Section 10

Math

1

Area, Volume and Conversions

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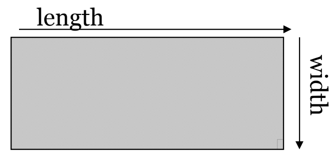
Area

- Surface of an object
- Two dimensional
- Measured in:
  - Square inches
  - Square feet
  - Square meters, etc.

Area Formulas

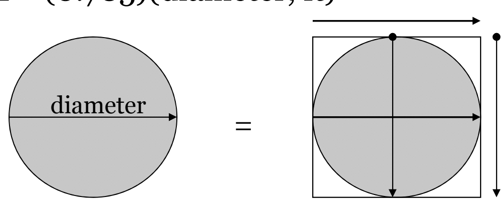
- Rectangle

  A = (length, ft)(width, ft)



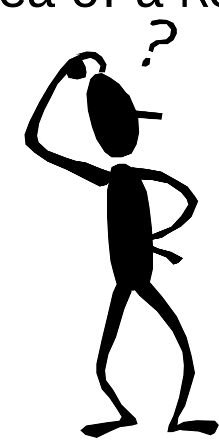
- Circle

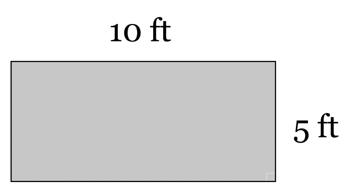
  A = $(0.785)(\text{diameter, ft})^2$



Diameter is equal to length and width of a square and a circle takes up 78.5% of square

Area of a Rectangle





A = (l, ft)(w, ft)

A = (10 ft)(5 ft)

A = 50 ft^2

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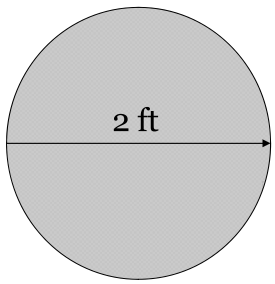
Area of a Circle



Diameter = 2 ft

$A = (0.785)(D, ft)^2$

$A = (0.785)(2ft)(2ft)$

$A = 3.14\ ft^2$

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Volume

- The amount of space an object occupies
- Volume = (area)(third dimension) or

  $V = (l)(w)(d)$

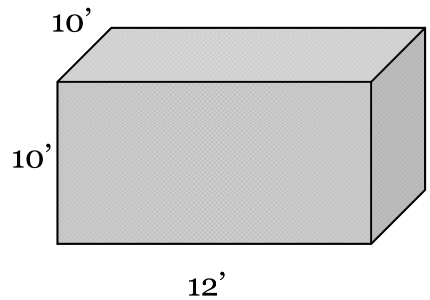
- Measured in:
  - Cubic inches
  - Cubic feet
  - Gallons
  - Acre-feet, etc.

Volume of a Rectangular Tank, ft^3

V = (length, ft)(width, ft)(depth, ft)

$V = (12\ ft)(10ft)(10ft)$

$V = 1200\ ft^3$



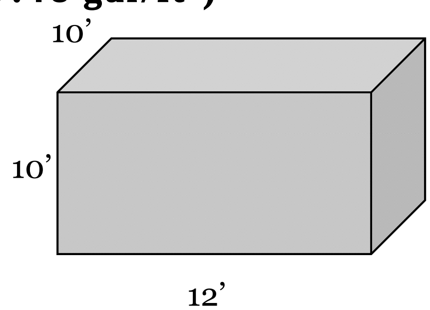
Volume of a Rectangular Tank, gal

$V, ft^3 = 1200\ ft^3$

$V, gal = (Volume, ft^3)(7.48\ gal/ft^3)$

$V, gal = (1200\ ft^3)(7.48)$

$V, gal = 8976\ gal$



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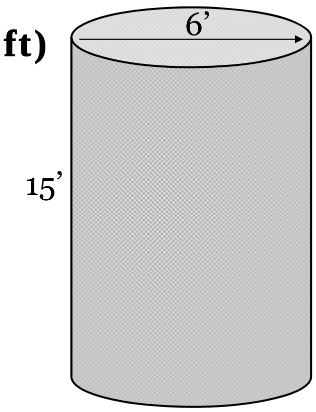
Volume of a Cylinder, ft^3

$V = (0.785)(D, ft)^2(height, ft)$

$V = (0.785)(6\ ft)(6\ ft)(15\ ft)$

$V = 424\ ft^3$



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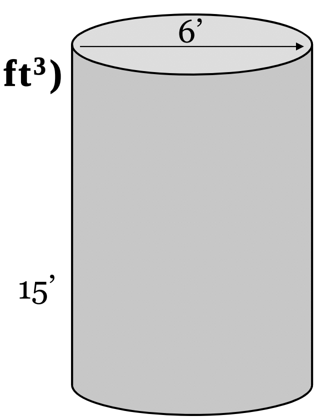
Volume of a Cylinder, gallons

$V, ft^3 = 424\ ft^3$

$V, gal = (Volume, ft^3)(7.48\ gal/ft^3)$

$V, gal = (424\ ft^3)(7.48)$

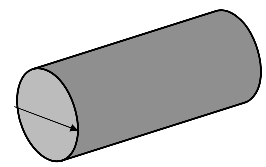
$V, gal = 3171.52\ gal$



Note

- When calculating area and volume, if you are given a pipe diameter in inches, convert it to feet.

$$8\ \cancel{\text{in.}} \times \frac{1\ \text{ft}}{12\ \cancel{\text{in}}} = 0.6667\ \text{ft}$$



Diameter = 8 in

Conversions

- Need to know:
- The number that relates the two units
  - Ex: 12 inches in a foot, 454 grams in a pound, 3785 mL in a gallon
- Whether to multiply or divide
  - Ex: smaller to larger or larger to smaller

Conversions

Conversion Factors

1 acre	=	43,560 ft^2
1 foot of head	=	0.433 psi
1 psi	=	2.31 feet of head
1 yd^3	=	27 ft^3
1 gal	=	3.785 Liters
1 gallon of water	=	8.34 lbs
1 cubic foot of water	=	7.48 gallons
1 lb	=	453.6 grams
1 mile	=	5280 feet
1%	=	10,000 mg/L

Multiply

- Just looking at the units, if you are given miles and you need feet, we are going from left to right on the page, therefore multiply

Conversions

- You have just laid ¼ mile of sewer line. How many feet is this?

¼ = 0.25 miles

(0.25 miles)(5280 feet/mile) = 1320 feet

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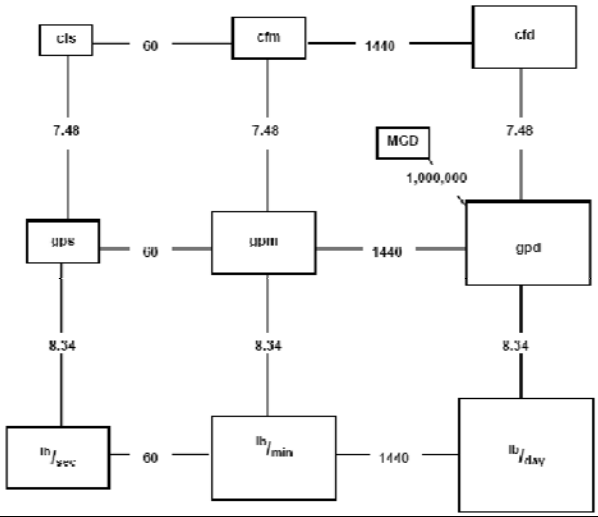
Flow Conversions – Box Method



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Percent to Decimal

Percent = per one hundred

20%	=	20/100	=	0.20
5%	=	5/100	=	0.05
12.25%	=	12.25/100	=	0.1225
0.5%	=	0.5/100	=	0.005

Move decimal 2 places to the left.

AREA, VOLUME, AND CONVERSIONS

Area

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

2. Calculate the surface area of a basin which is 90 feet long, 25 feet wide, and 10 feet deep.

3. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

4. Calculate the area (in ft^2) for an 18" main that has just been laid.

Volume

5. Calculate the volume (in ft^3) for a tank that measures 10 feet by 10 feet by 10 feet.

6. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

7. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

8. A new water main needs to be disinfected. The main is 30” in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

9. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to calculate 5% of the tank volume. How many gallons will this be?

Conversions

10. How many seconds in one minute?

11. How many minutes in one hour?

12. How many minutes in one day?

13. Convert 3.6 ft^3/sec to gps.

14. Convert 2.4 ft^3/sec to gpm.

15. A treatment plant produces 6.31 MGD. How many gpm is that?

16. A pump delivers 695 gpm. How many MGD will that be?

17. How many pounds of water are in a tank containing 800 gallons of water?

ANSWERS:

1.	540 ft^2	10.	60
2.	2,250 ft^2	11.	60
3.	3.14 ft^2	12.	1440
4.	1.77 ft^2	13.	26.9 gps
5.	1,000 ft^3	14.	1,077 gpm
6.	9,050.8 gal	15.	4,382 gpm
7.	359 gal	16.	1.0 MGD
8.	48,442.35 gal	17.	6672 lbs
9.	150,000 gal		

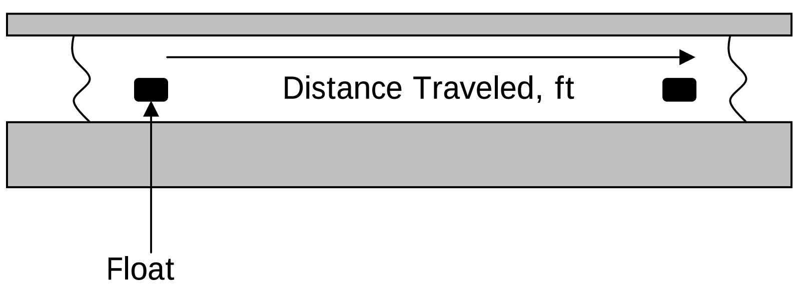
Applied Math for Wastewater
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

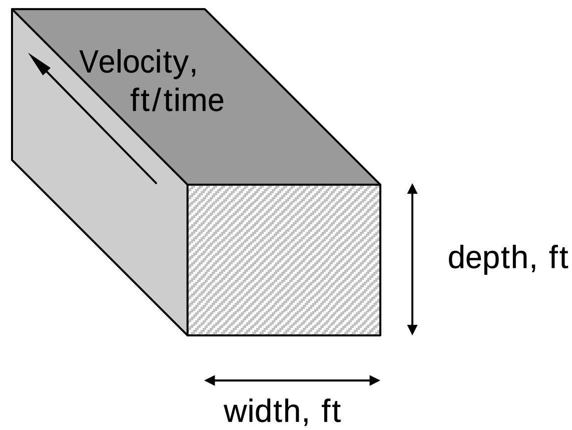
2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$



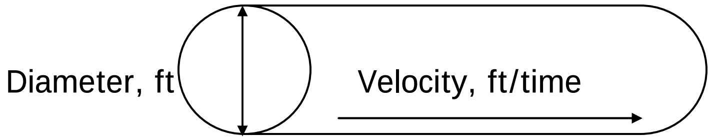
$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

<u>Flow in a channel</u>

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \; \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(0.785)\,(D)^2} \; \underset{(ft/time)}{(vel)}$$

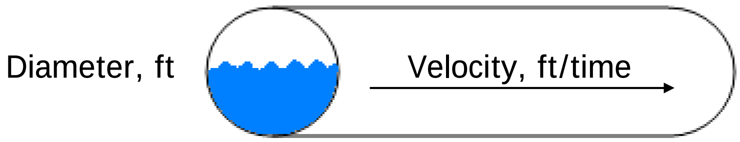
Flow through full pipe

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

10. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = \overbrace{(\text{Factor from d/D Table})\,\underset{(ft)(ft)}{(D)^2}} \quad \underset{(ft/time)}{(\text{vel})}$$

<u>Flow through pipe flowing less than full</u>

11. A 12-inch diameter pipeline has water flowing at a depth of 6 inches. What is the gpm flow if the velocity of the wastewater is 300 fpm?

12. A 10-inch diameter pipeline has water flowing at a velocity of 3.2 fps. What is the gpd flow rate if the water is at a depth of 5 inches?

13. An 8-inch pipeline has water flowing to a depth of 5 inches. If the flow rate is 415.85 gpm, what is the velocity of the wastewater in fpm?

Answers:
1. 185 ft/min
2. 2.2 ft/sec
3. 210 ft/min
4. 16.8 ft^3/sec
5. 900 ft^3/min and 9.69 MGD
6. 1.8 ft
7. 10 ft^3/sec
8. 0.59 ft^3/sec
9. 532 gpm
10. 6 in
11. 881 gpm
12. 563,980 gpd
13. 240 ft/min

Lagoon Math

BOD Loading

1. Calculate the BOD loading (lbs/day) on a pond if the influent flow is 390,000 gal/day with a BOD of 245 mg/L.

2. The BOD concentration of the wastewater entering a pond is 158 mg/L. If the flow to the pond is 220,000 gal/day, how many lbs/day BOD enter the pond?

3. The flow to a waste treatment pond is 175 gal/min. If the BOD concentration of the water is 221 mg/L, how many pounds of BOD are applied to the pond daily?

4. The BOD concentration of the influent wastewater to a waste treatment pond is 190 mg/L. If the flow to the pond is 125 gpm, how many pounds of BOD are applied to the pond daily?

Organic Loading Rate

5. A 7.5-acre pond receives a flow of 200,000 gal/day. If the influent flow has a BOD content of 190 mg/L, what is the organic loading rate in lbs/day/ac on the pond?

6. A pond has an average width of 400 feet and an average length of 710 feet. The flow to the pond is 157,000 gal/day with a BOD content of 147 mg/L. What is the organic loading rate in lbs/day/ac on the pond?

7. The flow to a pond is 70,000 gpd with a BOD content of 124 mg/L. The pond has an average width of 220 feet and an average length of 382 feet. What is the organic loading rate in lbs/day/ac on the pond?

BOD Removal Efficiency

8. The BOD entering a waste treatment pond is 207 mg/L. If the BOD in the pond effluent is 39 mg/L, what is the BOD removal efficiency of the pond?

9. The influent of a waste treatment pond has a BOD content of 262 mg/L. If the BOD content of the pond effluent is 130 mg/L, what is the BOD removal efficiency of the pond?

10. The BOD entering a waste treatment pond is 280 mg/L. If the BOD in the pond effluent is 45 mg/L, what is the BOD removal efficiency of the pond?

11. The BOD entering a waste treatment pond is 140 mg/L. If the BOD in the pond effluent is 56 mg/L, what is the BOD removal efficiency of the pond?

Hydraulic Loading Rate

12. A 20-acre pond receives a flow of 3.3 acre-feet/day. What is the hydraulic loading rate on the pond in in./day?

13. A 15-acre pond receives a flow of 5 acre-feet/day. What is the hydraulic loading rate on the pond in in./day?

Population Loading

14. A 4-acre wastewater pond serves a population of 1320 people. What is the population loading on the pond?

15. A wastewater pond serves a population of 5460 people. If the pond covers 18.5 acres, what is the population loading on the pond?

Detention Time

16. A waste treatment pond has a total volume of 17 ac-ft. If the flow to the pond is 0.42 ac-ft/day, what is the detention time of the pond (days)?

17. A waste treatment pond is operated at a depth of 6 feet. The average width of the pond is 440 feet and the average length is 680 feet. If the flow to the pond is 0.3 MGD, what is the detention time in days?

18. The average width of the pond is 240 feet and the average length is 390 feet. A waste treatment pond is operated at a depth of 5 feet. If the flow to the pond is 70,000 gal/day, what is the detention time, in days?

19. A waste treatment pond has an average length of 680 ft., an average width of 420 ft., and a water depth of 4 ft. If the flow to the pond is 0.47 ac-ft/day, what is the detention time for the pond in days?

ANSWERS:

1.	796.9 lbs/day
2.	289.9 lbs/day
3.	464.5 lbs/day
4.	285.2 lbs/day
5.	42.3 lbs/day/acre
6.	29.5 lbs/day/acre
7.	37.5 lbs/day/acre
8.	81%
9.	50%
10.	84%
11.	60%
12.	2 in/day
13.	4 in/day
14.	330
15.	295
16.	40 days
17.	45 days
18.	50 days
19.	56 days

Applied Math for BNS
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 4.4 MGD with a chlorine dose of 3.2 mg/L.

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

3. Determine the chlorinator setting (lbs/day) needed to treat a flow of 1.2 MGD with a chlorine dose of 1.7 mg/L.

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. 17.0 lbs/day
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

Applied Math for Wastewater Treatment Laboratory

Bacteriological, fecal coliform and *E. coli*

1. Calculate the geometric mean for the following fecal coliform test results: 60, 100, 0, 0, 40, 20, 20, 45, 55, 60, 20, 20

2. Calculate the geometric mean for the following fecal coliform test results: 0, 0, 50, 50, 25, 100, 100, 50, 75, 50

Solutions

3. How many mL of 0.7 N NaOH is needed to get 750 mL of 0.05 N NaOH?

4. How many mL of 0.5 N NaOH react with 800 mL of 0.1 N HCl?

Biochemical Oxygen Demand, BOD

- Blanks must not deplete more than 0.2 mg/L DO
- The sample must deplete at least 2.0 mg/L DO, if it does not, the dilution is too weak and report as inadequate depletion
- After 5 days of incubation at 20ºC ± 1.0ºC, the sample must have at least 1.0 mg/L DO, if less than, the sample was too strong

5. Given the following information, determine the BOD of the wastewater:

   Sample Volume = 5 mL
   BOD Bottle Volume = 300 mL
   Initial DO of Diluted Sample = 6 mg/L
   Final DO of Diluted Sample = 3.5 mg/L

6. Given the following information, determine the BOD of the wastewater:

   Sample Volume = 10 mL
   BOD Bottle Volume = 300 mL
   Initial DO of Diluted Sample = 8.3mg/L
   Final DO of Diluted Sample = 4.2 mg/L

7. Given the following primary effluent BOD test results, calculate the 7-day average:

   April 10 – 190 mg/L
   April 11 – 198 mg/L
   April 12 – 205 mg/L
   April 13 – 202 mg/L
   April 14 – 210 mg/L
   April 15 – 201 mg/L
   April 16 – 197 mg/L

Alkalinity

8. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 24 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.2 to 4.5.

9. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 10.1 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.5 to 4.5.

Temperature

10. The influent to a treatment plant has a temperature of 72ºF. What is the temperature expressed in degrees Celsius?

11. Convert 56º F to degrees Celsius.

12. The effluent of a treatment plant is 22ºC. What is this temperature expressed in degrees F?

Answers:

1. 21
2. 26
3. 53.6 mL
4. 160 mL
5. 150 mg/L
6. 123 mg/L
7. 200 mg/L
8. 240 mg/L
9. 101 mg/L
10. 22.2ºC
11. 13.3ºC
12. 71.6ºF

Applied Math for Wastewater
Pump Horsepower & Efficiency

1. A pump must pump 2,500 gpm against a total head of 73 feet. What horsepower (water horsepower) will be required to do the work?

