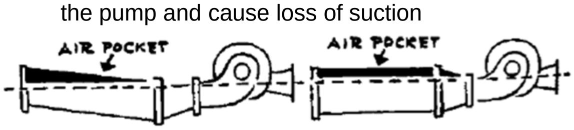
Let's Build a Centrifugal Pump

- Now we need a "straw" through which liquid can be sucked
  - Insure that the pipe does not put strain on the pump's casing
  - The horizontal pipe slopes upward toward the pump so that air pockets won't be drawn into the pump and cause loss of suction



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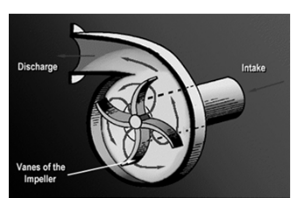
Let's Build a Centrifugal Pump

- We contain and direct the spinning liquid with a casing
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape



Let's Build a Centrifugal Pump

- Now our pump is almost complete, but it would leak like a sieve
  - As water is drawn into the spinning impeller, centrifugal force causes it to flow outward, building up high pressure at the outside of the pump (which will force water out) and creating low pressure at the center of the pump (which will draw water in)
    - Water tends to be drawn back from pressure to suction through the space between the impeller and casing – this needs to be plugged

Let's Build a Centrifugal Pump

- So we add wearing rings (aka wear rings) to plug internal liquid leakage
  - Restrict flow between impeller discharge and suction
  - Leakage reduces pump efficiency
  - Installed to protect the impeller and pump casing from excessive wear
  - Provides a replaceable wearing surface
  - Inspect regularly

Let's Build a Centrifugal Pump

- To keep air from being drawn in, we use stuffing boxes
  - We have two good reasons for wanting to keep air out of our pump
    - We want to pump water, not air
    - Air leakage is apt to cause our pump to lose suction
  - Each stuffing box we use consists of a casing, rings of packing and a gland at the outside end
    - A mechanical seal may be used instead

Stuffing Box

- Parts include:
  - Packing
  - Lantern ring
  - Gland follower

Packing vs. Mechanical Seals

- If a pump has packing, water should drip slowly

- If it has a mechanical seal, no leakage should occur

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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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
- Stagger joints 180º if only 2 rings are in stuffing box, space at 120º for 3 rings or **90º if 4 rings or more are in set**

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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

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Packing Rings vs. Mechanical Seal

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

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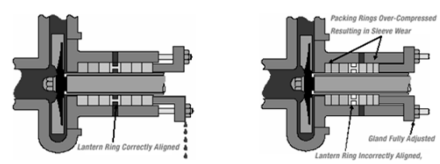
Lantern Rings

- Perforated ring placed in stuffing box
- A spacer ring in the packing gland that forms seal around shaft, helps keep air from entering the pump and lubricates packing



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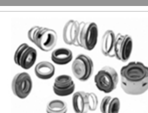
Mechanical Seals



- 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 160ºF (71ºC)
- Mechanical seals are always flushed in some manner to lubricate the seal faces and minimize wear
  - The flushing water pressure in a water-lubricated wastewater pump should be **3-5 psi higher** than the pump discharge pressure.

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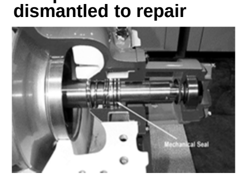
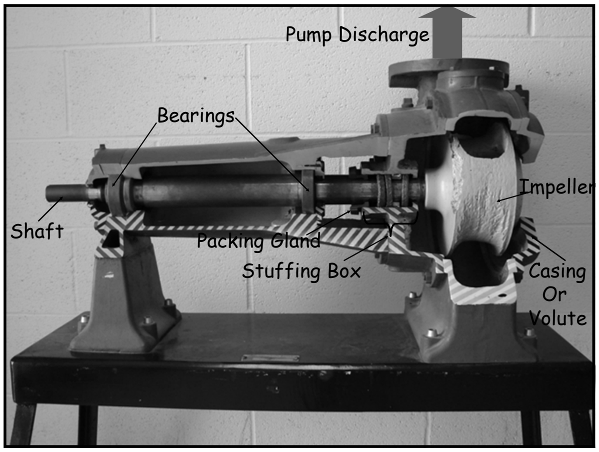
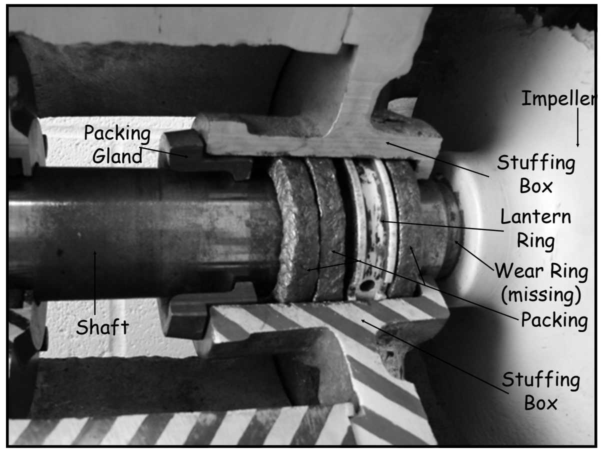
Mechanical Seal vs. Packing Rings

- Advantages
  - **Last 3-4 years**, which can be a savings in labor
  - Usually there is **no damage to shaft sleeve**
  - **Continual adjusting, cleaning or repacking is not required**
  - Possibility of flooding lift station because a pump has thrown its packing is eliminated; however mechanical seals can fail and lift stations can be flooded
- Disadvantages
  - **High initial cost**
  - **Great skill and care needed to replace**
  - When they fail, the pump must be shut down
  - **Pump must be dismantled to repair**







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Self-Priming Pump Basics – Part 1

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Self-Priming Pump Basics – Part 2

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Centrifugal Pump Operation

- Pump Starting -
  - Impeller must be submerged for a pump to start
    - Should never be run empty, except momentarily, because parts lubricated by water would be damaged
  - 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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Centrifugal Pump Operation

- Pump shut down for extended period of time -
  - Close the valve in the suction line
  - Close the valve in the discharge line
  - Drain the pump casing

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
  - Variable speed pumping equipment can be adjusted to match the inflow rate

Monitoring Operational Variables

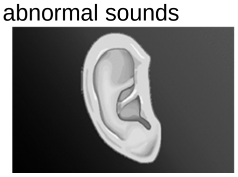
- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

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

Monitoring Operational Variables

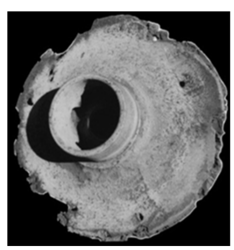
- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds



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
  - Improper motor to pump alignment

Monitoring Operational Variables

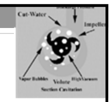


- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

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
- Best method to prevent it from occurring is to reduce the suction lift

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.

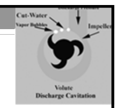
Information from http://www.pumpworld.com/Cavitation_discharge.htm

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

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

Inspection and Maintenance

- Inspection and maintenance prolongs life of pumps
  - Checking operating temperature of bearings
  - Checking packing glands
  - Operating two or more pumps of the same size alternatively to equalize wear
  - Check parallel and angular alignment of the coupling on the pump and motor
    - A feeler gauge, dial indicator calipers are tools that can be used to check proper alignment
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

Inspection: Impellers

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

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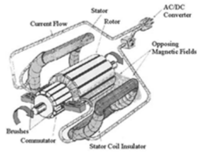
Pump Won't Start?



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

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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
- Machinery creating excessive noise shall be equipped with mufflers.

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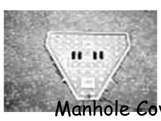
Pump Safety: Wet Wells

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



Manhole Cover, London

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Pump Facts

- Sewer pumps used in a lift station shall be capable of passing at least a 3 inch diameter sphere
- Pump suction and discharge opening shall be no less 4 inches in diameter
- Each pump must have its own intake line
- Wet wells should be designed to avoid turbulence near the intakes
- The velocity in the suction line of a pump should not exceed 6 fps
- The velocity in the discharge line of a pump should not exceed 8 fps

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Pump Facts

- Ventilation in wet wells shall provide for at least 12 complete air changes per hour if continuous and 30 changes per hour if intermittent
- Ventilation in dry wells shall provide for at least 6 complete air changes per hour if continuous and 30 changes per hour if intermittent

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Pump Facts

- The maximum recommended suction lift for a pump in a pumping station is 15 feet
- Minimum force main size is 4 inches
- A gasoline powered centrifugal pump in good condition can lift water (suction lift) up to 18 inches of mercury
  - 20 feet of possible suction lift
- Head is the amount of energy possessed by water at any point in a hydraulic system
  - Feet divided by 2.31 equals psi (pounds per square inch) in head

Types of Pumps Found in Collection Systems

- Incline screw pump
- Centrifugal
- Pneumatic ejectors
- Piston
- Close-coupled
- Submersible
- Progress cavity
- Flexible stator and rotor

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
  - Most are clamp on type

- Megger: checks insulation resistance on motors, feeders, grounds, and branch circuit wiring
  - Motors should be megged at least once a year

Tools, Meters & Testers

- Ohmmeter: measures resistance in a circuit.
  - An ohmmeter is used only when the electric circuit is off or de-energized
  - Tests fuses, relays, resistors and switches.

- Multimeter: checks for voltage
  - By holding one lead on ground and the other on a power lead, you can determine if power is available
  - You can also tell if it is AC or DC and the intensity or voltage (110, 220, 480 or whatever) by testing the different leads

Need for Maintenance

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

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Need for Maintenance

- Inspect & maintain electrical equipment annually.
- Inspection should include:
  - Thorough examination
  - Replacement of worn & expendable parts
  - Operational checks & tests
- Fuses and circuit breakers are protective devices used to protect operators, main circuits, branch circuits, heater, motors and various other electrical equipment.

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Electrical Protective Devices: Fuses

- Protect control panel from excess voltage or amperage
- Fusible metal strip melts and breaks circuit
- One-time use devices
  - Should never be jumped or bypassed
  - When removing any fuse, a fuse puller should be used

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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

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Transformer

- Allows energy to be transferred in an AC system for one circuit to another
- 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

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- Converters
  - Sometimes used to change the frequency in an AC power system
- Rectifiers
  - Changes AC to DC by allowing the current to flow in one direction only
- Inverters
  - Changes DC to AC

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D.C. versus A.C.

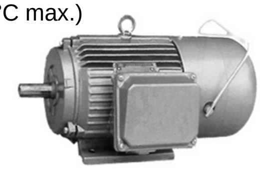
- Direct current (D.C.) is flowing in one direction only and is essentially free from pulsation
  - DC is seldom used in lift stations and wastewater treatment plants except in motor-generated sets, some control components of pump drives and standby lighting
  - DC is used exclusively in automotive equipment, 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

Batteries

- An electric battery is a device for the transformation of chemical energy into electric energy
- A primary battery is a battery that the chemical action is irreversible, like a flashlight battery
- A storage battery is one that the chemical action is almost completely reversible, like a car battery
- The most common battery is the lead-acid type
- Another common type of battery is the nickel-cadmium type

A.C. Induction Motor

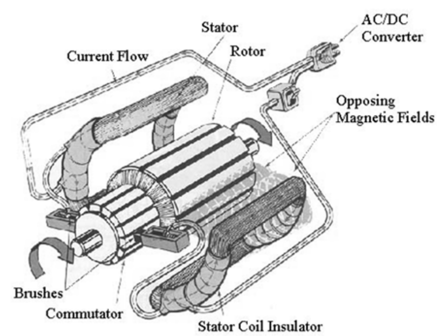
- Most common pump driver in wastewater pump stations
- Motors pull the most current on start up.
- Malfunction due to:
  - Thermal overload (40°C max.)
  - Contaminants
  - Single phasing
  - Old age
  - Rotor failure



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
    - Also referred to as a condenser and it will also store electricity when it is charged

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

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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 motor not coming to speed after starting – the motor has lost power to one or more phases

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Compressors

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

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Compressors

- Inspect suction filter at least monthly
  - Daily in dusty areas such as construction zones
- Inspect safety valves weekly
- 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

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Valves

- Controlling device in piping systems to stop, regulate, check, or divert flow of liquids or gases
- Types of valves found in a pumping station
  - Butterfly – used on suction and discharge
  - Gate – used on suction and discharge
  - Plug – used on suction and discharge
  - Swing or ball check – used on discharge
  - Knife – used on suction and discharge
  - Wafer – used on discharge

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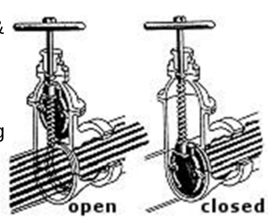
Valves

- 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



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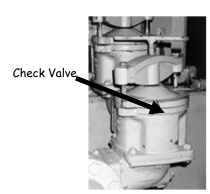
Valves

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



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Valves

- Butterfly valves: often clog on sewer lines when installed to carry stormwater or wastewater
- Plug valves: less susceptible to plugging; sludge pumping

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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

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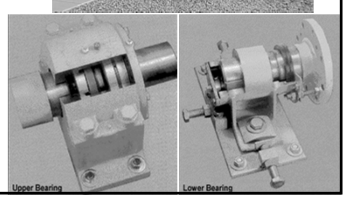
Bearings

- 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

- Only one person should be in charge on any maintenance program.
- 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

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 two types of safety devices found in main electrical panels or control units?

5. What is the most common pump driver 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 advantages of a pneumatic ejector?

9. What is the purpose of packing?

10. What is the purpose 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

Pump and Motor Review Questions

1. Leakage of water around the packing on a centrifugal pump is important because it acts as a (n):
   a. Adhesive
   b. Lubricant
   c. Absorbent
   d. Backflow preventer

2. What is the purpose of wear rings in a pump?
   a. Hold the shaft in place
   b. Hold the impeller in place
   c. Control amount of water leaking from discharge to suction side
   d. Prevent oil from getting into the casing of the pump

3. Which of the following does a lantern ring accomplish?
   a. Lubricates the packing
   b. Helps keep air from entering the pump
   c. Both (a.) and (b.)

4. Closed, open and semi-open are types of what pump part?
   a. Impeller
   b. Shaft sleeve
   c. Casing
   d. Coupling

5. When tightening the packing on a centrifugal pump, which of the following applies?
   a. Tighten hand tight, never use a wrench
   b. Tighten to 20 foot pounds of pressure
   c. Tighten slowly, over a period of several hours
   d. Tighten until no leakage can be seen from the shaft

6. Excessive vibrations in a pump can be caused by:
   a. Bearing failure
   b. Damage to the impeller
   c. Misalignment of the pump shaft and motor
   d. All of the above

7. What component can be installed on a pump to hold the prime?
   a. Toe valve
   b. Foot valve
   c. Prime valve
   d. Casing valve

8. The operating temperature of a mechanical seal should not exceed:
   a. 60°C
   b. 150°F
   c. 160°F
   d. 71°C
   e. c and d

9. What is the term for the condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound?
   a. Corrosion
   b. Cavitation
   c. Aeration
   d. Combustion

10. The first thing that should be done before any work is begun on a pump or electrical motor is:
    a. Notify the state
    b. Put on safety goggles
    c. Lock out the power source and tag it
    d. Have a competent person to supervise the work

11. Under what operating condition do electric motors pull the most current?
    a. At start up
    b. At full operating speed
    c. At shut down
    d. When locked out

12. As the impeller on a pump becomes worn, the pump efficiency will:
    a. Decrease
    b. Increase
    c. Stay the same

13. How do the two basic parts of a velocity pump operate?

14. What are two designs used to change high velocity to high pressure in a pump?

15. In what type of pump are centrifugal force and the lifting action of the impeller vanes combined to develop the total dynamic head?

16. Identify one unique safety advantage that velocity pumps have over positive-displacement pumps.

17. What is the multistage centrifugal pump? What effects does the design have on discharge pressure and flow volume?

18. What are two types of vertical turbine pump, as distinguished by pump and motor arrangement, which are commonly used to pump ground water from wells?

19. What type of vertical turbine pump is commonly used as an inline booster pump?

20. Describe the two main parts of a jet pump.

21. What is the most common used of positive-displacement pumps in water plants today?

22. What is the purpose of the foot valve on a centrifugal pump?

23. How is the casing of a double-suction pump disassembled?

24. What is the function of wear rings in centrifugal pumps of the closed-impeller design? What is the function of the lantern rings?

