Applied Math for Water Treatment

Grades 3 - 4

Course # 1101

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

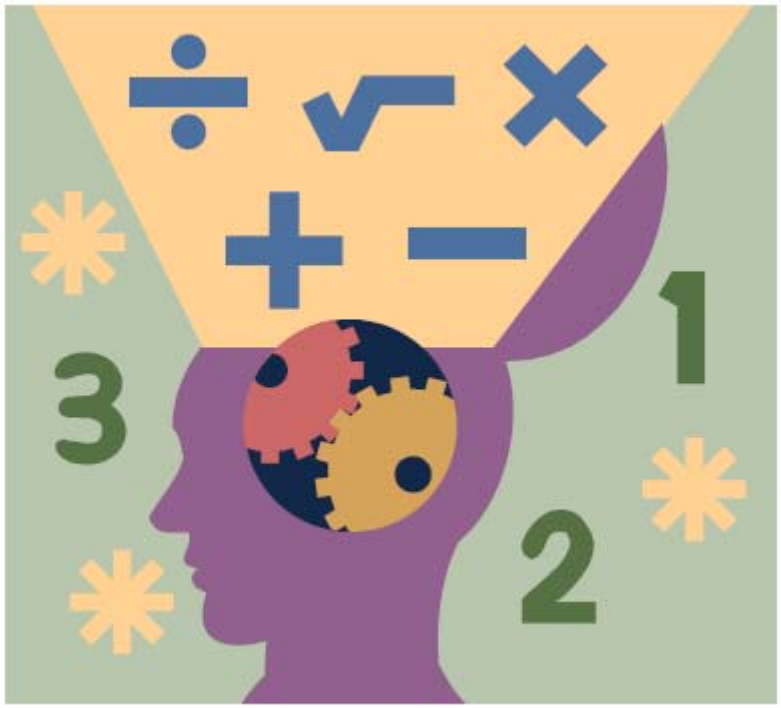
Fleming Training Center
April 22 – 26, 2013

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

Table of Contents

Section 1

Basic Math Review



Solving for the Unknown

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Basics

- The unknown is a variable in the equation that we are trying to solve.
- The unknown variable is usually represented by a letter such as, ***x***.

Basics

When solving for an unknown variable, ***x***.

1. ***X*** must be in the numerator.
2. ***X*** must be by itself on one side of the equation

What if x is not in the numerator?

$\frac{2}{x} = \frac{4}{}$

$\frac{2}{4} = x$

$0.5 = x$

- If x is in the denominator it can trade places with a number on the other side of the = sign.
- Flip-flop
- This is the only time you can move x.
- If x is in the numerator <u>DO NOT MOVE</u> x.

Practice

(23)(x)(7.48) = 542

Step 1. Determine if x is in the numerator
Step 2. Simplify the numbers
Step 3. Get x by itself
Step 4. Solve the equation

Step 1 yes
Step 2
(23) (7.48) = 172.04
(172.04) (x) = 542

Step 3
(172.04) (x) = 542

$$x = \frac{542}{172.04}$$

Step 4

x = 3.15

TDEC - Fleming Training Center 5

Practice

$$\frac{(8)(x)}{(3)(3)} = 21$$

Step 1. Determine if x is in the numerator
Step 2. Simplify the numbers
Step 3. Get x by itself
Step 4. Solve the equation

Step 1 yes
Step 2

$$\frac{(8)(x)}{9} = 21$$

Step 3

$$\frac{(8)(x)}{9} = 21 \qquad (8)(x) = (21)(9) \qquad x = \frac{(21)(9)}{8}$$

Step 4

x = 23.625

TDEC - Fleming Training Center 6

Practice

$\frac{80}{x} = 3700$

Step 1. Determine if x is in the numerator
Step 2. Simplify the numbers
Step 3. Get x by itself
Step 4. Solve the equation

Step 1
No

Step 2
Already simplified

Step 3

$\frac{80}{x} = 3700$

$80 = x$
3700

Step 4

$0.0216 = x$

Solving for x^2

- The procedure for solving for x^2 is the same as solving for x.
- There is one extra step at the end.

Step 1. Determine if x^2 is in the numerator
Step 2. Simplify the numbers
Step 3. Get x^2 by itself
Step 4. Solve the equation
Step 5. Take the square root of both sides of the equation

Solving for x^2

$(x^2)\ (0.785) = 2826$

Step 1 Yes

Step 2 already simplified

Step 3

$(x^2)\ (0.785) = 2826$

$(x^2) = \frac{2826}{0.785}$

Step 4

$(x^2) = 3600$

Step 5

$\sqrt{x^2} = \sqrt{3600}$

$x = 60$

Step 1. Determine if x^2 is in the numerator

Step 2. Simplify the numbers

Step 3. Get x^2 by itself

Step 4. Solve the equation

Step 5. Take the square root of both sides of the equation

TDEC - Fleming Training Center 9

Things to remember

- **<u>Only move x if it is the denominator.</u>**
- If x is in the numerator leave x where it is and move the other numbers away from x.
- It does not matter if x is on the left side or the right side of the equation.
- x = 5
- 5 = x
- They mean the same thing!

TDEC - Fleming Training Center 10

Math Problem Strategies

Use these rules of operation to approach math problems (*especially when working with formulas*):

1) Work from left to right.
2) Do all the work inside the parentheses first.
3) Do all the multiplication/division above the line (numerator) and below the line (denominator).
4) Then do all the addition and subtraction above and below the line.
5) Perform the division (divide the numerator by the denominator).

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

3. $\frac{233}{x} = 44$

4. $940 = \frac{x}{(0.785)(90)(90)}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

8. $2 = \frac{x}{180}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

11. $19{,}747 = (20)(12)(x)(7.48)$

12. $\dfrac{(15)(12)(1.25)(7.48)}{x} = 337$

13. $\dfrac{x}{(4.5)(8.34)} = 213$

14. $\dfrac{x}{246} = 2.4$

15. $6 = \dfrac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

16. $\dfrac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

17. $109 = \dfrac{x}{(0.785)(80)(80)}$

18. $(x)(3.7)(8.34) = 3620$

19. $2.5 = \dfrac{1{,}270{,}000}{x}$

20. $0.59 = \dfrac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

Finding x^2

21. $(0.785)(D^2) = 5024$

22. $(x^2)(10)(7.48) = 10{,}771.2$

23. $51 = \dfrac{64{,}000}{(0.785)(D^2)}$

24. $(0.785)(D^2) = 0.54$

25. $2.1 = \dfrac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾

2. ⅝

3. ¼

4. ½

Convert the following percents to decimals:

5. 35%

6. 99%

7. 0.5%

8. 30.6%

Convert the following decimals to percents:

9. 0.65

10. 0.125

11. 1.0

12. 0.05

Calculate the following:

13. 15% of 125

14. 22% of 450

15. 473 is what % of 2365?

16. 1.3 is what % of 6.5?

Answers for Solving for the Unknown

Basics – Finding x

1.	1.8	8.	360	15.	2817
2.	5.73	9.	1649.4	16.	4903.5
3.	5.29	10.	244.7	17.	547,616
4.	5,976,990	11.	10.99	18.	117
5.	8256.6	12.	4.99	19.	508,000
6.	8.06	13.	7993.89	20.	0.35
7.	0.005	14.	590.4		

Finding x^2

21.	80	23.	40	25.	10.94
22.	12	24.	0.83		

Percent Practice Problems

1.	0.75	7.	0.005	13.	18.75
2.	0.625	8.	0.306	14.	99
3.	0.25	9.	65%	15.	20%
4.	0.5	10.	12.5%	16.	20%
5.	0.35	11.	100%		
6.	0.99	12.	5%		

Section 2

Area, Volume, and Conversions

1

Area, Volume and Conversions

TDEC - Fleming Training Center

Fleming Training Center

2

Area

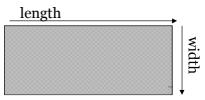
- Surface of an object
- Two dimensional
- Measured in:
  - Square inches
  - Square feet
  - Square meters, etc.

3

Area Formulas

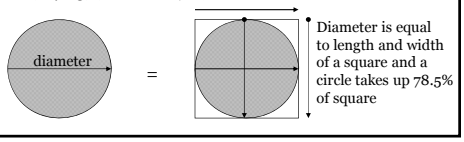
- Rectangle

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



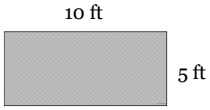
- Circle

A = (0.785)(diameter, ft)²



4

Area of a Rectangle



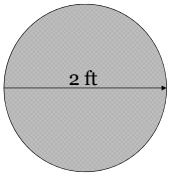
A = (l, ft)(w, ft)

A = (10 ft)(5 ft)

A = 50 ft²

5

Area of a Circle



Diameter = 2 ft

A = (0.785)(D, ft)²

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

A = 3.14 ft²

6

Volume

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

  V = (l)(w)(d)

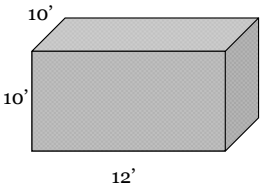
- Measured in:
  - Cubic inches
  - Cubic feet
  - Gallons
  - Acre-feet, etc.

Volume of a Rectangular Tank, ft^3

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

V = (12 ft)(10ft)(10ft)

V = 1200 ft^3



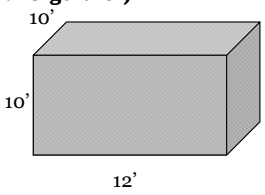
Volume of a Rectangular Tank, gal

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

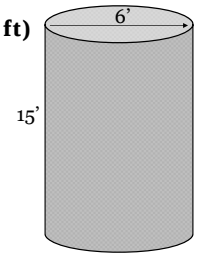


Volume of a Cylinder, ft^3

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

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

V = 424 ft^3



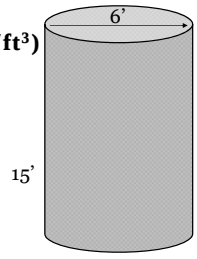
Volume of a Cylinder, gallons

V, ft^3 = 424 ft^3

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

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

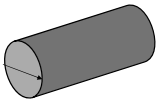
V, gal = 3171.52 gal



Note

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

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



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

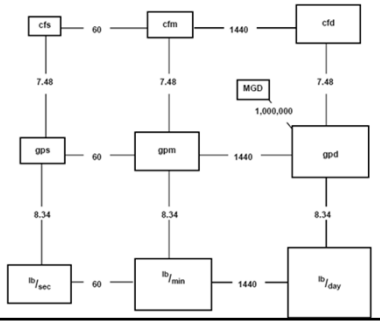
Conversions

- 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

Flow Conversions – Box Method



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.

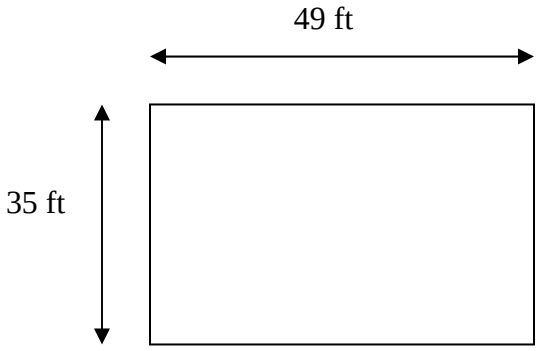
Math Problem Strategies

Strategy for solving word problems:

1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it make sense?

It might be helpful to write out everything that is known in one column and the unknown (what am I asked to find?) in another column. Identify the correct formula and write it in the middle, plug in the numbers and solve.

Known		**Unknown**
Length = 35 ft Width = 49 ft	$A = (l)(w)$ $A = (35\ ft)(49\ ft)$ $A = 1715\ ft^2$	Area = ?