2. A pump is delivering a flow of 1,035 gpm against 46.7 feet of head. What horsepower will be required?

3. If a pump is to deliver 630 gpm of water against a total head of 102 feet, and the pump has an efficiency of 78%, what power must be supplied to the pump?

4. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

5. What is the overall efficiency if an electric power equivalent to 36 hp is supplied to the motor and 16.3 hp of work is accomplished?

6. A pump is discharging 1,250 gpm against a head of 71 feet. The wire-to-water efficiency is 82%. If the cost of power is $0.028/kW hr, what is the cost of the power consumed during a week in which the pump runs 126 hours?

7. A wet well is 12 feet long and 10 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 2.6 feet during a 5-minute pumping test, what is the gpm pumping rate?

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. $71.93
7. 467 gpm

AREA, VOLUME, AND CONVERSIONS

Area

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

$$\text{Area} = (w, ft)(l, ft)$$
$$= (45 ft)(12 ft) = 540 ft^2$$

2. Calculate the surface area of a basin which is 90 feet long, 25 feet wide, and 10 feet deep.

$$\text{Area} = (90 ft)(25 ft)$$
$$= 2250 ft^2$$

fluff, you don't need

3. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

$$\text{Area} = (0.785)(D, ft)^2$$
$$= (0.785)(2 ft)(2 ft) = 3.14 ft^2$$

4. Calculate the area (in ft^2) for an 18″ main that has just been laid.

$18/12 = 1.5 ft$

$$\text{Area} = (0.785)(1.5 ft)(1.5 ft)$$
$$= 1.77 ft^2$$

Volume

5. Calculate the volume (in ft^3) for a tank that measures 10 feet by 10 feet by 10 feet.

$$\text{Vol}, ft^3 = (l, ft)(w, ft)(d, ft)$$
$$= (10 ft)(10 ft)(10 ft) = 1000 ft^3$$

6. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

$7.48\ gal/ft^3$

$$\text{Vol., gal} = (22 ft)(11 ft)(5 ft)(7.48) = 9051 \text{ gal}$$

Section 10

7. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

$8/12 = 0.6667\text{ ft}$

$\text{Vol., gal} = (12\text{ ft})(6\text{ ft})(0.6667\text{ ft})(7.48)$

$= 359\text{ gal}$

8. A new water main needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

$30/12 = 2.5\text{ ft}$

$(0.25)(5280) = 1320\text{ ft}$

$\text{Vol., gal} = (0.785)(2.5\text{ ft})(2.5\text{ ft})(1320\text{ ft})(7.48)$

$= 48{,}442\text{ gal}$

9. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to calculate 5% of the tank volume. How many gallons will this be?

$(3{,}000{,}000\text{ gal})(0.05) = 150{,}000\text{ gal}$

Conversions

10. How many seconds in one minute? 60 sec/min

11. How many minutes in one hour? 60 min/hr

12. How many minutes in one day? $\left(\frac{60\text{ min}}{\cancel{\text{hr}}}\right)\left(\frac{24\cancel{\text{hr}}}{\text{d}}\right) = \frac{1440\text{ min}}{\text{day}}$

13. Convert 3.6 ft^3/sec to gps. $\frac{3.6\cancel{\text{ft}^3}}{\text{sec}} \cdot \frac{7.48\text{ gal}}{\cancel{\text{ft}^3}} = 26.9\text{ gps}$

14. Convert 2.4 ft^3/sec to gpm. $\frac{2.4\cancel{\text{ft}^3}}{\cancel{\text{sec}}} \cdot \frac{7.48\text{ gal}}{\cancel{\text{ft}^3}} \cdot \frac{60\cancel{\text{sec}}}{\text{min}} = 1077\text{ gpm}$

15. A treatment plant produces 6.31 MGD. How many gpm is that?

$\frac{6.31\cancel{\text{MG}}}{\cancel{\text{D}}} \cdot \frac{1{,}000{,}000\text{ gal}}{1\cancel{\text{MG}}} \cdot \frac{1\cancel{\text{D}}}{1440\text{ min}} = 4382\text{ gpm}$

Math

16. A pump delivers 695 gpm. How many MGD will that be?

$$\frac{695\,\cancel{gal}}{\cancel{min}} \left| \frac{1440\,\cancel{min}}{D} \right| \frac{1\,MG}{1{,}000{,}000\,\cancel{gal}} = 1.0\,MGD$$

17. How many pounds of water are in a tank containing 800 gallons of water?

$$\frac{800\,\cancel{gal}}{} \left| \frac{8.34\,lbs}{1\,\cancel{gal}} \right. = 6672\ lbs$$

ANSWERS:

1.	540 ft^2	10.	60
2.	2,250 ft^2	11.	60
3.	3.14 ft^2	12.	1440
4.	1.77 ft^2	13.	26.9 gps
5.	1,000 ft^3	14.	1,077 gpm
6.	9,050.8 gal	15.	4,382 gpm
7.	359 gal	16.	1.0 MGD
8.	48,442.35 gal	17.	6672 lbs
9.	150,000 gal		

Applied Math for Collections
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

$$\text{Vel.} = \frac{\text{distance, ft}}{\text{time}} = \frac{370\text{ ft}}{2\text{ min}} = \boxed{185\text{ ft/min}}$$

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec? 2 min + 14 sec = 134 seconds total

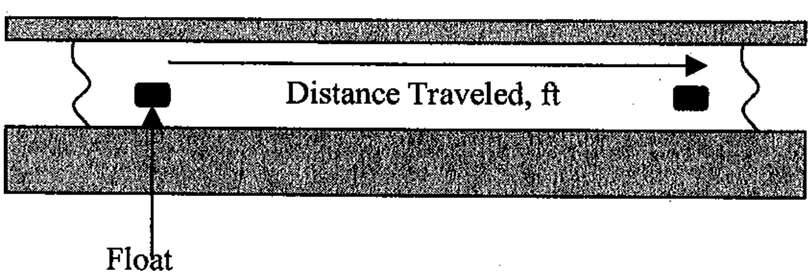
means we need time in seconds!!

$$\text{Vel} = \frac{300\text{ ft}}{134\text{ sec}} = \boxed{2.2\text{ ft/sec}}$$

3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min? 30 sec = 0.5 min

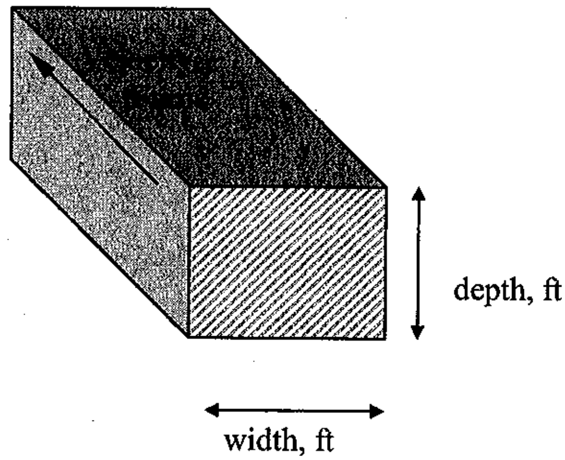
need time in minutes

$$\text{Vel} = \frac{105\text{ ft}}{0.5\text{ min}} = \boxed{210\text{ ft/min}}$$



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$



$$\underset{ft^3/\text{time}}{Q} = \underset{(ft)(ft)}{(A)} \quad \underset{(ft/\text{time})}{(V)}$$

Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

w = 48 in = 4 ft
d = 1.5 ft
vel = 2.8 ft/sec

$Q = (w)(d)(vel)$
$= (4ft)(1.5ft)(2.8 ft/sec)$
$= \boxed{16.8\ ft^3/sec}$

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

w = 3 ft
d = 2.5 ft
vel = 120 ft/min

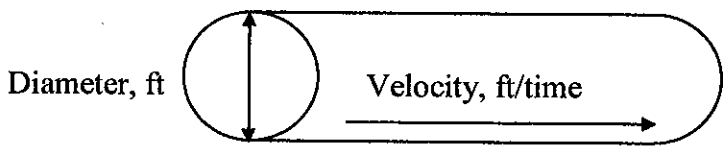
$Q = (3ft)(2.5ft)(120 ft/min) = \boxed{900\ ft^3/min}$

$\frac{(900 ft^3/min)(1440)(7.48)}{1,000,000} = \boxed{9.69\ MGD}$

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?

w = 3 ft
vel = 1.5 ft/sec
Q = 8.1 ft^3/sec

$Q = (w)(d)(vel)$
$\underset{ft^3/sec}{8.1} = \underset{ft}{(3)}\underset{ft}{(d)}\underset{ft/sec}{(1.5)}$
$8.1 = (4.5)(d)$
$\frac{8.1}{4.5} = d$
$\boxed{1.8 = d \text{ ft}}$



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\underset{(ft)(ft)}{(D)^2} \quad \underset{(ft/time)}{(vel)}$$

Flow through full pipe

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

D=2 ft
vel = 3.2 ft/sec

$Q = (0.785)(D, ft)(D, ft)(vel)$
$= (0.785)(2 ft)(2 ft)(3.2 ft/sec)$
$= \boxed{10\ ft^3/sec}$

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

D = 6 in = 0.5 ft
vel = 3 ft/sec

$Q = (0.785)(0.5 ft)(0.5 ft)(3 ft/sec)$
$= \boxed{0.59\ ft^3/sec}$

9. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

D = 8 in = 0.6667 ft
vel = 3.4 ft/sec

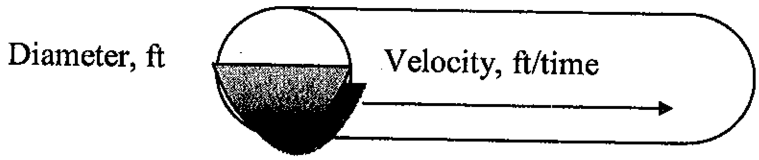
$Q = (0.785)(0.6667 ft)(0.6667 ft)(3.4 ft/sec)$
$= (1.1862\ ft^3/sec)(60)(7.48) = \boxed{532\ gpm}$

10. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

Q = 0.7 ft^3/sec
vel = 3.6 ft/sec

$Q = (0.785)(D, ft)(D, ft)(vel)$
$0.7 = (0.785)(D^2)(3.6)$
$0.7 = (2.826)(D^2)$
$\frac{0.7}{2.826} = D^2$
$\sqrt{0.25} = D^2$

0.50 = D
ft not inches
$\boxed{6 in}$ = 0.5 ft



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = \text{(Factor from d/D Table)} \underset{(ft)(ft)}{(D)^2} \quad \underset{(ft/time)}{(vel)}$$

<u>Flow through pipe flowing less than full</u>

11. A 12-inch diameter pipeline has water flowing at a depth of 6 inches. What is the gpm flow if the velocity of the wastewater is 300 fpm?

$D = 12 in = 1 ft$
$d = 6 in$
$vel = 300 ft/min$

$Q = (0.3927)(1 ft)(1 ft)(300 ft/min)$
$= (117.81 ft^3/min)(7.48) = \boxed{881 gpm}$

$d/D = 6/12 = 0.5$
$\rightarrow 0.3927$ on chart

12. A 10-inch diameter pipeline has water flowing at a velocity of 3.2 fps. What is the gpd flow rate if the water is at a depth of 5 inches?

$D = 10 in = 0.8333 ft$
$d = 5 in$
$vel = 3.2 ft/sec$

$Q = (0.3927)(0.8333 ft)(0.8333 ft)(3.2 ft/sec)$
$= (0.8727 ft^3/sec)(60)(1440)(7.48)$
$= \boxed{563{,}980 gpd}$

$d/D = 5/10 = 0.5$
$\rightarrow 0.3927$ on chart

13. An 8-inch pipeline has water flowing to a depth of 5 inches. If the flow rate is 415.85 gpm, what is the velocity of the wastewater in fpm? min – means flow needs to be in $ft^3/\underline{min}$

$D = 8 in = 0.6667 ft$
$d = 5 in.$

$Q = \frac{415.85 gpm}{7.48} = 55.5949 ft^3/min$

$d/D = 5/8 = 0.625 \approx 0.63$
$\rightarrow 0.5212$ on chart

$Q = (d/D \text{ number})(D, ft)(D, ft)(vel)$
$55.5949 ft^3/min = (0.5212)(0.6667 ft)(0.6667 ft)(vel)$
$55.5949 = (0.2316)(vel)$
$\frac{55.5949}{0.2316} = vel$
$\boxed{240 ft/min = vel}$

Lagoon Math

BOD Loading pg. 14-15

1. Calculate the BOD loading (lbs/day) on a pond if the influent flow is 390,000 gal/day with a BOD of 245 mg/L.

$$\text{BOD, lbs/d} = (\text{BOD, mg/L})(\text{Flow, MGD})(8.34)$$
$$= (245\ \text{mg/L})(0.39\ \text{MGD})(8.34)$$
$$= \boxed{796.9\ \text{lbs/d}}$$

2. The BOD concentration of the wastewater entering a pond is 158 mg/L. If the flow to the pond is 220,000 gal/day, how many lbs/day BOD enter the pond?

$$\text{BOD, lbs/d} = (158\ \text{mg/L})(0.22\ \text{MGD})(8.34)$$
$$= \boxed{289.9\ \text{lbs/d}}$$

3. The flow to a waste treatment pond is 175 gal/min. If the BOD concentration of the water is 221 mg/L, how many pounds of BOD are applied to the pond daily?

$$\frac{(175\ \text{gpm})(1440)}{1,000,000} = 0.252\ \text{MGD}$$

$$\text{BOD, lbs/d} = (221\ \text{mg/L})(0.252\ \text{MGD})(8.34)$$
$$= \boxed{464.5\ \text{lbs/d}}$$

4. The BOD concentration of the influent wastewater to a waste treatment pond is 190 mg/L. If the flow to the pond is 125 gpm, how many pounds of BOD are applied to the pond daily?

$$\frac{(125\ \text{gpm})(1440)}{1,000,000} = 0.18\ \text{MGD}$$

$$\text{BOD, lbs/d} = (190\ \text{mg/L})(0.18)(8.34)$$
$$= \boxed{285.2\ \text{lbs/d}}$$

Organic Loading Rate

5. A 7.5-acre pond receives a flow of 200,000 gal/day. If the influent flow has a BOD content of 190 mg/L, what is the organic loading rate in lbs/day/ac on the pond?

$$OLR = \frac{(\text{BOD, mg/L})(\text{Flow, MGD})(8.34)}{\text{Pond Area, Acres}}$$

$$= \frac{(190\ \text{mg/L})(0.2\ \text{MGD})(8.34)}{7.5\ \text{acres}}$$

$$= \boxed{42.3\ \text{lbs/d/acre}}$$

6. A pond has an average width of 400 feet and an average length of 710 feet. The flow to the pond is 157,000 gal/day with a BOD content of 147 mg/L. What is the organic loading rate in lbs/day/ac on the pond?

$$\text{Pond Area, acres} = \frac{(710\ \text{ft})(400\ \text{ft})}{43{,}560\ \text{ft}^2/\text{ac}} = 6.5197\ \text{ac.}$$

$$OLR = \frac{(147\ \text{mg/L})(0.157\ \text{MGD})(8.34)}{6.5197\ \text{ac}} = \boxed{29.5\ \text{lbs/d/acre}}$$

7. The flow to a pond is 70,000 gpd with a BOD content of 124 mg/L. The pond has an average width of 220 feet and an average length of 382 feet. What is the organic loading rate in lbs/day/ac on the pond?

$$\text{Pond Area, acres} = \frac{(220\ \text{ft})(382\ \text{ft})}{43{,}560\ \text{ft}^2/\text{ac}} = 1.92929\ \text{ac}$$

$$OLR = \frac{(124\ \text{mg/L})(0.07\ \text{MGD})(8.34)}{1.92929\ \text{ac}} = \boxed{37.5\ \text{lbs/d/acre}}$$

BOD Removal Efficiency

8. The BOD entering a waste treatment pond is 207 mg/L. If the BOD in the pond effluent is 39 mg/L, what is the BOD removal efficiency of the pond?

$$\text{BOD Removal\%} = \frac{207\,\text{mg/L} - 39\,\text{mg/L}}{207\,\text{mg/L}} \times 100\% = \boxed{81\%}$$

9. The influent of a waste treatment pond has a BOD content of 262 mg/L. If the BOD content of the pond effluent is 130 mg/L, what is the BOD removal efficiency of the pond?

$$\text{BOD Removal \%} = \frac{262 - 130}{262} \times 100 = \boxed{50\%}$$

10. The BOD entering a waste treatment pond is 280 mg/L. If the BOD in the pond effluent is 45 mg/L, what is the BOD removal efficiency of the pond?

$$\text{BOD Removal \%} = \frac{280 - 45}{280} \times 100 = \boxed{84\%}$$

11. The BOD entering a waste treatment pond is 140 mg/L. If the BOD in the pond effluent is 56 mg/L, what is the BOD removal efficiency of the pond?

$$\text{BOD Removal \%} = \frac{140 - 56}{140} \times 100 = \boxed{60\%}$$

Hydraulic Loading Rate

12. A 20-acre pond receives a flow of 3.3 acre-feet/day. What is the hydraulic loading rate on the pond in in./day?

$$\text{HLR} = \frac{\text{Flow, acre-feet/day}}{\text{Pond, acre}} \times 12\,\text{in/ft} = \frac{3.3}{20} \times 12 = \boxed{2\,\text{in/d}}$$

13. A 15-acre pond receives a flow of 5 acre-feet/day. What is the hydraulic loading rate on the pond in in./day?

$$\text{HLR} = \frac{5\,\text{acre-feet/day}}{15\,\text{acre}} \times 12\,\text{in/ft} = \boxed{4\,\text{in/d}}$$

Population Loading

14. A 4-acre wastewater pond serves a population of 1320 people. What is the population loading on the pond?

$$\text{Pop. Loading} = \frac{\text{persons}}{\text{acre}} = \frac{1320}{4} = \boxed{330}$$

15. A wastewater pond serves a population of 5460 people. If the pond covers 18.5 acres, what is the population loading on the pond?

$$\text{Pop. Loading} = \frac{5460 \text{ people}}{18.5 \text{ acres}} = \boxed{295}$$

Detention Time

16. A waste treatment pond has a total volume of 17 ac-ft. If the flow to the pond is 0.42 ac-ft/day, what is the detention time of the pond (days)?

$$DT = \frac{\text{vol, ac-ft}}{\text{flow, ac-ft/day}} = \frac{17 \text{ ac-ft}}{0.42 \text{ ac-ft/d}} = \boxed{40 \text{ days}}$$

17. A waste treatment pond is operated at a depth of 6 feet. The average width of the pond is 440 feet and the average length is 680 feet. If the flow to the pond is 0.3 MGD, what is the detention time in days?