25. Describe the two common types of seals used to control leakage between the pump shaft and the casing.

26. What feature distinguishes a close-coupled pump and motor?

27. What is the value of listening to a pump or laying a hand on the unit as it operates?

28. Define the term "racking" as applied to pump and motor control.

29. When do most electric motors take the most current?

30. What are three major ways of reducing power costs where electric motors are used?

31. What effect could over lubrication of motor bearings have?

32. Why should emery cloth not be used around electrical machines?

33. What are the most likely causes of vibration in an existing pump installation?

34. What can happen when a fuse blows on a single leg of a three-phase circuit?

35. Name at least three common fuels for internal-combustion engines.

36. List the type of information that should be recorded on a basic data card for pumping equipment.

37. What is the first rule of safety when repairing electrical devices?

Answers:

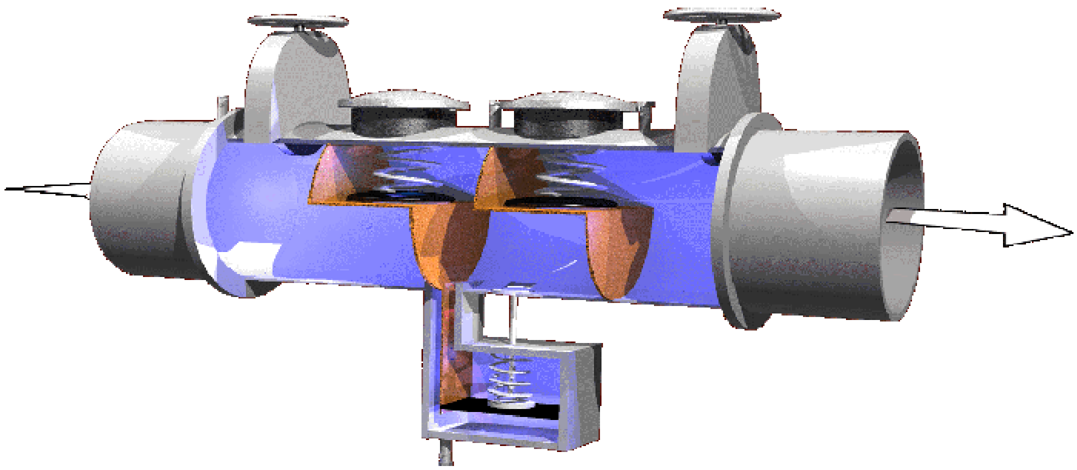
1. B	4. A	7. B	10. C
2. C	5. C	8. E	11. A
3. C	6. D	9. B	12. A

13. A spinning impeller accelerates water to a high velocity within a casing, which changes the high-velocity, low-pressure water to a low-velocity, high-pressure discharge.
14. Volute casing and diffuser vanes.
15. Mixed-flow pump (the design used for most vertical turbine pumps)
16. If a valve is closed in the discharge line, the pump impeller can continue to rotate for a time without pumping water or damaging the pump.

17. A multistage centrifugal pump is made up of a series of impellers and casings (housings) arranged in layers, or stages. This increases the pressure at the discharge outlet, but does not increase flow volume.
18. Shaft-type and submersible-type vertical turbines.
19. A close-coupled vertical turbine with an integral sump or pot.
20. The jet pump consists of a centrifugal pump at the ground surface and an ejector nozzle below the water level.
21. Positive-displacement pumps are generally used in water plants to feed chemical into the water supply.
22. The foot valve prevents water from draining when the pump is stopped, so the pump will be primed when restarted.
23. The bolts holding the two halves of the casing together are removed and the top half is lifted off.
24. Wear rings prevent excessive circulation of water between the impeller discharge and suction area. Lantern rings allow sealing water to be fed into the stuffing box.
25. (1) Packing rings are made of graphite-impregnated cotton, flax, or synthetic materials. They are inserted in the stuffing box and held snuggly against the shaft by an adjustable packing gland. (2) Mechanical seals consist of two machined and polished surfaces. One is attached to the shaft, the other to the casing. Spring pressure maintains contact between the two surfaces.
26. The pump impeller is mounted directly on the shaft of the motor.
27. An experienced operator can often detect unusual vibration by simply listening or touching. Vibration, especially changes in vibration level, are viewed as symptoms or indicators of other underlying problems in foundation, alignment and/or pump wear.
28. Racking refers to erratic operation that may result from pressure surges when the pump starts; it is often a problem when the pressure sensor for the pump control is located too close to the pump station.
29. During start-up.
30. (1) Increase system efficiency; (2) spread the pumping load more evenly throughout the day; (3) reduce power-factor charges
31. The bearings may run hot, and excess grease or oil could run out and reach the motor windings, causing the insulation to deteriorate.
32. The abrasive material on emery cloth is electrically conductive and could contaminate electrical components.
33. Imbalance of the rotating elements, bad bearings and misalignment
34. A condition called single-phasing can occur, causing the motor windings to overheat and eventually fail.
35. gasoline, propane, methane, natural gas and diesel oil (diesel fuel)
36. make, model, capacity, type, date and location installed, and other information for both the driver (motor) and the driven unit (pump)
37. Make sure the power to the device is disconnected. This is critical since rubber gloves, insulated tools and other protective gear are not guarantees against electrical shock.

Section 3

Cross Connection Control



Cross Connection Control

Outline

2

- Basics of Cross Connection Control
- Hydraulics
- Definitions
- Backflow Preventers
- Applications

Basics of Cross Connection Control

3

United States Environmental Protection Agency Cross Connection Control Manual
www.epa.gov/ogwdw/pdfs/crossconnection/crossconnection.pdf

Tennessee Department of Environment & Conservation Cross Connection Control Manual & Design Criteria
www.tn.gov/environment/water/docs/fleming/crossconnection.pdf

Authority

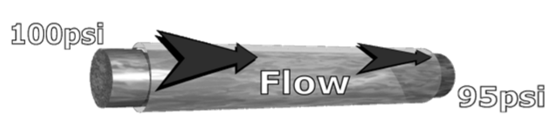
4

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

Hydraulics

5

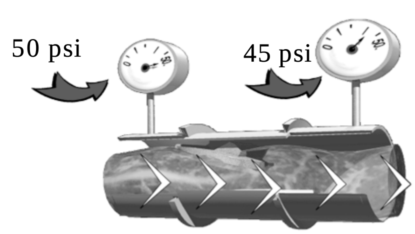
- Water pressure naturally tends to equalize



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

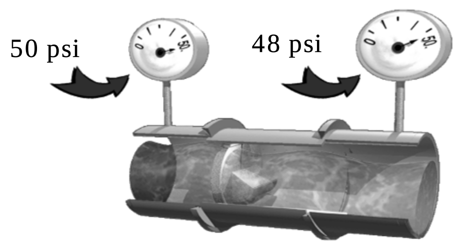
Normal Flow

6



No Flow

7



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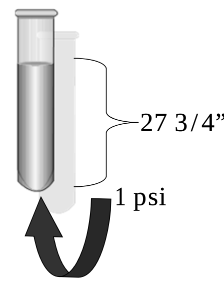
27 ¾ ” = 2.31 Feet of Head

8



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

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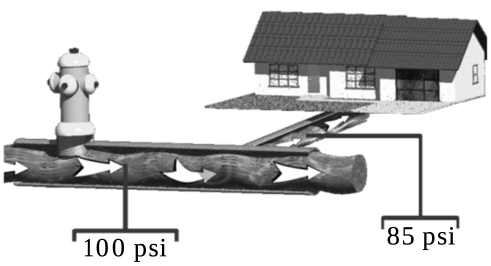
Normal Flow

9



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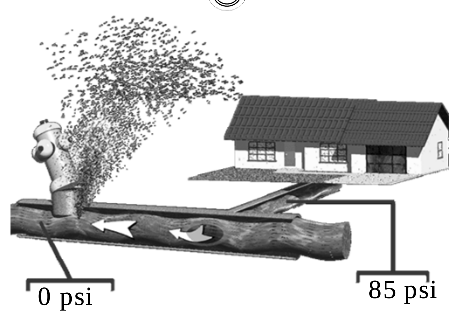
Reverse Flow

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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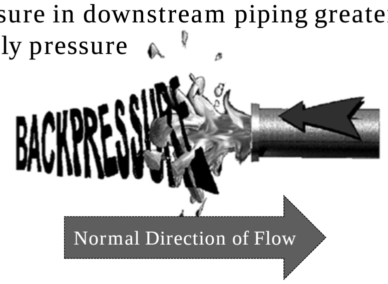
Backpressure

12

- Pressure in downstream piping greater than supply pressure



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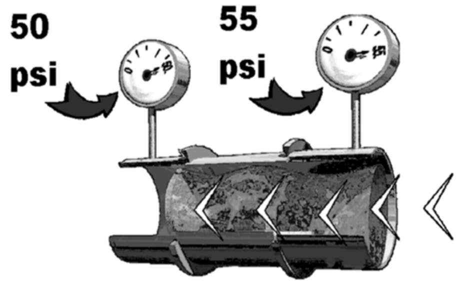
Backpressure

13



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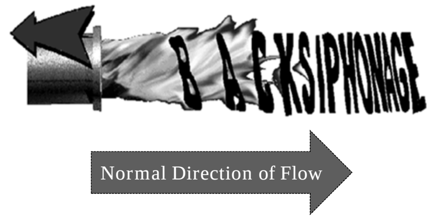
Backsiphonage

14

- Sub-atmospheric pressure in the water system



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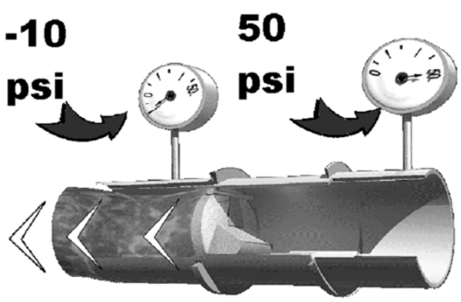
Backsiphonage

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

Submerged Inlet

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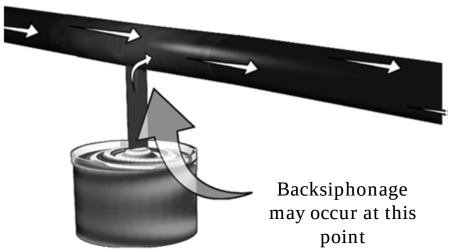
Aspirator Effect

19



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Degree of Hazard

20

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

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The Backflow Incident

21

For backflow to occur three conditions must be met:

1. There must be a Cross connection. A passage must exist between the potable water system and another source.
2. A hazard must exist in this other source to which the potable water is connected.
3. The hydraulic condition of either backsiphonage or backpressure must occur.

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Five Means of Preventing Backflow

22

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

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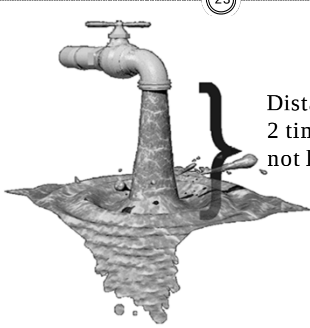
Air Gap

23



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Approved Air Gap Separation

24

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

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25

	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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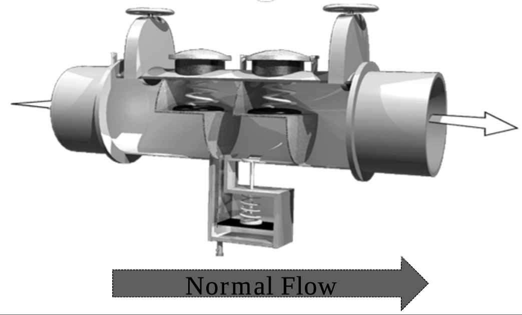
Reduced Pressure Principle Assembly

26



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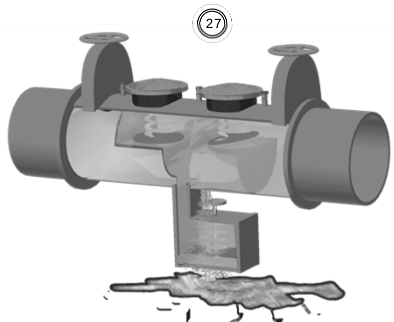
RP

27



Fouled Second Check with Backpressure

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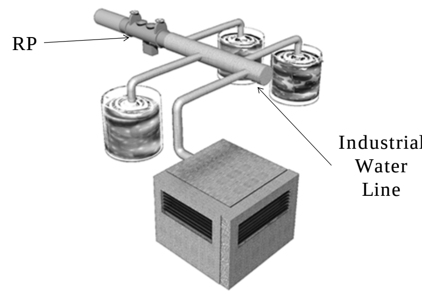
Where To Put an RP

28



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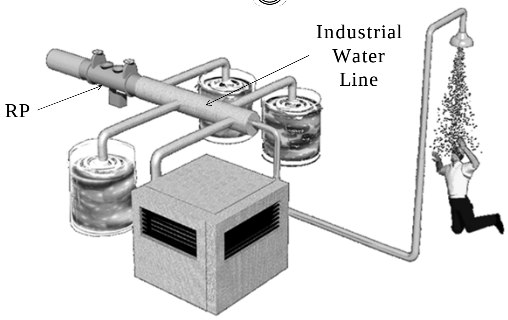
Where To Put an RP – Don't

29



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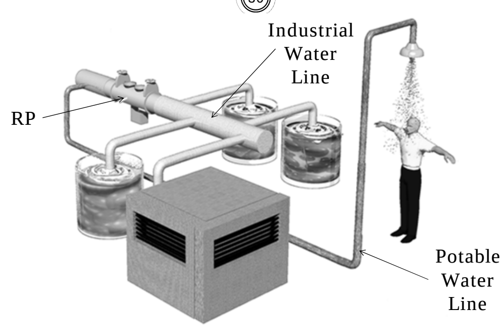
Where To Put an RP – Do

30



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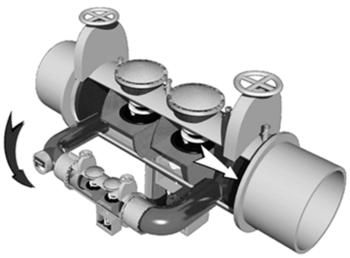
RP Detector Assembly

31

At least 3 GPM through bypass only



RP

32

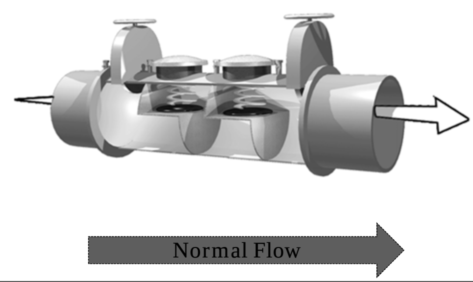
- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

33

	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**

Double Check Valve Assembly (DC)

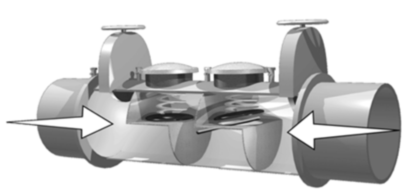
34



Double Check Valve Assembly (DC)

35

- Second check fouled during backpressure



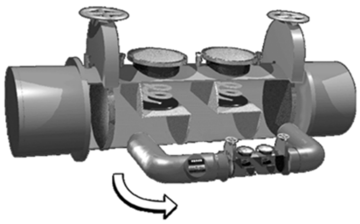
Double Check Valve Assembly (DC)

36

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

DC Detector Assembly

37



At least 3 GPM through bypass only

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38

	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

39

- 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

40

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

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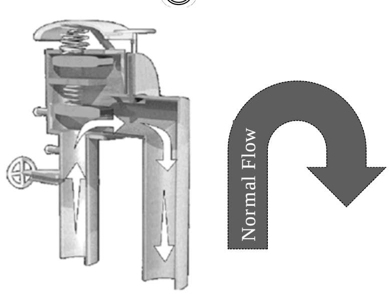
Pressure Vacuum Breaker (PVB)

41



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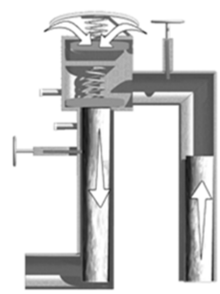
PVB Backsiphonage Condition

42



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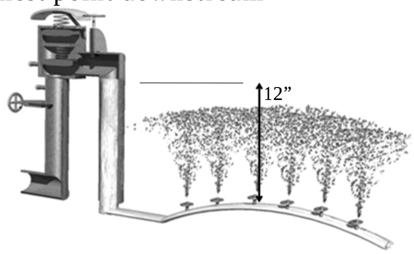
Installation of PVB

43

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



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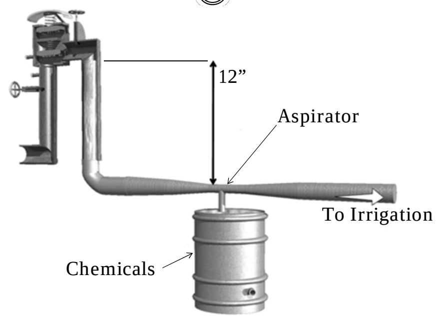
Pressure Vacuum Breaker

44



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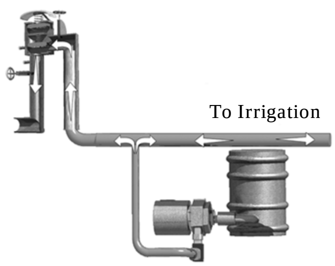
Pressure Vacuum Breaker

45

- Improper installation subject to backpressure



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Pressure Vacuum Breaker

46

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

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47

	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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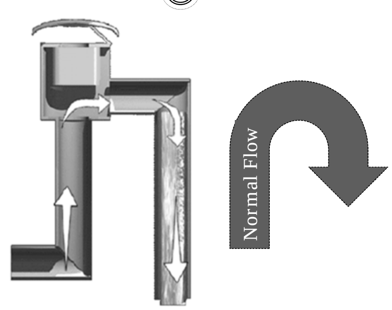
Atmospheric Vacuum Breaker (AVB)

48



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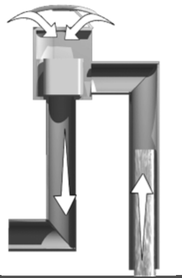
Atmospheric Vacuum Breaker (AVB)

49

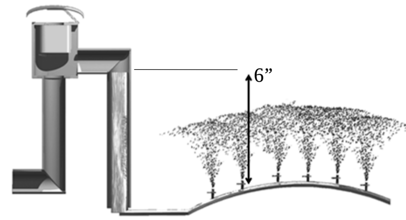
- Backsiphonage condition



Installation of AVB

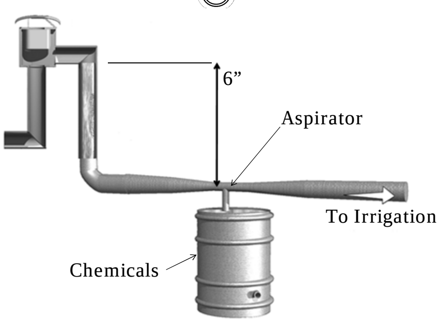
50

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



Atmospheric Vacuum Breaker

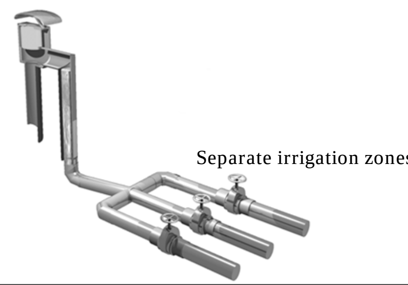
51



Atmospheric Vacuum Breaker

52

- Improper installation: downstream shutoff valves



Atmospheric Vacuum Breaker

53

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

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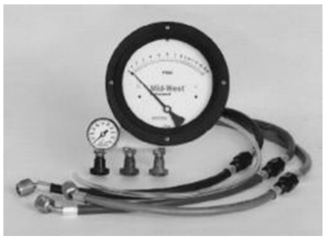
	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	PVB	PVB	
		AVB	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	PVB	
		AVB	