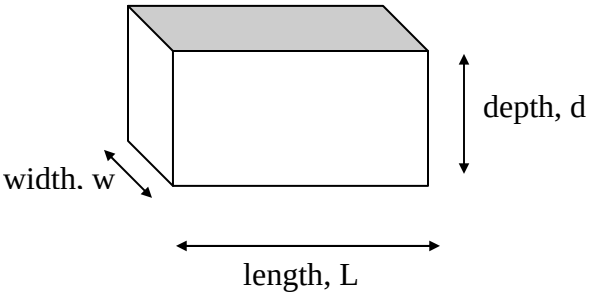


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

mega (M)	..	kilo (k)	hecto (h)	deka (da)	no prefix	deci (d)	centi (c)	milli (m)	..	micro (μ)
1,000,000		1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

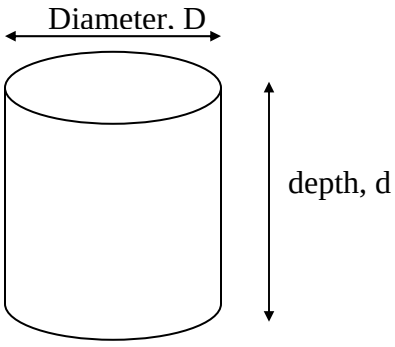
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



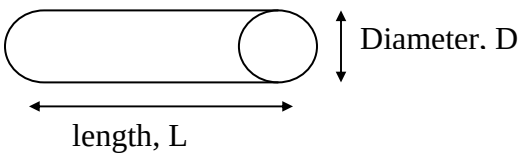
Volume = (L)(W)(d)

Cylindrical Tank



Volume = (0.785) (D)^2 (d)

Portion of a Pipeline



Volume = (0.785) (D)^2 (L)

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. A tank has a length of 90 feet, a width of 25 feet, and a depth of 10 feet. Calculate the surface area in ft^2.

3. Calculate the cross-sectional area (in ft^2) for a 2 foot main that has just been laid.

4. Calculate the cross-sectional area (in ft^2) for a 24" main that has just been laid.

5. Calculate the cross-sectional area (in ft^2) for a 2 inch line that has just been laid.

VOLUME

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

7. Calculate the volume (in gallons) of a basin that measures 22 feet by 11 feet by 5 feet deep.

8. Calculate the volume (in gallons) of water in a tank that is 254 feet long, 62 feet wide, and 10 feet deep if the tank only contains 2 feet of water.

9. Calculate the volume of water in a tank (in gallons) that is 12 feet long by 6 feet wide by 5 feet deep and contains 8 inches of water.

10. Calculate the maximum volume of water (in gallons) for a kids' swimming pool that measures 6 feet across and can hold 18 inches of water.

11. How much water (in gallons) can a barrel hold if it measures 3.5 feet in diameter and can hold water to a depth of 4 feet?

12. A water main has just been laid and 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?

13. A water main is 10” in diameter and has a length of 5,000 feet. How many million gallons of water will it hold?

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

15. What is 5% of a 1.2 MG tank?

CONVERSIONS

16. How many seconds in 1 minute?

17. How many minutes in 1 hour?

18. How many hours in 1 day?

19. How many minutes in 1 day?

20. The flow through a pipe is 3.6 cfs. What is the flow in gps?

21. The flow through a pipe is 2.4 cfs. What is the flow in gpm?

22. A pump produces 22 gpm. How many cubic feet per hour is that?

23. A treatment plant produces a flow of 6.31 MGD. What is the flow in gpm?

24. A pump produces 700 gpm. How many MGD will the pump flow?

25. A three-eighths mile segment of pipeline is to be repaired. How many feet of pipeline is this?

26. If there is a 2,200 gallon tank full of water, how many pounds of water is in the tank?

ANSWERS:

1. 540 ft^2
2. 2,250 ft^2
3. 3.14 ft^2
4. 3.14 ft^2
5. 0.0218 ft^2
6. 1,000 ft^3
7. 9,050.8 gal
8. 235,590 gal
9. 359 gal
10. 317 gal
11. 288 gal
12. 48,442 gal
13. 0.02 MG
14. 150,000 gal
15. 60,000 gal or 0.06 MG
16. 60
17. 60
18. 24
19. 1440
20. 26.9 gps
21. 1,077 gpm
22. 176.5 ft^3/hr
23. 4,382 gpm
24. 1.008 MGD
25. 1,980 ft
26. 18,348 lbs

Section 3

Specific Gravity

Density and Specific Gravity

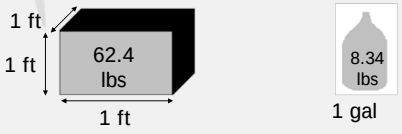
1 TDEC - Fleming Training Center

Density

- weight per unit volume
  - solids and gases expressed in lb/ft^3
  - liquids measured in lb/gal or lb/ft^3
- density of water varies slightly with temperature and pressure
- density of gases changes significantly with changes in temperature and pressure

TDEC - Fleming Training Center 2

Density of Water



The density of water is
62.4 lbs/ft^3
or
8.34 lbs/gal

TDEC - Fleming Training Center 3

Specific Gravity

- compares density of a substance to a standard density
- does not have units
- for solids and liquids
  - compare to standard density of water
    - 62.4 lb/ft^3
    - 8.34 lb/gal

TDEC - Fleming Training Center 4

Example #1

- The density of SAE 30 motor oil is 56 lb/ft^3. Find its specific gravity.

Specific gravity = $\frac{\text{density of motor oil}}{\text{density of water}}$

Specific gravity = $\frac{56 \text{ lb/ft}^3}{62.4 \text{ lb/ft}^3}$

= 0.90

Example #2

A sample of liquid alum has a density of 11.2 lb/gal. What is its specific gravity?

Specific gravity = $\frac{\text{density of alum}}{\text{density of water}}$

= $\frac{11.2 \text{ lb/gal}}{8.34 \text{ lb/gal}}$

= 1.34

Specific Gravity of Gases

Compare to standard density of air:

0.075 lb/ft^3

Specific Gravity of Chlorine Gas

S.G. of Cl_2 gas = $\frac{\text{density of } Cl_2 \text{ gas}}{\text{density of air}}$

= $\frac{0.187 \text{ lb/ft}^3}{0.075 \text{ lb/ft}^3}$

= 2.49

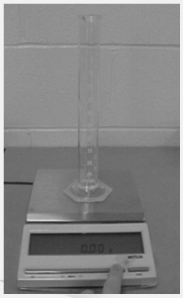
Place 100 mL graduated cylinder on a scale

130.90 g

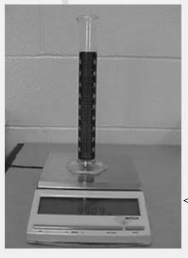
TDEC - Fleming Training Center 9

Tare the scale so it reads zero with the cylinder on it.

0.00 g



TDEC - Fleming Training Center 10



Weigh 100 mL of your sample or chemical.

99.09 g

TDEC - Fleming Training Center 11

$$\text{Specific Gravity} = \frac{\text{Wt of 100 mL of solution, g}}{100\ \text{g}}$$

$$\text{Specific Gravity} = \frac{99.09\ \text{g}}{100\ \text{g}}$$

$$\text{Specific Gravity} = 0.99$$

TDEC - Fleming Training Center 12

APPLIED MATH FOR WATER
DENSITY & SPECIFIC GRAVITY

Density: Weight per unit volume.

2 ways to express density: _____

_____

Specific gravity: Density of any substance compared to a "standard density."

Standard density of water: _____ lb/gal

_____ lb/ft^3

1. Find the specific gravity for rock granite if the density is 162 lbs/ft^3.

2. Find the specific gravity for SAE 30 motor oil if the density is 56 lbs/ft^3.

3. Find the specific gravity of dry alum if the density is 65 lbs/ft^3.

4. Find the specific gravity for liquid alum that weighs 11.07 lbs/gal.

5. Find the specific gravity for fluorosilicic acid that weighs 10.5 lbs/gal.

6. Find the specific gravity for ferric sulfate that weighs 12.34 lbs/gal.

7. Find the density (lbs/ft^3) of a certain oil that has a S.G. of 0.92.

8. Find the density (lbs/gal) of ferric chloride that has a S.G. of 1.140.

9. Find the density (lbs/gal) of caustic soda that has a S.G. of 1.530.

10. Find the density (lbs/ft^3) of potassium permanganate that has a S.G. of 1.522.

11. A tank holds 1,240 gallons of a certain liquid. The specific gravity is 0.93. How many pounds of liquid are in the tank?

12. Pump rate desired: 25 gpm
Liquid weight: 74.9 lbs/ft^3
How many pounds of liquid can be pumped per day?

13. A certain pump delivers 23 gallons per minute.
    A. How many lbs of water does the pump deliver in 1 minute?
    B. How many lbs/min will the pump deliver if the liquid weighs 71.9 lbs/ft^3?

14. A certain pump delivers 14 gallons per minute.
    A. How many lbs of water does the pump deliver in 24 hours?
    B. How many lbs/day will the pump deliver if the liquid weighs 8.1 lbs/gal?

15. Compare the density of chlorine gas with the density of air. Chlorine gas weighs 0.187 lbs/ft^3. (standard density of air = 0.075 lb/ft^3)

ANSWERS:

1. 2.6
2. 0.9
3. 1.04
4. 1.33
5. 1.26
6. 1.48
7. 57.4 lbs/ft^3
8. 9.5 lbs/gal
9. 12.76 lbs/gal
10. 95 lbs/ft^3
11. 9,617.7 lbs
12. 360,481 lbs/day
13. a. 191.8 lbs/min
    b. 221.1 lbs/min
14. a. 168,134.4 lbs/day
    b. 163,296 lbs/day
15. 2.49

Section 4

Flow and Velocity

Velocity and Flow

TDEC - Fleming Training Center 1

Velocity

Velocity = distance / time

Velocity is expressed in units such as ft/sec, miles/hour, ft/min, etc

The time unit of velocity can be different, as long as it is the same within each problem.

TDEC - Fleming Training Center 2

Velocity: Practice

The space shuttle travelled 4000 ft in 6 seconds, what was the velocity in ft/sec?

Velocity = distance / time

Velocity = 4000 ft / 6 sec = 666.67 ft/sec

TDEC - Fleming Training Center 3

Flow

Flow is symbolized by the letter Q.

Q = (Area) (velocity)

Basically, flow is a volume over time.

TDEC - Fleming Training Center 4

Flow through a channel

Q , ft^3/sec = (width, ft)(depth, ft)(velocity, ft/sec)

What is the flow in cfs for a channel that is 2 ft wide, 4 ft deep with water moving at 1.5 ft/sec?

Q, ft^3/sec = (width, ft)(depth, ft)(velocity ft/sec)

Q, ft^3/sec = (2 ft)(4 ft)(1.5 ft/sec) = 12 ft^3/sec

TDEC - Fleming Training Center 5

Flow through a pipeline

Q, ft^3 /sec = (0.785) (Diameter, ft)^2(velocity ft/sec)

What is the flow in cfs for a 2 ft diameter pipe flowing full at a velocity of 3 ft/sec?

Q, ft^3 /sec = (0.785)(Diameter, ft)^2(velocity, ft/sec)

Q, ft^3 /sec = (0.785)(2 ft)(2 ft)(3 ft/sec)

Q, ft^3 /sec = 9.42 ft^3/sec

TDEC - Fleming Training Center 6

Notes

1. Make sure you square the diameter.
2. Make sure you convert inches to ft.
3. Look at the units you are asked to find.
4. The flow formulas come out in ft^3/sec but you may be asked to find gal/min or MGD.
5. Use the flow conversion box chart on page 3 or use dimensional analysis to convert flows to the units desired.

TDEC - Fleming Training Center 7

Velocity and Flow

1. A bobber is placed in a channel and travels 450 feet in 2 ½ minutes. What is the velocity of the water flowing in the channel in ft/min?

2. A channel 30 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 2.75 ft/sec, what is the flow in the channel in ft^3/sec? And gal/min?