$$DT = \frac{\text{Vol, gal}}{\text{Flow, gpd}} = \frac{(440 \text{ ft})(680 \text{ ft})(6 \text{ ft})(7.48)}{300{,}000 \text{ gpd}} = \boxed{45 \text{ days}}$$

18. The average width of the pond is 240 feet and the average length is 390 feet. A waste treatment pond is operated at a depth of 5 feet. If the flow to the pond is 70,000 gal/day, what is the detention time, in days?

$$DT = \frac{(240 \text{ ft})(390 \text{ ft})(5 \text{ ft})(7.48)}{70{,}000 \text{ gpd}} = \boxed{50 \text{ days}}$$

19. A waste treatment pond has an average length of 680 ft., an average width of 420 ft., and a water depth of 4 ft. If the flow to the pond is 0.47 ac-ft/day, what is the detention time for the pond in days?

$$\text{Vol, ac-ft} = \frac{(420\text{ ft})(4\text{ ft})(680\text{ ft})}{43{,}560\text{ ft}^2/\text{ac}} = 26.2259\text{ ac-ft}$$

$$DT = \frac{26.2259\text{ ac-ft}}{0.47\text{ ac-ft/d}} = \boxed{56\text{ days}}$$

ANSWERS:

1.	796.9 lbs/day	11.	60%
2.	289.9 lbs/day	12.	2 in/day
3.	464.5 lbs/day	13.	4 in/day
4.	285.2 lbs/day	14.	330
5.	42.3 lbs/day/acre	15.	295
6.	29.5 lbs/day/acre	16.	40 days
7.	37.5 lbs/day/acre	17.	45 days
8.	81%	18.	50 days
9.	50%	19.	56 days
10.	84%		

Section 10

Applied Math for BNS
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 4.4 MGD with a chlorine dose of 3.2 mg/L.

$$\text{lbs/d} = (\text{dose, mg/L})(\text{flow, MGD})(8.34\ \text{lbs/gal})$$
$$= (3.2\ \text{mg/L})(4.4\ \text{MGD})(8.34)$$
$$= \boxed{117.4\ \text{lbs/d}}$$

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

$$\text{lbs/d} = (1.1\ \text{mg/L})(1.66\ \text{MGD})(8.34)$$
$$= \boxed{15.2\ \text{lbs/d}}$$

3. Determine the chlorinator setting (lbs/day) needed to treat a flow of 1.2 MGD with a chlorine dose of 1.7 mg/L.

$$\text{lbs/d} = (1.7\ \text{mg/L})(1.2\ \text{MGD})(8.34)$$
$$= \boxed{17.0\ \text{lbs/d}}$$

Math

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.

$$\text{lbs/d} = (10\text{ mg/L})(0.37\text{ MGD})(8.34)$$
$$= \boxed{30.9\text{ lbs/d}}$$

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?

$$\frac{(3.8\text{ cfs})(7.48)(60)(1440)}{1{,}000{,}000} = 2.4558\text{ MGD}$$
$$\text{lbs/d} = (15\text{ mg/L})(2.4558\text{ MGD})(8.34)$$
$$= \boxed{307\text{ lbs/d}}$$

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?

$$\text{vol.} = (0.785)(0.5\text{ ft})^2(450\text{ ft})(7.48) = 660.5775\text{ gal}$$
$$= 0.000660578\text{ MG}$$
$$\text{lbs} = (150\text{ mg/L})(0.000660578\text{ MG})(8.34)$$
$$= \boxed{0.83\text{ lbs}}$$

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.

$$\text{lbs/d} = \frac{(\text{dose, mg/L})(\text{flow, MGD})(8.34)}{\%\text{chem. purity}}$$
$$= \frac{(10.8\text{ mg/L})(2.77\text{ MGD})(8.34)}{0.65}$$
$$= \boxed{384\text{ lbs/d}}$$

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?

$$\text{lbs/d} = \frac{(4\text{ mg/L})(4.2\text{ MGD})(8.34)}{0.60}$$

$$= \boxed{234\text{ lbs/d}}$$

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?

$$\text{lbs/d} = \frac{(18\text{ mg/L})(1.095\text{ MGD})(8.34)}{0.15}$$

$$= \boxed{1096\text{ lbs/d}}$$

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?

$$\frac{(75\text{ gpm})(1440)}{1,000,000} = 0.108\text{ MGD}$$

$$\text{lbs/d} = \frac{(15\text{ mg/L})(0.108\text{ MGD})(8.34)}{0.65}$$

$$= \boxed{20.8\text{ lbs/d}}$$

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.)

pg. 9 formula book

$$\text{bleach, gpd} = \frac{(\text{dose, mg/L})(\text{flow, MGD})}{\%\text{ available}}$$

$$= \frac{(15\text{ mg/L})(0.108\text{ MGD})}{0.15} = \boxed{10.8\text{ gpd}}$$

12. To inactivate and control slime in the collection system, 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)

$$\text{vol.} = (0.785)(1\text{ ft})^2(800\text{ ft})(7.48) = 4697.44 \text{ gal}$$
$$= 0.00469744 \text{ MG}$$

$$\text{gpd} = \frac{(8{,}000 \text{ mg/L})(0.00469744)}{0.40}$$

$$= \boxed{93.9 \text{ gpd}}$$

Chlorine Dose, Demand and Residual, mg/L pg. 9 formula book

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?

$$\text{Dose} = \text{Demand} + \text{Residual}$$
$$= 4.8 + 0.9$$
$$= \boxed{5.7 \text{ mg/L}}$$

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?

$$8.4 = \text{demand} + 0.8$$
$$8.4 - 0.8 = \text{demand}$$
$$\boxed{7.6 \text{ mg/L}}$$

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?

$$\text{Dose} = 8 + 1.5 = 9.5$$

$$\text{lbs/d} = (9.5 \text{ mg/L})(3.9 \text{ MGD})(8.34)$$

$$= \boxed{309 \text{ lbs/d}}$$

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)?

$$\text{Dose} = 4.9 + 0.8$$
$$= \boxed{5.7 \text{ mg/L}}$$

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?

$$8.8 = \text{demand} +$$
$$8.8 - 0.9 = \text{demand}$$
$$\boxed{7.9 \text{ mg/L}}$$

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?

$$\text{Dose} = 7.9 + 0.6$$
$$= \boxed{8.5 \text{ mg/L}}$$

<u>Chemical Dosage, mg/L</u> pg. 5 formula book

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.

$$\text{Dose, mg/L} = \frac{\text{chemical feed, lbs/d}}{(\text{flow, MGD})(8.34 \text{ lbs/gal})}$$

$$= \frac{31.5 \text{ lbs/d}}{(1.6 \text{ MGD})(8.34)} = 2.36 \text{ mg/L}$$

$$2.36 \text{ mg/L} = 1.85 + \text{Residual}$$
$$2.36 - 1.85 = \boxed{0.51 \text{ mg/L}}$$

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?

$$\frac{(2570\,gpm)(1440)}{1{,}000{,}000} = 3.7008\ MGD$$

$$dose, mg/L = \frac{93\ lbs/d}{(3.7008)(8.34)} = \boxed{3.0\ mg/L}$$

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?

$$dose, mg/L = 9\ mg/L + 1.7\ mg/L = 10.7\ mg/L$$

$$lbs/d = (10.7\ mg/L)(4.0\ MGD)(8.34)$$

$$= \boxed{357\ lbs/d}$$

Hypochlorination pg. 9 formula book

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?

$$lbs, HTH = \frac{(\%\ conc.\ hypo)(hypo., gal)(8.34)}{\%\ available}$$

$$= \frac{(0.02)(15\ gal)(8.34)}{0.65} = \boxed{3.8\ lbs}$$

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

$$lbs, HTH = \frac{(0.03)(1\ gal)(8.34)}{0.65}$$

$$= \boxed{0.4\ lbs}$$

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

$$lbs, HTH = \frac{(0.18)(5\ gal)(8.34)}{0.65}$$

$$= \boxed{11.5\ lbs}$$

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?

$83 \text{ lbs} - 69 \text{ lbs} = \boxed{14 \text{ lbs/d}}$

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.)

$13{,}528{,}924 - 12{,}982{,}083 = 546{,}841 \text{ gal}$

$$\text{dose} = \frac{14 \text{ lbs/d}}{(0.546841 \text{ MG})(8.34)}$$

$= \boxed{3.1 \text{ mg/L}}$

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.?

$(14 \text{ lbs/d})(3 \text{ d}) = 42 \text{ lbs}$

$69 - 42 = \boxed{27 \text{ lbs}}$

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?

$(14 \text{ lbs/d})(30 \text{d}) = 420 \text{ lbs}$

$\frac{420}{150} = 2.8 \approx \boxed{3 \text{ cylinders}}$

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?

$$298 - 216 = 82 \text{ lbs}$$

$$\frac{82 \text{ lbs}}{8 \text{ hrs}} = (10.25 \text{ lbs/hr})(24 \text{ hrs/d}) = \boxed{246 \text{ lbs/d}}$$

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?

$$298 - 246 = \boxed{52 \text{ lbs}}$$

31. What is the minimum number of ton ~2000 lbs cylinders the operator will need in a month with 31 days (at this feed rate)?

$$(246 \text{ lbs/d})(31 \text{ d}) = \frac{7626 \text{ lbs}}{2000 \text{ lbs}} = 3.8 \approx \boxed{4 \text{ cylinders}}$$

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 10

Applied Math for Wastewater Treatment Laboratory

Bacteriological, fecal coliform and *E. coli*

1. Calculate the geometric mean for the following fecal coliform test results: 60, 100, 0, 0, 40, 20, 20, 45, 55, 60, 20, 20

$$\sqrt[12]{(60)(100)(1)(1)(40)(20)(20)(45)(55)(60)(20)(20)}$$

$$= \sqrt[12]{5.7024 \times 10^{15}} = \boxed{21}$$

2. Calculate the geometric mean for the following fecal coliform test results: 0, 0, 50, 50, 25, 100, 100, 50, 75, 50

$$\sqrt[10]{(1)(1)(50)(50)(25)(100)(100)(50)(75)(50)}$$

$$= \sqrt[10]{1.171875 \times 10^{14}} = \boxed{26}$$

Solutions

3. How many mL of 0.7 N NaOH is needed to get 750 mL of 0.05 N NaOH?

V_1 N_1 V_2 N_2

$$(V_1)(N_1) = (V_2)(N_2)$$

$$(V_1)(0.7) = (750)(0.05)$$

$$V_1 = \frac{(750)(0.05)}{0.7} = \boxed{53.6 \text{ mL}}$$

4. How many mL of 0.5 N NaOH react with 800 mL of 0.1 N HCl?

V_1 N_1 V_2 N_2

$$(V_1)(0.5) = (800)(0.1)$$

$$V_1 = \frac{(800)(0.1)}{0.5} = \boxed{160 \text{ mL}}$$

Biochemical Oxygen Demand, BOD

- Blanks must not deplete more than 0.2 mg/L DO
- The sample must deplete at least 2.0 mg/L DO, if it does not, the dilution is too weak and report as inadequate depletion
- After 5 days of incubation at 20°C ± 1.0°C, the sample must have at least 1.0 mg/L DO, if less than, the sample was too strong

Section 10

5. Given the following information, determine the BOD of the wastewater:

Sample Volume = 5 mL $5/300 = 0.01667 = P$
BOD Bottle Volume = 300 mL
Initial DO of Diluted Sample = 6 mg/L D_1
Final DO of Diluted Sample = 3.5 mg/L D_2

$$BOD = \frac{D_1 - D_2}{P} = \frac{6 - 3.5}{0.01667} = \boxed{150\ mg/L}$$

6. Given the following information, determine the BOD of the wastewater:

Sample Volume = 10 mL $10/300 = 0.0333 = P$
BOD Bottle Volume = 300 mL
Initial DO of Diluted Sample = 8.3mg/L D_1
Final DO of Diluted Sample = 4.2 mg/L D_2

$$BOD = \frac{8.3 - 4.2}{0.0333} = \boxed{123\ mg/L}$$

7. Given the following primary effluent BOD test results, calculate the 7-day average:

April 10 – 190 mg/L
April 11 – 198 mg/L
April 12 – 205 mg/L
April 13 – 202 mg/L
April 14 – 210 mg/L
April 15 – 201 mg/L
April 16 – 197 mg/L

$$\frac{190 + 198 + 205 + 202 + 210 + 201 + 197}{7}$$

$$= \frac{1403}{7} = \boxed{200\ mg/L}$$

Alkalinity

8. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 24 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.2 to 4.5.

$$\text{Total Alk} = \frac{(\text{mL of titrant})(\text{N of sulfuric acid})(50{,}000)}{\text{sample vol, mL}}$$

$$= \frac{(24\ mL)(0.02\ N)(50{,}000)}{100\ mL}$$

$$= \boxed{240\ mg/L}$$

Section 10

9. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 10.1 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.5 to 4.5.

$$Alk = \frac{(10.1\ mL)(0.02\ mL)(50{,}000)}{100\ mL}$$

$$= \boxed{101\ mg/L}$$

Temperature

10. The influent to a treatment plant has a temperature of 72°F. What is the temperature expressed in degrees Celsius?

$$°C = (0.556)(°F - 32)$$

$$= (0.556)(72 - 32) = (0.556)(40) = \boxed{22.2°C}$$

11. Convert 56° F to degrees Celsius.

$$°C = (0.556)(56 - 32)$$

$$= (0.556)(24) = \boxed{13.3°C}$$

12. The effluent of a treatment plant is 22°C. What is this temperature expressed in degrees F?

$$°F = (1.8)(°C) + 32$$

$$= (1.8)(22) + 32$$

$$= 39.6 + 32$$

$$= \boxed{71.6°F}$$

Answers:

1. 21
2. 26
3. 53.6 mL
4. 160 mL
5. 150 mg/L
6. 123 mg/L
7. 200 mg/L
8. 240 mg/L
9. 101 mg/L
10. 22.2°C
11. 13.3°C
12. 71.6°F

Section 10

Applied Math for Wastewater
Pump Horsepower & Efficiency

1. A pump must pump 2,500 gpm against a total head of 73 feet. What horsepower (water horsepower) will be required to do the work?

$$Whp = \frac{(\text{flow, gpm})(\text{head, ft})}{3960}$$

$$= \frac{(2{,}500\text{ gpm})(73\text{ ft})}{3960} = 46\text{ hp}$$

2. A pump is delivering a flow of 1,035 gpm against 46.7 feet of head. What horsepower will be required?

$$Whp = \frac{(1035\text{ gpm})(46.7\text{ ft})}{3960}$$

$$= 12.2\text{ hp}$$

3. If a pump is to deliver 630 gpm of water against a total head of 102 feet, and the pump has an efficiency of 78%, what power must be supplied to the pump?

$$Bhp = \frac{(\text{flow, gpm})(\text{head, ft})}{(3960)(\text{pump eff., \%})}$$

$$= \frac{(630\text{ gpm})(102\text{ ft})}{(3960)(0.78)} = 20.8\text{ hp}$$

4. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

$$Mhp = \frac{Bhp}{\%\text{ motor eff.}} \qquad Bhp = \frac{Whp}{\%\text{ pump eff.}}$$

OR

$$Mhp = \frac{Whp}{(\%\text{ motor eff.})(\%\text{ pump eff.})} = \frac{10.1}{(0.84)(0.73)} = 16.5\text{ hp}$$

Section 10

5. What is the overall efficiency if an electric power equivalent to 36 hp is supplied to the motor and 16.3 hp of work is accomplished?

$$\%\text{Eff, overall} = \frac{\text{Whp}}{\text{Mhp}} \times 100$$

$$= \frac{16.3}{36} \times 100 = 45\%$$

6. A pump is discharging 1,250 gpm against a head of 71 feet. The wire-to-water efficiency is 82%. If the cost of power is $0.028/kW hr, what is the cost of the power consumed during a week in which the pump runs 126 hours?

$$\text{Mhp} = \frac{(1250)(71)}{(3960)(.82)}$$

$$= 27.33\text{hp}$$

$$\text{Cost, \$/hr} = (\text{Mhp})(0.746\ \text{kW/hp})(\text{cost, \$/kW-hr})$$

$$= (27.33)(0.746)(0.028)$$

$$= (\$0.57/\text{hr})(126\ \text{hrs}) = \$71.93$$

7. A wet well is 12 feet long and 10 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 2.6 feet during a 5-minute pumping test, what is the gpm pumping rate?

$$\text{Pump Rate, gpm} = \frac{(l, ft)(w, ft)(d, ft)(7.48)}{\text{time, min}}$$

$$= \frac{(12ft)(10ft)(2.6ft)(7.48)}{5\ \text{min}}$$

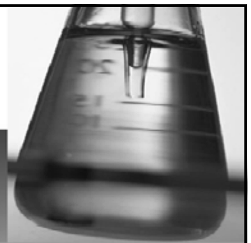
$$= 467\ \text{gpm}$$

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. $71.93
7. 467 gpm

Section 11

Lab



Laboratory

Biological Natural Systems

Chemical Names and Formulas

Chemical Name	Symbol
Calcium	Ca
Carbon	C
Chlorine	Cl
Hydrogen	H
Iron	Fe
Oxygen	O
Potassium	K
Sodium	Na
Sulfur	S

Beaker

- Most common piece of glassware
- Used for:
  - Mixing chemicals
  - Measure approximate volumes, they are NOT accurate for measurements

Graduated Cylinder

- Used to measure volumes more accurately than a beaker

Volumetric Flask

- Most accurate way to measure volume
- Disadvantage:
  - Only can measure one volume
  - Not used for storing or heating solutions

Pipet

- Pipets are glass or plastic tubes, usually open at both ends,which are used to transfer specific amounts of liquid from one container to another.
- They are usually used for volumes between 1 and 100 milliliters.

Types of Pipets

- Volumetric
- Measuring
  - Mohr
  - Serological

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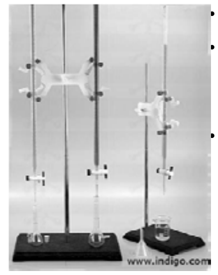
Buret



- Used for titration
- Glass stopcocks must be lubricated with stopcock grease
- Teflon stopcocks never needs lubricating

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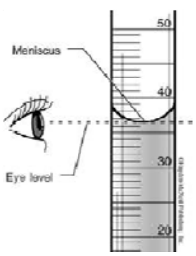
The Meniscus



- When water is placed in most containers, it clings to the sides
- Water slightly rises around the edges of the glassware, creating a curved surface to the water
- Read meniscus at eye level

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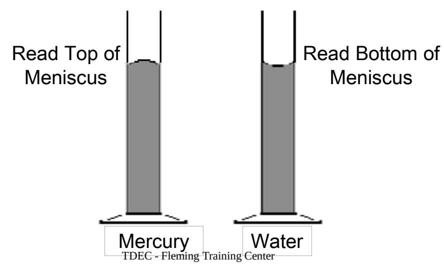
Water vs. Mercury



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Measuring Volume

- Beakers and Erlenmeyer flasks are used for measuring approximate volumes
  - Accurate within about 5%
- Graduated cylinders are generally accurate to within 1%
- When these are used for volume measurements, select a size that will be nearly filled up when making the measurement

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Flasks

- Flasks are used for containing and mixing chemicals

Distilling Flask

Erlenmeyer Flask

Flat Bottom Flask

Filter Flask

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Imhoff Cone

- Used to compare the amount of suspended solids that will settle out of liquids

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Centrifuge

- Used to separate materials of different density

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Autoclave

- Pressure cooker used to sterilize glassware, bottles, membrane filter equip, culture media and contaminated material to be discarded.
- Standard temperature is set at 121°C and 15 PSI

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Autoclave

- Because an autoclave uses saturated steam under high pressure to achieve sterilizing temperatures, proper use is important to ensure operator safety.