Testing of Assemblies

55

- Annual testing required
- Must be conducted by certified personnel



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Method / Device Review

RP

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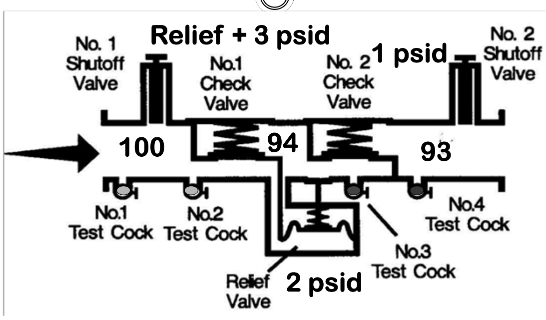

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DC

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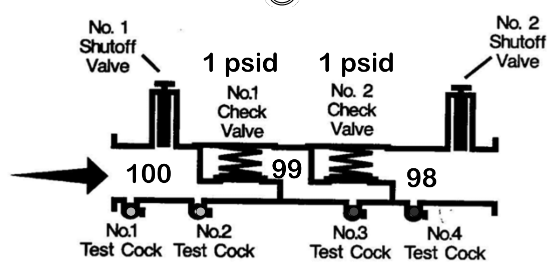

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PVB

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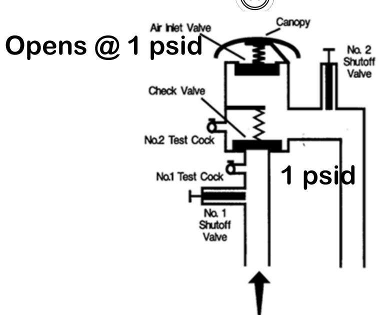

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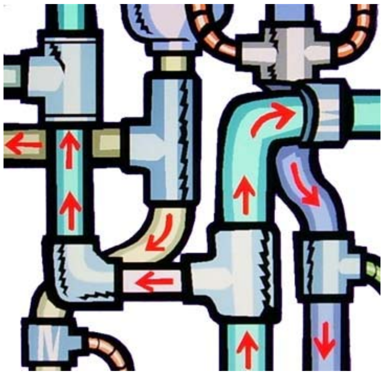


Vocabulary

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

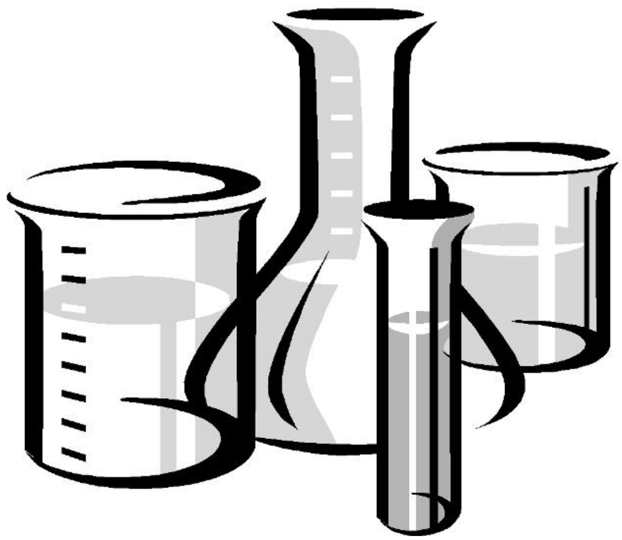
Review Question Answers:

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



INTRODUCTION TO WASTEWATER LABORATORY - 2017

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

NPDES Permit

- **1.0. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS**
- 1.1. NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS
- 1.2. MONITORING PROCEDURES
- 1.2.1. Representative Sampling
- 1.2.2. Sampling Frequency
- 1.2.3. Test Procedures
- 1.2.4. Recording of Results
- 1.2.5. Records Retention

NPDES Permit

- 1.3. REPORTING
- 1.3.1. Monitoring Results
- 1.3.2. Additional Monitoring by Permittee
- 1.3.3. Falsifying Results and/or Reports
- 1.3.4. Monthly Report of Operation
- 1.3.5. Bypass and Overflow Reporting
- 1.3.5.1. Report Requirements
- 1.3.5.2. Anticipated Bypass Notification
- 1.3.6. Reporting Less Than Detection
- 1.4. COMPLIANCE WITH SECTION 208
- 1.5. REOPENER CLAUSE
- 2.0. GENERAL PERMIT REQUIREMENTS
- 2.1. GENERAL PROVISIONS
- 2.1.1. Duty to Reapply
- 2.1.2. Right of Entry

NPDES Permit

- 2.1.3. Availability of Reports
- 2.1.4. Proper Operation and Maintenance
- 2.1.5. Treatment Facility Failure (Industrial Sources)
- 2.1.6. Property Rights
- 2.1.7. Severability
- 2.1.8. Other Information
- 2.2. CHANGES AFFECTING THE PERMIT
- 2.2.1. Planned Changes
- .
- .
- .
- **APPENDIX 1**
- **APPENDIX 2**
- **APPENDIX 3**
- **APPENDIX 4**

NPDES Permit

1.1 NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS

Total Suspended Solids (TSS)	<=	34	mg/L	Composite	Three Per Week	Daily Maximum
pH	>=	6	SU	Grab	Five Per Week	Minimum
pH	<=	9	SU	Grab	Five Per Week	Maximum

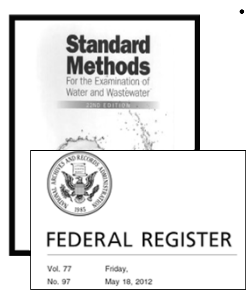
Description : External Outfall, Number : 001, Monitoring : Effluent Gross, Season : Summer

Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Base
CBOD, 5-day, 20 C	<=	11.2	mg/L	Composite	Three Per Week	Monthly Average
CBOD, 5-day, 20 C	<=	20	mg/L	Composite	Three Per Week	Daily Maximum
CBOD, 5-day, 20 C	<=	15	mg/L	Composite	Three Per Week	Weekly Average
CBOD, 5-day, 20 C	<=	375	lb/d	Composite	Three Per Week	Monthly Average
CBOD, 5-day, 20 C	<=	500	lb/d	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	52.5	lb/d	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	2	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	1	mg/L	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	1.6	mg/L	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	35	lb/d	Composite	Three Per Week	Monthly Average
Nitrogen, total (as N)	Report	-	mg/L	Composite	Twice Per Month	Daily Maximum
Nitrogen, total (as N)	<=	4	mg/L	Composite	Twice Per Month	Monthly Average
Phosphorus, total (as P)	Report	-	mg/L	Composite	Twice Per Month	Daily Maximum
Phosphorus, total (as P)	<=	3	mg/L	Composite	Twice Per Month	Monthly Average

Description : External Outfall, Number : 001, Monitoring : Effluent Gross, Season : Winter

Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Base
CBOD, 5-day, 20 C	<=	18.7	mg/L	Composite	Three Per Week	Monthly Average
CBOD, 5-day, 20 C	<=	750	lb/d	Composite	Three Per Week	Weekly Average
CBOD, 5-day, 20 C	<=	625	lb/d	Composite	Three Per Week	Monthly Average
CBOD, 5-day, 20 C	<=	22.5	mg/L	Composite	Three Per Week	Weekly Average
CBOD, 5-day, 20 C	<=	30	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	1.9	mg/L	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	65	lb/d	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	4	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	95	lb/d	Composite	Three Per Week	Weekly Average

Tools for Success



- When you are ready to perform tests, refer 40CFR part 136 for specific methods. Most can be found in Standard Methods for the Examination of Water and Wastewater. The 22nd edition has the current quality control information.

Tools for Success

- 40CFR136 - (NPDES Permit 1.2.3. Test Procedures)
  - **http://www.gpo.gov/fdsys/pkg/FR-2012-05-18/pdf/2012-10210.pdf**
    The **revised MUR (method update rule)** was signed by the Administrator on Dec. 15 2016. It will be published in Code of Federal Regulation very soon. The MDL is only recalculated every year
    - MDL values are checked once per quarter **https://www.epa.gov/cwa-methods/method-detection-limit-frequent-questions#main-content**
  - **Table Ia (bacteriological analyses)**
  - **Table Ib (inorganic analyses)**
  - **…**
  - **Table II (bottle, preservation, holding times)**

Tools for Success

- **40CFR136.7 Quality Assurance and Quality Control (MUR - method update rule)**

§ 136.7 Quality assurance and quality control.

The permittee/laboratory shall use suitable QA/QC procedures when conducting compliance analyses with any Part 136 chemical method or an alternative method specified by the permitting authority. These QA/QC procedures are generally included in the analytical method or may be part of the methods compendium for approved Part 136 methods from a consensus organization. For example, Standard Methods contains QA/QC procedures in the Part 1000 section of the Standard Methods Compendium. The permittee/laboratory shall follow these QA/QC procedures, as described in the method or methods compendium. If the method lacks QA/QC procedures, the permittee/laboratory has the following options to comply with the QA/QC requirements:

(a) Refer to and follow the QA/QC published in the "equivalent" EPA method for that parameter that has such QA/QC procedures;

(b) Refer to the appropriate QA/QC section(s) of an approved Part 136 method from a consensus organization compendium;

(c)(1) Incorporate the following twelve quality control elements, where applicable, into the laboratory's documented standard operating procedure (SOP) for performing compliance analyses when using an approved Part 136 method when the method lacks such QA/QC procedures. One or more of the twelve QC elements may not apply to a given method and may be omitted if a written rationale is provided indicating why the element(s) is/are inappropriate for a specific method.

(i) Demonstration of Capability (DOC);
(ii) Method Detection Limit (MDL);
(iii) Laboratory reagent blank (LRB), also referred to as method blank (MB);
(iv) Laboratory fortified blank (LFB), also referred to as a spiked blank, or laboratory control sample (LCS);
(v) Matrix spike (MS) and matrix spike duplicate (MSD), or laboratory fortified matrix (LFM) and LFM duplicate, may be used for suspected matrix interference problems to assess precision;
(vi) Internal standards (for GC/MS analyses), surrogate standards (for organic analysis) or tracers (for radiochemistry);
(vii) Calibration (initial and continuing), also referred to as initial calibration verification (ICV) and continuing calibration verification (CCV);
(viii) Control charts (or other trend analyses of quality control results);
(ix) Corrective action (root cause analysis);
(x) QC acceptance criteria;
(xi) Definitions of preparation and analytical batches that may drive QC frequencies; and
(xii) Minimum frequency for conducting all QC elements.

(2) These twelve quality control elements must be clearly documented in the written standard operating procedure for each analytical method not containing QA/QC procedures, where applicable.

Quick Reference for Method Update Rule

12 Steps of Lab Quality Assurance

Parameter	Method	DOC	MDL	Method Blank	LFB	LFM / LFMD	Dup	ICV / CCV	Control Charts	Corrective Action	QC Acceptance	Batch Size	*QC Frequency
Ammonia	SM4500-NH3 D - 2011	X	X	X	X	X		X, Calibrate meter daily	X	X	X	20	Depends on Permit
BOD₅ / CBOD₅	SM5210 B - 2011	X		X	X		X	X, Calibrate meter daily	X	X	X	20	Depends on Permit
Chlorine, TR	SM4500-Cl G - 2011	X	X	X	X		X	X, verify meter daily w Secondary Gel Standards	X	X	X	20	Depends on Permit
pH	SM4500-H+ B - 2011	X					X	X, Calibrate meter daily		X	X	20	Depends on Permit
Oxygen, dissolved	SM4500-O G - 2011	X					X	X, Calibrate meter daily & verify with air-saturated water		X	X	20	Depends on Permit
	Hach Method 10360 Luminescence Oct. Rev 1.2 2011	X					X	X, Calibrate meter daily & verify with air-saturated water		X	X	20	Depends on Permit
Phosphorus, total	SM4500-P B and E - 2011	X	X	X	X	X		X, verify meter	X	X	X	20	Depends on Permit
TSS	SM2540 D - 2011	X	*	X	X		10%	X, verify scale daily		X	X	10/20	Depends on Permit
Sett. Solids	SM2540 F - 2011						X			X		20	Depends on Permit
Temperature	SM2550 B - 2010							X, verify against NIST thermometer		X			Annually

DOC – Demonstration of Capability
- Each analyst should have a file kept from where they have calibrated and analyzed 4 standards to demonstrate they can accurately run this test
- Documentation (signed form) that analyst has read and understands all appropriate SOPs and Methods
- All analysts must do this once a year (as of Dec 15, 2016, 40CFR136)

MDL – Method Detection Limit
- Annually run at least 7 samples at low levels
- Quarterly run 2 MDL spikes. (as of Dec 15, 2016, 40CFR136) See MDL guidance document.

Method Blank – aka Laboratory Reagent Blank (LRB)
- Analyze distilled/deionized water as a sample
- * All routine method blanks should be included in the MDL blanks population (as of Dec 15, 2016, 40CFR136)

LFB – Laboratory Fortified Blank
- Analyze a known standard

Tools for Success

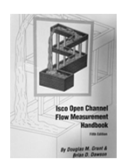
- **40CFR136.6 (Flexibility to Modify Methods)**
- **Hach ® EPA compliant methods (http://www.hach.com/epa)**
  - **Confirm method of analysis (WW or DW)**
  - **equivalent, acceptable or approved (EPA compliant)**
- **FTC website (https://tn.gov/environment/article/wr-ftc-waste-water-information)**
- **Standard Methods for Water and Wastewater Analyses (consensus body approved methods)**
- **State of TN, design criteria (Technical/Engineering Documents) http://www.tn.gov/environment/article/wr-wq-water-quality-reports-publications**

Tools for Success

- **Standard Operating Procedures (**NPDES Permit 1.2.3 Test Procedures; 40CFR136.7**)**
  - **Yearly review/signature**
  - **Update**
  - **training**
- **Review of log books** (NPDES Permit 1.2.3 Test Procedures; 1.2.4 Recording Results; 1.2.5. Records Retention)
  - **Instrument calibration (daily)**
  - **Temperature**
  - **Maintenance**
  - **Sampler**
  - **Standard preparation**
  - **Calibration**

Tools for Success

- **lab instruments - yearly maintenance check (or more frequently)** (NPDES Permit 1.2.4 Proper Operation and Maintenance) including thermometers and weights
- **flow measurement devices – yearly maintenance check** (NPDES Permit 1.2.1 Representative Sampling)



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Reliable sampling data are obtained by collecting samples

(NPDES Permit 1.2.1 Representative Sampling)

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


Operator with Improvised Sampling Device


Automated Samplers

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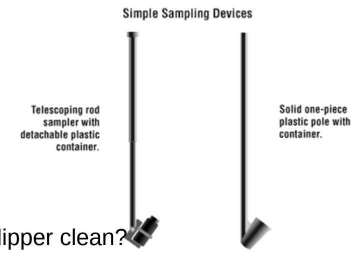
Samplers

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



- Is the dipper clean?

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Sample Types

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

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Grab Samples

- Single volume of water
- Representative of water quality at exact time and place of sampling (NPDES Permit 1.2.1 Representative 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

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DEFINITIONS AND ACRONYMS

- (NPDES Permit 4.1 Definitions)

- 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.

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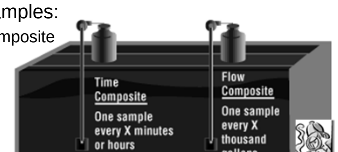
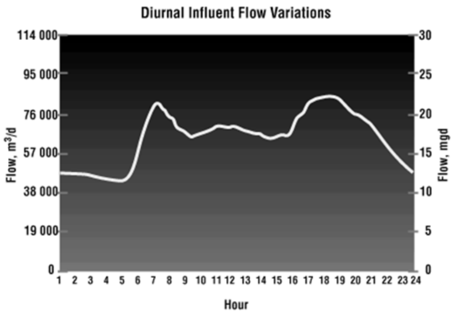
Composite Sample

- 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
- Types of composite samples:
  - Fixed volume or time composite
  - Flow proportioned.



Flow Variations



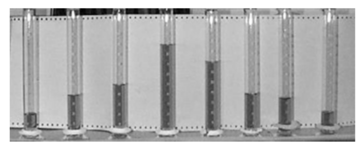
Example of Flow-Proportioned Sample Collection

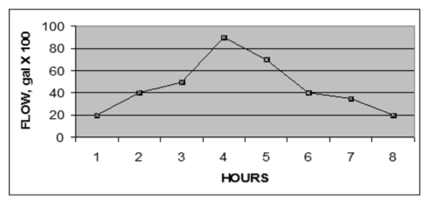
Time	Flow	Sample Volume
10:00 am	18 MGD	180 mL
10:00 pm	12 MGD	120 mL

Composite Sample

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

  - Note: The permittee shall achieve 85% removal of $CBOD_5$ and TSS on a monthly average basis. (NPDES Permit 1.1 Numeric and Narrative Effluent Limitations - note following the parameter table)





WEA's PT Certification class

Preventative sampler maintenance

- Pump tubing replacement
- Suction line replacement
- Container replacement
- Diagnostic routines
- Volume calibration
- Desiccant replacement

Sample Volume and Storage

- Volume depends on test requirements
  40CFR136 - (NPDES Permit 1.2.3. Test Procedures)

- 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

This is a summary of the containers, sample volume, preservation and max holding time out of 40 CFR Part 136 Table II.