3. The flow through a 24 inch pipe is moving at a velocity of 5.4 ft/sec. What is the flow rate in gal/min?

Applied Math for Water Treatment
Flow Conversions

1. Express a flow of 5 cfs in terms of gpm.

2. What is 38 gps expressed as gpd?

3. Convert a flow of 4,270,000 gpd to cfm.

4. What is 5.6 MGD expressed as cfs? (round to nearest tenth)

5. Express 423,690 cfd as gpm.

6. Convert 2730 gpm to gpd.

1.) 2244 gpm 2.) 3,283,200 gpd 3.) 396.4 ft^3/min 4.) 8.7 ft^3/min 5.) 2200.8 gpm 6.) 3,931,200 gpd

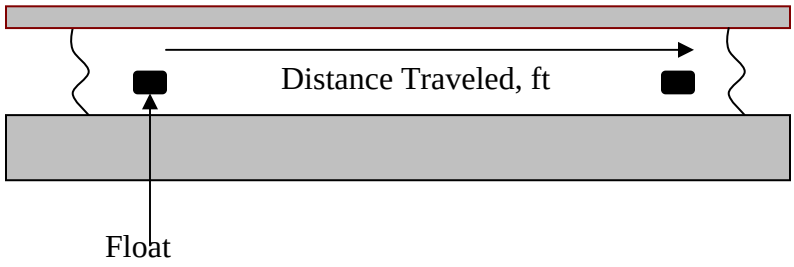
Applied Math for Water Treatment
Flow and Velocity

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?

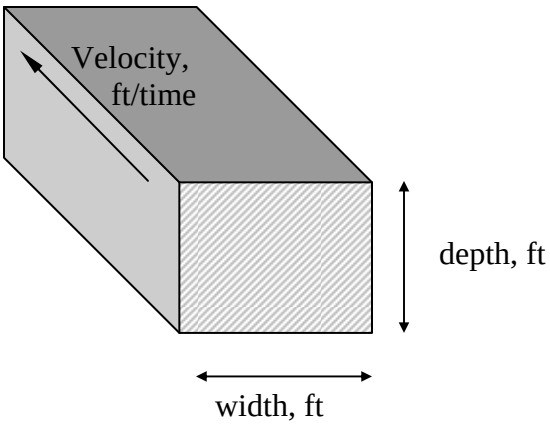
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



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

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

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



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

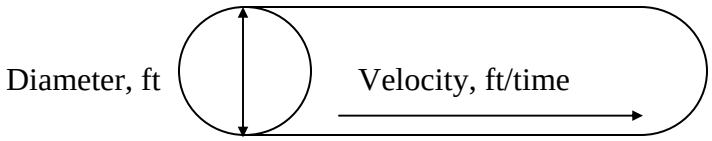
Flow in a channel

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?

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?

4.) 16.8 ft^3/sec 5.) 900 ft^3/min; 9.7 MGD 6.) 1.8 ft



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

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

Flow through a 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. 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?

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

7.) 10.05 ft3/sec 8.) 0.59 ft3/sec 9.) 6 in 10.) 532.4 gpm

APPLIED MATH FOR WATER
FLOW RATE

$Q = AV$

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min?

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe?

5. What would be the gpd flow rate for a 6” line flowing at 2 feet/second?

6. A 36” water main has just been installed. If the main is flushed at 2.5 ft/second, how many gallons/minute of water should be flushed from the hydrant?

7. A 36” water main has just been installed. If the main is flowing at a velocity of 2 ft/second, how many MGD will the pipe deliver?

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

9. A water crew is flushing hydrants on a 12-inch diameter main. The pitot gage reads 560 gpm being flushed from the hydrant. What is the flushing velocity (in feet/min) through the pipe?

VELOCITY (OPEN CHANNEL)

10. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the flow velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

11. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

12. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

AQUIFER FLOW

13. Geologic studies show that the water in an aquifer moves 25 feet in 60 days. What is the average velocity of the water in ft/day?

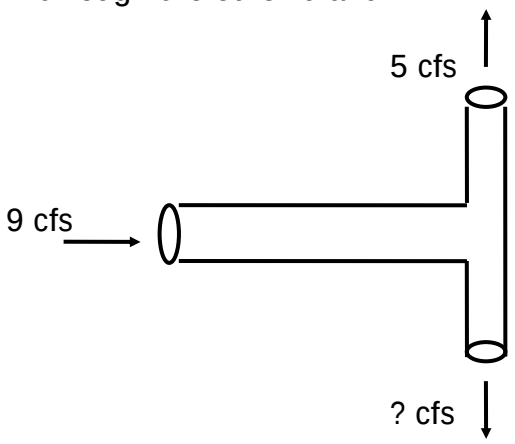
14. If the water in a water table aquifer moves 2 feet per day, how far will the water travel in 13 days?

15. If the water in a water table aquifer moves 2.25 feet per day, how long will it take the water to move 61 feet?

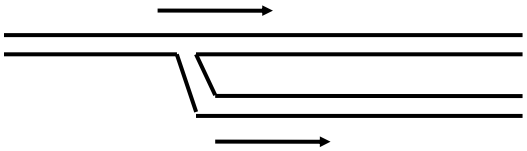
FLOW

16. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24” main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that one month?

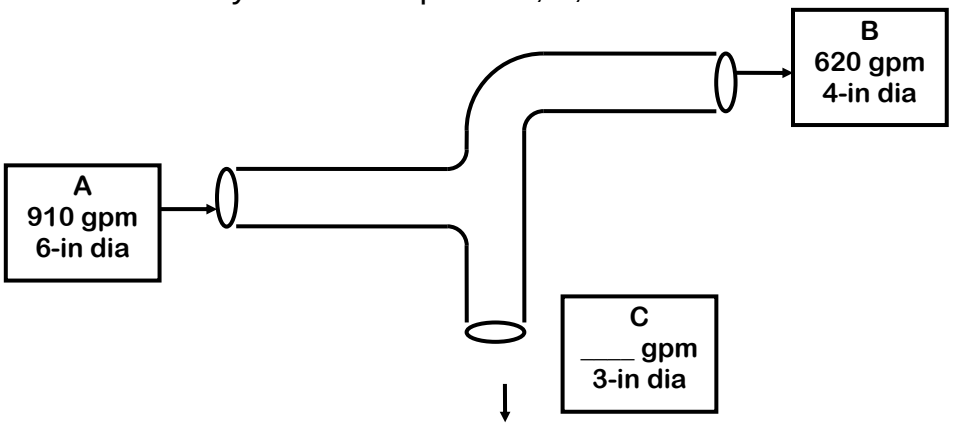
17. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?



18. A water line has been run to a new subdivision. The flow through the main line is 468 gpm. The line splits into two lines (each serving half of the subdivision). If one line flows 210 gpm, what should be the flow from the other line?



19. Determine the velocity in ft/sec at points A, B, & C.



ANSWERS:

1. 10.8 ft^3/sec
2. 86.4 ft^3/min
3. 2,404.5 gpm
4. 7,170,172 gpd
5. 253,662 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.5 MGD
9. 95.4 ft/min
10. 120 ft/min
11. 1.5 ft/sec
12. 1,533.3 ft^3/min
13. 0.42 ft/day
14. 26 ft
15. 27.1 days
16. 136.8 MG
17. 4 ft^3/sec
18. 258 gpm
19. A. 10.33 ft/sec
    B. 15.84 ft/sec
    C. 13.17 ft/sec

Section 5

Sedimentation

TDEC - Fleming Training Center 1

SEDIMENTATION MATH AND DETENTION TIME

Applied Math for Water Treatment
Fleming Training Center

TDEC - Fleming Training Center

Two types of overflow rates:

2

- Surface Overflow Rate
  - SOR
- Weir Overflow Rate
  - WOR

TDEC - Fleming Training Center

Surface Overflow Rate

3

- measured in gpd/ft^2
- SOR = $\frac{\text{flow, gpd}}{\text{area, ft}^2}$
- Area, rectangle = (length, ft)(width, ft)
  Area, circle = (0.785)(Diameter, ft)^2

TDEC - Fleming Training Center

Weir Overflow Rate

4

- measured in gpd/ft
- WOR = $\frac{\text{flow, gpd}}{\text{length of weir, ft}}$
- Length of Weir
  - Rectangular = 2(length, ft) + 2(width, ft)
  - Circular = (3.14)(Diameter, ft)

TDEC - Fleming Training Center

Surface Overflow Rate

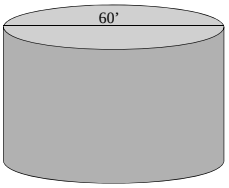
5

- A circular clarifier has a diameter of 60 feet. What is the surface overflow rate if the flow to the clarifier is 2.5MGD?

- SOR = $\frac{\text{flow, gpd}}{\text{area, ft}^2}$

  = $\frac{2{,}500{,}000 \text{ gpd}}{(0.785)(60 \text{ ft})(60 \text{ ft})}$

  = 884.6 gpd/ft^2



TDEC - Fleming Training Center

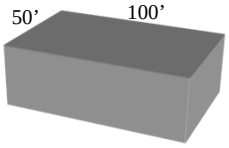
SOR

6

- A sedimentation tank is 100 feet long and 50 feet wide and receives a flow of 3.76MGD. What is the SOR in gpd/ft^2?

- SOR = $\frac{3{,}760{,}000 \text{ gpd}}{(100 \text{ ft})(50 \text{ ft})}$

  = 752 gpd/ft^2



TDEC - Fleming Training Center

Weir Overflow Rate

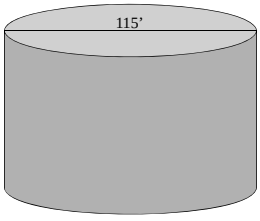
7

- A clarifier has a diameter of 115 feet and a flow of 5.76 MGD. What is the WOR?

- WOR = $\frac{\text{flow, gpd}}{\text{length of weir, ft}}$

  = $\frac{5{,}760{,}000 \text{gpd}}{(3.14)(115 \text{ ft})}$

  = 15,951.3 gpd/ft



TDEC - Fleming Training Center

WOR

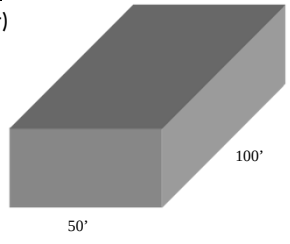
8

- The weir in a basin measures 50 feet by 100 feet. What is the WOR if the daily flow is 1 MG?

- WOR = $\frac{1{,}000{,}000 \text{ gpd}}{2(50\text{ft})+2(100\text{ft})}$

  = $\frac{1{,}000{,}000 \text{ gpd}}{300 \text{ ft}}$

  = 3333 gpd/ft



TDEC - Fleming Training Center

Detention Time

9

- DT, sec = $\frac{\text{(volume, gal)(1440 min/day)(60sec/min)}}{\text{flow, gpd}}$
- DT, min = $\frac{\text{(volume, gal)(1440 min/day)}}{\text{flow, gpd}}$
- DT, hr = $\frac{\text{(volume, gal)(24 hr/day)}}{\text{flow, gpd}}$

TDEC - Fleming Training Center

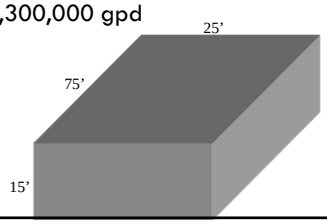
Detention Time

10

- A clarifier is 75 feet long, 25 feet wide and 15 feet deep. If the daily flow is 2.3 MGD, what is the detention time in hours for the basin?
- DT, min = $\frac{\text{(75ft)(25ft)(15ft)(7.48ft}^3\text{/gal)(1440min/day)}}{\text{2,300,000 gpd}}$

  = $\frac{\text{131.713 min}}{\text{60 min/hour}}$

  = 2.2 hours



Sedimentation

1. The flow to a sedimentation tank is 200,000 gpd. If the tank is 50 feet long and 30 feet wide, what is the surface overflow rate in gpd/ft^2?

2. A tank has a length of 75 ft and 25 ft wide. What is the weir length around the basin in feet?

3. A clarifier has a diameter of 90 feet. What is the length of the weir around the clarifier in feet?

4. The diameter of weir in a circular clarifier is 105 feet. What is the weir overflow rate in gpd/ft if the flow over the weir is 1.83 MGD?