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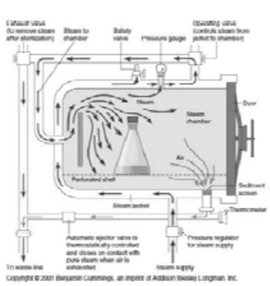
Autoclave

- Racks of test tubes, stacks of culture media and trays of used needles awaiting sterilization prior to disposal were splattered across the room by the tremendous concussion.
- Metal shrapnel penetrated the walls.
- A few minutes sooner or later and those projectiles could have easily struck a lab worker.
- Luckily, the room was unoccupied at the critical moment.



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Autoclave

- Prevent injuries when using the autoclave by observing the following rules:
  - Wear heat resistant gloves, eye protection, closed toed shoes and a lab coat, especially when unloading the autoclave.
  - Prevent steam burns and shattered glassware by making sure that the pressure in the autoclave chamber is near zero before opening the door at the end of a cycle. Slowly crack open the autoclave door and allow the steam to escape gradually.

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Autoclave

- Prevent injuries when using the autoclave by observing the following rules:
  - Allow items to cool for 10 minutes before removing them from the autoclave.
  - Never put sealed containers in an autoclave. They can explode. Large bottles with narrow necks may also explode if filled too full of liquid.
  - Never put solvents, volatile or corrosive chemicals (such as phenol, chloroform, bleach, etc.), or radioactive materials in an autoclave.

Refrigerators

- Sample storage should maintain between 1- 10°C
- Never store samples and chemicals together

Incubators

- Artificially heated container used for growing bacteria cultures
- Dry-Heat types hold temperatures to ±0.5°C
- For E. coli and Total coliform = 35 ±0.5°C
- Water Bath for fecals = 44.5 ±0.2°C

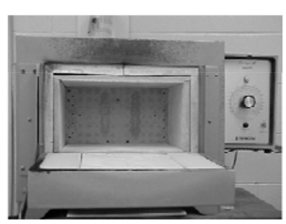
Incubators

- For BOD incubation at 20 ±1°C
- Do not store chemical solutions and samples in same refrigerator

Drying Oven

- For solids testing set oven at 103-105ºC

Muffle Furnace



- High temp oven used to ignite or burn solids.
- Usually operate at temps of 550°C.
- More often used in Wastewater lab work.

Sample Types

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

Grab Samples

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

Composite Sample

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

Composite Sample

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

Composite Sample

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

Sample Volume and Storage

- Volume depends on test requirements
- Use proper sampling container
- Follow recommended holding times and preservation methods
  - If bottle already has preservative or dechlorinator in it, don’t over fill or rinse out
- If you have questions regarding volume, container or holding times, check 40 CFR Part 136 Table II or contact the lab if you have an outside lab do your analysis

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 in the dark

Biochemical Oxygen Demand

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

Biochemical Oxygen Demand

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

Biochemical Oxygen Demand

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

Biochemical Oxygen Demand

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

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

Dissolved Oxygen

- Determines the amount of oxygen dissolved in samples of water
- Two options for testing DO
  - DO probe and meter
  - Winkler method

Suspended Solids

- The SS test measures the amount of solids in suspension that can be removed by filtration
  - The sample is filtered through a pre-weighed filter paper and dried in an oven at 103-105ºC

Suspended Solids

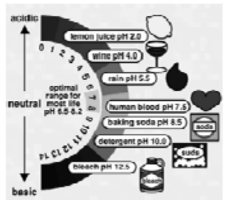
Technician Performing SS Test

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 milivolts, then converts into pH units
  - Temperature affects milivolts generated, therefore you need a temperature probe as well for corrections

pH

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

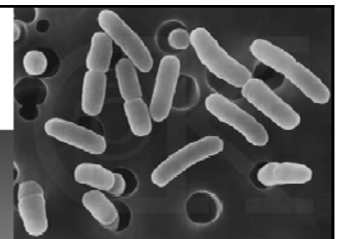


Chlorine Residual

- 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

- DPD colorimetric method most commonly used
  - Match color of sample to a standard
  - Swirl sample for 20 seconds to mix
  - Wait three minutes then place in colorimeter to read
  - *Note: DPD color comparator method is not approved*



Fecal Coliform

Summary of Method

- A 100 mL volume of sample is filtered through a 47-mm diameter sterile, white, grid marked filter (0.45µm pore size) membrane filter using standard techniques.
- Filter is transferred to a 50-mm petri plate containing an absorbent pad saturated with mFC Broth.
- Invert filter and incubate at 44.5±0.2°C for 24 hrs.
- Count blue colonies.

Interferences

- No interferences
- Excess particulates may cause colonies to grow together on a crowded filter or slow the sample filtration process.

Safety

- Follow standard safety practices appropriate to microbiological laboratories.
- Materials suspected of containing viable bacteria should be decontaminated using an autoclave or by using an appropriate disinfectant before discarding.

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Equipment

- Water bath or air incubator operating at 44.5±0.2°C
- Vacuum pump
- UV sterilizer or boiling water bath
- 10-15 X dissecting microscope; should have fluorescent illuminator
- Alcohol burner

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Supplies and Glassware

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

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Sampling

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

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Sampling

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

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Fecal Data Analysis

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

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Fecal Data Interpretation

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

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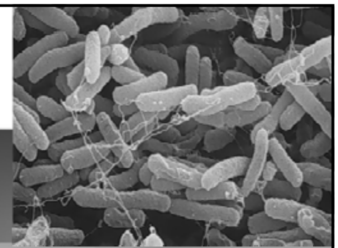

Escherichia coli (E.coli)

Colilert

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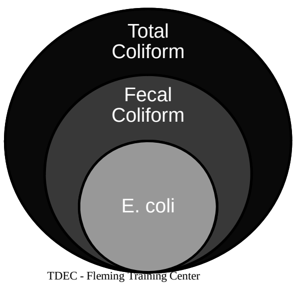
Family Portrait

- Indicators of water contamination



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Techniques for Measuring

- Most Probable Number (MPN)
- Membrane Filter

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Colilert® & Colilert-18®

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

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Colilert® & Colilert-18®

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

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Colilert® & Colilert-18®

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

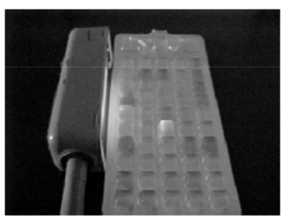
Colilert® & Colilert-18®

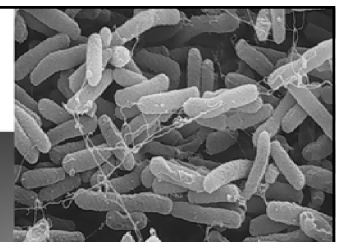
- Examine tray for appropriate color change
- Yellow is an indicator of total coliforms

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.

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





Escherichia coli (E.coli)

Modified mTEC Agar with Membrane Filtration

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

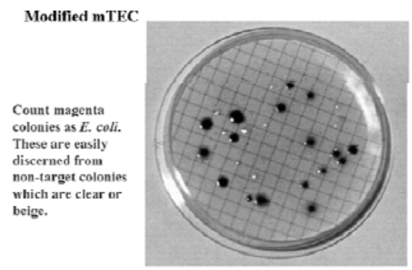
Method 1603

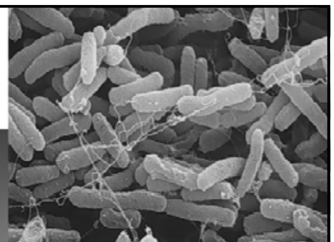
- Invert dish and incubate for 35± 0.5°C for 2 hours
  - Resuscitates injured or stressed bacteria
- Then incubate at 44.5± 0.2°C for 22 hours
- After incubation, remove the plate from the water bath or dry air incubator

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

Method 1603





Escherichia coli (E.coli)

m-ColiBlue24® with Membrane Filtration

m-ColiBlue24®

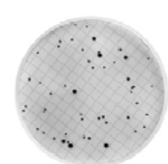
- Membrane Filter
- Filter sample dilutions through a 47mm diameter sterile, white, grid marked filter (0.45µm pore size)

m-ColiBlue24®

- Place sample in a petri dish with absorbent pad containing 2 mL mColiBlue 24 broth
- Invert dish and incubate at 35± 0.5°C for 24 ±2 hours

m-ColiBlue24®

- After incubation, remove the plate from the water bath or dry air incubator
- Count and record the number of blue colonies (verify with stereoscopic microscope)
- See the USEPA microbiology methods manual, Part II, Section C, 3.5, for general counting rules



E. coli Data Analysis

- Maximum sample hold time: 6 hrs
- Samples and equipment known or suspected to have viable E. coli attached or contained must be sterilized prior to disposal.

E. coli Data Interpretation

- Permit limit: 126 colonies/100 mL monthly average
- For MF method:
  - Select sample volumes to produce 20-80 colonies on the membranes.
  - Run minimum of 3 dilutions.
  - Must use sterile buffered water for dilutions and to rinse filtration unit.

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*

Expected Reactions of Various Microorganisms

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

Expected Reactions of Various Microorganisms

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

Expected Reactions of Various Microorganisms

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

•*Serratia species*	•*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

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

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All Bacteriological Checks

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

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Sampling and Analysis Plan

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

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QA / QC Program

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

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QA / QC Program

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

Record Keeping

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

Quality Control Tests

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

Duplicates

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

Common Source of Errors for Duplicates

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

Blanks

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

Blanks

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

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Blanks

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

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Laboratory Standards

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

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Unknown Laboratory Samples

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

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Spikes

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

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Spikes

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

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Other Samples

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

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Sampling and Analysis Plan

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

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Lab Safety

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

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TDEC - Fleming Training Center 00

Lab Hygiene

- Food and drink are not to be stored or prepared in laboratories or chemical storerooms
- Use appropriate personal protective equipment and wash your hands regularly when working with chemical reagents, especially before meals or snacks.
- Smoking in laboratories is prohibited.

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Lab Hygiene

- Loose sleeves are a hazard and should not be worn in the lab.
- If you have long hair, ensure that it is properly tied back.
- Wearing of contact lenses in the lab is strongly discouraged.
  - If it is unavoidable, advise your supervisor and co-workers so that this information is known in the event of a chemical splash in the eyes.

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Personal Practices

- No inappropriate clothing and shoes (shorts, sandals, slippers, etc.)
- Gloves removed before handling telephone, door handle or leaving laboratory
- No pipeting by mouth

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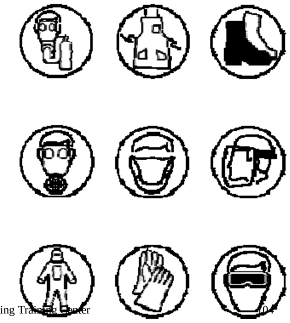
Personal Practices

- Lab coats and safety glasses/ goggles worn by all where necessary
- Proper gloves are used as needed
- Other personal protective equipment used properly as needed



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MSDS

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

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MSDS

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

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MSDS

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

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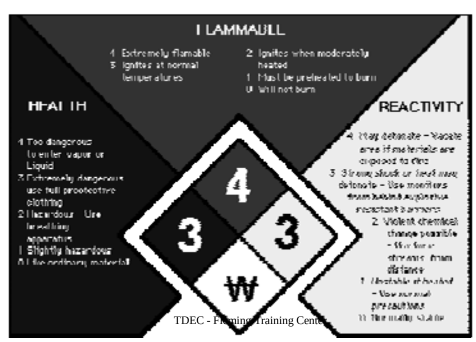
Chemical Label



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NFPA

- National Fire Protection Association
- Chemical hazard label
  - Color coded
  - Numerical system
    - Health
    - Flammability
    - Reactivity
  - Special precautions
- Labels are required on all chemicals in the lab

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Degrees of Hazard

- Each of the colored areas has a number in it regarding the degree of hazard
  - 4 → extreme
  - 3 → serious
  - 2 → moderate
  - 1 → slight
  - 0 → minimal

TDEC - Fleming Training Center 110

Special

- W
  - Water reactive
- Ox
  - Oxidizing agent

TDEC - Fleming Training Center 111

Design Criteria for Sewage Works

http://tn.gov/environment/wpc/publications/pdf/dcChapter7_16.pdf

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13.1 Purpose

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

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13.2.1.4 Flow Management

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

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13.2.2 Parshall Flumes

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

13.3.1.2 Sampling

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

13.3.1.5 Sampling

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

13.3.2 Manual Sampling

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

13.3.4 Sampling Schedules

- Samples must be taken and analyzed for two purposes: permit compliance and process control.
- The designer shall provide safe access points to collect representative influent and effluent samples of all treatment units and to collect samples of all sludge transmission lines.
- This makes it possible to determine the efficiency of each treatment process.
- Additional information about methods of analyses can be obtained from the Federal Register 40 CFR Part 136.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

TABLE IB – LIST OF APPROVED INORGANIC TEST PROCEDURES

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

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

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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]

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

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

STATE OF TENNESSEE

NPDES PERMIT

No. TN00-----

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

Issued By

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

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

Discharger: **--- STP**

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

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

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

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

This permit shall become effective on:

This permit shall expire on:

Issuance date:

Paul E. Davis, Director
Division of Water Pollution Control

CN-0759
(Template Rev. 1-05)

RDAs 2352 and 2366

1.0. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1.1. NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS

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

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

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

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

Note: See Part 1.2.3 for test procedures.

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

Total residual chlorine (TRC) monitoring shall be applicable when chlorine, bromine, or any other oxidants are added. The acceptable methods for analysis of TRC are any methods specified in Title 40 CFR, Part 136 as amended. The method detection level (MDL) for TRC shall not exceed 0.05 mg/l unless the permittee demonstrates that its MDL is higher. The permittee shall retain the documentation that justifies the higher MDL and

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

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

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

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

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

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

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

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

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

1.2. MONITORING PROCEDURES

1.2.1. Representative Sampling

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

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

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

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

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

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

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

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

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

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

1.2.2. Sampling Frequency

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

1.2.3. Test Procedures

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

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

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

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

1.2.4. Recording of Results

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

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

b. The exact person(s) collecting samples;

c. The dates and times the analyses were performed;

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

e. The analytical techniques or methods used, and;

f. The results of all required analyses.

1.2.5. Records Retention

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

1.3. REPORTING

1.3.1. Monitoring Results

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

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

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

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

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

1.3.2. Additional Monitoring by Permittee

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

1.3.3. Falsifying Results and/or Reports

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

1.3.4. Monthly Report of Operation

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

1.3.5. Bypass and Overflow Reporting

1.3.5.1. Report Requirements

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

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

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

1.3.5.2. Anticipated Bypass Notification

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

1.3.6. Reporting Less Than Detection

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

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

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

1.4. COMPLIANCE WITH SECTION 208

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

1.5. REOPENER CLAUSE

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

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

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

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

2.0. GENERAL PERMIT REQUIREMENTS

2.1. GENERAL PROVISIONS

2.1.1. Duty to Reapply

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

2.1.2. Right of Entry

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

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

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

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

2.1.3. Availability of Reports

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

2.1.4. Proper Operation and Maintenance

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

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

2.1.5. Treatment Facility Failure (Industrial Sources)

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

2.1.6. Property Rights

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

2.1.7. Severability

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

2.1.8. Other Information

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

2.2. CHANGES AFFECTING THE PERMIT

2.2.1. Planned Changes

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

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

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

2.2.2. Permit Modification, Revocation, or Termination

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

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

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

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

2.2.3. Change of Ownership

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

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

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

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

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

2.2.4. Change of Mailing Address

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

2.3. NONCOMPLIANCE

2.3.1. Effect of Noncompliance

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

2.3.2. Reporting of Noncompliance

a. 24-Hour Reporting

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

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

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

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

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

b. Scheduled Reporting

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

2.3.3. Overflow

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

b. Overflows are prohibited.

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

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

to a Monthly Operating Report submitted to the local TDEC Environmental Field Office. The data measurement period shall be sufficient to account for seasonal rainfall patterns and seasonal groundwater table elevations.

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

2.3.4. Upset

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

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

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

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

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

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

2.3.5. Adverse Impact

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

2.3.6. Bypass

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

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

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

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

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

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

2.3.7. Washout

a. For domestic wastewater plants only, a "washout" shall be defined as loss of Mixed Liquor Suspended Solids (MLSS) of 30.00% or more. This refers to the MLSS in the aeration basin(s) only. This does not include MLSS decrease due to solids wasting to the sludge disposal system. A washout can be caused by improper operation or from peak flows due to infiltration and inflow.

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

2.4. LIABILITIES

2.4.1. Civil and Criminal Liability

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

2.4.2. Liability Under State Law

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

3.0. PERMIT SPECIFIC REQUIREMENTS

3.1. CERTIFIED OPERATOR

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

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

3.2. POTW PRETREATMENT PROGRAM GENERAL PROVISIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

d. Reporting Requirements

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

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

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

(approved and developing programs)

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

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

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

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

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

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

v. A description of all substantive changes made to the permittee's pretreatment program. Any such changes shall receive prior approval. Substantive

changes include, but are not limited to, any change in any ordinance, major modification in the program's administrative structure, local limits, or a change in the method of funding the program.

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

3.3. SLUDGE MANAGEMENT PRACTICES

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

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

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

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

POLLUTANT	CONCENTRATION (mg/kg[1])	POLLUTANT	CONCENTRATION (mg/kg[1])
Arsenic	75	Mercury	57
Cadmium	85	Molybdenum	75
Zinc	7500	Nickel	420
Copper	4300	Selenium	100
Lead	840		

1 Dry Weight Basis

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

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

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

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

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

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

If sludge disposal is to a municipal solid waste landfill:

The current method of sludge disposal is to a municipal solid waste landfill (or co - composting facility). This method of disposal is controlled by the rules of the Tennessee Division of Solid Waste Management (DSWM) and Federal Regulations at 40 CFR 258. If the permittee anticipates changing its disposal

practices to either land application or surface disposal, the Division of Water Pollution Control shall be notified prior to the change. A copy of the results of pollutant analyses required by the Tennessee Division of Solid Waste Management (DSWM) and / or 40 CFR 258 shall be submitted to the Division of Water Pollution Control.