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	28 days.

NPDES Permit , Section 1.2.1

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. 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.

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

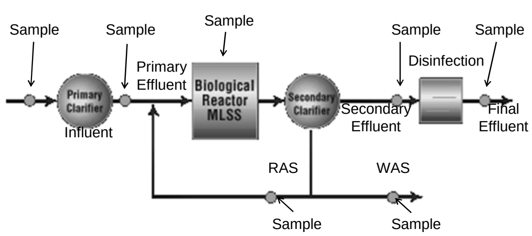
c. The dissolved oxygen can drop in the outfall line; therefore, D.O. measurements are required at the discharge end of outfall lines greater than one mile long. Systems with outfall lines less than one mile may measure dissolved oxygen as the wastewater leaves the treatment facility. For systems with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

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

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

Sample Points

(NPDES Permit 1.2.1 Representative Sampling



Sample Points

Virtual Wastewater

http://virtualwastewater.hach.com/

Process Monitoring and Control Tests

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

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 ± 1º C for 5 days ± 6 hours 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
- 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.

Biochemical Oxygen Demand

REQUIREMENTS FOR VALID BOD_5 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

Biochemical Oxygen Demand

- Typically a composite sample
- Not useful for process control
- Need minimum of 3 dilutions and run a duplicate every 20th sample
  - Influent and effluent are considered separate samples, so if you run BOD 5/week, that would be considered as 20 samples within that week.

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

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

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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Seeding Calculations

Bottle	**DO_I**	**DO_F**		**Depletion**		**mL seed**		**DO depletion per mL seed**
Seed 1	**8.5**	**0.3**	**X**	**8.2**		**30**		**----**
Seed 2	**8.4**	**1.6**		**6.8**	**÷**	**20**	**=**	**0.34**
Seed 3	**8.4**	**4.3**		**4.1**	**÷**	**10**	**=**	**0.41**

Average the seed controls that meet depletion criteria (0.34 + 0.41) ÷ 2 = 0.375 mg/L DO depletion per mL seed

So, 2 mL undiluted seed is added to each sample bottle. 0.375 X 2 = 0.75 mg/L

Therefore, 0.75 mg/L is subtracted from the depletion of each BOD depletion to obtain BOD result.

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BOD Calculation

- Now take the previous example and apply the seed control correction.
- 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
  - Seed added = 2 mL
  - Seed factor = 0.375 (seed previous slide for seed controls)

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BOD Calculation

- Initial DO = 8.1 mg/L
- Final DO = 4.0 mg/L
- Sample Volume = 12 mL
- BOD_5, mg/L = $\frac{D_1 - D_2}{P}$
- Where P = % sample
  - 12/300 = 0.04
- Seed factor
  - 0.375 x 2 mL = 0.75
- BOD_5, mg/L = $\frac{8.1 - 4.0 - 0.75}{0.02}$

  = 83 mg/L

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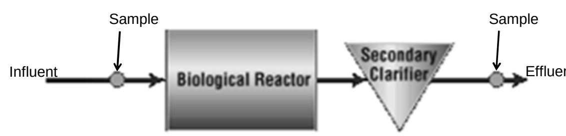
BOD Sampling Locations



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Chemical Oxygen Demand

- The COD test is used for more rapid assessment of organic strength. Also, a means of rapidly estimating the BOD of a sample
- This test differs from the BOD test in that it chemically oxidizes almost all the organic compounds that can be oxidized.

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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.

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Total 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 TSS test measures the amount of solids in suspension that can be removed by filtration
  - The sample is filtered through a pre-weighed filter paper, dried in an oven at 103-105ºC, cooled in desiccator, weighed. Drying cycle must be repeated.

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Suspended Solids

Technician Performing SS Test

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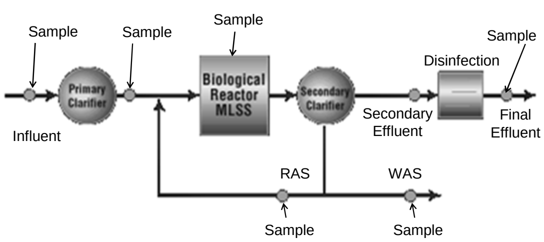
Suspended Solids Sample Points



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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**

1 mg = 0.001 g or 1 g = 1000 mg
1 mL = 0.001 L or 1 L = 1000 mL
Milli means 1000

- SS, **mg/L** = (A – B)g * 1000 mg * 1000 mL
- g * L * mL of sample
- = (A - B) * 1,000,000

- Where A = final weight of pan, filter and residue in grams
  - B = weight of prepared filter and pan, in grams

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MLSS Calculation

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

1 mg = 0.001 g
1 mL = 0.001 L
Milli means 1000

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

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

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

$$= 3868\text{ mg/L}$$

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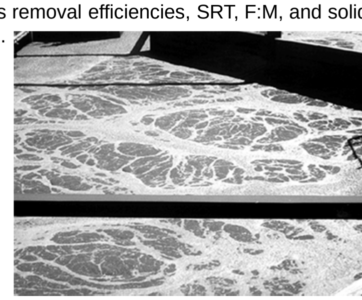
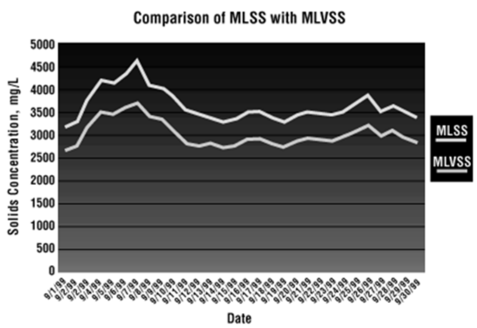
Suspended Solids

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

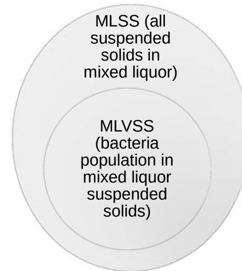


MLSS vs. MLVSS



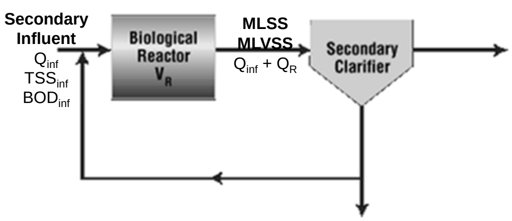
MLVSS

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



F:M Ratio

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



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
  - $\text{Target F:MCOD} = \frac{\text{Target F:}M_{BOD}}{\text{BOD:COD}}$

F:M Example

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

- $F:M = \frac{(BODinf, mg/L)(Qinf, MGD)(8.34 \text{ lbs/gal})}{(MLVSS, mg/L)(\text{Aerator Vol, MG})(8.34 \text{ lbs/gal})}$
- $F:M = \frac{(145 \text{ mg/L})(15 \text{ MGD})(8.34 \text{ lbs/gal})}{(2500 \text{ mg/L})(2 \text{ MG})(8.34 \text{ lbs/gal})} = 0.44$
- **https://www.dep.state.pa.us/dep/deputate/waterops/redesign/calculators/FMDetails.htm**

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

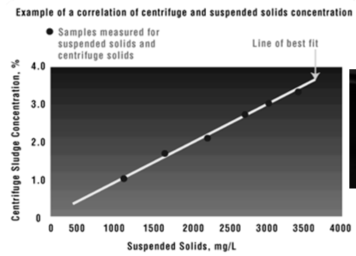
- Excess sludge to waste:
  - Excess M to waste (Microorganisms) = $\frac{\text{Current M – F (Food)}}{\text{F:M Target}}$

F:M Ratio

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

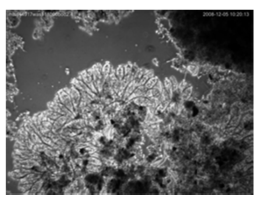
Centrifuge Spin Test

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



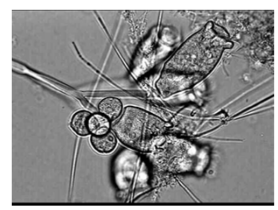
Microscopic Examination

- Microscopic examination of the mixed liquor provides valuable information.



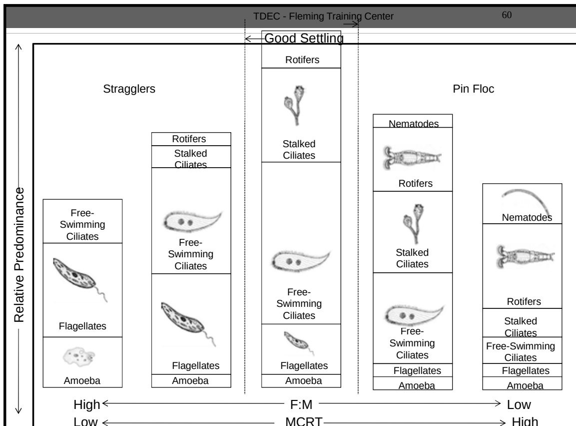
Microscopic Examination

- Microscopic examinations should be performed immediately after sample collection.



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



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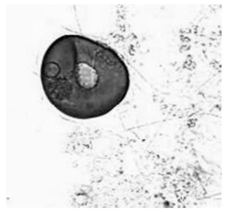
Sludge Age Indicator

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



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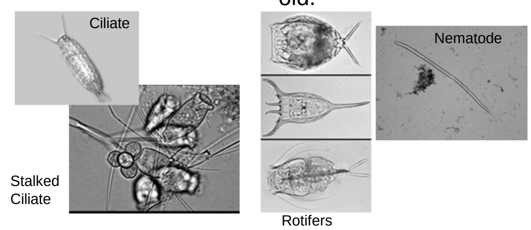
Sludge Age Indicator

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



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OUR

- The oxygen uptake rate (OUR) quickly indicates biological activity.
- The microorganisms are consistently using DO to oxidize organic matter for new cell growth and energy
- The rate of oxygen used varies considerably with the age of the solids and the incoming organic load
- If there is excess food for the microorganisms, they will reproduce quickly
- As they do, they use up oxygen at a high rate, this results in a high OUR
- As the food supply is used up or the microorganisms are affected by a toxic condition, the growth rate decreases, therefore the OUR would be low

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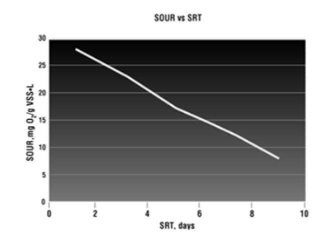
OUR

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



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OUR

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

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

  = $\frac{6.1 – 1.4}{4.5 \text{ min}}$ X 60 min/hr

  = 62.7 mg/L/hr

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SOUR

- Specific Oxygen Uptake Rate in Biosolids (SOUR) –

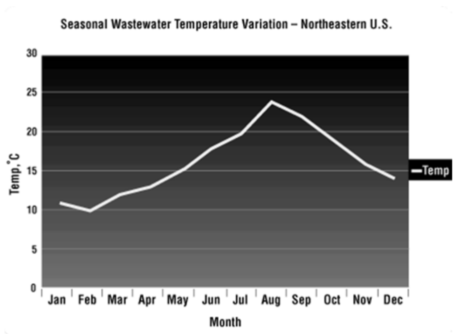
  Microorganisms in sewage sludge use oxygen as they consume organic matter. The level of microbial activity in sludge is indicated by the microorganisms' oxygen uptake rate.

  High oxygen uptake rates indicate high microbial activity and high organic matter content;

  low oxygen uptake rates indicate low microbial activity and low organic matter content.

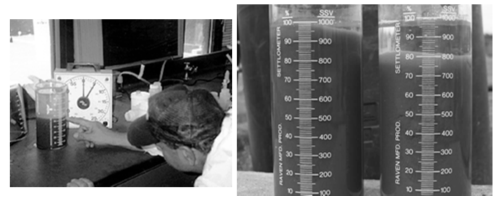
- SOUR, mg O_2/hr/gm = $\frac{\text{(OUR, mg/L/hr)(1000 mg/gram)}}{\text{MLSS, mg/L}}$

Temperature



Thirty-Minute Settleometer

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

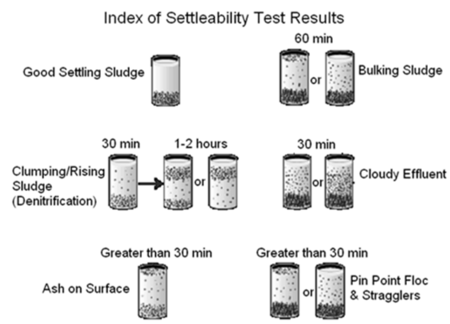


Thirty-Minute Settleometer

https://www.youtube.com/watch?v=GTLKoGGo0dM

- To produce a good quality effluent, the activated sludge must settle well in the final clarifiers.
- The purpose of the 30-min test is to indicate the solids – liquid separation capability of the sludge that is going to the secondary clarifiers
- To performs this test, take a 2-L sample of well-mixed mixed liquor and pour it into the settleometer as soon as possible after taking sample
- Allow it to settle for 30 minutes and record the level of the sludge blanket
- Note the color and clarity of the liquid and if there are any gas bubbles
- SVI can be determined with this number along with your MLSS, mg/L

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 mg/g**.

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

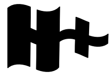
Thirty-Minute Settleometer

- The proper SVI range for your plant is determined at the time your final effluent is in the best condition regarding solids and BOD removals and clarity.
  - Preferable range is 50-150 mL/gram

  http://waterfacts.net/Formulas/SVI/svi.html

- The chart is mostly used to view the slope of the settling rate.
- The higher the slope, the older the sludge.
- The flatter the slope, the younger the slope, **or** there is bulking.

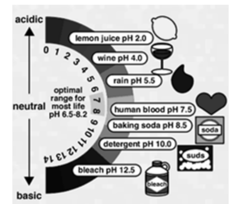
pH



- 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 – Automatic temperature compensator (ATC)
- If the pH of the mixed liquor varies too far from neutral (pH=7.0), microorganisms may become inhibited or may start to die.

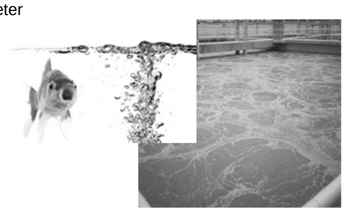
pH

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



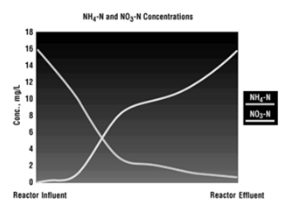
Dissolved Oxygen

- 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



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



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

Chlorine Residual

- Approved Methods:
  - Amperometric titration (low level)
  - Iodometric titration – starch endpoint
  - Back titration
  - DPD - FAS
  - Spectrophotometric, DPD
  - Electrode
- NOTE: DPD color **comparator** is **NOT** an **approved** method

Chlorine Residual

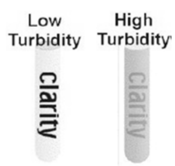
- DPD colorimetric method most commonly used
  - Match color of sample to a standard
  - ***Swirl sample for 20 seconds*** to mix
  - Wait ***three minutes*** (Hach method)
  - Place it into colorimeter and take reading

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 $CaCO_3$

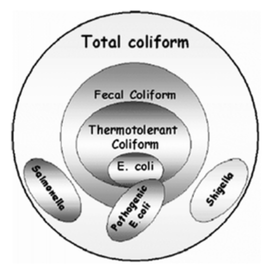
Turbidity

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



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

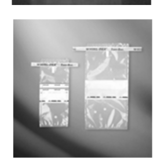


Coliform Bacteria

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

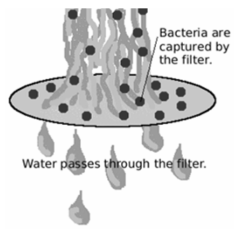
Sampling

- 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.

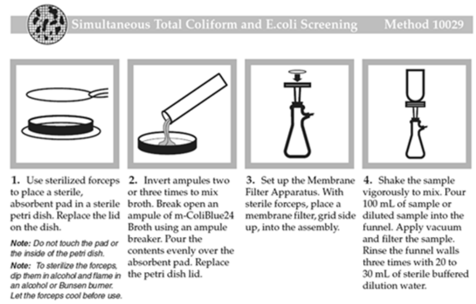


Approved Methods

- Coliform (fecal)
  - Number per 100 mL
    - Membrane filtration (SM9222 D-1997 2006)
- E. coli
  - Number per 100 mL
    - Membrane filtration
      - m-ColiBlue24®
      - Modified mTEC agar (EPA Method 1603)
    - Multiple tub/multiple well (Colilert®), (SM9223 B-2004)



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.

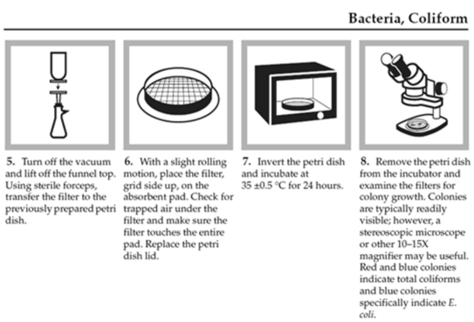
2. Invert ampules two or three times to mix broth. Break open an ampule of m-ColiBlue24 Broth using an ampule breaker. Pour the contents evenly over the absorbent pad. Replace the petri dish lid.