5. A clarifier is 45 feet long, 30 feet long and 10 feet deep. If the daily flow is 3.5 MGD, what is the detention time (in minutes) in the basin?

Applied Math for Water

Sedimentation and Detention Time

Surface Overflow Rates (SOR)

1. A tank has a length of 100 feet, a width of 25 feet and a depth of 15 feet. What is the surface area in ft^2?

2. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the surface area of the clarifier in ft^2?

3. The flow to a sedimentation tank is 3.05 MGD. If the tank is 80 feet long and 20 feet wide, what is the surface overflow rate in gallons per day per square foot?

4. The flow to a sedimentation tank is 50,000 gpd. If the tank is 55 feet long and 15 feet wide, what is the surface overflow rate (gpd/ft^2)?

5. A sedimentation tank is 90 feet long and 40 feet wide and receives a flow of 5.04 MGD. Calculate the SOR in gpd/ft^2.

6. A circular clarifier has a diameter of 80 feet. If the flow to the clarifier is 3.8 MGD, what is the surface overflow rate (gpd/ft^2)?

7. A clarifier has a flow rate of 4,600 gpm and a diameter of 75 feet. What is the surface overflow rate in gpd/ft^2?

8. A clarifier with a diameter of 55 feet receives a flow of 2.075 MGD. What is the surface overflow rate (gpd/ft^2)?

9. What is the gpd/ft^2 overflow to a circular clarifier that has the following:
   Diameter: 70 feet
   Flow: 1,950 gpm

10. A rectangular clarifier receives a flow of 5.4 MGD. The length of the clarifier is 99 feet 7 inches and the width is 78 feet 6 inches. What is the SOR in gpd/ft^2?

Weir Overflow Rates (WOR)

11. A tank has a length of 100 feet, a width of 25 feet, and a depth of 15 feet. What is the weir length around the basin in feet?

12. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the length of the weir around the clarifier in ft?

13. A sedimentation tank has a total of 150 feet of weir over which the water flows. What is the weir overflow rate in gallons per day per foot of weir when the flow is 1.7 MGD?

14. The diameter of the weir in a circular clarifier is 85 feet. What is the weir overflow rate (gpd/ft) if the flow over the weir is 2.24 MGD?

15. A sedimentation tank has a total of 200 feet of weir which the water flows over. What is the weir overflow rate (gpd/ft) when the flow is 2.2 MGD?

16. The diameter of the weir in a circular clarifier is 125 feet. The flow is 6.33 MGD. What is the weir overflow rate (gpd/ft)?

17. A tank has a diameter of 49.4 feet. What is the gallons/day per foot of weir overflow when the tank receives 1,953,000 gpd?

18. The flow rate to a particular clarifier is 528 gpm and the tank has a length of 30 feet and a width of 17.5 feet. What is the gpd/ft of weir?

19. The weir in a basin measures 30 feet by 15 feet. What is the weir overflow rate (gpd/ft) when the flow is 1,098,000 gpd?

20. What is the weir overflow rate of a clarifier that is 50 feet 4 inches by 44 feet 3 inches and has an influent flow of 1.87 MGD?

Detention Time

21. A tank has a length of 100 feet, a width of 25 feet and a depth of 15 feet. What is the volume in gallons?

22. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the volume of the clarifier in gallons?

23. A circular clarifier handles a flow of 0.9 MGD. The clarifier is 50 feet in diameter and 8 feet deep. What is the detention time in hours?

24. A clarifier is 70 feet long, 25 feet wide and 10 feet deep. If the daily flow is 2,780,000 gpd, what is the detention time (in hours) in the basin?

25. What is the detention time in hours of a circular clarifier that receives a flow of 3,300 gpm and the clarifier is 65 feet in diameter and 12 feet deep?

26. A sedimentation tank is 60 feet long, 12 feet wide and has water to a depth of 12 feet. If the flow to the tank is 21,600 gph, what is the detention time in hours?

27. A circular clarifier receives a flow of 920 gpm. If it has a diameter of 55 feet and a water depth of 7 feet, what is the detention time in hours?

28. A clear well is 70 feet long, 20 feet wide and has a water to a depth of 8 feet. If the daily flow is 698 gpm, what is the detention time in minutes?

Answers:

1. 2,500 ft^2
2. 5,278.34 ft^2
3. 1,906.25 gpd/ft^2
4. 60.61 gpd/ft^2
5. 1,400 gpd/ft^2
6. 756.37 gpd/ft^2
7. 1,500.13 gpd/ft^2
8. 873.82 gpd/ft^2
9. 730.01 gpd/ft^2
10. 690.78 gpd/ft^2
11. 250 ft
12. 257.48 ft
13. 11,333.33 gpd/ft
14. 8,392.66 gpd/ft
15. 11,000 gpd/ft
16. 16,127.39 gpd/ft
17. 12,590.58 gpd/ft
18. 8003.37 gpd/ft
19. 12,200 gpd/ft
20. 9,885.47 gpd/ft
21. 280,500 gal
22. 473,783.80 gal
23. 3.13 hr
24. 1.13 hr
25. 1.5 hr
26. 2.99 hrs
27. 2.25 hrs
28. 120 min

Applied Math for Water
Sedimentation Practice Quiz

1. The flow to a sedimentation tank is 3.85 MGD. If the tank is 70 feet long and 35 feet wide, what is the surface overflow rate (gpd/ft^2)?

2. The diameter of the weir in a circular clarifier is 110 feet. The flow is 5.75 MGD. What is the weir overflow rate (gpd/ft)?

3. A rectangular clarifier handles a flow of 3.28 MGD. The clarifier is 60 feet long, 40 feet wide and 25 feet deep. What is the detention time in minutes?

4. A circular clarifier receives a flow of 3,472.2 gpm. What is the detention time in the clarifier (in hours)? The clarifier has a diameter of 62.5 feet and a depth of 21 feet.

Answers:

1. 1571.43 gpd/ft^2
2. 16,647.37 gpd/ft
3. 197.03 min
4. 2.31 hours

Section 6

Pumps

Horsepower and Efficiency

Applied Math for Pumps and Motors

TDEC - Fleming Training Center

Understanding Work & Horsepower

- Work: The exertion of force over a specific distance.
  - Example: Lifting a one-pound object one foot.
- Amount of work done would be measured in foot-pounds
  - (feet) (pounds) = foot-pounds
- (1 pound object) (moved 20 ft) = 20 ft-lbs of work

2 TDEC - Fleming Training Center

Understanding Power

- Power is the measure of how much work is done in a given amount of time
- The basic units for power measurement is foot-pounds per minute and expressed as (ft-lb/min)
  - in electric terminology ⇒ Watts
- This is work performed per time (work/time)
- One Horsepower: 1 HP = 33,000 ft-lb/min
- In electric terms: 1 HP = 746 Watts

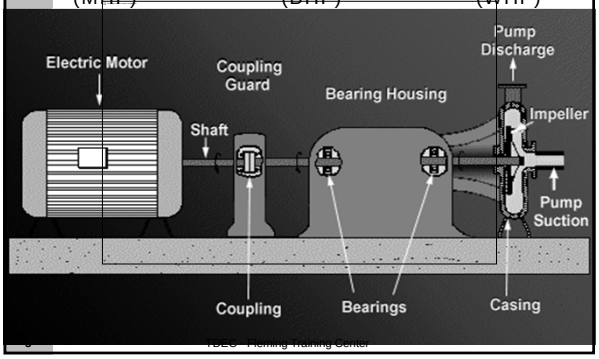
3 TDEC - Fleming Training Center

Types of Horsepower

- **Motor Horsepower** is related to the watts of electric power supplied to a motor
- **Brake Horsepower** is the power supplied to a pump by a motor
- **Water Horsepower** is the portion of power delivered to a pump that is actually used to lift the water
  - Water horsepower is affected by elevation and location of the pump.

4 TDEC - Fleming Training Center

Motor Horsepower (MHP) *Brake Horsepower* (BHP) *Water Horsepower* (WHP)



Computing Water Horsepower

- It is the amount of horsepower required to lift the water
- Formula for water horsepower (WHP)

$$WHP = \frac{(\text{flow gpm})\ (\text{total head feet})}{3{,}960}$$

$$\frac{33{,}000 \text{ ft-lb/min}}{8.34\ {}^{\text{lbs}}/_{\text{gal}}} = 3960$$

6 TDEC - Fleming Training Center

Computing Water Horsepower

- For example: A pump must pump 3,000 gpm against a total head of 25 feet. What water horsepower will be required?
- WHP = $\frac{(3000\ gpm)(25\ head\ in\ ft)}{3960}$
  = 18.94

7 TDEC - Fleming Training Center

Brake Horsepower

- BHP = $\frac{(flow,\ gpm)\ (head,\ ft)}{(3960)\ (\%\ pump\ efficiency)}$
- BHP = $\frac{water\ HP}{(\%\ pump\ efficiency)}$

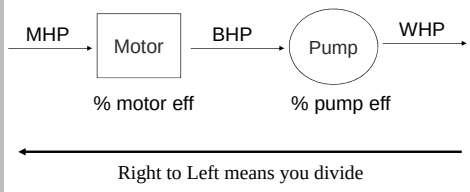
8 TDEC - Fleming Training Center

Motor Horsepower

- MHP = $\frac{(flow,\ gpm)\ (head,\ ft)}{(3960)(\%\ pump\ eff.)(\%\ motor\ eff.)}$
- MHP = $\frac{brake\ HP}{(\%\ motor\ efficiency)}$

9 TDEC - Fleming Training Center

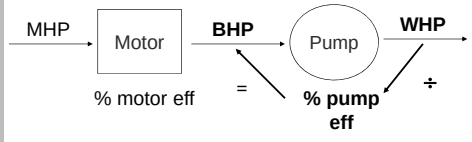
Pumps



Right to Left means you divide

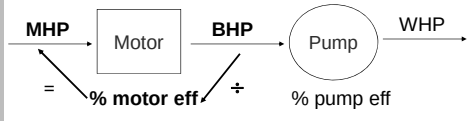
10 TDEC - Fleming Training Center

Pumps - BHP



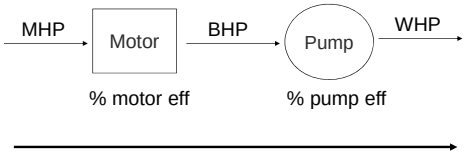
11 TDEC - Fleming Training Center

Pumps - MHP



12 TDEC - Fleming Training Center

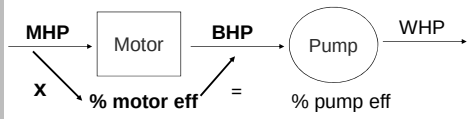
Pumps



Left to Right means you multiply

13 TDEC - Fleming Training Center

Pumps - BHP



14 TDEC - Fleming Training Center

Motor and Pump Efficiency

- Neither the motor nor the pump will ever be 100% efficient
- Not all the power supplied by the motor to the pump (Brake Horsepower) will be used to lift the water (Water Horsepower)
- Power for the motor and pump is used to overcome friction
- Power is also lost when energy is converted to heat, sound, etc.

15 TDEC - Fleming Training Center

Typical Efficiency

- Pumps are generally 50-85 % efficient
- Motors are usually 80-95% efficient
- Combined efficiency of the motor and pump is called wire-to-water efficiency
- Wire-to-Water is obtained by multiplying the motor and pump efficiencies together

16 TDEC - Fleming Training Center

Typical Efficiency

- Example:
  Motor Efficiency = 82%
  Pump Efficiency = 67%
  Wire to Water Efficiency
  (0.82) (0.67) = 0.55
  0.55 x 100% = 55%
- Note: If not given, you will have to calculate both motor and pump efficiency.