Sludge language for lagoon systems:

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

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

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

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

3.4. BIOMONITORING REQUIREMENTS, CHRONIC

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.5. BIOMONITORING REQUIREMENTS, ACUTE

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

All tests will be conducted using four separate grab samples of final effluent, to be used in four separate tests, and shall be collected at evenly spaced (6-hour) intervals over a 24-hour period. If in any control, more than 10% of the test organisms die in 48 hours, the test (control and effluent) is considered invalid and the test shall be repeated within two (2) weeks. Furthermore, if the results do not meet the acceptability criteria in Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012 (or the most current edition), if the required concentration-response review fails to yield a valid relationship per

guidance contained in Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing, EPA-821-B-00-004 (or the most current edition), that test shall be repeated. Any test initiated but terminated before completion must also be reported along with a complete explanation for the termination.

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

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

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

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

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

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

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

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

3.6. PLACEMENT OF SIGNS

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

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

Permitted CSO or unpermitted bypass/overflow point:

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

NPDES Permitted Municipal/Sanitary Outfall:

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

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

3.7. ANTIDEGRADATION

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

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

3.8. PUMP/LIFT STATION INSPECTION

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

4.0. DEFINITIONS AND ACRONYMS

4.1. DEFINITIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.2. ACRONYMNS AND ABBREVIATIONS

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

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

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

BAT – best available technology economically achievable

BCT – best conventional pollutant control technology

BDL – below detection level

BOD_5 – five day biochemical oxygen demand

BPT – best practicable control technology currently available

$CBOD_5$ – five day carbonaceous biochemical oxygen demand

CFR – code of federal regulations

CFS – cubic feet per second

CFU – colony forming units

CIU – categorical industrial user

CSO – combined sewer overflow

DMR – discharge monitoring report

D.O. – dissolved oxygen

E. coli – *Escherichia coli*

EFO – environmental field office

LB(lb) - pound

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

IU – industrial user

IWS – industrial waste survey

LC_{50} – acute test causing 50% lethality

MDL – method detection level

MGD – million gallons per day

MG/L(mg/l) – milligrams per liter

ML – minimum level of quantification

ml – milliliter

MLSS – mixed liquor suspended solids

NODI – no discharge

NOEC – no observed effect concentration

NPDES – national pollutant discharge elimination system

PL – permit limit

POTW – publicly owned treatment works

RDL – required detection limit

SIU – significant industrial user

SSO – sanitary sewer overflow

STP – sewage treatment plant

TCA – Tennessee code annotated

TDEC – Tennessee Department of Environment and Conservation

TIE/TRE – toxicity identification evaluation/toxicity reduction evaluation

TMDL – total maximum daily load

TRC – total residual chlorine

TSS – total suspended solids

WQBEL – water quality based effluent limit

RATIONALE

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

1. FACILITY INFORMATION

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

2. RECEIVING STREAM INFORMATION

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

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

3. CURRENT PERMIT STATUS

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

Section 12

Packed Bed Filters

Packed Bed Filters

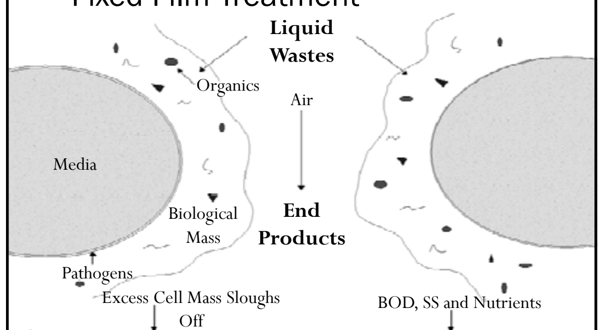
Packed Bed Filters Introduction

- Secondary treatment units
- Follow primary treatment in a septic tank
- Fixed film treatment systems
  - Biomass grows on media
- A passive aerobic system
- Examples: open sand filter, RSF, open cell foam, textile, peat moss.

PBF Treatment Process

- Wastewater applied in small doses
- Percolates over media in thin film
- Organisms on media contact wastewater
  - Can't let them dry out
- ***Air maintained in media pores***
- Oxygen transferred into the thin film and to organisms
- Aeration may be active or passive

Fixed Film Treatment



Theory of Operation

- Organisms are "fixed" on media surface
- WW is "micro-dosed" to the filter
- WW is treated as it moves over media surfaces in contact with organisms

Modes of Treatment

- Filtration and trapping of organic matter and pathogens
- Adsorption of pathogens, ammonium and some phosphorus
- Biological decomposition of organic matter
- Biochemical transformations

Typical Concentrations of Effluent from Septic Tanks and PBFs

	BOD, mg/L	TSS, mg/L	Nitrate – N, mg/L	Ammonia – N, mg/L	DO, mg/L	Fecal Coliform, cfu/100 mL
Septic Tank	130 – 250	30 – 130	0 – 2	25 – 60	Less than 2	$10^5 – 10^7$
PBF	5 – 25	5 – 30	15 – 30	0 – 4	3 – 5	$10^2 – 10^4$

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Packed Bed Filter Effluent vs. Septic Tank Effluent

- Low oxygen demand (BOD) → 90% removed
- Low in total and volatile solids → 90% removed
- Will not form a significant biomat in soils
- Low in pathogens → 99% removed
- Significant reduction total nitrogen – 40-80% removed

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Two Major Categories of PBF

- Single Pass: through once
- Recirculating: part passes through more than once

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Media Types

- Natural and mineral media
  - Sand and gravel
  - Expanded shale
  - Cinders
  - Limestone
  - Activated carbon
  - Peat or peat fiber

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Manufactured Media Types

- Textile fabric
- Open cell foam cubes
- Hard plastic
- Crushed recycled glass
- Chipped recycled tires
- Processed slag

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Sand and Gravel Filters

- Designed and constructed to operate in either single pass or recirculating mode
- Media must meet specific specifications
- Must (generally) be processed to provide the right gradation
  - Sometimes crushed
  - Screened for proper gradation
  - Washed
- Must be handled carefully after processing to maintain the specification and remain free of fines

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Biological Processes

- Biofilm forms on sand grains
- Oxygen around the film promotes aerobic activity
- Many microorganism species present at all times
- Most in the upper 12 inches
- Insufficient food limits organisms in lower layers
- Most BOD removal occurs in the top few inches
- Organic matter consumed by microbes in the biofilm

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Important Biological Design Parameters

- Choice of media
  - Surface area
  - Void space
- Provision for aeration
  - Active
  - Passive
- Small doses of wastewater applied uniformly
  - Keeps flow in the biofilm – i.e. unsaturated flow
  - Provides residence time in thin films on surfaces
  - Prevents displacing air from voids

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More on Biological Processes

- Nitrogen removal is a biological process
- Nitrifying bacteria convert ammonium-N (NH_4)and organic-N to nitrate-N (NO_3)
- Most conversion to NO_3 occurs in the top 12 inches
- In small pores and lower in the filter, oxygen concentrations are reduced and biological Denitrification is thought to occur in smaller saturated pores
- Nitrogen gas (N_2) is released to the air

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Oxygen Requirements of a PBF

- Based on the BOD_5 and Nitrogen load applied
- BOD_5 load applied is determined by flow and concentration of applied effluent
  - lbs BOD_5/day = (BOD_5, mg/L)(Q, MGD)(8.34)
  - lbs TKN/day = (TKN, mg/L)(Q, MGD)(8.34)
  - lbs O_2/day = (1.2)(BOD_5, lbs/day) + (4.6)(TKN, lbs/day)

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Single Pass Systems

- Any of the media options may be used in either single pass or recirculating mode
- Natural/Mineral media are more likely to be used in single pass mode
- Manufactured media are usually used in recirculating mode

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Single Pass Sand Filters

- Several designs are in use
  - Free access (open)
  - Buried single pass
  - Pressure dosed single pass

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Free Access Sand Filters

- Oldest form for individual sites
- Used for community wastewater treatment since late 1800's in Massachusetts
- May be large – several acres in size
- Depth ranged from 3 to 8 feet

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Free Access Sand Filters

- Wastewater is pump or siphon dosed to the filter, discharged at a single point
- Gravity flow over the surface of the filter
- Require frequent maintenance of the surface to break up or remove accumulated solids

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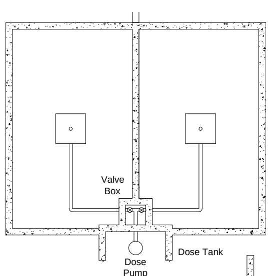
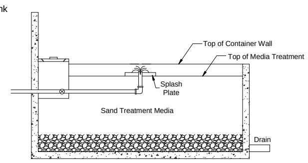
Two Cell Open or Free Access Sand Filter



←Plan View

Cross Section →



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Buried, Gravity Fed Single Pass Sand Filters

- Distribution is through 4-inch diameter pipe with large (1/2" +) perforations
- Septic tank effluent flows by gravity to the filter at whatever rate it flows from the tank
- Poor distribution limits the life
- Effluent quality is better than might be expected, similar to pressure dosed single pass systems

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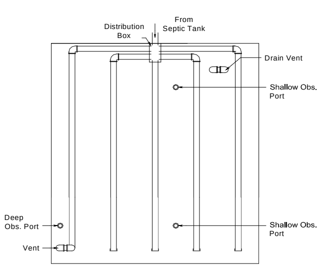
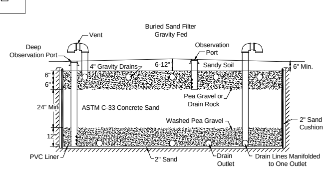
Buried Gravity Flow Single Pass Sand Filter



← Plan View

Cross Section →



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Pressure Dosed Single Pass Sand Filters (SPSF)

- The preferred system – uniform application
- Pump control can include a timer so that effluent can be "micro-dosed" to the sand filter uniformly over time as well as space
- Provides the ultimate in slow, unsaturated flow
  - Assures film flow
  - Long residence time for biological reactions
  - Air remains in pores for oxygen diffusion into the moisture films on surfaces – to microbes

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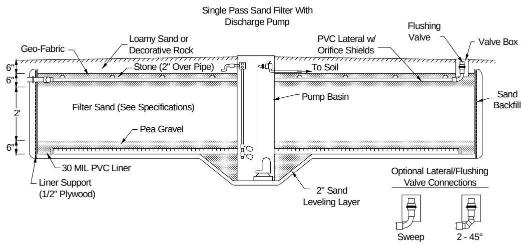
Single Pass Pressure Dosed Sand Filter With Pump Basin – Cross Section



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SPSF Sand System Design

- **Surface area loading = 1–1.25 gpd/ft^2 (design Q)**
- **Media depth 24 inches**
- Maximum soil cover 8–12 inches
- Texture of soil cover: sand or loamy sand
- Bottom layer: 6–8 inches of pea gravel around drain
- Maximum flow distance to 4" slotted drain: 15 ft

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SPSF Cut-Away Illustration

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SPSF Showing Valve Boxes Over Cleanouts

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Hydraulic and Organic Loading -- SPSF

- Typical design hydraulic loading is 1–1.2 gpd/ft^2
- For cold climates, keep hydraulic load < 1.0 gpd
- Dose volume < 0.5 gal/orifice/dose
- Typical doses per day: 18–24

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Maintenance For SPSF

- Good maintenance is key
- Maintenance minimum annually
- First visit MUST be within the first few weeks of use
  - To catch construction damage or errors
  - To be sure controls are set correctly for the use pattern
  - To check for leaks, including leaky tanks
  - To advise owner/resident on SPSF use
  - To be sure landscaping does not add depth, compact or cause other damage

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Maintenance Routine for the SPSF

- The septic tank(s) should be inspected periodically (not every visit) and pumped as needed
- Flush pressure pipe network
- Check pressure at end of laterals: compare with previous
- Check sand filter for ponding (in monitoring tubes)
- Check pump controls for proper operation
- Read pump run-time meter and event counter
- Check pump voltage (off and while pumping) and amp draw while pumping
- Pull and observe the final effluent in a clear sample bottle checking for clarity and odor.

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Drainfield Check as Part of Maintenance Visit

- Check for wetness around the drainfield
- Note vegetation patterns
- Note ponding level in observation tubes
- Observe surface flow patterns
  - Be sure surface runoff is directed away from drainfield and SPSF
  - Roof water/downspout drainage away from system

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Recirculating Systems

- Recirculation is used in many wastewater treatment processes, usually to retain organism populations
- Recirculating sand filter concept was introduced by Hines and Favreau in the 1970's.
- Involve mixing a portion of the filtered effluent with incoming septic tank effluent
- This blended effluent can be applied to filter media at higher loading rates

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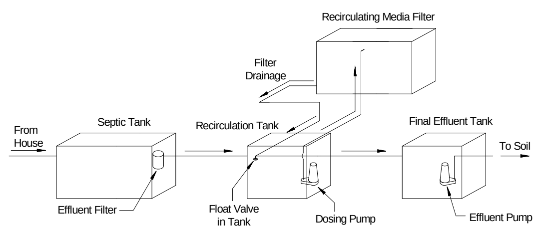
Recirculating Packed Bed Filter Schematic



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Achieving Recirculation

- Drainage from the filter is directed through a flow divider
  - One part is sent to final dispersal
  - 3 – 5 parts, more or less, are returned to the recirc. tank for another pass through the filter
- The pump control timer is set to deliver the desired total quantity of flow to the filter daily
  - Qf = Qi (Rr +1)

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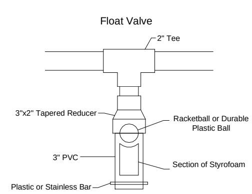
Simple Float Valve Illustration



- Valve is mounted in the recirc. tank on the filter drain return line
- When the valve is closed, all the flow is sent to final dispersal
- When the valve is open, all the flow drops into the tank
- By setting the timer for the correct total daily flow to the filter, the system provides the proper recirculation ratio.

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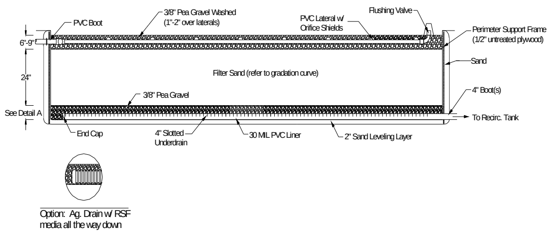
Typical RSF Cross Section



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Adapted from Orenco Systems, Inc.
Note, this may not be the best drawing

Benefits of Recirculation

- Diluted effluent is applied to the filter
  - Can apply effluent a greater forward flow loading rate
  - Less odor
- Smaller filter for a given flow
- Can withstand somewhat higher strength incoming wastewater
- Can cope with flow variations, including peak flows
- Provides a means for making adjustments for variations in flow and strength through varying recirculation ratios

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Typical RSF Media

- Fine gravel media with effective size of 2.5 – 3 mm
- Note lack of fines on the media
- This is a good material for an RSF for domestic effluent

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Recirculation Tank Design

- Size: volume equal to daily design flow
- Configuration:
  - Septic tank effluent and return flow from filter enter at same end of the tank to mix
  - Pump(s) to filter are at opposite end of tank
  - Provide long flow path to pump end
  - Pumps mounted up off tank floor
    - Preferably in a vault with effluent screen ahead of pump intake
    - Intake to pump system at mid-depth of tank

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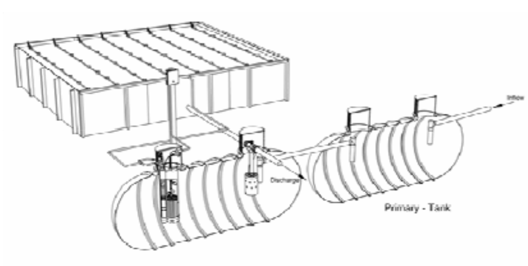
RSF -- Recirculation Tank Illustration



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Multiple Cell Community RSF Makes Maintenance Easier

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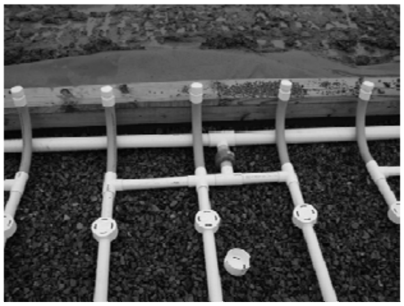
Laterals End with Constant Flow Out



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Sand Filter Frame Ready for Media

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Sand Filter Drain Network

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RSF Effluent Quality

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RSF Maintenance Tasks

- Check observation sumps in S.F. for ponding
- Flush distribution system lines
- Check pressure to determine orifice clogging
- Clean orifices as needed
- Make sure drain(s) are not submerged and can "breath" air into filter

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RSF Maintenance Tasks

- Check pump controls for proper operation and adjustment
- Check pump voltage – off and while pumping
- Check pump amp draw while pumping
- Check Soil Absorption System observations sumps
- Check sludge and scum in septic tank(s) & pump tank

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PBF Controls

- Control systems for pumps and dosing are critical to proper operation
- Uniform distribution and small, frequent doses are required for best treatment
- Timer control for pumps is preferred
- For single pass systems, timers can be turned on and off by floats

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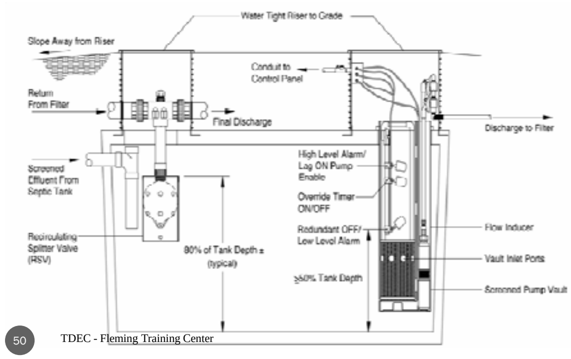
Pump in a recirc. tank with floats to control the timer, alarms, and a second pump



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Float Type Controls

- Floats may contain mechanical or mercury switches
- Should be mounted on a separate bracket or float "tree"
  - Separate from pump discharge pipe
  - Removable as a unit for float position adjustment
  - Allow pump removal without disturbing floats
- Floats must be positioned so as not to become inhibited by chords, other floats, or piping

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Pump Selection

- Pumps used are usually submersible
  - High head turbine pumps – a converted well pump
  - Effluent pumps – higher flow, low head
- Turbine pumps are desirable for feeding distribution systems with small holes (typical 1/8")
  - Steep curve assists in providing self cleaning
  - Head increases rapidly as flow is reduced
- If effluent pumps are used, in-line screens can be added to help protect against orifice clogging
- Both types of pumps, if selected for effluent applications, will provide long service life
- Liquid levels should be designed to keep pumps submerged.

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Peat Filters

- Peat is excellent media for PBFs
- Forms: fiber, moss, pellets or prefabricated peat bales
- Modular, ready to set in place and connect up
- Peat is carefully chosen and often processed

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Peat Filters (cont.)