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

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

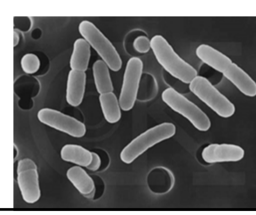
Membrane Filtration Equipment

- 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

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

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 ± 2 hrs.
- Fecal coliform density reported as number of colonies per 100 mL of sample.
  - Fecal coliforms appear blue.
  - Colonies = colony forming unit = cfu
- NPDES permit limit: monthly average of 200 cfu/100 mL; daily maximum of 1000 cfu/100 mL.
- 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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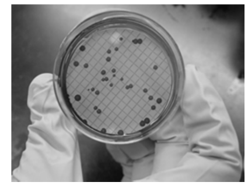
Fecal Coliform

- Maximum hold time is 8 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.
- Visually determine colony counts on membrane filters.
- Verify using 10-15 X binocular wide-field microscope.



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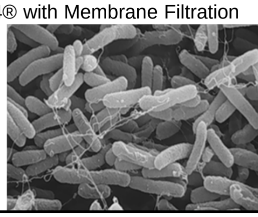
ESCHERICHIA COLI (E.COLI)

m-ColiBlue24® with Membrane Filtration



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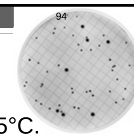

E. coli m-ColiBlue24®

- Incubation time is 24 ± 2 hrs at 35 ± 0.5°C.
- *E. coli* density reported as number of colonies per 100 mL of sample.
- *E. coli* appear blue
- NPDES permit limit typically has a monthly average of 126 cfu/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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E. coli m-ColiBlue24®

- Maximum hold time is 8 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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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*
- *Escherichia coli* will produce a **blue colony**
  - *E. coli* O157:H7 will not produce a blue colony, but will grow as a red colony

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

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

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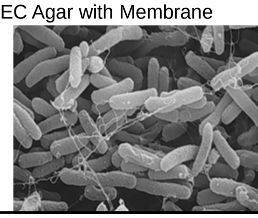
ESCHERICHIA COLI (E.COLI)

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
- 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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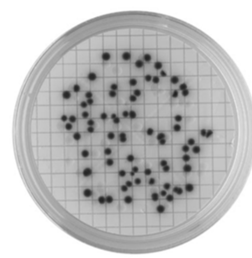
Method 1603

- 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

- 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

- 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
- 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

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Method 1603

- 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 35ºC ± 0.5ºC.
  - Absence of growth indicates sterility of the filter
  - Run daily
- 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 for 24 ± 2 hours at 35ºC ± 0.5ºC
  - Absence of growth indicates sterility of the buffer and filtration assembly
  - Run daily

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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.

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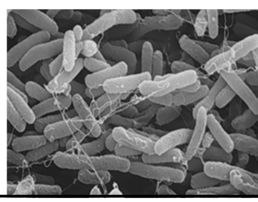
ESCHERICHIA COLI (E.COLI)

Colilert



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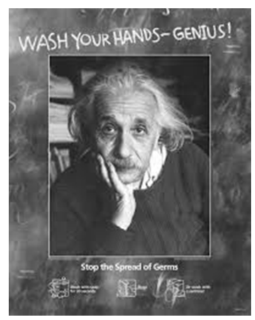
Colilert® & Colilert-18® MPN Method



Collect exactly 100 mL of sample in **sterile** bottle provided.

(Another **sterile** bottle may be used to collect the sample, then sample poured into the sterile IDEXX bottle.)

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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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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

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All Bacteriological Checks

- Temperatures are documented twice daily at least 4 hours apart, when samples are being incubated
- Thermometers are certified at least annually against NIST thermometers
- Reagents for storage requirements and expiration dates
- E. coli colonies identified correctly
- Calculations are correct
- Holding Times are met
  - Sample collection
  - Analysis start
  - End times

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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

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

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

  - **Remember to count 0 as a 1**.

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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

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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

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Geometric Mean – Alternative (TI 60)

- Geometric Mean – $(X_1)(X_2)(X_3)\ldots(X_n)^{1/n}$
- Step 1: 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 2: Punch the INV y^x button, then type in the number of numbers that you multiplied together then punch =.
- 6000 INV y^x 4 = 8.8011

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Geometric Mean

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

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Geometric Mean

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

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Sampling and Analysis Plan

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

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40 CFR 136 Method Update Rule

- You Have Heard it All Before
  - More Rules
  - More Testing
  - More Paperwork
  - More Cost
- But everything we do is regulated.

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2012 Update of 136 Updated 2016

Federal Register May 18, 2012

- Standard Methods approved by date not Edition
- Section 136.7 Quality Assurance and Quality Control.

Approved Dec 15, 2016, updated MUR soon to be promulgated

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Section 136.7 Lab QA

- "…suitable QA/QC procedures…"
- "…QA/QC procedures are generally included in the method or may be found in the methods compendium…" (Ex. Standard Methods)
- "The permittee/lab shall follow these QA/QC procedures, as described in the method or methods compendium." (Ex. Standard Methods)
- "If the method lacks QA/QC…"

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Three QA Options

- A. …follow equivalent EPA procedures
- B. Refer to QA/QC in consensus organization compendium. (Follow Standard Methods) Didn't we have that on the previous slide?
- **C. Follow the 12 Steps where applicable.**
- **The 13th step requires an SOP (standard operating procedures)**

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12 Quality Control Elements

1. DOC – demonstration of capability
2. MDL – method detection level
3. LRB/MB – method blank
4. LFB – laboratory fortified blank (standard)
5. LFM/LFMD – laboratory fortified matrix/duplicate (spike)
6. Internal standards, surrogate standards or tracer – ***only applies to organic analysis and radiochemistry***
7. Calibration- initial and continuing
8. Control charts or other trend analysis
9. Corrective action – root cause analysis
10. QC acceptance criteria
11. Definition of a batch (preparation and analytical)
12. Minimum frequency for conducting all QC elements
13. Unwritten 13th Step – SOP – Standard Operating Procedures need to be written and followed for all lab sampling and analyses

Not all of these items apply to all tests, there are many exceptions!

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Can you defend what you do?

- How do you interpret your Permit language or the Rule?
- Can you defend that interpretation, will a judge or jury support you?
- What do Regulators say and what is written?
  - Is it clear?
  - Don't be afraid to ask Why?
  - Don't be afraid to ask for directives in writing.

What You Are Already Doing

- Most Labs are doing lots of QA/QC stuff – especially contract labs
- Write down what you do….SOP
- Summarize QC Data
  - Table Form
  - Average, Max, Min.
  - Control Charts

Demonstration of Capability

- DOC once for each analyst
- Standard Methods 1020.B.1
  - As a minimum, include a reagent blank and at least 4 LFBs at a concentration between 10 times the MDL and the midpoint of a calibration curve.
  - Something to keep along with these records is a signed form (documentation) that analyst has read and understands all appropriate SOPs and Methods.
- What tests does this apply to?
  - Ammonia, BOD/cBOD, Chlorine, pH, DO, Total Phosphorus, TSS
- How often?
  - Once for each analyst.
    - Recommended yearly for backup analyst who does not perform tests frequently
    - EPA highly recommends running every 2-3 years for every analyst
  - Each analyst should have a file kept on their training within and for the lab.
  - Have you run your DMRQA's or other standards in the past? These no longer count! ☺

Demonstration of Capability

- **2014 Update**
  - **DMRQA's were removed as acceptable DOC**
    - **Analyst have had a year, there should be at least 4 standards that have been analyzed and within limits to demonstrate capability.**

Method Detection Level

- MDL
- Standard Methods 1020.B.4
  - As a starting point for selecting the concentration to use when determining the MDL, us an estimate of five times the estimated true detection level
  - Initial MDL - Ideally, prepare and analyze at least 7 portions of this solution over a 3-day period to ensure the MDL determination is more representative of routine measurements performed in the laboratory – use multiple analysts and instruments.
- What tests does this apply to?
  - Ammonia, Chlorine and Total Phosphorus
- How often?
  - Annually, but at least every 13 months (updated MUR, Dec 2016)
  - Ongoing data collection and MDL validation is now required quarterly (MDL guidance coming soon)

What the heck IS an MDL study?

- It is a calculation that statistically gives the lowest concentration that a lab/facility can "see", that is detect an analyte
- Not practical for many analyses
- It is a bit tricky the first time, but KEEP RECORDS so next year it will be a breeze.
- Fresh samples prepared daily are preferred and it is recommended that samples are run over 3 days to give a more accurate account of how samples are run.

How MDL Studies are Performed

- Make seven very low level blank spikes (can be lower than the lowest point on your curve)
- Analyze all seven over several days and calculate the standard deviation
- Multiply the standard deviation by the "student t" for 7 values (3.14)
- You cannot "cherry pick" your results, they must be 7 samples in a row

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MDL Calculations

- The result is the MDL (method detection level)
- ~~The MDL must be greater than 1/10 the concentration of each spike~~
  - ~~Example: if the spike was 3, the MDL cannot be lower than 0.3 (3 divided by 10)~~ No longer an issue (Dec, 2016)
- Use the same spike concentration unless the acceptance criteria is not met for ongoing MDL verification. (40CFR136, Appendix B; see MDL guidance for details)
- Quarterly MDL spikes and blanks now used to validate MDL (see MDL guidance document for specific information)

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Laboratory Reagent Blank

- LRB
- Also known as Method Blank
- Standard Methods 1020.B.5
  - A reagent blank (method blank) consists of reagent water and all reagents that normally are in contact with a sample during the entire analytical procedure (distillation, incubation, etc.)
- What tests does this apply to?
  - Ammonia, BOD/cBOD, Chlorine, Total Phosphorus and TSS
- How often?
  - Depends on method QA/QC

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Laboratory Fortified Blank

- LFB
- Standard Methods 1020.B.6
  - A laboratory-fortified blank is a reagent water sample to which a known concentration of the analyte of interest has been added
  - Sample batch = 5% basis = 1 every 20 samples
    - At least once a month
  - Use an added concentration of at least 10 times the MDL, or less than or equal to the midpoint of the calibration curve
- What tests does this apply to?
  - Ammonia, BOD/cBOD, Chlorine, Total Phosphorus, TSS
- How often?
- For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria:
  - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
  - If a permit stated 5 analyses per week, we would suggest twice a month.
  - Once per month would be the minimum requirement.

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Laboratory Fortified Matrix and Duplicate

- LFM/LFMD
- Also known as a spike and spike dup
- Standard Methods 1020.B.7
  - A laboratory matrix (LFM) is an additional portion of a sample to which a known amount of the analyte of interest is added before sample preparation
  - The LFM is used to evaluate analyte recovery in a sample
  - Sample batch = 5% basis = 1 every 20 samples
    - At least once a month
  - Add a concentration less than or equal to the midpoint of the calibration curve
  - Preferably the same concentration as the LFB (laboratory fortified blank)
- Also called a Matrix Spike/Matrix Spike Duplicate (MS/MSD)
- Shows if there are interferences in the effluent matrix
- What tests does this apply to?
  - Ammonia and Total Phosphorus
- How often?
- For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria:
  - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
  - If a permit stated 5 analyses per week, we would suggest twice a month.
  - Once per month would be the minimum requirement.

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Laboratory Fortified Matrix and Duplicate

- Also called a Matrix Spike/Matrix Spike Duplicate (MS/MSD)
  - Calculate RPD between Spike and Spike Dup
- Shows if there are interferences in the effluent matrix
- ~~**2014 Update – Spike volume should be less than 1% of the volume.**~~
  - ~~**Example: spike with 1 mL of 1000 mg/L into 100 mL sample will equal a 10 mg/L increase in ammonia concentration.**~~

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Duplicate

- Not a part of the 12 Steps of QA, an addition from the State of TN
- Standard Methods 1020.B.8
  - As a minimum, include one duplicate sample with each sample set or on a 5% basis
- Standard Methods 1020.B.12
  - Calculate the RPD (relative percent difference)
  - Equal to or less than 20% RPD
- What tests does this apply to?
  - BOD/CBOD, chlorine, pH, DO, TSS and Settleable Solids
- How often?
  - For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria: (10% would be once every 10 samples for TSS)
    - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
    - If a permit stated 5 analyses per week, we would suggest twice a month.
    - Once per month would be the minimum requirement.

Initial Calibration Verification & Continuing Calibration Verification

- ICV
  - Standard Methods 1020.B.11.b
    - Perform initial calibration using at least three concentrations of standards for linear curves
  - Calibrate meter (DO, pH or ISE) or verify scale, colorimeter/spectrophotometer and thermometer
- CCV
  - Standard Methods 1020.B.11.c
    - Analysts periodically use a calibration standard to confirm that the instrument performance has not changed significantly since initial calibration.
    - Verify calibration by analyzing one standard at a concentration near or at the mid-point of the calibration range.
  - Verify the calibration (especially if preset by manufacturer) at beginning of day, after every 10 readings and at the end of the batch
  - **Daily**

Control Charts

- Accuracy Control Charts
- Standard Methods 1020 B.13.a
  - The accuracy chart for QC samples (e.g., reagent blanks, LFBs, calibration check standards and LFMs) is constructed from the average and standard deviation of measurements.
  - The accuracy chart includes upper and lower warning levels (WL) and upper and lower control levels (CL).
  - Common practice is to use ±2*s* and ±3*s* limits for the WL and CL, respectively, where *s* represents standard deviation.
- Precision Control Charts
- Standard Methods 1020 B.13.b
  - The precision chart also is constructed on the average and standard deviation of a specified number of measurements (e.g., %RSD [relative standard deviation] or RPD) for a replicate or duplicate analyses of the analyte of interest.

Control Charts

- **2014 Update** - Create and maintain control charts if you have 20-30 data points within 90 days.
  - If you do not meet the above criteria, follow QC Acceptance Criteria below.
    - Blanks < MDL
    - LFB ± 15%
    - ICV/CCV ± 10%
    - LFM/LFMD ± 20%
    - RPD < 20%
    - Reporting limit = MDL

Corrective Action

- Standard Methods 1020 B.15
  - QC data that are outside the acceptance limits or exhibit a trend are evidence of unacceptable error in the analytical process.
  - Take corrective action promptly to determine and eliminate the source of error.
  - Do not report data until the cause of the problem is identified and either corrected or qualified (see Table 1020:II)
- The corrective action plan needs to be in your SOP for each method on what to do if your QC tests fail or are out of range
- If you have a “boo boo”, write down how you fixed it
- Any issues should be recorded and a sentence on how it can be prevented, if possible, in the future
- Common problems and their corrections should be covered in your Standard Operating Procedures (SOP)
  - If you see things frequently, you can give them qualifiers that are noted in your SOP

QC Acceptance

- Have in SOP for each method the acceptance ranges for standards, duplicates, spikes, etc. and make sure they match the method requirements.
- If not mentioned in method, these are the accepted criteria for QC:
  - Blank < reporting limit
  - LFB ± 15%
  - MS/MSD ± 20%
  - ICV/CCV ± 10%
  - RPD ± 20%

Batch Size & QC Frequency

- Each “Batch” could be daily, every 10 samples or every 20 samples.
- Check method
- If you sample only once a month, need to run QC each time.
- QC Frequency is usually lumped in with the definition of a “batch” and should be in the SOP of some kind

Standard Operating Procedure

- Here's that "13th Step", your SOP
- All procedures must be documented in some type of SOP
- It can be very simple but must provide the information necessary for someone who is not familiar with the test to perform it
  - Step by step instructions on how and where to collect the samples and then how to run the test.
- It must include the QC Acceptance Criteria, the definition of a "Batch" and the minimum frequency of QC checks

Ammonia SM4500-NH_3 D -1997 2011

- Standard Methods
  - 4500-NH3 A.1 – In general, direct manual determination of low concentrations of ammonia is confined to drinking waters, clean surface or groundwater and good-quality nitrified wastewater effluent.
  - 4500-NH3 D.1.b. – Sample distillation is unnecessary.
- Tennessee recommends that one sample is run yearly to compare the distilled and undistilled results and that the results are within 20% of each other.
  - Note – if distilled sample and undistilled sample are below detection limit, you cannot calculate the percent difference.

Ammonia SM4500-NH_3 D -1997

- DOC
- MDL
- LRB
- LFB
- LFM/LFMD
- ICAL/CCV
- Control Charts
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency

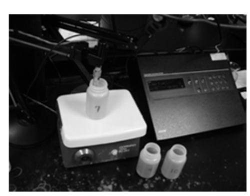
BOD_5/$cBOD_5$ SM5210 B – 2001 & Hach Method 10360

- DOC
- LRB
- LFB
- Dup
- ICAL/CCV
- Control Charts
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency

BOD5/cBOD5 SM5210 B – 2001 & Hach Method 10360

- Method Blanks
  - Real people language: analyze dilution water
    - Preferably one at the beginning and one at end
    - **2014 Update – Removed** – If reporting CBOD5 results, then also add one Nitrification Inhibitor (NI Blank)
  - Run on daily (day of)
  - Target value is less than 0.20 mg/L (preferably less than 0.10 mg/L)

pH SM4500-H^+ B – 2000 Electrometric Method



- DOC
- Dup
- ICAL/CCV
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency

TSS SM2540 D – 1997 Dried at 103-105ºC

- DOC
- LRB
- LFB
- Dup
- ICAL
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency

Temperature SM2550 B – 2000 Thermometric Measurement

- ICAL
  - Have thermometers verified **annually** by an NIST thermometer
- Corrective Action
- QC Frequency

Questions/Comments

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Part II

Environmental Protection Agency

40 CFR Parts 136, 260, et al.
Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Analysis and Sampling Procedures; Final Rule

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. <u>E</u>. <u>coli</u>, 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. <u>Salmonella</u>, number per gram dry weight[11]	MPN multiple tube	1682[23]			
Aquatic Toxicity:					
9. Toxicity, acute, fresh water organisms, LC_{50}, percent effluent	<u>Ceriodaphnia dubia</u> acute	2002.0[26]			
	<u>Daphnia puplex</u> and <u>Daphnia magna</u> acute	2021.0[26]			
	Fathead Minnow, <u>Pimephales promelas</u>, and Bannerfin shiner, <u>Cyprinella leedsi</u>, 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.