17 TDEC - Fleming Training Center

Overall Efficiency

- Must Know the WHP and the MHP
  - If not given you will have to compute both.
- % Efficiency, overall = $\frac{\text{WHP}}{\text{MHP}}$
- % Over All Efficiency = $\frac{18.5 \text{ WHP}}{35 \text{ MHP}} \Rightarrow 53\%$
- ***In all cases, the bottom number will be larger than the top number.***

18 TDEC - Fleming Training Center

Determining Pumping Costs

What was your electric bill last month?

Determining Pumping Costs

- Electrical Power is sold in units of kilowatt-hours
- One Horsepower = 0.746 kilowatt
- To compute pumping costs, need to know the power requirements (power demand) of the motor and the length of time the motor runs

Determining Pumping Costs

- For example, if you have a pumping job that requires 25 HP and the cost is $0.035/kW-hr. What is the pumping cost for one hour?
- Cost, $/hr = (MHP)(0.746 kW/HP)(cost, $/kW-hr)
  = (25 HP)(0.746)($0.035/ kW-hr)
  = $0.65/hr

A Few Electrical Terms...

- Power (Watts) - amount of work done
- Voltage (volts) - electrical “pressure” available to cause flow of electricity
- Amperage (amps) - the amount of flow of electricity
- Power = (voltage)(amperage)
  or
- Watts = (volts)(amps)

Motor Ratings, Volts, Amps, Single and Multiple Phases

- Power in reference to motors is in watts
  - determined by multiplying the volts and ampere spec for the particular motor used
- For example, a 220 volt motor that pulls 100 amps would have a power wattage of 22,000 watts. What would be the horsepower of this motor?
- $HP = \frac{(volts)(amps)}{746\ watts/horsepower} = \frac{(220)(100)}{746} = 29hp$

Wattage Power Factor of Motors

- There are two type of motors that we usually use. They are:
  - Single-Phase Motors
  - Three-Phase Motors (usually any motor over 2 hp)
- kW, Single Phase = $\frac{(volts)(amps)(power\ factor)}{1{,}000\ ^{Watts}/_{kilowatt}}$
- kW, Three Phase = $\frac{(volts)(amps)(power\ factor)(1.732)}{1{,}000\ ^{Watts}/_{kilowatt}}$

Remember, if you are asked to find watts, don’t divide by 1,000

Power Factor of Motors

- The power factor of a motor is computed by dividing the watts by the volt and amp rating of the motor
- Power Factor = watts / (volts)(amps)
- The power factor might be on the data plate, but will always be in the manual

25 TDEC - Fleming Training Center

Amperes Single and Three Phase

- amps, Single Phase = (746)(horsepower) / (volts)(%eff.)(power factor)
- amps, Three Phase = (746)(horsepower) / (1.732)(volts)(%eff.)(power factor)

26 TDEC - Fleming Training Center

Pumping Rates

TDEC - Fleming Training Center

Pumping Rates

- During a 60-minute pumping test, 11,250 gallons were pumped into a tank that is 15 feet in diameter and 20 feet deep. What is the gal/min pumping rate?
- gal/min = Volume, gal / Time, min
  = 11,250 gal / 60 min
  = 187.5 gal/min

There are four formulas for these types of problems on pg. 6

28 TDEC - Fleming Training Center

Time to Fill

- During a pumping test, 15,000 gallons are pumped into a tank. If the pump is rated at 250 gal/min, how many minutes would it take to fill the tank?
- Time to fill, min = Tank Volume, gal / Flow Rate, gal/min
  = 15,000 gal / 250 gal/min
  = 60 min

29 TDEC - Fleming Training Center

Pumps

1. A pump must pump 4,500 gpm against a total head of 75 feet. What horsepower will be required to do the work?

2. If a pump is to deliver 325 gpm of water against a total head of 75 feet, and the pump has an efficiency of 87%, what horsepower must be supplied to the pump?

3. The manual indicates that the output of a certain motor is 40 hp. How much horsepower must be supplied to the motor if the motor is 95% efficient?

4. The water horsepower was calculated to be 20 hp. If the motor supplies the pump with 23 hp, what must be the efficiency of the pump?

5. What is the overall efficiency if 40 hp is supplied to the motor and 26 hp of work is accomplished?

6. Given that 30 kilowatts (kW) power is supplied to a motor and the brake horsepower is 31 hp, what is the efficiency of the motor?

7. A pump is discharging 1200 gpm against a head of 55 feet. The wire-water-efficiency is 75 percent. If the cost of power is $0.038/kW hr, what is the cost of the power consumed during a run of 105 hours?

8. What is the horsepower for a motor that is rated at 55 amps and 440 volts?

9. Determine the power factor for a system that uses 4971 watts and pulls 12 amps at 440 volts.

10. If a single-phase motor pulls 15 amps at 220 volts and has a power factor of 1.2, how many kilowatts of power does it use?

11. How many watts of power does a three-phase motor use if it pulls 30 amps at 440 volts and has a power factor of 0.93?

APPLIED MATH FOR WATER TREATMENT
PUMP HORSEPOWER/EFFICIENCY/COST/MOTORS

HORSEPOWER

1. A pump must pump 3,000 gpm against a total head of 25 feet. What horsepower (water horsepower) will be required to do the work?

2. A flow of 555 gpm must be pumped against a head of 40 feet. What is the horsepower required?

3. Suppose a pump is pumping a total head of 76.2 feet. If 900 gpm is to be pumped, what is the water horsepower requirement?

4. Suppose a pump is pumping against a total head of 46 feet. If 850 gpm is to be pumped, what is the horsepower requirement?

5. A pump is delivering a flow of 835 gpm against a total head of 35.6 feet. What is the water horsepower?

6. What is the water horsepower of a pump that is producing 1,523 gpm against a head of 65 feet?

EFFICIENCY

7. If a pump is to deliver 360 gpm of water against a total head of 95 feet, and the pump has an efficiency of 85 percent, what horsepower must be supplied to the pump?

8. If a pump is to deliver 450 gpm of water against a total head of 90 feet, and the pump has an efficiency of 70 percent, what horsepower must be supplied to the pump?

9. The motor nameplate indicated that the output of a certain motor is 35 hp. How much horsepower must be supplied to the motor, if the motor is 90% efficient?

10. The motor nameplate indicated that the output of a certain motor is 20 hp. How much horsepower must be supplied to the motor if the motor is 90 percent efficient?

11. You have calculated that a certain pumping job will require 9 whp. If the pump is 80 percent efficient and the motor is 72 percent efficient, what motor horsepower will be required?

12. You have calculated that a certain pumping job will require 6 whp. If the pump is 80 percent efficient and the motor is 90 percent efficient, what motor horsepower will be required?

13. Based on the gallons per minute to be pumped and the total head the pump must pump against, the water horsepower requirement was calculated to be 18.5 whp. If the motor supplies the pump with 21 hp, what must be the efficiency of the pump?

14. What is the overall efficiency if an electric power equivalent to 35 hp is supplied to the motor and 18.5 hp of work is accomplished?

15. Suppose that 31 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 19 bhp, what is the efficiency of the motor?

16. Suppose that 10 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 12 bhp, what is the efficiency of the motor?

PUMPING COST

17. The motor horsepower required for a particular pumping job is 39 hp. If your power cost is $0.08/kW hr, what is the cost of operating the motor for one hour?

18. The motor horsepower required for a particular pumping job is 30 hp. If your power cost is $0.05/kW hr, what is the cost of operating the motor for one hour?

19. You have calculated that the minimum motor horsepower requirement for a particular pumping problem is 25 mhp. If the cost of power is $0.025/kW hr, what is the power cost in operating the pump for 14 hours?

20. A pump is discharging 1100 gpm against a head of 65 feet. The wire-to-water efficiency is 70 percent. If the cost of power is $0.025/kW hr, what is the cost of the power consumed during a week in which the pump runs 80 hours?

21. Given a brake horsepower of 18.5, a motor efficiency of 88 percent and a cost of $0.015/kW hr, determine the daily power cost for operating a pump.

22. A pump is discharging 1500 gpm against a head of 80 feet. The wire-to-water efficiency is 68 percent. If the cost of power is $0.035/kW hr, what is the cost of the power consumed during a week in which the pump runs 90 hours?

MOTORS

23. What would be the horsepower on a motor that is rated at 36 amps and 440 volts?

24. What would be the horsepower on a motor that is rated at 12 amps and 440 volts?

25. What would be the horsepower on a motor that is rated at 16 amps and 440 volts?

26. How many watts of power does a single-phase motor use if it pulls 12 amps at 110 volts and has a power factor of 1?

27. How many watts of power does a single-phase motor use if it pulls 12 amps at 220 volts and has a power factor of 0.8?

28. How many watts of power does a single-phase motor use if it pulls 12 amps at 110 volts and has a power factor of 0.3?

29. How many watts of power does a three-phase motor use if it pulls 20 amps at 440 volts and has a power factor of 0.85?

30. How many watts of power does a three-phase motor use if it pulls 40 amps at 440 volts and has a power factor of 0.9?

31. How many kilowatts of power does a three-phase motor use if it pulls 20 amps at 440 volts and has a power factor of 0.85?

32. What is the power factor on a system that uses 3872 watts and pulls 11 amps at 440 volts?

33. What is the power factor on a system that uses 3960 watts and pulls 10 amps at 440 volts?

ANSWERS

HORSEPOWER

1. 18.9 hp
2. 5.6 hp
3. 17.3 hp
4. 9.9 hp
5. 7.5 hp
6. 25 hp

EFFICIENCY

7. 10.2 hp
8. 14.6 hp
9. 38.9 hp
10. 22.2 hp
11. 15.6 hp
12. 8.3 hp
13. 88%
14. 53%
15. 45.7%
16. 89.5%

PUMPING COST

17. $2.33/hr
18. $1.12/hr
19. $6.53
20. $38.48
21. $5.65
22. $104.72

MOTORS

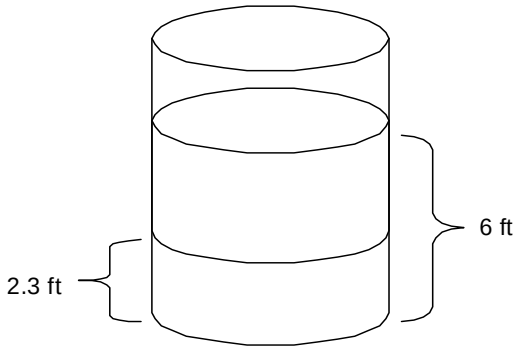
23. 21.2 hp
24. 7.1 hp
25. 9.4 hp
26. 1,320 watts
27. 2,112 watts
28. 396 watts
29. 12,955.4 watts
30. 27,434.9 watts
31. 13 kW
32. 0.8
33. 0.9

APPLIED MATH FOR WATER TREATMENT
PUMP RATES PROBLEMS

1. During a 60-minute pumping test, 9,456 gallons are pumped into a tank that has a length of 10 feet, width of 8 feet, and depth of 6 feet. The tank was empty before the pumping test was started. What is the GPM rate?

2. During a 30-minute pumping test, 3680 gallons are pumped into a tank, which has a diameter of 10 ft. The water level before the pumping test was 3 ft. What is the GPM rate?

3. A 50-ft diameter tank has water to a depth of 6 feet. The inlet valve is closed and a 2-hour pumping test is begun. If the water level in the tank at the end of the test is 2.3 feet, what is the pumping rate in gallons per minute?



4. A tank has a length of 12 feet, a depth of 12 feet, a width of 12 feet, and has water to a depth of 10 feet. If the tank can be emptied in 1 hour 37 minutes, what is the pumping rate in gallons per minute?

5. During a pumping test, water was pumped into an empty tank 10 feet by 10 feet by 5 feet deep. The tank completely filled with water in 10 minutes 30 seconds. Calculate the pumping rate in GPM.

6. During a 60 minute pumping test, 11,321 gallons are pumped into a tank that has a length of 15 feet, a width of 10 feet and a depth of 8 feet. The tank was empty before the pumping test was started. What is the GPM rate?