- Typically used in single pass mode
- Peat houses a wide variety of microflora from bacteria to nematodes
- Peat deteriorates over time and must be replaced
- Good, long term performance
- Effluent quality similar to sand filters, but much less space required: about 1/6 as much

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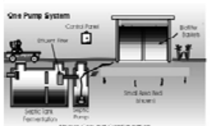
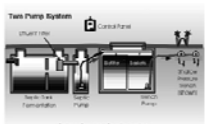
Open Cell Foam Filters

- Developed for use in Ontario as the "Waterloo Biofilter"
- Polyurethane foam (2" cubes)
- Wastewater sprayed over the top of media
- Long retention time in the filter provides good treatment
- Sometimes requires forced air





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Waterloo® Open Cell Foam Filters

- Foam cubes have large surface area and large void volume percentage.
- Foam is not decomposed by organisms in wastewater.
- Media 36 to 102" deep.
- Doses/day: 80 to 140.

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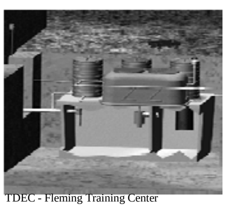
SCAT® Open Cell Foam Filter

- Hydraulic load: 11 to 16 gpd/ft^2
- Helical spray nozzle @ 5 to 8 psi
- Void space: 30%
- Dose Volume: 1.2 to 1.5 gal/ft^2



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AdvanTex® Textile Filter

- Most has geosynthetic or geotextile fabric
- Vertical sections of fabric are 2 ft long hung side by side
- Wastewater applied in small, uniform doses several times per hour
- Hydraulic load:
  - 25 to 35 gpd/ft^2 (very high due to increased surface area)

South Blount Utility has these and the effluent then goes to a drip field

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AdvanTex® Textile Filter

- Operated in recirculating mode
- Aerobic conditions maintained due to large volume of pore space (90%)
- BOD and TSS removed efficiently
- Ammonia is nitrified
- Denitrification for nitrogen removal possible

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Section 13

Disinfection

Wastewater Disinfection and Chlorination

Removal of Pathogenic Microorganisms

- Wastewater treatment removes some of the pathogenic microorganisms through these processes:
  - Physical removal through sedimentation and filtration
  - Natural die-off in an unfavorable environment
  - Destruction by chemicals introduced for treatment purposes

Disinfection vs. Sterilization

- Disinfection is the destruction of all pathogenic microorganisms
  - Chlorination of wastewater is considered adequate when the fecal coliform count has been reduced to 200 cfu/100 mL or less
- Sterilization is the destruction of ALL microorganisms

Pathogenic Organisms

- Diseases that are spread through water are:
  - Viral
    - Polio
    - Hepatitis A
  - Protozoa
    - Amebic Dysentary
    - Giardiasis
    - Cryptosporidiosis
  - Bacterial
    - Choler
    - Typhoid
    - Salmonellosis
    - Shigellosis, a bacillary dysentery
    - Gastroenteritis from enteropathogenic Escherichia coli

Disinfection

- The main objective of disinfection is to prevent the spread of disease by protecting:
  - Public water supplies
  - Receiving waters used for recreational purposes
  - Shellfish growing areas

Chlorine Chemicals

- Elemental chlorine
  - Yellow-green gas or amber liquid
  - 100% chlorine
- Sodium hypochlorite – bleach
  - Clear, pale yellow liquid
  - 5-15% chlorine
- Calcium hypochlorite – HTH
  - White, pale yellow granules or tablets
  - 65% chlorine
- Chlorine dioxide
  - Green-yellow gas generated on-site

Chlorine

- Reacts with:
  - Organic matter
  - Hydrogen sulfide (H_2S)
  - Iron
  - Phenols
  - Manganese
  - Nitrite
  - Ammonia
  - And lastly used for disinfection

Chemistry of Chlorination

$Cl_2 + H_2O \rightarrow HOCl + HCl$

hypochlorous acid hydrochloric acid

- Hypochlorous acid
  - Most effective disinfectant
  - Prevalent at pH less than 7
    Dissociates at higher pH:

    $HOCl \rightarrow H^+ + OCl^-$

    hypochlorite ion
  - Hypochlorite ion is only 1% as effective as hypochlorous acid.

Chemistry of Hypochlorination

$NaOCl + H_2O \rightarrow HOCl + NaOH$

hypochlorous acid

- Sodium hypochlorite will slightly raise the pH because of the sodium hydroxide (NaOH)

$Ca(OCl)_2 + 2H_2O \rightarrow Ca(OH)_2 + 2HOCl$

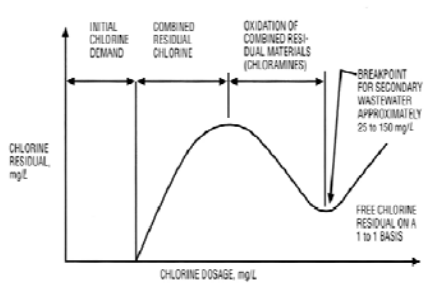
- Calcium hypochlorite does the same

Chlorine Dioxide (ClO_2): Chemistry

- Made onsite and very unstable
- $2NaClO_2 + Cl_2 \rightarrow 2NaCl + 2ClO_2$
  Sodium Chlorite, Chlorine, Sodium Chloride, Chlorine Dioxide

- $2ClO_2 + H2O \rightarrow ClO_3^- + ClO_2^- + 2H^+$
  Chlorine dioxide, Water, Chlorate Ion, Chlorite Ion, Hydrogen Ion

Breakpoint Chlorination Curve



Factors Influencing Disinfection

- Injection point and method of mixing
- Design or shape of contact chamber
- Contact time
  - Most contact chambers are designed to give 30 min contact time
- Effectiveness of upstream processes
  - The lower the SS, the better the disinfection
- Temperature
- Dose and type of chemical
- pH
- Numbers and types of microorganisms

Chlorine Demand

- Chlorine demand can be caused by environmental factors such as:
  - Temperature
  - pH
  - Alkalinity
  - Suspended solids
  - Biochemical and chemical oxygen demand
  - Ammonia nitrogen compounds

Application Points for Chlorination

- Collection system
- Prechlorination
- Plant chlorination
- Chlorination before filtration
- Post-chlorination

Collection System

- Odor control
  - Aeration may be most cost efficient
- Corrosion control
- BOD control
  - Decrease the load imposed on the STP

Prechlorination

- The addition of chlorine to wastewater at the entrance to the treatment plant, ahead of settling units and prior to the addition of other chemicals
  - Aids in:
    - Odor control
    - Decrease BOD load
    - Settling
    - Oil removal

Plant Chlorination

- Chlorine can be added to wastewater during treatment
  - The point of application depends on the desired results
- Emergency measure only, use extreme care when chlorinating in the treatment process because you may interfere or inhibit biological treatment processes
- Aids in:
  - Control of odors
  - Corrosion
  - Sludge bulking
  - Digester foam
  - Filter flies
  - Trickling Filter Ponding

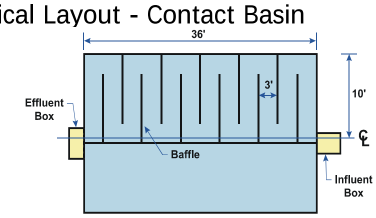
Chlorination Before Filtration

- Kills algae and other large biological organisms in water or in filters
  - Biological growth may cause filters to clog which would cause the need to backwash more frequently

Post-chlorination

- Post-chlorination is defined as the addition of chlorine to municipal or industrial wastewater following other treatment processes
  - Point of application should be called a Chlorine Contact Chamber or Basin
  - Sole purpose is disinfection

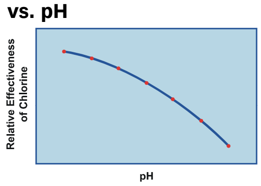
Typical Layout - Contact Basin



- Requirements:
  - 30:1 length to width
    - The total length of the channel created by the baffles should be 30 times the distance between the baffles
  - 15 min. contact time at peak hourly flow
  - 30 min. contact time at max monthly avg. flow

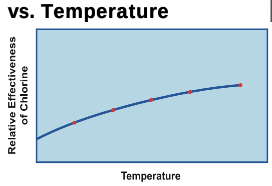
Relative Effectiveness

vs. pH



The lower the ph (<7), the disinfection action increases because hypochlorous acid is formed from chlorine and has 40 to 80 times greater disinfection potential.

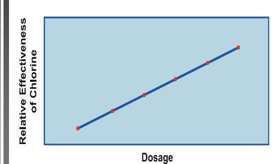
vs. Temperature



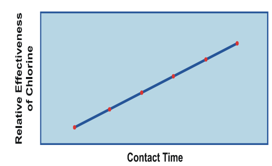
When the temperature increases the disinfection action of chlorine increases.

Relative Effectiveness

vs. Dosage

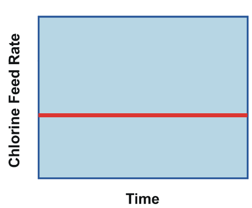


vs. Contact Time

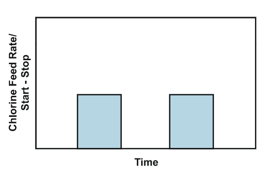


Types of Feed Control

Manual Control

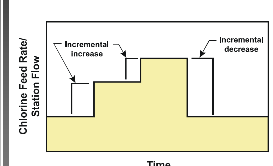


Start Stop Control

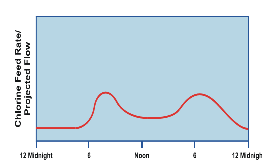


Types of Feed Control

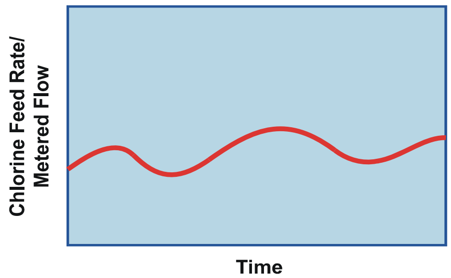
Step Rate Control



Timed Program Control



Flow Proportional Control



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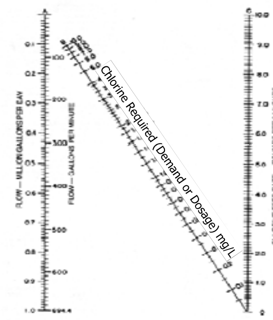
Chlorination Control Nomograph

- Nomogram is a chart or diagram containing three or more scales used to solve problems with three or more variables



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Chlorine Hazards

- Chlorine gas is:
  - 2.5 times heavier than air
  - Extremely toxic
  - Corrosive in moist atmospheres

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Chlorine Leaks

- To locate chlorine leaks you should use a commercial ammonia water
  - The ammonia water can be put in a polyethylene squeeze bottle about half full and squeeze the ammonia vapors around potential Cl_2 leak.
  - When ammonia vapor comes in contact with chlorine, a white cloud of ammonia chloride is formed.
  - A ammonia soaked rag wrapped around a stick will also do.
  - Household ammonia is not strong enough.
- Never put water on a chlorine leak
- because the mixture of water and chlorine will increase the rate of corrosion at the leak.

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Physiological Response to Chlorine Gas

Effect	Parts of Chlorine Gas per Million Parts of Air by Volume (ppm)
Slight symptoms after several hours' exposure	1*
Detectable odor	0.08 – 0.4
60-min inhalation without serious effects	4
Noxiousness	5
Throat irritation	15
Coughing	30
Dangerous from ½ - 1 hour	40
Death after a few deep breaths	1,000

*OSHA regs specify that exposure to chlorine shall at NO time exceed 1 ppm.

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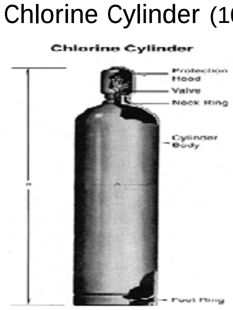
Chlorine Cylinder (100 or 150 lb.)



- The fusible plug melts at 158-165 F to prevent build-up of excessive pressure and possible rupture
- Cylinders must be kept away from direct heat

Net Cylinder Contents	Approx. Tare, Lbs.*	Dimensions, inches A	Dimensions, inches B
100 Lbs.	73	8¼	54½
150 Lbs.	92	10¾	54½

* Stamped tare weight on cylinder shoulder does not include valve protection hood.

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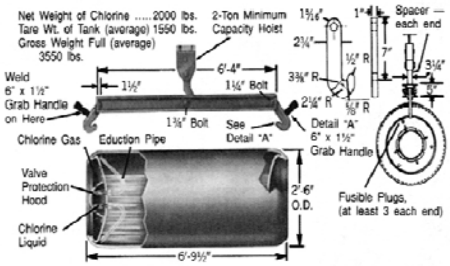
Ton Container



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Ton Container

- Ton tanks weigh ~ 3,700 pounds
- Most ton tanks have 6-8 fusible plugs that are designed to melt at the same temperature range as the safety plug in the cylinder valve
- Ton tanks should be stored and used on their sides, above the floor or ground on steel or concrete supports
- Ton tanks should be placed on trunnions
- The upper valve will discharge chlorine gas and he lower valve will discharge liquid chlorine

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Chlorine Repair Kits

Kit A

Kit B

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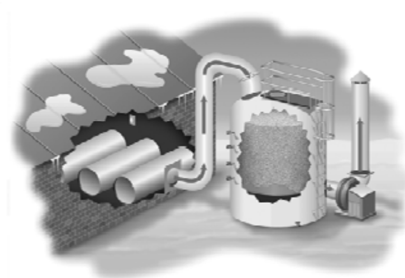
Chlorine Scrubber



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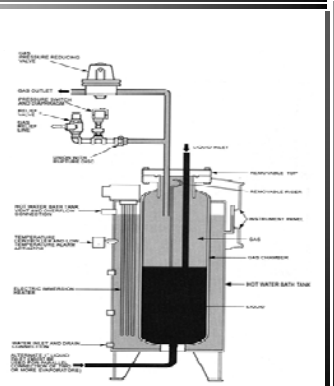
Evaporator

- Installed where large amounts of chlorine are fed
- An evaporator is a hot water heater surrounding a steel tank and the liquid chlorine is evaporated to gas at 110-120 F



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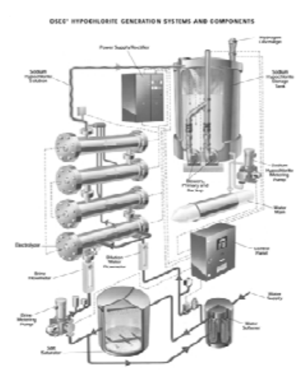
Hypochlorite Generator



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Dechlorination

- Dechlorination is the physical or chemical removal of all traces of residual chlorine remaining after the disinfection process and prior to the discharge of the effluent to the receiving waters
- Removal methods:
  - Aeration
  - Sunlight
  - Long detention time
  - Chemicals

Chemicals Used for Dechlorination

- Sulfur dioxide
  - SO_2
  - One-to-one basis
  - Most popular
- Sodium sulfite
  - Na_2SO_3
- Sodium bisulfate
  - $NaHSO_3$
- Sodium metabisulfite
  - $Na_2S_2O_5$
- Sodium Thiosulfate
  - $Na_2S_2O_3$

Sulfur Dioxide

- Colorless gas with a characteristic pungent odor
- Not flammable or explosive
- Not corrosive unless in a moist environment it can form sulfuric acid

Application Point

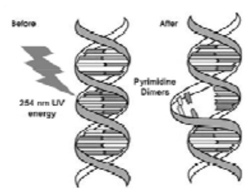
- The typical application point is just before discharge into receiving stream
- This allows for maximum time for disinfection to take place

Physiological Response to Sulfur Dioxide

Effect	Concentration
Lowest concentration detectable by odor	3-5 ppm
Lowest concentration immediately irritating to throat	8-12 ppm
Lowest concentration immediately irritating to eyes	20 ppm
Lowest concentration causing coughing	20 ppm
Maximum allowable concentration for 8-hr exposure	10 ppm
Maximum allowable concentration for 1-hr exposure	50-100 ppm
Tolerable (briefly)	150 ppm
Immediately dangerous concentration	400-500 ppm
OSHA 8-hour TWA (Time Weighted Average) is 2 ppm and the 15-minute STEL (Short Term Exposure Limit) is 5 ppm	

Ultraviolet Radiation

- Ultraviolet radiation is commonly referred to as ultraviolet light or UV
- When UV is absorbed by the cells of microorganisms, it damages the genetic material so that they can no longer grow or reproduce
  - This will ultimately kill them

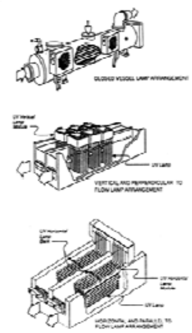


Ultraviolet Radiation

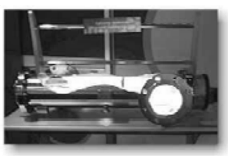
- With growing concern with safety of chlorine handling and the possible health effects of chlorination by-products, UV is gaining popularity
- UV disinfection may become a practical alternative to chlorine disinfection at STP

Typical UV Lamp Configurations

- Closed vessel lamp arrangements are more typically found in drinking water plants
- Wastewater plants normally have UV bulbs placed in an open channel either horizontal or perpendicular to flow



Typical UV Lamp Configurations



Safety with Ultraviolet Light Systems

- The light from a UV lamp can cause serious burns to your eyes and skin
- Always take precautions to protect your eyes and skin
- NEVER look into the uncovered sections of the UV chamber without protective glasses
- UV lamps contain mercury vapor, which is a hazardous substance that can be released if the lamp is broken

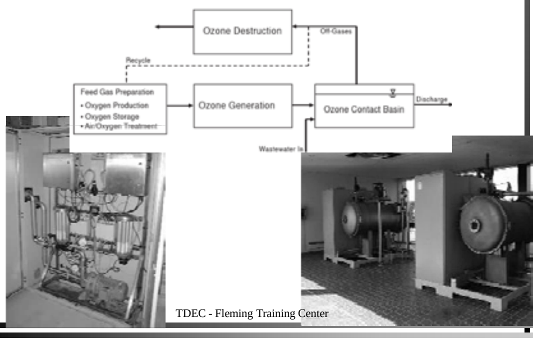
UV Operation

- Lamp output declines as they age
  - Operators must monitor output and replace bulbs that no longer meet design standards
- Turbidity and flow must be monitored
  - Suspended particles can shield microorganisms from the UV light
  - Flows should be somewhat turbulent to ensure complete exposure of all organisms to the bulbs

UV Operation

- UV light does NOT leave a residual like chlorine
  - Bacteriological tests must be run frequently to ensure adequate disinfection is taking place
  - Microorganisms that were not killed may be able to heal themselves

Process of Ozone Disinfection



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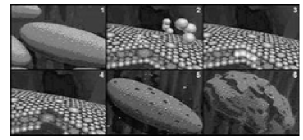
Effects of Ozone on Bacteria



Ozone disinfection steps:

1 – Computer animation of a bacterial cell
2 – Close-up of an ozone molecule on the bacterial cell wall
3 – Ozone penetrates the cell wall and causes corrosion
4 – Close-up of the effect of ozone on the cell wall
5 – Bacterial cell after it has come in contact with a number of ozone molecules
6 – Cell destruction (lysis)

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Design Criteria

http://state.tn.us/environment/wpc/publications/

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Chapter 10 - Disinfection

- 10.1.1 – Disinfection as a minimum shall
  A. Protect public water supply
  B. Protect fisheries and shellfish waters
  C. Protect irrigation and agricultural waters
  D. Protect water where human contact is likely

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Chapter 10 - Disinfection

- 10.1.2.1 – Chlorination
  – Chlorination using dry chlorine is the most commonly applied method of disinfection and should be used unless other factors, including chlorine availability, costs, or environmental concerns, justify an alternative method

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Chapter 10 - Disinfection

- 10.1.3 – Dechlorination
  – Capability to add dechlorination should be considered in all new treatment plants. Dechlorination of chlorinated effluents shall be provided when permit conditions dictate the need

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Chapter 10 - Disinfection

- 10.2.1.4 – Chlorine Gas Withdrawal Rates
  - The maximum withdrawal rate for 100- and 150- pound cylinders should be limited to 40 pounds per day per cylinder
  - When gas is withdrawn from 2,000-pound containers, the withdrawal rate should be limited to 400 pounds per day per container

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Chapter 10 - Disinfection

- 10.2.2.4 – Contact Period
  - Contact chambers shall be sized to provide a minimum of 30 minutes detention at average design flow and 15 minutes detention at daily peak design flow, whichever is greater. Contact chambers should be designed so detention times are less than 2 hours for initial flows.