[12] Carbonaceous biochemical oxygen demand ($CBOD_5$) must not be confused with the traditional BOD_5 test method which measures "total BOD." The addition of the nitrification inhibitor is not a procedural option, but must be included to report the $CBOD_5$ parameter. A discharger whose permit requires reporting the traditional BOD_5 may not use a nitrification inhibitor in the procedure for reporting the results. Only when a discharger's permit specifically states $CBOD_5$ is required can the permittee report data using a nitrification inhibitor.

[13] OIC Chemical Oxygen Demand Method. 1978. Oceanography International Corporation.

[14] Method 8000, Chemical Oxygen Demand, Hach Handbook of Water Analysis, 1979. Hach Company.

[15] The back titration method will be used to resolve controversy.

[16] Orion Research Instruction Manual, Residual Chlorine Electrode Model 97–70. 1977. Orion Research Incorporated. The calibration graph for the Orion residual chlorine method must be derived using a reagent blank and three standard solutions, containing 0.2, 1.0, and 5.0 mL 0.00281 N potassium iodate/100 mL solution, respectively.

[17] Method 245.7, Mercury in Water by Cold Vapor Atomic Fluorescence Spectrometry, EPA–821–R–05–001. Revision 2.0, February 2005. US EPA. .

[18] National Council of the Paper Industry for Air and Stream Improvement (NCASI) Technical Bulletin 253, December 1971. .

[19] Method 8506, Biocinchoninate Method for Copper, Hach Handbook of Water Analysis. 1979. Hach Company.

[20] When using a method with block digestion, this treatment is not required.

[21] Industrial Method Number 378–75WA, Hydrogen ion (pH) Automated Electrode Method, Bran & Luebbe (Technicon) Autoanalyzer II. October 1976. Bran & Luebbe Analyzing Technologies.

[22] Method 8008, 1,10-Phenanthroline Method using FerroVer Iron Reagent for Water. 1980. Hach Company.

[23] Method 8034, Periodate Oxidation Method for Manganese, Hach Handbook of Wastewater Analysis. 1979. Hach Company.

[24] Methods for Analysis of Organic Substances in Water and Fluvial Sediments, Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 5, Chapter A3, (1972 Revised 1987) p. 14. 1987. USGS.

[25] Method 8507, Nitrogen, Nitrite-Low Range, Diazotization Method for Water and Wastewater. 1979. Hach Company.

[26] Just prior to distillation, adjust the sulfuric-acid-preserved sample to pH 4 with 1 + 9 NaOH.

[27] The colorimetric reaction must be conducted at a pH of 10.0±0.2.

[28] Addison, R.F., and R. G. Ackman. 1970. Direct Determination of Elemental Phosphorus by Gas–Liquid Chromatography, Journal of Chromatography, 47(3):421–426.

[29] Approved methods for the analysis of silver in industrial wastewaters at concentrations of 1 mg/L and above are inadequate where silver exists as an inorganic halide. Silver halides such as the bromide and chloride are relatively insoluble in reagents such as nitric acid but are readily soluble in an aqueous buffer of sodium thiosulfate and sodium hydroxide to pH of 12. Therefore, for levels of silver above 1 mg/L, 20 mL of sample should be diluted to 100 mL by adding 40 mL each of 2 M $Na_2S_2O_3$ and NaOH. Standards should be prepared in the same manner. For levels of silver below 1 mg/L the approved method is satisfactory.

[30] The use of EDTA decreases method sensitivity. Analysts may omit EDTA or replace with another suitable complexing reagent provided that all method specified quality control acceptance criteria are met.

[31] For samples known or suspected to contain high levels of silver (e.g., in excess of 4 mg/L), cyanogen iodide should be used to keep the silver in solution for analysis. Prepare a cyanogen iodide solution by adding 4.0 mL of concentrated NH_4OH, 6.5 g of

KCN, and 5.0 mL of a 1.0 N solution of I2 to 50 mL of reagent water in a volumetric flask and dilute to 100.0 mL. After digestion of the sample, adjust the pH of the digestate to >7 to prevent the formation of HCN under acidic conditions. Add 1 mL of the cyanogen iodide solution to the sample digestate and adjust the volume to 100 mL with reagent water (NOT acid). If cyanogen iodide is added to sample digestates, then silver standards must be prepared that contain cyanogen iodide as well. Prepare working standards by diluting a small volume of a silver stock solution with water and adjusting the pH>7 with NH_4OH. Add 1 mL of the cyanogen iodide solution and let stand 1 hour. Transfer to a 100-mL volumetric flask and dilute to volume with water.

[32] Water Temperature–Influential Factors, Field Measurement and Data Presentation," Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 1, Chapter D1. 1975. USGS.

[33] Method 8009, Zincon Method for Zinc, Hach Handbook of Water Analysis, 1979. Hach Company.

[34] Method AES0029, Direct Current Plasma (DCP) Optical Emission Spectrometric Method for Trace Elemental Analysis of Water and Wastes. 1986–Revised 1991. Thermo Jarrell Ash Corporation.

[35] In-Situ Method 1004-8-2009, Carbonaceous Biochemical Oxygen Demand (CBOD) Measurement by Optical Probe. 2009. In-Situ Incorporated.

[36] Microwave-assisted digestion may be employed for this metal, when analyzed by this methodology. Closed Vessel Microwave Digestion of Wastewater Samples for Determination of Metals. April 16, 1992. CEM Corporation

[37] When determining boron and silica, only plastic, PTFE, or quartz laboratory ware may be used from start until completion of analysis.

[38] Only use n-hexane (n-Hexane – 85% minimum purity, 99.0% min. saturated C6 isomers, residue less than 1 mg/L) extraction solvent when determining Oil and Grease parameters–Hexane Extractable Material (HEM), or Silica Gel Treated HEM (analogous to EPA Methods 1664 Rev. A and 1664 Rev. B). Use of other extraction solvents is prohibited.

[39] Method PAI-DK01, Nitrogen, Total Kjeldahl, Block Digestion, Steam Distillation, Titrimetric Detection. Revised December 22, 1994. OI Analytical.

[40] Method PAI–DK02, Nitrogen, Total Kjeldahl, Block Digestion, Steam Distillation, Colorimetric Detection. Revised December 22, 1994. OI Analytical.

[41] Method PAI–DK03, Nitrogen, Total Kjeldahl, Block Digestion, Automated FIA Gas Diffusion. Revised December 22, 1994. OI Analytical.

[42] Method 1664 Rev. B is the revised version of EPA Method 1664 Rev. A. US EPA. February 1999, Revision A. Method 1664, n-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated n-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry. EPA-821-R-98-002. US EPA. February 2010, Revision B. Method 1664, n-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated n-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry. EPA-821-R-10-001.

[43] Method 1631, Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry, EPA–821–R–02–019. Revision E. August 2002, US EPA. The application of clean techniques described in EPA's Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels, EPA–821–R–96–011,are recommended to preclude contamination at low-level, trace metal determinations.

[44] Method OIA–1677-09, Available Cyanide by Ligand Exchange and Flow Injection Analysis (FIA). 2010. OI Analytical.

[45] Open File Report 00–170, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory–Determination of Ammonium Plus Organic Nitrogen by a Kjeldahl Digestion Method and an Automated Photometric Finish that Includes Digest Cleanup by Gas Diffusion. 2000. USGS.

[46] Open File Report 93–449, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory–Determination of Chromium in Water by Graphite Furnace Atomic Absorption Spectrophotometry. 1993. USGS.

[47] Open File Report 97–198, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory–Determination of Molybdenum by Graphite Furnace Atomic Absorption Spectrophotometry. 1997.. USGS.

[48] Open File Report 92–146, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory–Determination of Total Phosphorus by Kjeldahl Digestion Method and an Automated Colorimetric Finish That Includes Dialysis. 1992. USGS.

[49] Open File Report 98–639. Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory–Determination of Arsenic and Selenium in Water and Sediment by Graphite Furnace-Atomic Absorption Spectrometry. 1999. USGS.

[50] Open File Report 98-165, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory–Determination of Elements in Whole-water Digests Using Inductively Coupled Plasma-Optical Emission Spectrometry and Inductively Coupled Plasma-Mass Spectrometry. 1998.. USGS.

[51] Open File Report 93–125, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory–Determination of Inorganic and Organic Constituents in Water and Fluvial Sediments. 1993.. USGS.

[52] Unless otherwise indicated, all EPA methods, excluding EPA Method 300.1-1, are published in US EPA. May 1994. Methods for the Determination of Metals in Environmental Samples, Supplement I, EPA/600/R–94/111; or US EPA. August 1993. Methods for the Determination of Inorganic Substances in Environmental Samples, EPA/600/R–93/100. EPA Method 300.1 is US EPA. Revision 1.0, 1997, including errata cover sheet April 27, 1999. Determination of Inorganic Ions in Drinking Water by Ion Chromatography.

[53] Styrene divinyl benzene beads (e.g., AMCO–AEPA–1 or equivalent) and stabilized formazin (e.g., Hach StablCal™ or equivalent) are acceptable substitutes for formazin.

[54] Method D6508, Test Method for Determination of Dissolved Inorganic Anions in Aqueous Matrices Using Capillary Ion Electrophoresis and Chromate Electrolyte. December 2000. Waters Corp.

[55] Kelada-01, Kelada Automated Test Methods for Total Cyanide, Acid Dissociable Cyanide, and Thiocyanate, EPA 821–B–01–009, Revision 1.2, August 2001. US EPA. Note: A 450–W UV lamp may be used in this method instead of the 550–W lamp specified if it provides performance within the quality control (QC) acceptance criteria of the method in a given instrument. Similarly, modified flow cell configurations and flow conditions may be used in the method, provided that the QC acceptance criteria are met.

[56] QuikChem Method 10–204–00–1–X, Digestion and Distillation of Total Cyanide in Drinking and Wastewaters using MICRO DIST and Determination of Cyanide by Flow Injection Analysis. Revision 2.2, March 2005. Lachat Instruments.

[57] When using sulfide removal test procedures described in EPA Method 335.4-1, reconstitute particulate that is filtered with the sample prior to distillation.

[58]U nless otherwise stated, if the language of this table specifies a sample digestion and/or distillation "followed by" analysis with a method, approved digestion and/or distillation are required prior to analysis.

[59] Samples analyzed for available cyanide using OI Analytical method OIA–1677-09 or ASTM method D6888–09 that contain particulate matter may be filtered only after the ligand exchange reagents have been added to the samples, because the ligand exchange process converts complexes containing available cyanide to free cyanide, which is not removed by filtration. Analysts are further cautioned to limit the time between the addition of the ligand exchange reagents and sample filtration to no more than 30 minutes to preclude settling of materials in samples.

[60] Analysts should be aware that pH optima and chromophore absorption maxima might differ when phenol is replaced by a substituted phenol as the color reagent in Berthelot Reaction ("phenol-hypochlorite reaction") colorimetric ammonium determination methods. For example when phenol is used as the color reagent, pH optimum and wavelength of maximum absorbance are about 11.5 and 635 nm, respectively--see, Patton, C.J. and S.R. Crouch. March 1977. Anal. Chem. 49:464-469. These reaction parameters increase to pH > 12.6 and 665 nm when salicylate is used as the color reagent--see, Krom, M.D. April 1980. The Analyst 105:305-316.

[61] If atomic absorption or ICP instrumentation is not available, the aluminon colorimetric method detailed in the 19th Edition of Standard Methods may be used. This method has poorer precision and bias than the methods of choice.

[62] Easy (1-Reagent) Nitrate Method, Revision November 12, 2011. Craig Chinchilla.

[63] Hach Method 10360, Luminescence Measurement of Dissolved Oxygen in Water and Wastewater and for Use in the Determination of BOD_5 and $cBOD_5$. Revision 1.2, October 2011. Hach Company. This method may be used to measure dissolved oxygen when performing the methods approved in Table IB for measurement of biochemical oxygen demand (BOD) and carbonaceous biochemical oxygen demand (CBOD).

[64] In-Situ Method 1002-8-2009, Dissolved Oxygen (DO) Measurement by Optical Probe. 2009. In-Situ Incorporated.

[65] Mitchell Method M5331, Determination of Turbidity by Nephelometry. Revision 1.0, July 31, 2008. Leck Mitchell.

[66] Mitchell Method M5271, Determination of Turbidity by Nephelometry. Revision 1.0, July 31, 2008. Leck Mitchell.

[67] Orion Method AQ4500, Determination of Turbidity by Nephelometry. Revision 5, March 12, 2009. Thermo Scientific

[68] EPA Method 200.5, Determination of Trace Elements in Drinking Water by Axially Viewed Inductively Coupled Plasma-Atomic Emission Spectrometry, EPA/600/R-06/115. Revision 4.2, October 2003. US EPA.

[69] Method 1627, Kinetic Test Method for the Prediction of Mine Drainage Quality, EPA-821-R-09-002. December 2011. US EPA.

[70] Techniques and Methods Book 5-B1, Determination of Elements in Natural-Water, Biota, Sediment and Soil Samples Using Collision/Reaction Cell Inductively Coupled Plasma-Mass Spectrometry, Chapter 1, Section B, Methods of the National Water Quality Laboratory, Book 5, Laboratory Analysis,. 2006. USGS.

[71]Water-Resources Investigations Report 01-4132, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory – Determination of Organic Plus Inorganic Mercury in Filtered and Unfiltered Natural Water With Cold Vapor-Atomic Fluorescence Spectrometry,.2001. USGS.

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 °C[18]	7 days until extraction, 40 days after extraction
82-84. Nitrosamines[11, 14]	G, FP-lined cap	Cool, ≤6 °C[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 °C[18]	1 year until extraction, 1 year after extraction
54, 55, 75, 79. Nitroaromatics and isophorone[11]	G, FP-lined cap	Cool, ≤6 °C[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 °C[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 °C[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 °C[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 °C[18], 0.008% $Na_2S_2O_3$[5], pH<9	1 year
Solids and Mixed-Phase Samples: Field Preservation	G	Cool, ≤6 °C[18]	7 days
Tissue Samples: Field Preservation	G	Cool, ≤6 °C[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 °C[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

the table. A permittee or monitoring laboratory is obligated to hold the sample for a shorter time if it knows that a shorter time is necessary to maintain sample stability. See 136.3(e) for details. The date and time of collection of an individual grab sample is the date and time at which the sample is collected. For a set of grab samples to be composited, and that are all collected on the same calendar date, the date of collection is the date on which the samples are collected. For a set of grab samples to be composited, and that are collected across two calendar dates, the date of collection is the dates of the two days; e.g., November 14–15. For a composite sample collected automatically on a given date, the date of collection is the date on which the sample is collected. For a composite sample collected automatically, and that is collected across two calendar dates, the date of collection is the dates of the two days; e.g., November 14–15. For static-renewal toxicity tests, each grab or composite sample may also be used to prepare test solutions for renewal at 24 h, 48 h, and/or 72 h after first use, if stored at 0–6 °C, with minimum head space.

[5] ASTM D7365–09a specifies treatment options for samples containing oxidants (e.g., chlorine). Also, Section 9060A of Standard Methods for the Examination of Water and Wastewater (20th and 21st editions) addresses dechlorination procedures.

[6] Sampling, preservation and mitigating interferences in water samples for analysis of cyanide are described in ASTM D7365–09a. There may be interferences that are not mitigated by the analytical test methods or D7365–09a. Any technique for removal or suppression of interference may be employed, provided the laboratory demonstrates that it more accurately measures cyanide through quality control measures described in the analytical test method. Any removal or suppression technique not described in D7365–09a or the analytical test method must be documented along with supporting data.

[7] For dissolved metals, filter grab samples within 15 minutes of collection and before adding preservatives. 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), filter the sample within 15 minutes after completion of collection and before adding preservatives. If it is known or suspected that dissolved sample integrity will be compromised during collection of a composite sample collected automatically over time (e.g., by interchange of a metal between dissolved and suspended forms), collect and filter grab samples to be composited (footnote 2) in place of a composite sample collected automatically.

[8] Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9] If the sample is not adjusted to pH 2, then the sample must be analyzed within seven days of sampling.

[10] The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11] When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity (i.e., use all necessary preservatives and hold for the shortest time listed). When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to ≤ 6 ºC, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6 - 9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (regarding the requirement for thiosulfate reduction), and footnotes 12, 13 (regarding the analysis of benzidine).

[12] If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0 ± 0.2 to prevent rearrangement to benzidine.

[13] Extracts may be stored up to 30 days at < 0 ºC.

[14] For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7-10 with NaOH within 24 hours of sampling.

[15] The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

[16] Place sufficient ice with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, immediately measure the temperature of the samples and confirm that the preservation temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature cannot be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature. Aqueous samples must not be frozen. Hand-delivered samples used on the day of collection do not need to be cooled to 0 to 6 °C prior to test initiation.

[17] Samples collected for the determination of trace level mercury (<100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. A sample collected for dissolved trace level mercury should be filtered in the laboratory within 24 hours of the time of collection. However, if circumstances preclude overnight shipment, the sample should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. If sample integrity will not be maintained by shipment to and filtration in the laboratory, the sample must be filtered in a designated clean area in the field within the time period necessary to maintain sample integrity. A sample that has been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

[18] Aqueous samples must be preserved at ≤ 6 ºC, and should not be frozen unless data demonstrating that sample freezing does not adversely impact sample integrity is maintained on file and accepted as valid by the regulatory authority. Also, for purposes of NPDES monitoring, the specification of "≤ ºC" is used in place of the "4 ºC" and "< 4 ºC" sample temperature requirements listed in some methods. It is not necessary to measure the sample temperature to three significant figures (1/100th of 1 degree); rather, three significant figures are specified so that rounding down to 6 ºC may not be used to meet the ≤6 ºC requirement. The preservation temperature does not apply to samples that are analyzed immediately (less than 15 minutes).