7. A wet well is 15 feet long and 12 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 1.25 feet during a 5-minute pumping test, what is the gpm pumping rate?

8. A pump is discharged into a 55-gallon barrel. If it takes 35 seconds to fill the barrel, what is the pumping rate in GPM?

9. A pump is rated at 300 gpm. A pump test is conducted for 3 minutes. What is the actual gpm pumping rate if the wet well is 10 feet long and 8 feet wide and the water level drops 1.33 feet during the pump test?

10. During a pumping test, 12,600 gallons are pumped into a tank. If the pump is rated at 210 gpm, how many minutes did it take to fill the tank?

11. If a tank 12 feet long, 12 feet wide, 12 feet deep, and holding water to a depth of 8 feet can be emptied at a pumping rate of 575 gpm, how many minutes will it take to remove all the water?

ANSWERS

1. 157.6 gpm
2. 122.7 gpm
3. 452.6 gpm
4. 111 gpm
5. 356.2 gpm
6. 188.7 gpm
7. 336.6 gpm
8. 94.3 gpm
9. 265.3 gpm
10. 60 minutes
11. 15 minutes

Applied Math for Water Treatment
Pump Math
Extra Problems

1. The brake horsepower of a pump is 22 hp. If the water horsepower is 17 hp, what is the efficiency of the pump?

2. If the motor horsepower is 50 hp and the brake horsepower is 43 hp, what is the percent efficiency of the motor?

3. The motor horsepower is 25 hp. If the motor is 89% efficient, what is the brake horsepower?

4. A total of 50 hp is supplied to a motor. If the wire-to-water efficiency of the pump and motor is 62%, what will the Whp be?

5. The brake horsepower is 34.4 hp. If the motor is 86% efficient, what is the motor horsepower?

6. A pump must pump 1500 gpm against a total head of 40 ft. What horsepower is required for this work?

7. If 20 hp is supplied to a motor (Mhp), what is the Bhp and Whp if the motor is 85% efficient and the pump is 80% efficient?

8. A total of 35 hp is required for a particular pumping application. If the pump efficiency is 85%, what is the brake horsepower required?

9. The motor horsepower requirement has been calculated to be 45 hp. How many kilowatts electric power does this represent? (Remember, 1 hp = 746 watts)

10. The motor horsepower requirement has been calculated to be 75 hp. During the week, the pump is in operation a total of 144 hours. If the electricity cost is $0.06125 per kW-hr, what would be the power cost that week for the pumping?

5. 77%
6. 86%
7. 22.25 Bhp
8. 31 Whp

5. 40 Mhp
6. 15 Whp
7. 17 Bhp, 13.6 Whp
8. 41.2 Bhp

9. 33.57 kW
10. $493.48

Section 7

Disinfection

TDEC - Fleming Training Center

DISINFECTION MATH

1

Chlorination:
Demand and Dosage
Dilutions
Substitutions

TDEC - Fleming Training Center

CHLORINE

- Chlorine and chlorine compounds are the most commonly used disinfectants for water systems in the U.S.
  - Chlorine, Cl_2
    - 100%
  - Calcium hypochlorite (HTH), $Ca(OCl)_2$
    - 65%
  - Sodium hypochlorite (liquid bleach), NaOCl
    - 5-15%

2

TDEC - Fleming Training Center

PURPOSE OF CHLORINATION

- Chlorination does not destroy all organisms in the water
- Chlorine only destroys pathogenic, or disease-causing organisms.

3

TDEC - Fleming Training Center

FORMULA BOOKLET

- Disinfection formulas are on pages 12-13

4

CHLORINE DEMAND

- If the chlorine dosage is 4.5 mg/L and the residual is 1.2 mg/L, what is the demand?

Cl_2 demand = Cl_2 dose, mg/L - Cl_2 residual, mg/L

= 4.5 mg/L - 1.2 mg/L

= 3.3 mg/L

5

CHLORINE DOSAGE

- A water plant treats 12 MGD and wants to treat the water with 4.2 mg/L Cl_2. How many pounds per day will the plant use?

Cl_2, lb/day = (dosage, mg/L)(flow,MGD)(8.34 lb/gal)

= (4.2 mg/L)(12 MGD)(8.34 lb/gal)

= 420.3 lb/day

6

CHLORINE DOSAGE

- A water plant treats 3.5 MGD and wants to treat the water with 3.2 mg/L of 65% calcium hypochlorite. How many pounds per day will the plant use?

$$\text{lb/day} = \frac{\text{(dosage, mg/L)(flow,MGD)(8.34 lb/gal)}}{\text{(\% chemical purity, expressed as decimal)}}$$

$$= \frac{\text{(3.2 mg/L)(3.5 MGD)(8.34 lb/gal)}}{0.65}$$

= 143.7 lb/day

7

CHLORINE DOSAGE

- A water plant treats 300,000 gallons of water a day and wants to treat the water with 3.8 mg/L of 15% sodium hypochlorite. How many pounds per day will the plant use?

$$\text{lb/day} = \frac{\text{(dosage, mg/L)(flow,MGD)(8.34 lb/gal)}}{\text{(\% chemical purity, expressed as decimal)}}$$

$$= \frac{\text{(3.8 mg/L)(0.3 MGD)(8.34 lb/gal)}}{0.15}$$

= 63.4 lbs/day

8

TDEC - Fleming Training Center

CHLORINE DOSAGE

- Determine the dosage in mg/L for a plant treating 15 MGD using 440 lbs of Cl_2 gas

$$\text{mg/L} = \frac{\text{(lbs/day)(\% available chlorine, as decimal)}}{\text{(MGD)(8.34 lbs/gal)}}$$

$$= \frac{\text{(440 lbs/day)(1)}}{\text{(15 MGD)(8.34 lbs/gal)}}$$

$$= 3.52 \text{ mg/L}$$

9

TDEC - Fleming Training Center

CHLORINE DOSAGE

- Determine the dosage in mg/L for a plant treating 650,000 gpd with 21 gallons 15% hypochlorite

$$\text{mg/L} = \frac{\text{(gallons hypochlorite/day)(\% conc. as decimal)}}{\text{MGD}}$$

$$= \frac{\text{(21 gallons)(0.15)}}{\text{0.65 MGD}}$$

$$= 4.85 \text{ mg/L}$$

10

TDEC - Fleming Training Center

HYPOCHLORINATION

- How many pounds of 65% HTH are required to make 10 gallons of 1% solution?

$$\text{lbs HTH} = \frac{\text{(\% desired conc.)(desired gal)(8.34 lb/gal)}}{\text{\% available HTH}}$$

$$= \frac{\text{(0.01)(10 gal)(8.34 lb/gal)}}{\text{0.65}}$$

$$= 1.28 \text{ lb HTH}$$

11

TDEC - Fleming Training Center

DILUTIONS

- How many gallons of 15% bleach will be required to make 60 gallons of 5% bleach?

$$\text{gal} = \frac{\text{(\% desired conc., as decimal)(desired vol., gal)}}{\text{\% bleach conc., as decimal}}$$

$$= \frac{\text{(0.05)(60 gal)}}{\text{0.15}}$$

$$= 20 \text{ gal}$$

12

SUBSTITUTIONS

- A water plant has just switched from sodium hypochlorite to chlorine gas. If they used an average of 43 gal/day of 15% sodium hypochlorite, how many pounds per day will they use of Cl_2?

lbs Cl_2 = (% bleach, as dec.)(gal bleach)(8.34 lbs/gal)

= (0.15)(43 gal)(8.34 lbs/gal)

= 53.8 lbs Cl_2

13

SUBSTITUTIONS

- A water plant has run out of calcium hypochlorite for disinfecting a storage tank. If they needed 75 lbs HTH, how many gallons of 15% NaOCl will they need?

$$\text{gal bleach} = \frac{(\%\text{HTH, as decimal})(\text{lbs. HTH})}{(\%\text{ available bleach})(8.34\text{ lbs/gal})}$$

$$= \frac{(0.65)(75\text{ lbs})}{(0.15)(8.34\text{ lbs/gal})}$$

= 39 gallons NaOCl

14

STORAGE TANK DISINFECTION

- A 500,000 gallon storage tank is disinfected with 50 mg/L using 65% HTH. How many pounds of HTH are required?

$$\text{lbs HTH} = \frac{(\text{dosage, mg/L})(\text{MG})(8.34\text{ lbs/gal})}{\%\text{ HTH}}$$

$$= \frac{(50\text{ mg/L})(0.5\text{MG})(8.34)}{0.65}$$

= 320.8 lbs

15

WATER MAIN DISINFECTION

- How many pounds of 65% available HTH will be needed to disinfect a section of pipe 250 feet long and 12 inches in diameter with a dose of 50 mg/L?

volume = $(0.785)(\text{diameter})^2(\text{third dimension})$

$= (0.785)(1\text{ ft})(1\text{ ft})(250\text{ ft})(7.48\text{ gal/ft}^3)$

= 1466 gal

$$\text{lbs} = \frac{(\text{dosage, mg/L})(\text{volume, MG})(8.34\text{ lbs/gal})}{\%\text{ available, as decimal}}$$

$$= \frac{(50\text{mg/L})(0.001466\text{MG})(8.34\text{lbs/gal})}{0.65}$$

= 0.94 lbs HTH

16

Disinfection

1. A treatment plant wants to have 1.4 mg/L residual chlorine in the distribution system. Due to a main break the demand has climbed to 0.8 mg/L. What is the required dose?

2. A city has a combined residual of 0.5 mg/L and a free residual of 1.8 mg/L. What is the total residual in mg/L?

3. A water plant treats 4.3 MGD. If the chlorine dose needs to be 4.5 mg/L, what is the chlorine feed requirement in lb/day?

4. Determine the chlorine dose in mg/L if 17 lbs of chlorine are fed while treating 1.3 MGD of water.

5. How many pounds of 65% available HTH is needed to make 4 gallons of a 7% solution?

6. How many gallons of bleach (12.5% available chlorine) will it take to make a 5 % solution when added to enough water to make 50 gallons of hypochlorite?

7. A water plant has just switched from sodium hypochlorite to chlorine gas. If they used an average of 32 gal/day of 15% sodium hypochlorite, how many pounds per day will they use of Cl_2?

8. A chlorine cylinder weighs 150 pounds. Twenty four hours later the same cylinder weighs 103 pounds. What is the chlorinator feed rate in lb/day?

a. Estimate the chlorine dose in mg/L for the chlorinator. The flow totalizer reads 13, 597,405 gallons and 15, 078,687 gallons 24 hrs later.

b. If the setting on chlorinator does not change, how many pounds of chlorine will be left in the cylinder 2 days later?

c. How many 150lb cylinders will this plant need in a month (with 30 days)?

APPLIED MATH FOR WATER
DISINFECTION MATH

DOSE & DEMAND

1. A water system has a chlorine demand of 4.1 mg/L and wants to have a 1.1 mg/L residual. What would be the dose?

2. A city wants to have 1.4 mg/L chlorine in the distribution system. Due to a main break the demand has climbed to 1.0 mg/L. What is the residual?

3. A system just had a main break. The chlorine level of 3.3 mg/L has dropped to 0.3 mg/L. What is the chlorine demand?

4. A city doses the water to have a residual of 1.9 mg/L. The demand has risen because of a main break to 1.8 mg/L. What is the free residual?

5. A city has a combined residual of 0.2 mg/L and a free residual of 1.7 mg/L. What is the total residual in mg/L?

6. The total residual in a clearwell is 2.7 mg/L. If the free residual is 2.5 mg/L, what is the combined residual?

7. The total residual in the clearwell is 2.5 mg/L. If the free residual is 2.2 mg/L, what is the combined residual?

DOSAGE

8. A water plant treats 7.5 MGD. If the chlorine dose needs to be 3 mg/L, what is the chlorine requirement in pounds per day?

9. If the water plant treats 1.8 MGD and wants to dose the water with 2.8 mg/L of chlorine, what would be the lbs/day feed rate?