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- 10.2.2.5 – Contact Chambers
  - The contact chambers should be baffled to minimize short-circuiting and backmixing of the chlorinated wastewater to such an extent that plug flow is approached.
  - Provision shall be made for removal of floating and settleable solids from chlorine contact tanks or basins without discharging inadequately disinfected effluent

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Chapter 10 - Disinfection

- 10.2.2.5 – Contact Chambers (continued)
  - A readily accessible sampling point shall be provided at the outlet end of the contact chamber

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Chapter 10 - Disinfection

- 10.2.2.6 (a) – Dechlorination with Sulfur Dioxide
  - Sulfur dioxide can be purchased, handled and applied to wastewater in the same way as chlorine
  - Sulfur dioxide dosage required for dechlorination is 1 mg/L of SO_2 for 1 mg/L of chlorine residual expressed as Cl_2

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Chapter 10 - Disinfection

- 10.2.2.8 – Residual Chlorine Testing
- Equipment should be provided for measuring chlorine residual.
- There are five EPA accepted methods for analysis of total residual chlorine and they are
  - 1) Ion Selective Electrode
  - 2) Amperometric End Point Titration Method
  - 3) Iodometric Titration Methods I & II
  - 4) DPD Colormetric Method
  - 5) DPD Ferrous Titrimetric Method

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Chapter 10 - Disinfection

- 10.2.2.8 – Residual Chlorine Testing (continued)
- Where the discharge occurs in critical areas, the installation of facilities for continuous automatic chlorine residual analysis and recording systems may be required.

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Chapter 10 - Disinfection

- 10.2.3.1(a) – Design Details (Housing - General)
  - An enclosed structure shall be provided for the chlorination equipment
  - Chlorine cylinder or container storage area shall be shaded from direct sunlight

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Chapter 10 - Disinfection

- 10.2.3.1(a) – Design Details (Housing - General) (continued)
  - Chlorination systems should be protected from fire hazards and water should be available for cooling cylinders or containers in case of fire
  - If gas chlorination equipment and chlorine cylinders or containers are to be in a building used for other purposes, a gastight partition shall separate this room from any other portion of the building

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Chapter 10 - Disinfection

- 10.2.3.1(b) – Design Details (Housing - Heat)
  - Chlorinator rooms should have a means of heating and controlling the room air temperature above a minimum of 55°F
  - A temperature of 65° F is recommended

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Chapter 10 - Disinfection

- 10.2.3.1(b) – Design Details (Housing - Heat) (continued)
  - The room housing chlorine cylinders or containers in use should be maintained at a temperature less than the chlorinator room, but in no case less than 55°F unless evaporators are used and liquid chlorine is withdrawn
  - All rooms containing chlorine should also be protected from excess heat

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Chapter 10 - Disinfection

- 10.2.3.1(c) – Design Details (Housing - Ventilation)
  - All chlorine feed rooms and rooms where chlorine is stored should be force-ventilated, providing one air change per minute except “package” buildings with less than 16 ft^2 of floor space
  - The entrance to the air exhaust duct from the room should be near the floor and the point of discharge should be so located as not to contaminate the air inlet to any building or inhabited areas

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Chapter 10 - Disinfection

- 10.2.3.1(e)
  - Dechlorination equipment (SO_2) shall not be placed in the same room as the Cl_2 equipment. SO_2 equipment is to be located such that the safety requirements of handling Cl_2 are not violated in any form or manner

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Chapter 10 - Disinfection

- 10.2.3.6 – Handling Equipment
  - Handling equipment should be provided as follows for 100- and 150-pound cylinders:
    - A hand truck specifically designed for cylinders
    - A method for securing cylinders to prevent them from falling over

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Chapter 10 - Disinfection

- 10.2.3.6 – Handling Equipment (continued)
  - Handling equipment should be provided as follows for 2,000-pound container:
    - Two-ton capacity hoist
    - Cylinder lifting bar
    - Monorail or hoist with sufficient lifting height to pass one cylinder over another
    - Cylinder trunnions to allow rotating the cylinders for proper connection

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Chapter 10 - Disinfection

- 10.2.4.1 – Leak Detection and Controls
  - A bottle of 56% ammonium hydroxide solution shall be available for detecting chlorine leaks
  - All installations utilizing 2,000-pound containers and having less than continuous operator attendance shall have suitable continuous chlorine leak detectors

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Chapter 10 - Disinfection

- 10.2.4.2 – Breathing Apparatus
  - At least **two** gas masks in good operating condition and of a type approved by the National Institute for Occupational Safety and Health (NIOSH) as suitable for high concentrations of chlorine gas shall be available at all installations where chlorine gas is handled and shall be stored outside of any room where chlorine is used or stored

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Chapter 10 - Disinfection

- 10.3.2 – Ultraviolet Disinfection – Application
  - UV disinfection may be substituted for chlorination, particularly whenever chlorine availability, cost or environmental benefits justify its application. For tertiary treatment plants where dechlorination is required for chlorine toxicity is suspected, UV disinfection is a viable alternative

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Disinfection Vocabulary

______1. Breakpoint	______8. Free Chlorine Residual
______2. Chlorination	______9. Organic Substance
______3. Combined Residual	______10. Ozone Generator
______4. CxT Value	______11. Sterilization
______5. Disinfection Residual	______12. Trihalomethane
______6. Disinfection	______13. UV Disinfection
______7. Disinfection By-Product	______14. Waterborne Disease

A. The process of destroying all organisms in water.
B. The product of the residual disinfectant concentration C and the corresponding disinfectant contact time T.
C. The water treatment process that kills disease-causing organisms in water.
D. A device that produces ozone by passing an electrical current through air or oxygen.
E. The point at which the chlorine dose has met the demand.
F. A chemical substance of animal or vegetable origin, having carbon in its molecular structure.
G. Disinfection using ultraviolet light.
H. The process of adding chlorine to water to kill disease-causing organisms.
I. The residual formed after the chlorine demand has been satisfied.
J. An excess of chlorine left in water after treatment. Indicates that an adequate amount of disinfectant has been added to ensure complete disinfection.
K. Compound formed when organic substances such as humic and fulvic acids react with chlorine.
L. Chemical compounds that are formed by the reaction of disinfectants with organic compounds in water.
M. The chlorine residual produced by the reaction of chlorine with substances in the water. It is not as effective as free residual.
N. A disease caused by waterborne organism.

Disinfection Review Questions

1. List four infectious diseases that can be transmitted by water:
   -
   -
   -
   -

2. What are limitations of UV disinfection?

3. Name the three types of chlorine commonly used in wastewater treatment and give a short description of each:
   -
   -
   -

4. Define breakpoint.

5. When chlorine is added to water, it breaks down into two products. Name them:
   -
   -

6. Which of the two products (in #5) is the most effective disinfectant?

7. Why is chlorination less effective at a higher pH?

Answers to Vocabulary and Questions

Vocabulary:

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

Questions:

1. Typhoid fever, infectious hepatitis, dysentery, cholera
2. Water must pass close to lamp; water must be of good quality; no residual
3.
   - gas – greenish-yellowish gas; pungent, noxious odor; toxic if inhaled; 2.5x heavier than air
   - NaOCl – Sodium hypochlorite, liquid, bleach; can cause burns on skin; 5-15% strength
   - $Ca(Ocl)_2$ – Calcium hypochlorite, solid; 65% strength, fire hazard, can cause burns
4. Addition of chlorine to water or wastewater until the chlorine demand has been satisfied. At this point, further additions of chlorine result in a residual that is directly proportional to the amount of chlorine added beyond the breakpoint.
5. HOCl (hypochlorous acid) and OCl^- (hypochlorite ion)
6. HOCl (hypochlorous acid)
7. Hypochlorous acid breaks down into hypochlorite ion, which is only 1% as effective

Section 14

Rules and Regs

CHAPTER 15

Managed Wastewater Dispersal Using Drip Irrigation

DECENTRALIZED DOMESTIC WASTEWATER TREATMENT SYSTEMS

15.1 Preface

This chapter presents the method to determine the proper design for decentralized wastewater treatment systems (DWWTS). DWWTS are systems that are not the traditional, centralized/regionalized wastewater treatment systems. DWWTS treat domestic, commercial and industrial wastewater using water tight collection, biological treatment, filtration and disinfection. These systems typically will utilize land application with either surface or subsurface effluent dispersal.

15.2 General Considerations

15.2.1 Ownership

Plans for sewer systems including domestic wastewater treatment systems will not be approved unless ownership and responsibility for operation are by a municipality, publicly owned utility, or a privately owned public utility regulated by the Tennessee Regulatory Authority (TRA). The owner is defined as the entity responsible for the operation of the system. The property being served is defined as the user.

Legal title to tanks, pumps, or other components should be vested with the owner. The objective of having title invested to the owner rather than the user is to avoid potential for cost disputes over equipment selection and repair methods. Regardless of where title is vested, the owner should completely control all tanks, pumps, service lines and other components of the system on private property. This requirement is essential to assure operable hydraulics and overall system reliability.

The owner shall possess a recorded general easement or deed restriction to enter the private property being served, and to access the system and its components. Access must be guaranteed to operate, maintain, repair, restore service and remove sludge.

Owners should operate and maintain facilities without interruption, sewage spills on the grounds, sewage backup into buildings, or other unhealthy conditions.

15.2.2 Planning

The applicant should contact the Division of Water Pollution Control as early as possible in the planning process. If a discharge to surface waters is proposed, the treatment works will be designated an appropriate Reliability Classification as detailed in Chapter 1 of this design criteria. Also for proposed surface water discharges, the designer should refer to the Wastewater Discharge Checklist, Appendix 15-A.

15.3 Design Basis

Small systems are more sensitive to influent problems due to a reduction in hydraulic or organic buffering capacity. Small systems are much more susceptible to flow variations due to daily, weekend or seasonal fluctuations. An accurate characterization of the waste and flow conditions should be projected for the site and should include flow, BOD_5, TSS, ammonia and, oil and grease.

15.3.1 Hydraulic Loading

For residential developments, the flows given below are generally considered appropriate for design purposes. For developments that include a preponderance of larger homes, higher flows should be considered. For non-residential flows, the engineer should use the tables given in Appendix 15-A. If the engineer determines that it is necessary to deviate from those values, then he/she must submit the basis for design flow, both average and peak. The type of collection system should be given serious consideration when determining total flow to the wastewater treatment plant.

For systems using water tight collection, the recommended design flow should be 300 gallons per day per unit. For projects dealing with commercial or very large residential developments, design flows should reflect expected variations from conventional systems and be evaluated and approved by the Division of Water Pollution Control based upon site-specific evaluation.

15.3.2 Engineering Report

An engineering report is required for all wastewater treatment projects. Small treatment plants require different design considerations than larger plants. During the design of a small treatment facility, the design engineer should evaluate the feasibility of various process alternatives. Except for systems proposed to serve single residential units, all other small flow systems or systems proposing to use land application for effluent dispersal should also submit an application for an NPDES permit or a State Operation Permit (SOP) to the Division of Water Pollution Control (Note: Exceptions may be contained in Memorandum of Agreement between the Divisions of Water Pollution Control and Ground Water Protection). The SOP application should include an engineering report, Water Pollution Control soils map, soil profile descriptions derived from soil borings and pit evaluations to determine soil type, texture and structure for all areas proposed for drip dispersal or spray irrigation as described in Chapters 17 and 16 of this criteria.

15.3.3 Pollutant Loading

While best engineering judgments for waste characterizations are sometimes necessary, an attempt should be made to project this character from similar facilities, instead of the absolute use of flow tables. For example, excess ammonia should be considered during design of a treatment system for a rest stop, truck stop or recreational vehicle park.

These types of facilities can have a significantly higher influent ammonia concentration than typical domestic systems

15.4 Preliminary Treatment

Preliminary treatment involves the removal of large solids that could damage pumps and equipment in the downstream treatment process. Such treatment may include properly designed and water tight septic tanks, or filters.

15.4.1 Septic Tank Effluent Pumping (**STEP**) and Septic Tank Effluent Gravity (**STEG**) Systems

An effluent sewer is a wastewater collection and treatment system shared by multiple users, consisting of multiple watertight septic tanks (to capture and remove gross solids, oil and grease), and small diameter watertight piping to convey wastewater from the tanks to a treatment facility and common dispersal area. Treated "clear" effluent from the mid-depth of the septic tank is filtered (through an effluent filter or screened pump vault) and transported under pressure via the pressurized collection system. An effluent sewer may include septic tank effluent pumping (STEP) systems, or septic tank effluent gravity (STEG) systems, or both. In a STEP system, the effluent is pumped from the septic tank under pressure while in a STEG system, pressurization is achieved using hydrostatic pressure (gravity).

Septic tanks should be sized to accommodate a minimum of two and one-half (2.5) times the design daily sewage flow anticipated to flow through the tank. Additionally, septic tanks may be either compartmentalized or not, since unbaffled tanks allow the tank to be pumped from either end. **All tanks regardless of size must be water-tight as evidenced by post installation testing and structurally sound by design as certified by a Licensed Professional Engineer stamp on tank plans and structural analysis**. Tanks may be made of concrete or other structurally sound materials such as fiberglass Water testing is preferred with the water level being a minimum of 3-inches above the top of the cover for the tank. If vacuum testing, it is preferred that the tank be capable of maintaining 4-inches of mercury (HG) without loss for five (5) minutes. However, at minimum the tank must meet the water pressure testing and vacuum testing in accordance with ASTM C1227. Structural soundness will usually require reinforcing bars incorporated into the tank walls, sides, top, and bottom. Acceptable burial depths and loading conditions should be explicitly noted on the drawings and made available to installers.

All tanks should be equipped with rubber inlet and outlet boots installed through the tank wall and sealed to the piping with stainless steel band clamps. All tanks should be equipped with water-tight risers over the inlet and outlet of the tank. The riser should have a water tight seal to the top of the tank. Access risers should extend to grade and be equipped with a water-tight lid bolted or locked to the riser.

15.4.1.1 - STEP Tanks

In a typical septic tank system, household sewage is pretreated in a watertight septic tank where gross solids and grease are held back. A "clear" effluent from the mid-depth of the tank is transported to a common or lateral sewer. In a septic tank effluent pump (STEP) system, the effluent is pumped from the septic tank under pressure to a small-diameter, pressurized collector sewer.

In most cases, a single phase, ½ HP effluent pump is adequate for septic tank effluent. However, if a working head over 150 feet is expected, a higher horsepower pump may be required.

The effluent pump should be located within a screened pump vault. The vault, at a minimum, should be fitted with 1/8-inch mesh polyethylene screen and a 4-inch diameter PVC (or equivalent) flow inducer for a high head pump.

The pump chamber should also include float switches that turn the pump on and off and activate high and low level alarms.

15.4.1.2 - STEG Tanks

Effluent may also flow by gravity, where available hydraulic gradient allows, to small-diameter gravity collector lines. Gravity system tanks should be equipped with an effluent filter that at a minimum consists of a 1/8-inch mesh polyethylene screen housed within a PVC (or equivalent) vault. The lateral from the tank to the collection line should be laid at a uniform grade with no high points.

15.4.2 Grinder Pumps

For systems served by grinder pumps, all raw wastewater should be collected from individual buildings/dwellings and transported to the pressure or gravity system by appropriately sized pumps. For restaurants or facilities with commercial-grade kitchen facilities, grease and oil interceptors (as described in 15.4.4) should be installed prior to the grinder pump.

All pumps must have adequate operating curves that allow for pumping into the pressurized common line under maximum head conditions. Additionally, each pump must be equipped with properly installed and approved backflow prevention assembly. Furthermore, tanks must be watertight and located above the seasonal groundwater table where possible. Where it is not possible to locate tanks above the seasonal groundwater table, the design engineer must provide antibuoyancy calculations and specify appropriate antiflotation devices. Installations should ensure that odors are minimized.

15.4.3 Grease and Oil

Facilities with commercial-grade kitchen facilities should be equipped with an effective grease and oil interceptor. Other potential sites of grease/oil production should be investigated by the design engineer.

One or more interceptors in series are required where grease or oil waste is produced that could hinder sewage disposal or treatment, and/or create line stoppages. Interceptors must be located so as to provide easy access for inspection, cleaning and maintenance. In commercial-grade kitchen facilities, the dishwasher(s) must not be connected to the primary grease trap and/or separator. A separate device may be required to allow for cooling of the dishwasher discharge prior to primary treatment.

As vegetable oil usage has become more common, it should be understood that oils will not solidify until approximately 70^{o} F. or less. Therefore, the minimum interceptor design should be a baffled, three-compartment, elongated chamber to allow for cooling with a capacity of at least 1,500 gallons. The design should be in accordance with accepted engineering practice. Tanks must also be sized in accordance with local requirements. The tank should be buried, with manhole accesses to all compartments. Tanks should be manufactured and furnished with access openings having a minimum diameter of twenty-one (21) inches. The tank top should be able to support a minimum of 2500 lb. wheel load. Inlet plumbing should be designed to penetrate 18 inches or more below the discharge invert elevation. In order to demonstrate water-tightness, tanks (including all risers and lids) must be tested prior to acceptance by filling with either air or water in accordance with ASTM standard C1227-05.

15.5 Secondary Treatment Design

The following secondary systems should be evaluated for small flow designs.

15.5.1 Fixed Media Biological Reactors

A fixed media biological reactor (FMBR) is an aerobic, fixed film process that uses sand, gravel or other media to provide secondary treatment of septic tank effluent. The FMBR typically consists of a septic tank and recirculating tank, media bed with a special distribution system installed within a structure or excavation lined with impervious synthetic liner and a flow splitter device.