[19] An aqueous sample may be collected and shipped without acid preservation. However, acid must be added at least 24 hours before analysis to dissolve any metals that adsorb to the container walls. If the sample must be analyzed within 24 hours of collection, add the acid immediately (see footnote 2). Soil and sediment samples do not need to be preserved with acid. The allowances in this footnote supersede the preservation and holding time requirements in the approved metals methods.

[20] To achieve the 28-day holding time, use the ammonium sulfate buffer solution specified in EPA Method 218.6. The allowance in this footnote supersedes preservation and holding time requirements in the approved hexavalent chromium methods, unless this supersession would compromise the measurement, in which case requirements in the method must be followed.

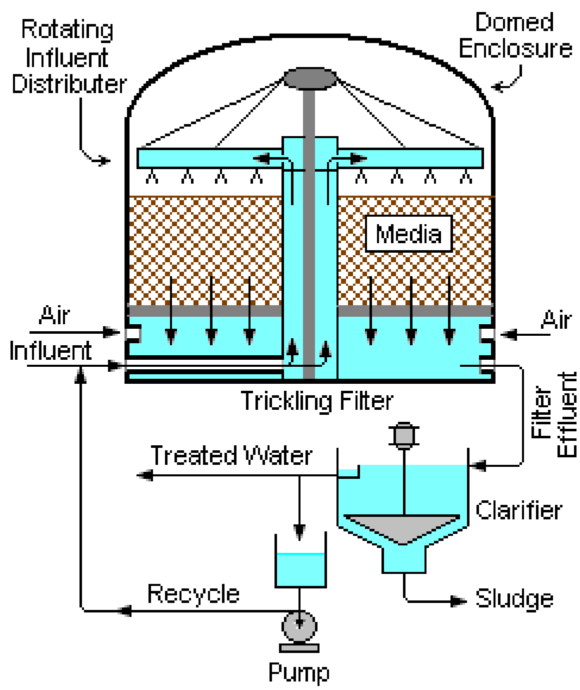
[21] Holding time is calculated from time of sample collection to elution for samples shipped to the laboratory in bulk and calculated from the time of sample filtration to elution for samples filtered in the field.

[22] Sample analysis should begin as soon as possible after receipt; sample incubation must be started no later than 8 hours from time of collection.

[23] For fecal coliform samples for sewage sludge (biosolids) only, the holding time is extended to 24 hours for the following sample types using either EPA Method 1680 (LTB–EC) or 1681 (A–1): Class A composted, Class B aerobically digested, and Class B anaerobically digested.

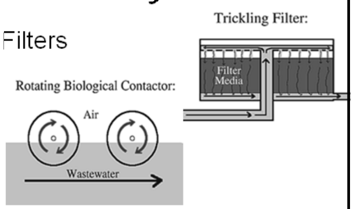
Section 5

Attached Growth



Attached Growth Wastewater Treatment Systems

Trickling Filters
RBCs
MBBR
IFAS



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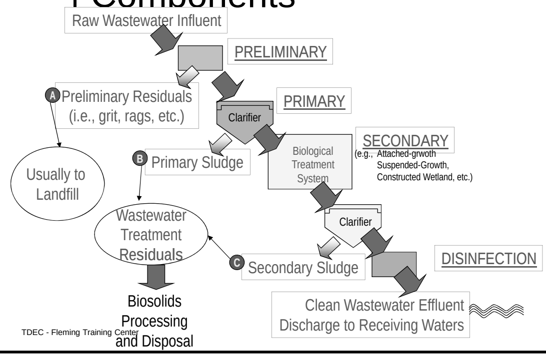
General Overview of Plant Components



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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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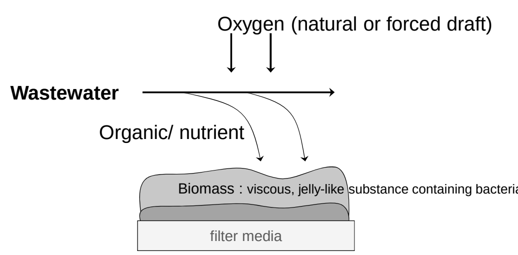
Cross-section of Attached Growth Biomass Film



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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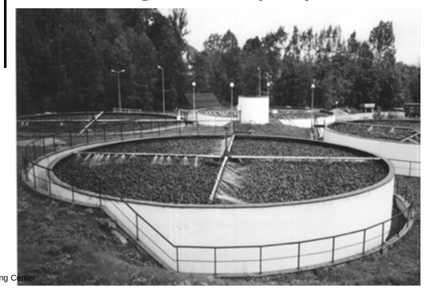
Trickling Filter (TF)



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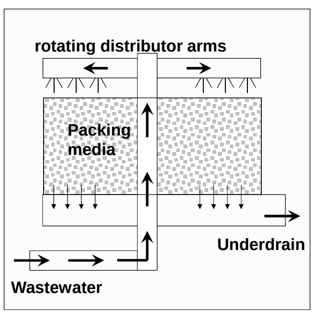
Trickling Filter (TF)- Side View



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

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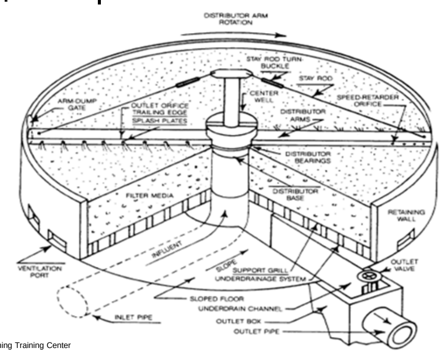
Components



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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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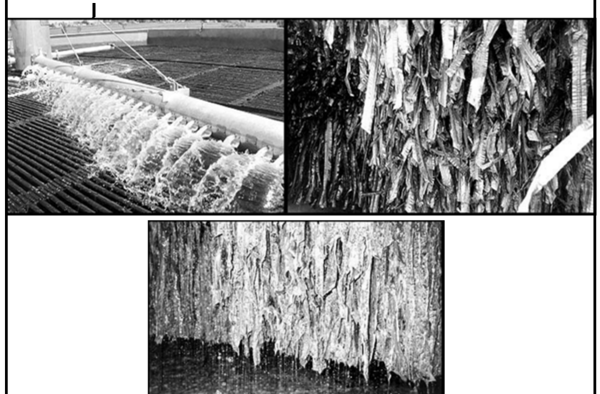

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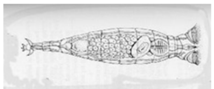
What is Zoogleal Film (Biomass)?

- 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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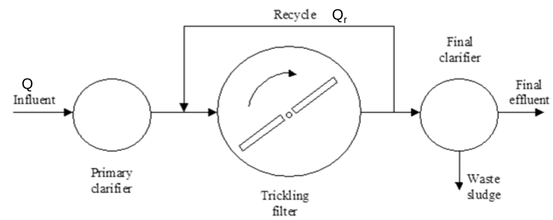
Flow & Recirculation Rates

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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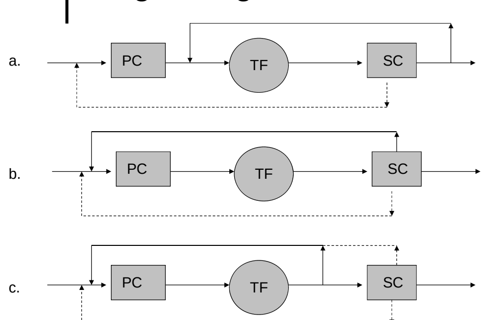
Single stage



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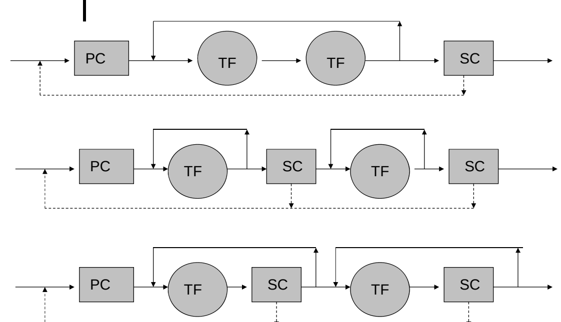
Two Stage



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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 recircirculation
- 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

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

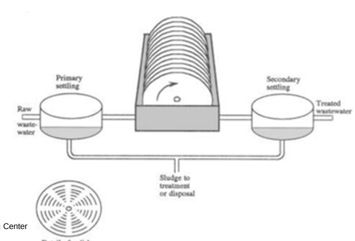
Control of Insects, Snails & Algae

- 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

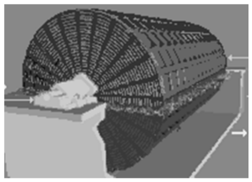
Typical Loading Rates

	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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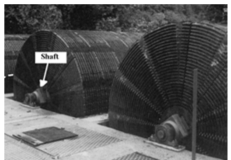
Air Driven Units

- 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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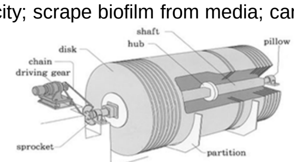
Motor with Chain Drive Unit

- 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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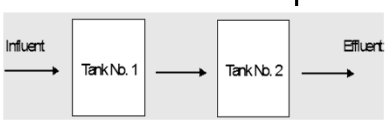
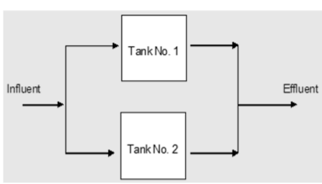
Series vs. Parallel Operation





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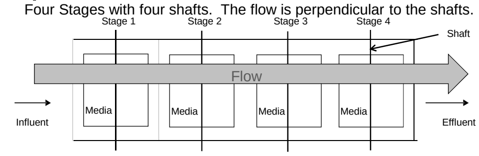
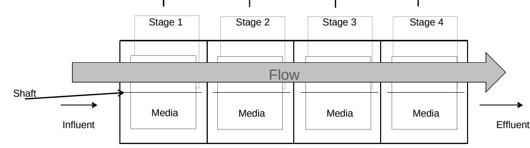
Flow

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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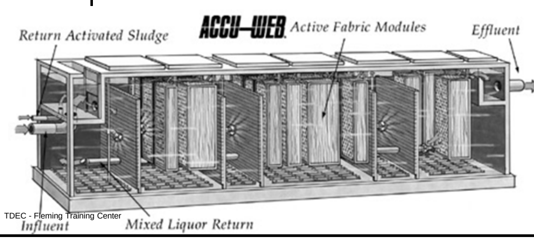
Integrated Fixed-film Activated Sludge



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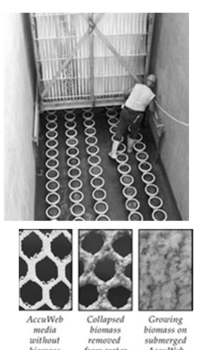
IFAS

- 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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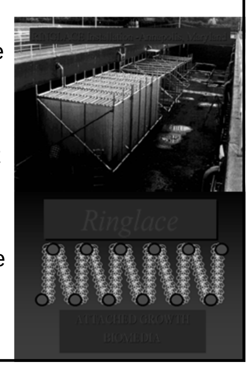
IFAS

- 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

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.?

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

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

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?

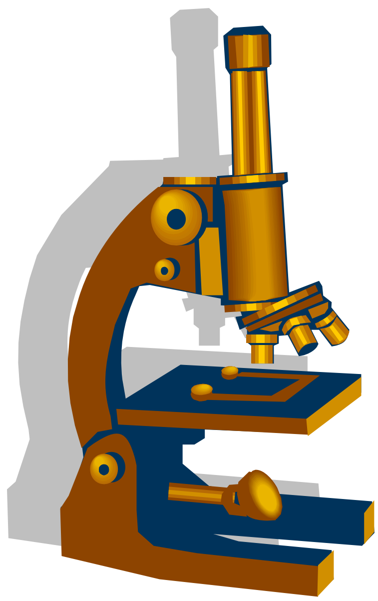
$$\text{Efficiency, \%} = \left(\frac{\text{in} - \text{out}}{\text{in}}\right)(100)$$
$$= \left(\frac{210 - 67}{210}\right)(100) = \boxed{68.1\%}$$

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



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Microscopic Exam

Wastewater

1

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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

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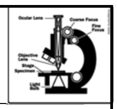
How Light Microscopes Work



- 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

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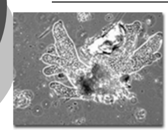
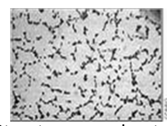
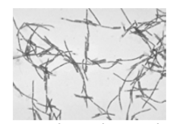
Images Produced by Light Microscopes



Amoeba

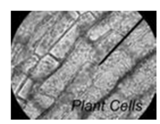


Streptococcus bacteria

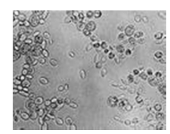


Anthrax bacteria

Human cheek cells



Plant cells



Yeast cells

4

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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

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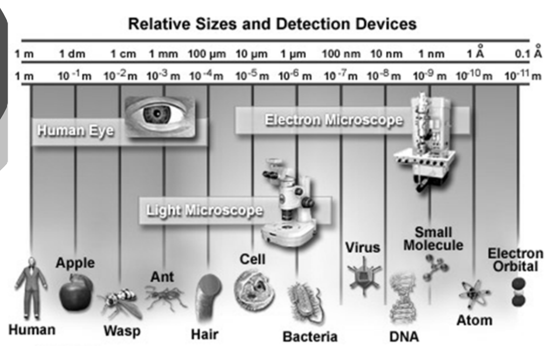


Figure 1

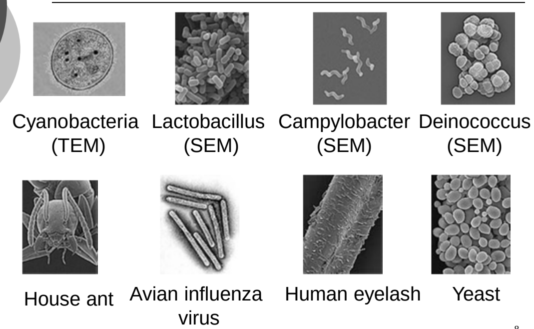
6

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



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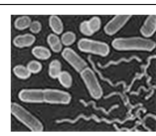
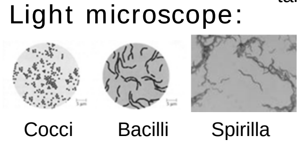
Using Microscopes to Visualize the Three Shapes of Bacteria

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



Three shapes of bacteria taken with an SEM

Light microscope:



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

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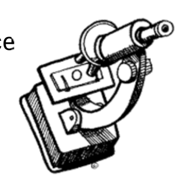
Using the Microscope

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



11

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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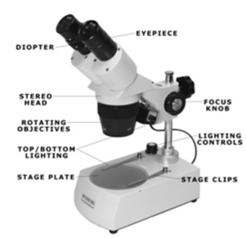
Stereo Microscope Uses

- 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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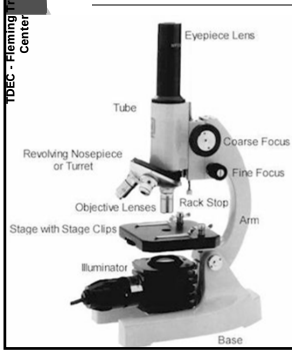
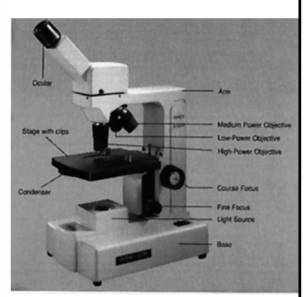
Compound Scope Parts





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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!!

20

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.

21

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.