10. How many pounds per day of chlorine are required to treat 14 million gallons of water with 3.3 mg/L of chlorine gas?

11. Determine the chlorine dose in mg/L if 13 pounds of chlorine are fed while treating 968,000 gallons of water.

12. Determine the chlorine dose in mg/L if 28 lbs/day is fed for a flow of 1,750,000 gpd.

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

14. What should the setting be on a chlorinator in lbs/24 hours if a pump usually delivers 600 gpm and the desired chlorine dosage is 4 mg/L?

15. 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.

USE THE FOLLOWING INFORMATION FOR PROBLEMS 16 – 19:

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.

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

17. 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.)

18. 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.?

19. 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 20 – 22:

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.

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

21. 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?

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

HYPOCHLORINATION

23. How many pounds of 65% available chlorine HTH is needed to make 1 gallon of 10% solution?

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

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

26. How many gallons of bleach (15% available chlorine) will it take to make a 4% solution when added to enough water to make 50 gallons of hypochlorite?

27. 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?

28. How many gallons of bleach (5.25% available chlorine) will it take to make a 2% solution when added to enough water to make 8 gallons of hypochlorite?

29. Water from a well is being treated by a hypochlorinator. If the hypochlorinator is set at a pumping rate of 25 gallons per day and uses a 2% available chlorine solution, what is the chlorine dose in mg/L if the pump delivers 140 gpm?

30. A water plant has just switched from sodium hypochlorite to chlorine gas. If they used an average of 26 gal/day of 15% sodium hypochlorite, how many pounds per day will they use of Cl_2?

31. A water plant has run out of calcium hypochlorite for disinfecting a storage tank. If they needed 55 pounds of HTH, how many gallons of 15% sodium hypochlorite will they need?

USE THE FOLLOWING INFORMATION TO ANSWER #32 – 34:

A section of pipe 250 feet long and 10 inches in diameter is filled with water. You need to disinfect it with a chlorine dose of 50 mg/L.

32. How many pounds of chlorine gas will be required?

33. How many pounds of 65% available HTH will be required?

34. How many gallons of 5.25% available bleach will be required?

35. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 3 to disinfect the tank. This method requires you to make up a 50 mg/L available chlorine solution that will fill approximately 5% of the tank volume. The tank holds 3 MG. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to meet the above mentioned requirements?

36. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to disinfect a tank that holds 100,000 gallons using the above mentioned requirements?

Answers:

1. 5.2 mg/L
2. 0.4 mg/L
3. 3.0 mg/L
4. 0.1 mg/L
5. 1.9 mg/L
6. 0.2 mg/L
7. 0.3 mg/L
8. 187.65 lbs/day
9. 42.03 lbs/day
10. 385.31 lbs/day
11. 1.61 mg/L
12. 1.92 mg/L
13. 3.01 mg/L
14. 28.82 lbs/24hr
15. 0.51 mg/L
16. 14 lbs/day
17. 3.07 mg/L
18. 27 lbs
19. 3 cylinders
20. 246 lbs/day
21. 52 lbs
22. 4 cylinders
23. 1.28 lbs
24. 11.55 lbs
25. 0.38 lbs
26. 13.3 gallons bleach
27. 3.85 lbs
28. 3.05 gallons
29. 2.48 mg/L
30. 32.53 lbs
31. 28.58 gal
32. 0.43 lbs
33. 0.65 lbs
34. 0.97 gallons
35. 150,000 gallons, 96.23 lbs
36. 5000 gallons, 3.21 lbs

Section 8

Fluoridation

Fluoride Math

Objectives :

To calculate dosages and feed rates for

different forms of fluoride

1

Determining Feed Rate

- Fluoride is not in pure form when purchased
- It is combined with other elements for stability and ease of handling
- To calculate the correct dosage, you must know the following:
  - Ion concentration
  - Percent purity

2

Fluoride Chemicals Purity

- Sodium Fluoride = 98% purity
  - NaF
- Sodium Fluorosilicate = 98.5% purity
  - Na_2SiF_6
  - AKA Sodium Silicofluoride
- Fluorosilicic Acid = 18-23% purity
  - H_2SiF_6
  - AKA Hydrofluosilicic Acid

3

Fluoride Chemicals

Ion Concentration Percent (AFI)

- Sodium Fluoride = 45.2%
- Sodium Fluorosilicate = 60.7%
- Fluorosilicic Acid = 79.2%

4

Optimal Dosage

- The optimal dosage for fluoride in drinking water in Tennessee is 0.7 mg/L
- To determine fluoride dosage, subtract the naturally occurring fluoride concentration from the desired concentration

5

Fluoride Dose

- A water plant wants a fluoride concentration of 1.00 mg/L in the finished water. If the raw fluoride content is 0.25 mg/L, how much fluoride needs to be added?

Fluoride dose = Total fluoride, mg/L - raw fluoride, mg/L
= 1.00 mg/L - 0.25 mg/L
= 0.75 mg/L

6

Calculating Feed Rate

- A water plant treats 750,000 gpd and wants to add 0.9 mg/L of fluoride to the water using sodium fluoride. How many pounds per day will be used?

lbs/day = (dosage, mg/L)(flow, MGD)(8.34 lbs/gal)
(AFI, as decimal)(purity, as decimal)

= (0.9 mg/L)(0.75 MGD)(8.34 lbs/gal)
(0.452)(.98)

= 12.7 lbs/day

7

Calculating Feed Rate

- A water plant treats 200,000 gpd and wants to add 0.82 mg/L of fluoride to the water using sodium fluorosilicate. How many pounds per day will they use?

lbs/day = (dosage, mg/L)(flow, MGD)(8.34 lbs/gal)
(AFI, as decimal)(purity, as decimal)

= (0.82 mg/L)(0.20 MGD)(8.34 lbs/gal)
(0.607)(.985)

= 2.29 lbs/day

8

Calculating Feed Rate

- A water plant treats 12.0 MGD and wants to add 0.75 mg/L of fluoride using fluorosilicic acid to the water. How many pounds per day will be used?

lbs/day = (dosage, mg/L)(flow, MGD)(8.34 lbs/gal)
(AFI, as decimal)(purity, as decimal)

= (0.75mg/L)(12 MGD)(8.34 lbs/gal)
(0.792)(.230)

= 412 lbs/day

9

Feed Rate for Saturator

- A water plant produces 250 gpm. The plant uses a saturator. Determine the feed rate in gallons per day if the dosage is 1.0 mg/L?

gal/min = (capacity, gpm)(dosage, mg/L)
(18,000 mg/L)

= (250 gpm)(1.0 mg/L)
18,000 mg/L

gal/day = (0.014 gal/min)(1440 min/day)
= 20.16 gallons a day

10

Dosages

- A total of 25 lbs of sodium fluorosilicate is used to treat 1.75 MGD. What is the concentration of fluoride in the water in mg/L?

mg/L = (fluoride fed, lbs)(AFI, as dec)(purity, as dec)
(MGD)(8.34 lbs/gal)

= (25 lbs)(.607)(.985)
(1.75 MGD)(8.34 lbs/gal)

= 1.02 mg/L

11

Dosages

- A total of 5 lbs of sodium fluoride is used to treat 0.2 MGD. What is the concentration of fluoride in the water in mg/L?

mg/L = (fluoride fed, lbs)(AFI, as dec)(purity, as dec)
(MGD)(8.34 lbs/gal)

= (5 lbs)(.452)(.98)
(0.2 MGD)(8.34 lbs/gal)

= 1.33 mg/L

12

Dosages

- A water plant uses 284 lbs of fluorosilicic acid to treat 6.2 MGD. What is the concentration of fluoride in the water in mg/L?

mg/L = (fluoride fed, lbs)(AFI, as dec)(purity, as dec)
(MGD)(8.34 lbs/gal)

= (284 lbs)(.792)(.23)
(6.2 MGD)(8.34 lbs/gal)

= 1.0 mg/L

13

Saturator Dosages

- A water plant uses 9 gallons of sodium fluoride from a saturator to treat 200,000 gpd. There is 0.18 mg/L fluoride in the raw water. What is the total concentration of fluoride in mg/L?

mg/L = (solution fed, gal)(18,000)
(gpd)

= (9 gal)(18,000)
(200,000)

= 0.81 mg/L

0.81 mg/L + 0.18 mg/L = **0.99 mg/L**

•you can only use NaF in saturators because it has a constant saturation point 14

Fluoridation

1. A water plant produces 1,750 gpm and the town wants to have a 0.8 mg/L of fluoride in the finished water. If fluorosilicic acid is used, what would be the fluoride feed rate in lb/day?

2. A water plant produces 275,000 gpd. What would be the fluoride feed rate from a saturator in gpd to obtain 0.7 mg/L in the water?

3. A plant uses 90 lb of sodium fluorosilicate in treating 9.6 MGD. What is the calculated dosage in mg/L?

4. The fluoride for a plant's raw water source was measured to be 0.2 mg/L. If the city wants the finished water to contain the recommended amount of 0.7 mg/L, what mg/L of fluoride should the water plant dose?

Applied Math for Water Fluoride

Feed Rates

1.a. A water plant produces 2,000 gpm, and the city wants to have 1.1 mg/L of fluoride in the finished water. If sodium fluorosilicate were used, what would the fluoride feed rate be in lbs/day?

1.b. Give that there are 453.6 grams in a pound, what would the fluoride feed rate for the previous problem be in gram/min?

2. A water plant has a daily average production of 695 gpm, and the city wants to have a 1.0 mg/L fluoride in the finished water. The natural fluoride level is less than 0.1 mg/L. Find the fluoride feed rate in lbs/day using sodium fluorosilicate.

3. If it is known that the plant rate is 4,000 gpm and the dosage needed is 0.8 mg/L, what is the fluoride feed rate in lbs/min using fluorosilicic acid?

4. What is the fluoride feed rate in lbs/day using fluorosilicic acid if the plant rate is 1.0 MGD, the natural fluoride content is 0.2 mg/L, and the desired fluoride content is 1.2 mg/L?

5. If a small water plant wishes to use sodium fluorosilicate in a dry feeder and the water plant has a flow of 180 gpm, what would the fluoride feed rate be in lbs/min? Assume 0.1 mg/L natural fluoride and 1.0 mg/L is the desired concentration in the finished water.

Sodium Fluoride Feed Rates for Saturator

6. A water plant produces 1.0 MGD. What would the fluoride feed rate be from a saturator in gpd to obtain 1.0 mg/L in the water?

7. A small water plant has a daily production rate of 180 gpm and the natural fluoride level is 0.1 mg/L. If 1.0 mg/L fluoride is desired in the water, what feed rate in mL/min of sodium fluoride from a saturator must be maintained?

Calculated Dosages

8. A plant uses 65 lbs of sodium fluorosilicate in treating 5,540,000 gallons of water in one day. What is the calculated dosage in mg/L?

9. A plant uses 26 lbs of sodium fluorosilicate to treat 1,756,000 gallons of water. What is the calculated dosage for this plant in mg/L?

10. A water plant has an actual production rate of 0.8 MGD. If 10 lbs of sodium fluorosilicate was fed in one day, what is the calculated dosage in mg/L?

11. A plant uses 43 lbs of fluorosilicic acid in treating 1,226,000 gallons of water. What is the calculated dosage in mg/L?

12. A plant uses 898 lbs of fluorosilicic acid in treatment of 17,058,000 gallons of water. What is the calculated dosage in mg/L?

13. A water plant uses a total of 2,800 lbs of fluorosilicic acid at 28% purity during 4 days to fluoridate 52 million gallons of water. What would be the calculated dosage in mg/L?

14. A water plant feeds sodium fluoride in a dry feeder. They use 5.5 lbs of the chemical to fluoridate 240,000 gallons of water. What is the calculated dosage in mg/L?

15. A plant uses 10 gallons of sodium fluoride from a saturator in treating 200,000 gallons of water. What is the calculated dosage in mg/L?

16. A plant uses 19 gallons of solution from its saturator in treating 360,000 gallons of water. What is the calculated dosage in mg/L?