Design considerations include the media size, type and surface area, the required bed area and depth, dose volumes and dosing frequency.

All sites for fixed media reactors should be properly prepared before installation. For reactors that are installed directly on soil with a synthetic liner (as opposed to package units with rigid bottoms), the liner may lie directly on the graded soil if it is free from material that might puncture the liner. Otherwise, a layer of sand or other suitable material should be placed below the liner to protect it from puncturing.

15.5.1.1 Granular Media Reactor

The media bed should be sized by comparing the organic and hydraulic loads and then using the more restrictive of the two. Table 15-1 gives suggested design parameters for the reactor, support bedding and underdrain media. All media should be washed and screened to limit fines to less than 1% by weight passing a 100 screen (0.15 mm).

Table 15-1. Suggested Design Parameters for Granular Media Reactors

Design Parameter	Effective Size (D_{10})	Depth	Design Value
Reactor Media:			
Sand or other, similar granular media	1.5-2.5 mm (Uniformity Coefficient = 1-3)	24 to 30 inches	3-5 gpd/ft^2 (hydraulic loading – forward flow) ≤ 6.2 lb BOD_5 /1000 ft^2/day (organic loading)
Gravel or other, similar granular media	0.6 - 1 cm diameter	24 – 30 inches	10 - 15 gpd/ft^2 (hydraulic loading – forward flow) ≤ 10 lb BOD_5 /1000 ft^2/day (organic loading)
Underdrain Media	#57 inch stone	12-18 inches	

A synthetic media may also be used as long as it meets the above criteria.

A minimum of 30 mil impermeable synthetic liner is required for the bottom and sides of the filter.

15.5.1.2 Other Fixed Media Reactors

These systems will be approved on a case-by-case basis. The design engineer must provide adequate rationale that such systems are preferable to more traditional granular media reactors.

15.5.1.3 Distribution and Underdrain System

15.5.1.3.1 – Spacing

Distribution mechanisms should ensure uniform application of the applied flow to the surface of the media. These mechanisms may involve spray nozzles in synthetic media reactors or drilled or perforated pipe in sand filter or other fixed media reactors. For sand filters, the distribution pipes should be spaced on 18-inch centers or less.

Underdrain lines, where used, should be spaced no farther than 8-feet on center.

15.5.1.3.2 – Sizing of Lines

Distribution pipes should be no smaller than 1-inch.

Clean-out caps should be provided on the ends of the distribution pipes.

In the underdrain system, pipes should have a minimum inside diameter of 4 inches. As an alternative, collection vaults may also be employed.

15.5.1.4 Recirculation Tank and Pump System

Where a separate recirculation tank is used, the tank may serve as a wetwell for the septic tank effluent and treated, recirculated effluent to be pumped to the media bed. The minimum tank volume should equal the design daily flow.

The tank should be equivalent in strength and materials to the septic tank as described in 15.4.1. No internal baffles are necessary. An access manhole is necessary for replacement of submersible dosing pumps if such are used.

A minimum of two alternating recirculation pumps are required for commercial multiuser FMBRs. Recirculating pump operation should be time-controlled. Float switches are required and should be wired in parallel with the timer to control the pumps during periods of either low or high wastewater flows, and as a back-up in case of timer malfunction.

A quick disconnect coupler and hanger pipe are recommended for pump removal and convenience. Additionally, panels for operation of FMBRs should also feature programmable digital timers and multiple settings for optimizing dosing during normal and peak flow conditions.

15.5.1.5 Flow Splitter

The system should be equipped with a device or computerized process control that allows for reactor effluent to be split between the recycle stream and discharge to either the disinfection system and/or drip disposal area. It is recommended that the designer choose a device that provides flexibility in setting the recycle ratio.

15.5.1.6 Dosing Chamber

Where the treated effluent is intended to be distributed through a drain field, drip dispersal system or other land application mechanisms, a dosing chamber should be employed, sized and equipped to provide timed-dosing of the daily wastewater flow with adequate reserve storage capacity for system malfunctions. The dosing chamber should be equipped with an audible visual or other approved high-water alarm set to provide notification to the owner/operator of a malfunction when the design high water level is exceeded and the emergency reserve capacity is being used. A low-water cutoff device must be provided to prevent damage to the pump during low-water conditions. A programmable timer and control panel should be employed to regulate the dosing frequency and volume, and to record wastewater flow, the number of doses and other pertinent dosing data.

Time dosing should be utilized to dose the absorption field or zones. The frequency of dosing must be based upon the soil's hydraulic loading rate and the design flow. Fields or zones should be time dosed to ensure the total twenty-four (24) hour wastewater effluent flow is applied in a 24-hour period.

15.6 Disinfection and Fencing

Disinfection of effluent is required prior to spray irrigation. Disinfection of effluent will be required for drip dispersal of unfenced drip irrigation if the drip field access is classified as either "Open Access" (where drip areas are used for ball fields, playgrounds, picnic areas, golf courses, etc.) or "Attractive Access" (where open spaces are maintained similar to residential lawns with easy access and with grass maintained at short heights, but with the area undeveloped for recreational purposes). In these cases, if the entire drip dispersal area is properly fenced, disinfection of the effluent is not required.

Disinfection of effluent may not be required for drip dispersal of unfenced drip irrigation if the drip field access is classified as either "Inhibited Access" (where drip areas are allowed to return to natural vegetation and are used for wildlife food plots or other similar uses and where routine access by humans is discouraged by growth of vegetation) or "Difficult Access" (where drip areas are located on generally steep, greater than 10% slopes, on heavily wooded slopes, and access by humans will be rare due to terrain, location, or vegetation).

In the design of UV disinfection units there are three basic areas that should be considered:

a. Reactor hydraulics – adequate residence time.

b. Factors affecting transmission of UV light to the microorganisms.

c. Properties of the wastewater being disinfected.

In addition, an automatic self-cleaning mechanism is recommended to ensure proper performance of the UV system.

As an alternative to disinfection, the drip field may be fenced with a 4-foot chain link, woven wire fence, wooden, four-strand barbed wire, or other as approved by the Department of Environment and Conservation.

15.7 Oxidation Ponds and Artificial Wetlands

15.7.1 Oxidation Ponds

1. The maximum design loading on the primary cell(s) should be 30 lbs BOD_5 per acre per day.

2. The design average flow rate should be used to determine the volume required to provide a minimum combined storage capacity of 90 days in the stabilization ponds. The minimum recommended operating depth is 3 feet for facultative ponds and 10 feet for aerated ponds.

3. The minimum number of cells should be three when the system is designed to discharge to surface waters.

4. The shape of the cells should be such that there are no narrow, L-shaped or elongated portions. Round or rectangular ponds are most desirable. Rectangular ponds should generally have a length not exceeding three times the width. Dikes should be rounded at the corners to minimize accumulation of floating material.

15.7.2 Basis of Wetland Design

The artificial wetland treatment system has been around since the 1980's. Like other land application systems, artificial wetlands are site specific. Consequently, all proposals will be reviewed on a site-by-site basis. This section is limited to subsurface flow wetlands utilizing gravel or other granular media. Free-water surface wetlands can also be used, but their design follows different parameters and approval will be on case-by-case basis.

1. Design

    a. Artificial wetlands designed to discharge to surface waters will have to meet NPDES permit limits at all times and must be designed accordingly.

    b. Artificial wetlands are designed on the basis of a BOD removal rate which is assumed to follow the classic first order removal equation corrected for temperature.

    c. The minimum recommended detention time for treatment of normal domestic waste in the artificial wetland system is 4 to 7 days.

    d. The recommended depth of flow in the wetland system should be between 18 and 24 inches, with twenty-four (24) inches as the recommended optimum depth.

    e. The aspect ratio of the wetland is determined by the design flow and substrate cross sectional area perpendicular to the flow. The aspect ratio should be such that one-third (⅓) of the available flow rate, as determined by Darcy' Law, is preserved and all flow remains subsurface. This will generally result in a rectangular configuration with a length to width ratio of between 1:1 and 1:3.

f. Seepage rates in the artificial wetland areas will be addressed on a site-by-site basis based upon in-situ material, groundwater depth and the groundwater use. Generally, no compaction will be required on wetland pond bottoms. The berms should be compacted to at least 90 percent of Standard Proctor Density.

g. The bottom of the artificial wetland treatment units should not have a slope greater than 0.2%.

h. Due consideration should be given to multiple wetland cells and to possible future expansion on suitable land when the original land acquisition is made for flexibility and for maximum operational capability.

2. Construction

a. The project site should be protected from surface inflow waters. The site should also be protected such that the top of the wetland surface is at least one foot above the 100 year flood elevation.

b. In order to prevent erosion and channelization at the inlet of the wetland, a discharge header should be utilized. The header should be equipped with removable end-plugs so the line may be drained to prevent freeze-up. Uniform distribution of wastewater to prevent short-circuiting through the wetland should be assured. It is recommended that the header outlet elevation be at or above the maximum design depth.

c. It is recommended that pipes and flumes located in or near inlet and discharge structures will not be in a completely submerged condition to maintain the integrity of the system and reduce freeze-up problems.

d. A suitable discharge structure from the wetland should be utilized. The structure should be adjustable so that the depth in the wetland may be modified as needed.

e. Care should be taken to establish the vegetation as soon as possible after construction. However, it is difficult to establish the vegetation in winter or mid to late summer. The emergent vegetation, once established, should prevent the erosion of the berms of the system. Riprap may be required around the inlet and outlet structures of the wetland. A cover crop may be planted on the interior slopes to prevent erosion prior to the establishment of the emergent vegetation. Consideration may be given to the use of excelsior blanket over seeding.

f. The exterior and interior slopes of the wetland berms surrounding the wetland basins should not be steeper than 3H:1V.

g. The top width of the berms should be a minimum of eight feet.

h. Following the final grade, the substrate should consist of a minimum of two feet of clean ¾-inch to 11/2-inch stone (#57).

i. The dike elevation should be a minimum of two feet above the high water level in the wetland.

j. If groundwater contamination is a potential problem, the bottom of the wetland may be sealed with a suitable material. However, generally no liner will be necessary in the artificial wetland.

k. Aluminum, concrete, or PVC pipe or other material generally accepted for sewers should be specified for the piping requirements in the wetland. Provisions may be required to prevent the settling of the piping structures under load. It is recommended where structures are partially or completely submerged in ice conditions that a flexible piece of pipe be installed to allow for some movement of structure.

l. The effluent discharge structure should be equipped with a suitable flow monitoring device, such as a flume or V-Notch weir, to monitor flows leaving the treatment site. Staff gages for measuring depths in structures should be provided where flow monitoring is required.

m. In order to accurately monitor influent flows to the artificial wetland system, an influent measurement structure should be included.

n. The entire wetland area must be enclosed with a suitable fence to provide public safety, exclude livestock and to discourage trespassing.

o. Warning signs must be provided along the fence around the treatment facility. There must be at least one sign on each side of the facility, with a minimum spacing of 500 feet.

p. Removable screens should be provided on pipe ends to prevent entrance of trash and wildlife.

3. Vegetation Establishment

   a. Specifications for the seeding of the artificial wetland should as a minimum include:

      1. Plant species
      2. Plant distribution (vegetative zone)
      3. Planting (including time restraints)
      4. Fertilization
      5. Water level control and site maintenance.

   b. Placing top soil in the graded wetland area is generally not required. Substrate properties generally do not limit the establishment of a wetland.

c. Only indigenous plant species should be used, preferably collected within a 100 mile radius. Preferred species include, but are not limited to:

   1. Typha Latifolia - Common cattail,
   2. Typha Angustifolia - Narrow leaf cattail,
   3. Scirpus spp. - Bullrush, and/or
   4. Phragmites communis - Reed.

d. Transplanting of live or dormant plant stock will achieve greater success than seed. However, the plants have to be set into the gravel with their roots near the water level in the wetland. Transplanting of reeds is by placing a section of rhizome containing the "eye" in the shallow surface of the gravel.

e. Seeding should generally be accomplished in the spring. Also, at least one fertilization should be required, preferably shortly after seed germination or at one month. The recommended fertilizer is the standard 10- 10-10 or 20-10-10 mixture at a rate of 600 lbs/ac or 300 lbs/ac, respectively. Where wastewater stabilization ponds exist, fertilization may not be necessary, as the nutrients in wastewater may suffice.

f. For seeding, the following is recommended:

   The seed should be broadcast uniformly over the substrate at a rate of 10 viable seeds per square foot. The seeds should be cultivated to subsurface depths of 0 to 1 inch followed by lightly packing, rolling or dragging the tilled surface. Flood the site with 1-2 inches of water until the seeds germinate and become several inches tall. At this time, the area should be fertilized.

g. For transplanting (the recommended method of vegetation establishment) the propagule should be transplanted, as a minimum, on a two foot grid. The number of transplants required may be calculated from Equation 15-1:

$$N = (L/D + 1) \times (W/D + 1)$$ (**Equation 15-1**)

where:

N = Number of transplants

D= Distance between transplants

L = Length of site (ft.)

W = Width of site (ft.)

Transplanting on a two foot grid should provide a uniform vegetative cover in one growing season. Transplants should be kept moist, but not flooded to submerged conditions. The transplants should also be fertilized, preferably with controlled release fertilizer such as Osmocote 18-5-11 for fall and winter planting, Osmocote 18-6-12 for spring planting, and Osmocote 19-6-12 for summer planting. Refer to suppliers instructions when transplanting.

15.8 **Lagoons** (***Note: This chapter does not replace Chapter 9***)

- The maximum allowable seepage is 0.0625 inches per day.
- A lagoon must be artificially lined with clay, bentonite, plastic, rubber, concrete, or other materials to prevent groundwater pollution.
- Lagoons can be round, square, or rectangular with rounded corners. Their length should not exceed three times their width, and their banks should have outside slopes of about three units horizontal to one unit vertical.
- A lagoon must be surrounded by a 4-foot high fence with a locking gate and sign.
- There should be a 2 x 2 ft concrete pad in the center of the lagoon directly below the opening of the outlet pipe to protect the integrity of the liner.

There should be a minimum of 2 feet between the bottom of the lagoon and groundwater. The liquid depth of a lagoon should be maintained between 2 to 5 feet.

There should be a depth marker near the center of the lagoon.

A minimum of 1 foot of freeboard should be maintained.

15.9 **Package Activated Sludge Plants**

For any activated sludge or fixed film process, the criteria presented in Chapters 4, 5, 6, 7, 8, 10, 11, and 12 of these design criteria must be utilized for each unit process.

The design should include aerobic digestion or sludge holding for sludge wasting. A sludge wasting schedule should be included in the engineering report to better define operator time requirements. The disposal site or landfill should be given. Where tertiary filters are employed, the use of an equalization tank is mandatory. Also, based on the Reliability Classification as determined by the appropriate WPC field office, multiple units and standby power (or a generator) may be required. These costs should be included in the cost effective/reliability analysis.

APPENDIX 15-A

Table A-1. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Airport	Passenger	2 - 4	3
Apartment House	Person	40 - 80	50
Automobile Service Station	Vehicle served	8 - 15	12
	Employee	9 - 15	13
Bar	Customer	1 - 5	3
	Employee	10 - 16	13
Boarding House	Person	25 - 60	40
Department Store	Toilet Room	400 - 600	500
	Employee	8 - 15	10
Hotel	Guest	40 - 60	50
	Employee	8 - 13	10
Industrial Building (Sanitary waste only)	Employee	7 - 16	13
Laundry (self-service)	Machine	450 - 650	550
	Wash	45 - 55	50
Office	Employee	7 - 16	13
Public Lavatory	User	3 - 6	5
Restaurant (with toilet)	Meal	2 - 4	3
Conventional	Customer	8 - 10	9
Short order	Customer	3 - 8	6
Bar/cocktail lounge	Customer	2 - 4	3
Shopping Center	Employee	7 - 13	10
	Parking Space	1 - 3	2
Theater	Seat	2 - 4	3

Table A-2. Typical Wastewater Flow Rates from Institutional Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Assembly Hall	Seat	2 - 4	3
Hospital, Medical	Bed	125 -240	165
	Employee	5 - 15	10
Hospital, Mental	Bed	75 - 140	100
	Employee	5 - 15	10
Prison	Inmate	80 - 150	120
	Employee	5 - 15	10
Rest Home	Resident	50 - 120	90
	Employee	5 - 15	10
School, day-only:			
With cafeteria, gym, showers	Student	15 - 30	25
With cafeteria only	Student	10 - 20	15
Without cafeteria, gym, or showers	Student	5 - 17	11
School, boarding	Student	50 - 100	75

Table A-3. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Apartment, resort	Person	50 - 70	60
Bowling Alley	Alley	150 - 250	200
Cabin, resort	Person	8 - 50	40
Cafeteria	Customer	1 - 3	2
	Employee	8 - 12	10
Camps:			
Pioneer Type	Person	15 - 30	25
Children's, with central toilet/bath	Person	35 - 50	45
Day, with meals	Person	10 - 20	15
Day, without meals	Person	10 - 15	13
Luxury, private bath	Person	75 - 100	90
Trailer Camp	Person	75 - 125	125
Campground-developed	Person	20 - 40	30
Cocktail Lounge	Seat	12 - 25	20
Coffee Shop	Customer	4 - 8	6
	Employee	8 - 12	10
Country Club	Guests on-site	60 - 130	100
	Employee	10 -15	13
Dining Hall	Meal Served	4 - 10	7
Dormitory/bunkhouse	Person	20 - 50	40
Fairground	Visitor	1 - 2	2
Hotel, resort	Person	40 - 60	50
Picnic park, flush toilets	Visitor	5 - 10	8
Store, resort	Customer	1 - 4	3
	Employee	8 - 12	10
Swimming Pool	Customer	5 - 12	10
	Employee	8 - 12	10
Theater	Seat	2 - 4	3
Visitor Center	Visitor	4 - 8	5

APPENDIX 15-B

Recirculation Tank/Pump System Example Calculation

Given: 20,000 gpd (14 gpm) system a desired 4:1 recycle rate and numerous small doses.

1. Pumping volume = (1440 min/day / (On + Off time)) x On time x # of pumps x Pump Capacity
2. 80,000 gpd = (1440 min/day / (On Off Time) x On Time x 4 x 45 gpm
3. 80,000 gpd/(1440 min/day x 4 x 45 gpm) = On time/(On + Off time)
4. On time/(On + Off time) = 0.31
5. On time = 0.31 On + 0.31 Off
6. 0.69 On = 0.31 Off
7. Off = 2.22 On
8. Choose 2 minutes On: Off = 4.44 minutes
9. Total dosing cycle = 6.44 minutes.
10. Adjust dose cycle if calculated pumping volume is less than minimum recommended for selected recycle rate
11. Note: The above is an iterative process. The quickest solution is to pick a cycle time, divide it into 1440 min/day, multiply by the On time, multiply by the number of pumps, and multiply by the pump capacity. Compare this number to the desired total pumping volume including recycle. If too little increase On time. If too much decrease on time. .