23

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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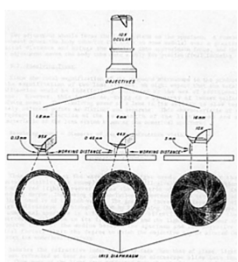
Magnification

- Two-lens system
  - Ocular (Closest the eye)
  - Objective(Closest the specimen)
- Total Magnification =
  - Ocular rating X Objective Rating



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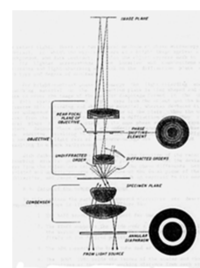
Phase Contrast Microscopes

- 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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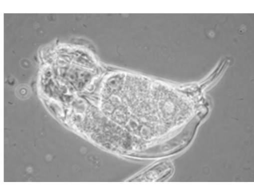
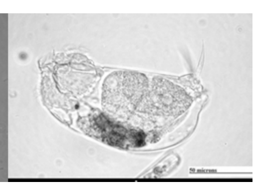
Phase Contrast / Bright Field


Phase Contrast


Bright Field

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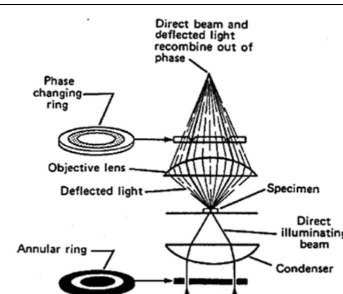
Phase Contrast



c. Phase contrast light path
(Courtesy of Polaroid Corporation)

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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

34

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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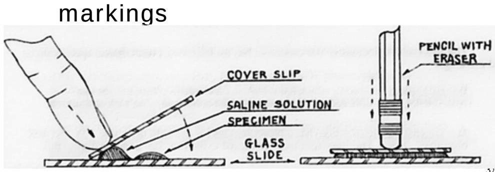
Cover Slide Prep, Wet

- 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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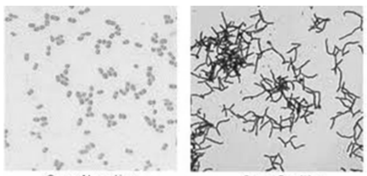
Gram Stains, How-To

- Stain w/ Safranin Solution for 1 minute
- Examine using 1000X mag under oil immersion
  - Blue-Violet is Positive
  - Pink-Red is Negative



Gram Negative Gram Positive

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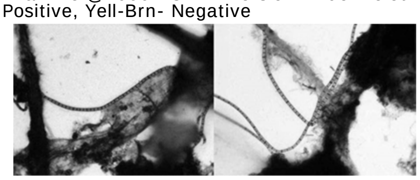
Neisser Stains, How-to

- 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

- India Ink can be purchased at hobby stores
- Mix 1 drop India Ink w/ one drop Activated Sludge on slide
- Cover slide and view @ 1000X
- OR drop India Ink next to cover slide after you have covered one drop of Mixed Liquor, the ink will draw in under the slide
- 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

- 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

- 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

- 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

- 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

- 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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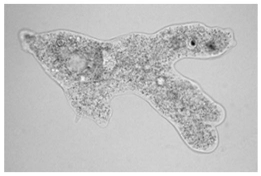
Amoebae



- 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

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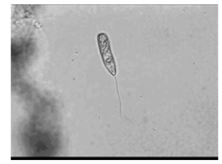
Flagellates



- 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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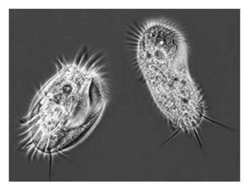
Free & Stalked Ciliates



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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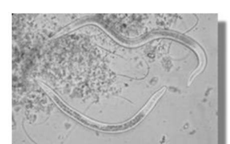
Nematodes



- 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

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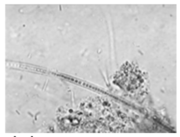
Algae/Fungi



- 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 and 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.*

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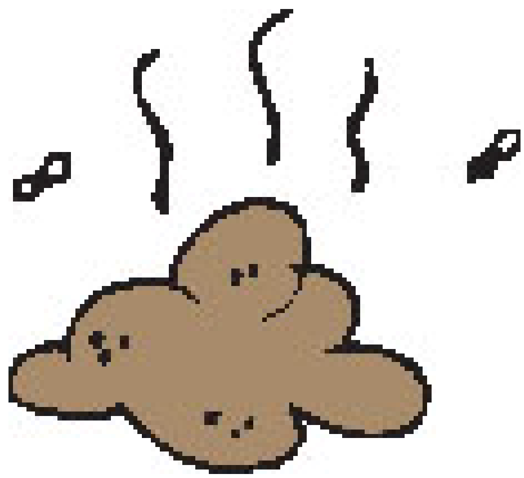
Troubleshooting – continued

- 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.*

66

Section 7

Sludge Thickening, Digestion and Dewatering



Sludge Thickening, Digestion, and Dewatering

- or -

Now What Do We Do With It?

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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

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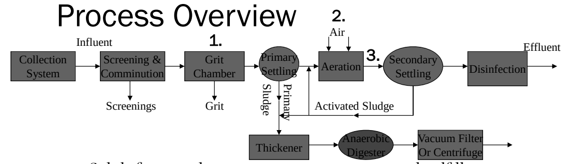
Process Overview



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

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Sludge Thickening

Main component of sludge is water

~90% or more before treatment

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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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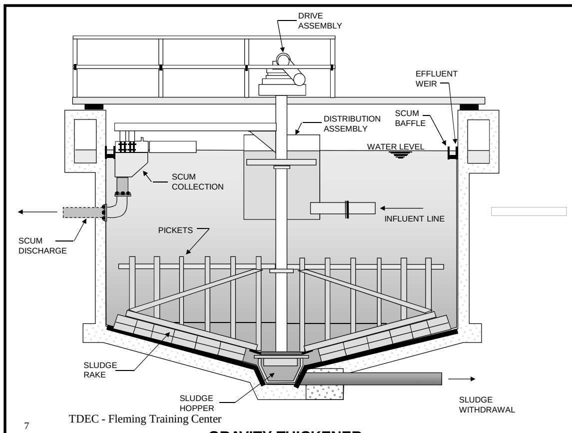

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GRAVITY THICKENER

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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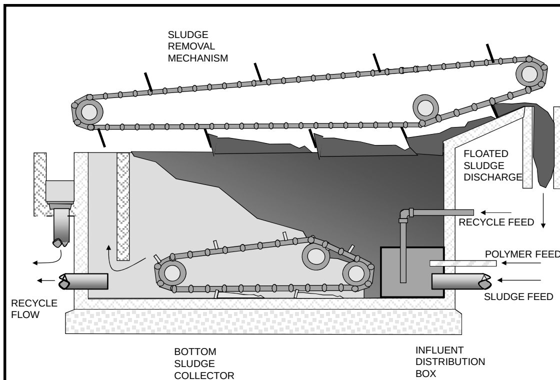

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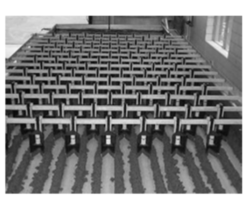
Gravity Belt Thickener

- 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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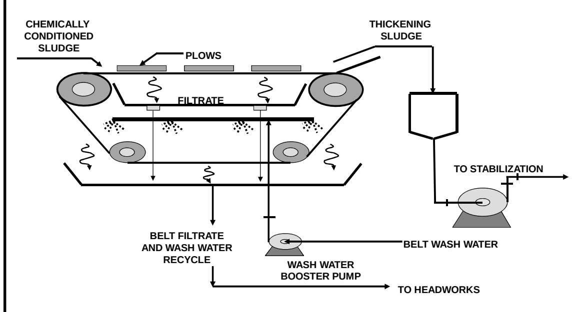

Gravity Belt Filter Thickener

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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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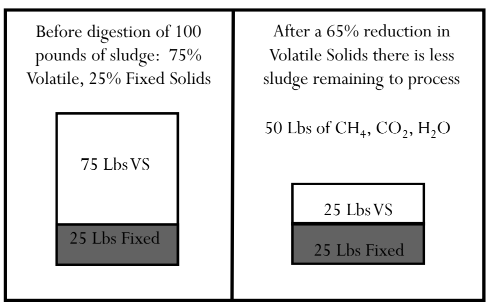
General Overview



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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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Anaerobic Digestion

- The object of good digester operation is to maintain conditions in the digester for growing (reproducing) populations of both acid formers and methane fermenters.
- You must do this by controlling:
  - Loading rate of food supply (organic solids/cBOD)
  - Volatile acid/Alkalinity ratio
  - Mixing
  - Temperature

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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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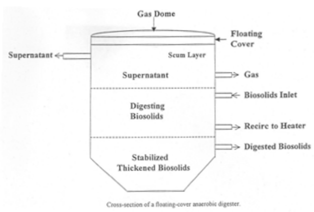
Anaerobic Digestion



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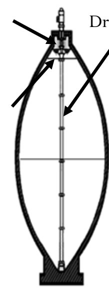
Cross-Section of an Egg-Shaped Digester



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

- The anaerobic digestion process (depending on the characteristics of the sludge) produces
  - 8-12 ft^3 of gas for every pound of volatile matter **added**
  - 12-18 ft^3 for every pound of volatile matter **destroyed**
- 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%.

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Gas Production

- Digester gas is used in plants in various ways:
  - For heating and mixing the digesters
  - Heating the plant buildings
  - Running engines
  - Air blowers for the activated sludge process
  - Electrical power for the plant

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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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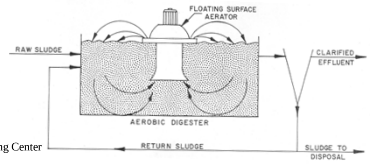
Aerobic Digestion

- 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

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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

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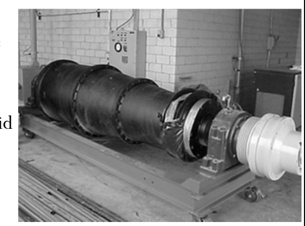
Centrifuge

- 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)



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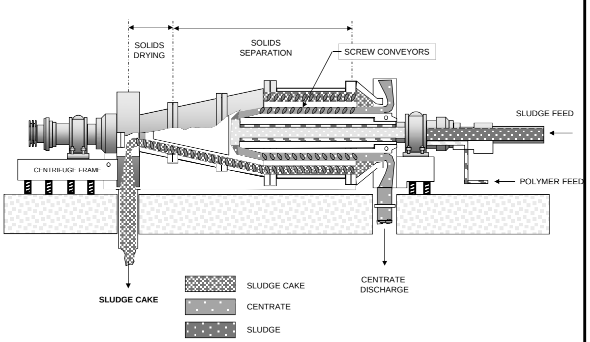

SCROLL CENTRIFUGE

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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

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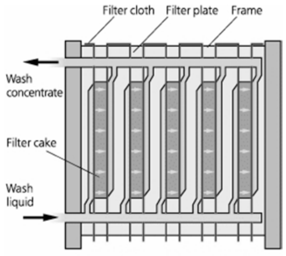
Plate-and-Frame



Filter cake washing in a plate and frame filter press

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Plate-and-Frame

JVAP (US Filter) – Chattanooga

- Modified plate and frame that is vacuum assisted
- Steam heated at 163.4°F for 30 min
- Entire process takes about 4 hours

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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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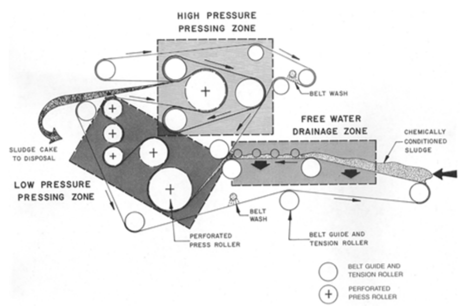
Belt Filter Press



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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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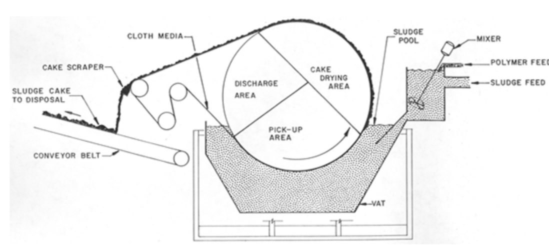
Vacuum Filter



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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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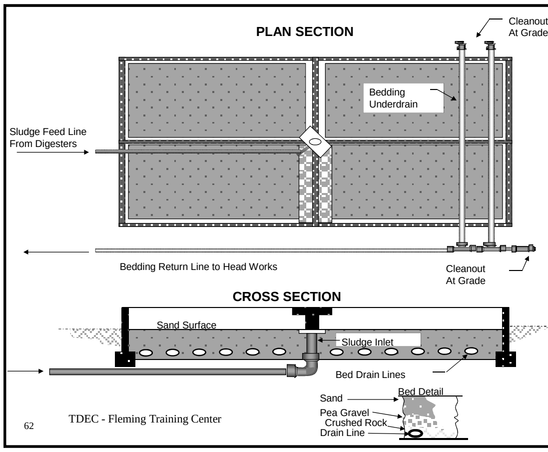

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503 Regs

- 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 uptake rate for aerobically treated biosolids
- Use aerobic processes at greater than 40°C (avg. temp 45°C) for 14 days or longer (during biosolids composting)
- Add alkaline materials to raise the pH under specified conditions

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Requirements in one of the following options must be met for vector attraction reduction

- Reduce the moisture content of biosolids that do not contain unstabilized solids from other than primary treatment to at least 75% solids
- Reduce the 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
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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 <u>Conditioning</u>

______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.

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

Section 7

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 / ft^3

* ~ 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?

$$\text{Digester Loading} = \frac{(26{,}400 \text{ gpd})(8.34)(0.057)(0.71)}{(0.785)(40 ft)^2(18 ft)}$$
$$= \frac{8910.52}{22608} = \boxed{0.39 \text{ lbs VS added/day/ft}^3}$$

Sludge Thickening, Digestion and Dewatering

- 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?

$$VA/Alk\ ratio = \frac{\text{Volatile Acids, mg/L}}{\text{Alkalinity mg/L}}$$

$$= \frac{170\ mg/L}{2150\ mg/L} = \boxed{0.08}$$

- 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?

$$VA/Alk\ ratio = \frac{215\ mg/L}{1957\ mg/L} = \boxed{0.11}$$

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?

$$\%\ VS\ Reduction = \frac{(In - Out)}{(In - (In)(Out))} \times 100$$

$$= \frac{0.69 - 0.53}{0.69 - (0.69)(0.53)} \times 100$$

$$= \frac{0.16}{0.69 - 0.3657} \times 100$$

$$\rightarrow \frac{0.16}{0.3243} \times 100 = \boxed{49\%}$$

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?

$$\%\ VS\ Reduction = \frac{0.72 - 0.51}{0.72 - (0.72)(0.51)} \times 100$$

$$= \frac{0.21}{0.72 - 0.3672} \times 100$$

$$= \frac{0.21}{0.3528} \times 100 \rightarrow \boxed{59.5\%}$$

Sludge Thickening, Digestion and Dewatering

Section 7

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?

$$\text{VS destroyed, lbs VS/day/ft}^3 = \frac{(\text{Sludge, gpd})(8.34)(\%\text{ Solids})(\%\text{ VS})(\%\text{ VS reduc.})}{(0.785)(\text{D, ft})^2(\text{d, ft})}$$

$$= \frac{(3750\text{ gpd})(8.34)(0.063)(0.68)(0.54)}{35{,}000\text{ ft}^3}$$

$$= \boxed{0.021\text{ lbs VS/day/ft}^3}$$

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

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.

$$\text{Digestion Time, days} = \frac{(0.785)(D, ft)^2(d, ft)(7.48)}{\text{Sludge Flow Rate, gpd}}$$

$$= \frac{(0.785)(40 ft)^2(12 ft)(7.48)}{8200 \text{ gpd}}$$

$$= 13.7 \text{ days}$$

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.

$$\text{Digestion Time, days} = \frac{(0.785)(50 ft)^2(10 ft)(7.48)}{9500 \text{ gpd}}$$

$$= 15.5 \text{ days}$$

(OUR)
Oxygen Uptake Rate, mg/L/hr • Indicates biomass activity
• an increase means increase microorganism activity
• a decrease occurs when bugs are less active

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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

$$\text{OUR, mg/L/hr} = \frac{\text{start DO} - \text{end DO}}{\text{elapsed time}} \times 60$$

$$= \frac{6.1 - 3.9}{3 \text{ min}} \times 60$$

$$= 44 \text{ mg/L/hr}$$

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

$$\text{OUR mg/L} = \frac{5.0 - 2.9}{3 \text{ min}} \times 60$$

$$= 42 \text{ mg/L/hr}$$

Sludge Thickening, Digestion and Dewatering

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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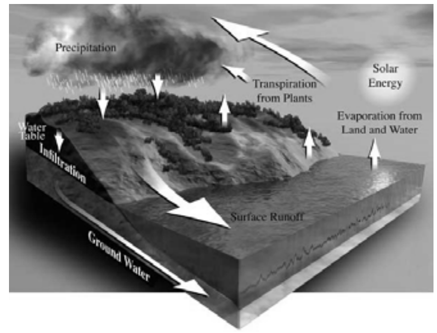
Hydrologic Cycle



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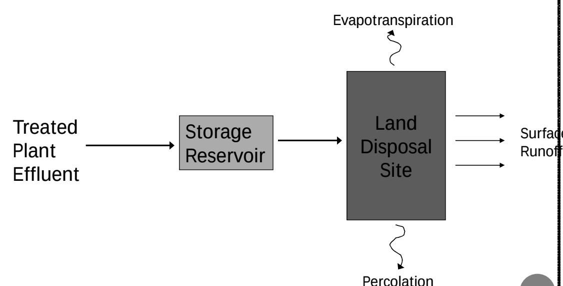
Land Application System

- 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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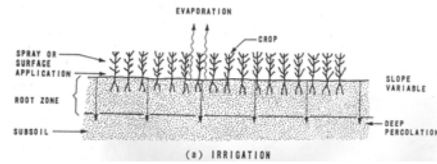
IRRIGATION



- 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

Center pivot, moving spray irrigation

Fixed spray irrigation on risers

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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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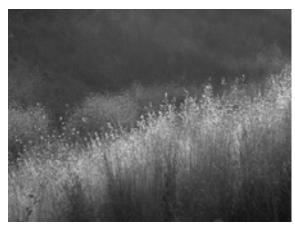
Overland Flow



- 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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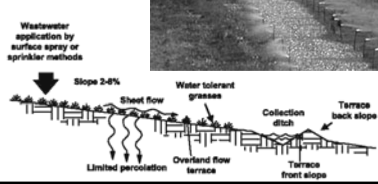
Overland Flow



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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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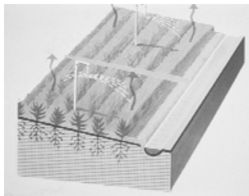
Overland Flow



- 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
Cool Season Grass	Tall fescue	Perennial	bunch	seed	90-120
Cool Season Grass	Rye grass	Annual	sod	seed	60-90
Cool Season Grass	Redtop	Perennial	sod	seed	60-90
Cool Season Grass	KY bluegrass	Perennial	sod	seed	30-75
Cool Season Grass	Orchard grass	Perennial	bunch	seed	15-60
Warm Season	Common Bermuda	Perennial	sod	seed	30-45
Warm Season	Coastal Bermuda	Perennial	sod	sprig	30-60
Warm Season	Dallis grass	Perennial	bunch	seed	60-120
Warm Season	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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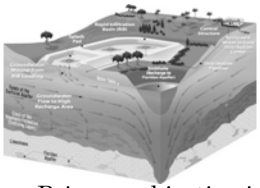
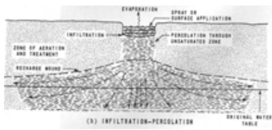
Rapid Infiltration





- 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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