17. A small water plant uses sodium fluoride from a saturator at a rate of 1.0 gpd and the plant treats 4500 gpd. What is the calculated dosage in mg/L?

Answers:

1.a. 44.19 lbs/day
1.b. 13.9 grams/min
2. 13.96 lbs/day
3. 0.15 lbs/min
4. 45.78 lbs/day
5. 0.002 lbs/min
6. 55.56 gpd
7. 34.07 mL/min
8. 0.84 mg/L
9. 1.06 mg/L
10. 0.90 mg/L
11. 0.77 mg/L
12. 1.15 mg/L
13. 1.43mg/L
14. 1.22 mg/L
15. 0.9 mg/L
16. 0.95 mg/L
17. 4.0 mg/L

Applied Math for Water

Fluoride Practice Quiz

1. A water plant has a daily average production of 1,736 gpm and the city wants to have a 1.0 mg/L fluoride level in the finished water. How many lbs/day of sodium fluorosilicate would be required to reach this dosage?

2. What is the fluoride feed rate in lbs/day using fluorosilic acid if the plant rate is 1.0 MGD, the natural fluoride level is 0.3 mg/L, and the desired fluoride level is 1.2 mg/L?

3. A small water plant wishes to use sodium fluoride in a dry feeder and the water plant has a capacity (flow) of 220 gpm, what would the fluoride feed rate be in grams/min? Assume a 0.1 mg/L natural fluoride and 1.0 mg/L is desired in the drinking water.

4. A plant uses 69 lbs of sodium fluorosilicate in treating 4,950,000 gallons of water in one day. What is the calculated dosage in mg/L?

5. A water plant produces 0.75 MGD. What would the fluoride feed rate from a sodium fluoride saturator be, in gph, to obtain 1.0 mg/L in the water?

Answers:
1. 34.9 lbs/day
2. 41.2 lbs/day
3. 1.7 grams/min
4. 1.0 mg/L
5. 1.7 gph

Section 9

Stabilization

Langelier Index &
Aggressive Index

STABILIZATION MATH

Langelier Index

- Calculate the Langelier Index using the following lab results:
  - pH = 7.4
  - Temperature = 20°C
  - TDS = 200 mg/L
  - Total Alkalinity = 120 mg/L as $CaCO_3$
  - Ca Hardness = 90 mg/L as $CaCO_3$

Langelier Index

- Langelier Index = pH – pH_s
- pH_s = A + B – log Ca Hardness – log Total Alk
  - Where A = Temperature
  - Where B = TDS

Langelier Index

Values of "A" for various Temperatures, °C	
Temperature, °C	A
0	2.34
5	2.27
10	2.2
15	2.12
20	2.04
25	1.98
30	1.91
40	1.76
50	1.62
60	1.47

Values for "B" for various levels of	
TDS, mg/L	B
0	9.63
50	9.72
100	9.75
200	9.8
400	9.86
800	9.94
1,600	10.04

Langelier Index

Values of log of Ca or Alkalinity as $CaCO_3$ in mg/L	
mg/L	log_{10}
10	1.00
20	1.30
30	1.48
40	1.60
50	1.70
60	1.78
70	1.84
80	1.90
90	1.95
100	2.00
200	2.30
300	2.48
400	2.60
500	2.70
600	2.78
700	2.84
800	2.90
900	2.95
1,000	3.00

Langelier Index

- There isn't a 120 in the chart for Total Alkalinity ☹
- Use your calculator
  - Take the log of 120
  - Equals 2.07918…
  - Round up to 2.08

Langelier Index

- Langelier Index = pH – pH_s
- pH_s = A + B – log Ca Hardness – log Total Alk
  = 2.04 + 9.80 – 1.95 – 2.08
  = 7.81
- Langelier Index = 7.4 – 7.81
  = -0.41

Langelier Index

- Now determine how aggressive your water is

Corrosivity Characteristics as Addressed by Indices		
Corrosive Characteristics	Langelier Index (LI)	Aggressive Index (AI)
Highly Aggressive	< - 2.0	< 10.0
Moderately Aggressive	- 2.0 to < 0.0	10.0 to < 12.0
Non-aggressive	> 0.0	> 12.0

Aggressive Index

- Calculate the Aggressive Index using the following lab results:
  - pH = 7.8
  - Total Alkalinity = 100 mg/L as $CaCO_3$
  - Ca Hardness = 200 mg/L as $CaCO_3$
- AI = pH + log Ca Hard + log Total Alk

Aggressive Index

Values of log of Ca or Alkalinity as $CaCO_3$ in mg/L	
mg/L	log_{10}
10	1.00
20	1.30
30	1.48
40	1.60
50	1.70
60	1.78
70	1.84
80	1.90
90	1.95
100	2.00
200	2.30
300	2.48
400	2.60
500	2.70
600	2.78
700	2.84
800	2.90
900	2.95
1,000	3.00

Aggressive Index

- AI = pH + log Ca Hard + log Total Alk
  = 7.8 + 2.00 + 2.30
  = 12.10

Aggressive Index

- Now determine how aggressive your water is

Corrosivity Characteristics as Addressed by Indices		
Corrosive Characteristics	Langelier Index (LI)	Aggressive Index (AI)
Highly Aggressive	< - 2.0	< 10.0
Moderately Aggressive	- 2.0 to < 0.0	10.0 to < 12.0
Non-aggressive	> 0.0	> 12.0

Stabilization

1. Calculate the Langlier Index for a water sample based on the following information:

pH	=	7.8
temperature	=	20°C
TDS	=	100 mg/L
calcium	=	90 mg/L as $CaCO_3$
alkalinity	=	170 mg/L as $CaCO_3$

2. Calculate the Aggressive Index for a water sample based on the following information:

total alkalinity	=	100 mg/L as $CaCO_3$
calcium	=	65 mg/L as $CaCO_3$
pH	=	7.2

Applied Math for Water

Stabilization Math

Langelier Index – Determine the LI and the corrosive characteristics:

1. Calculate the Langelier Index for the following information:
   - pH = 7.65
   - temperature = 15°C
   - TDS = 200 mg/L
   - Calcium = 80 mg/L as $CaCO_3$
   - Alkalinity = 100 mg/L as $CaCO_3$

2. Calculate the Langelier Index for the following information:
   - pH = 7.4
   - temperature = 20°C
   - TDS = 200 mg/L
   - Calcium = 80 mg/L as $CaCO_3$
   - Alkalinity = 100 mg/L as $CaCO_3$

3. Calculate the Langelier Index for the following information:
   - pH = 7.4
   - temperature = 20°C
   - TDS = 400 mg/L
   - Calcium = 100 mg/L as $CaCO_3$
   - Alkalinity = 100 mg/L as $CaCO_3$

4. Calculate the Langelier Index for the following information:

pH	=	7.0
temperature	=	15°C
TDS	=	200 mg/L
Calcium	=	10 mg/L as $CaCO_3$
Alkalinity	=	10 mg/L as $CaCO_3$

5. Calculate the Langelier Index for the following information:

pH	=	7.6
temperature	=	25°C
TDS	=	400 mg/L
Calcium	=	150 mg/L as $CaCO_3$
Alkalinity	=	170 mg/L as $CaCO_3$

6. Calculate the Langelier Index for the following information:

pH	=	8.6
temperature	=	15°C
TDS	=	200 mg/L
Calcium	=	50 mg/L as $CaCO_3$
Alkalinity	=	100 mg/L as $CaCO_3$

Aggressive Index – Determine the AI and the corrosive characteristics:

7. Calculate the aggressive index for the following information:
   Total alkalinity = 100 mg/L as $CaCO_3$
   Calcium = 70 mg/L as $CaCO_3$
   pH = 7.6

8. Calculate the aggressive index for the following information:
   Total alkalinity = 270 mg/L as $CaCO_3$
   Calcium = 200 mg/L as $CaCO_3$
   pH = 7.3

9. Calculate the aggressive index for the following information:
   Total alkalinity = 100 mg/L as $CaCO_3$
   Calcium = 50 mg/L as $CaCO_3$
   pH = 7.2

10. Calculate the aggressive index for the following information:
    Total alkalinity = 100 mg/L as $CaCO_3$
    Calcium = 70 mg/L as $CaCO_3$
    pH = 7.2

11. Calculate the aggressive index for the following information:

Total alkalinity	=	100 mg/L as $CaCO_3$
Calcium	=	80 mg/L as $CaCO_3$
pH	=	7.1

12. Calculate the aggressive index for the following information:

Total alkalinity	=	20 mg/L as $CaCO_3$
Calcium	=	15 mg/L as $CaCO_3$
pH	=	7.0

Answers:

1. – 0.37 MA
2. – 0.55 MA
3. – 0.51 MA
4. – 2.92 HA
5. 0.17 NA
6. 0.38 NA
7. 11.45 MA
8. 12.03 NA
9. 10.9 MA
10. 11.05 MA
11. 11.0 MA
12. 9.48 HA

Section 10

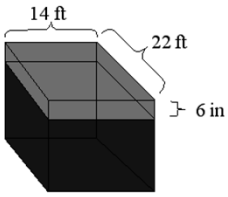
Filtration

Filter Math

TDEC - Fleming Training Center 1

Filter Rate (Hook Gauge)

- A filter measures 22 ft by 14 ft. The influent is closed and the effluent is opened. The water level drops 6 inches in 120 sec, 124 sec and 128 sec during three tests. What is the filter rate in gpm?



TDEC - Fleming Training Center 2

Filter Rate Steps (Hook Gauge)

- Find volume in gallons
- Find average time in minutes
- Find sand bed area in ft^2

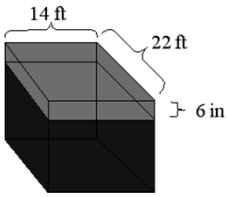
TDEC - Fleming Training Center 3

Volume, gal

$V=(l, ft)(w, ft)(d, ft)(7.48\ gal/ft^3)$

$V=(22\ ft)(14\ ft)(0.5\ ft)(7.48\ gal/ft^3)$

$V= 1151.9\ gal$



TDEC - Fleming Training Center 4

Average Time, min

120 sec, 124 sec and 128 sec

$$\text{Avg time, min} = \frac{\text{sec}_1 + \text{sec}_2 + \text{sec}_3}{(3)(60\ \text{sec/min})}$$

$$\text{Avg Time, min} = \frac{120+124+128}{(3)(60\ \text{sec/min})}$$

Avg Time, min = 2.0667 min

Sand Bed Area

A filter measures 22 ft by 14 ft.

Sand Area, ft^2 = (length, ft)(width, ft)

Sand Area, ft^2 = (22 ft)(14 ft)

Sand Area, ft^2 = 308 ft^2

Filter Rate, gpm (Hook Gauge)

$$\text{Filter rate, gpm (Hook Gauge)} = \frac{\text{volume, gal}}{\text{average time, min}}$$

$$\text{Filter rate, gpm} = \frac{1151.9\ \text{gal}}{2.0667\ \text{min}}$$

Filter rate, gpm = 557.4 gpm

Filter Rate, gpm/ft^2

$$\text{Filter rate gpm/ft}^2 = \frac{\text{filter rate, gpm}}{\text{sand area, ft}^2}$$

$$\text{Filter rate, gpm/ft}^2 = \frac{557.4\ \text{gpm}}{308\ \text{ft}^2}$$

Filter rate, gpm/ft^2 = 1.8 gpm/ft^2

Backwash Volume

- A filter sand area measures 32 ft by 20 ft. Assuming a backwash rate of 20 gpm/ft^2 and a backwash time of 10 minutes, how many gallons of backwash water are required?

Backwash, gal. = (rate, gpm/ft^2)(time, min)(area, ft^2)

= (20 gpm/ft^2)(10 min)(32 ft)(20 ft)

= 128,000 gal

TDEC - Fleming Training Center 9

Filter Efficiency

- During a filter run of 95 hours, a total of 3.78 MG was filtered. If 35,000 gallons were used to backwash, calculate the % of the filtered water used for backwashing.

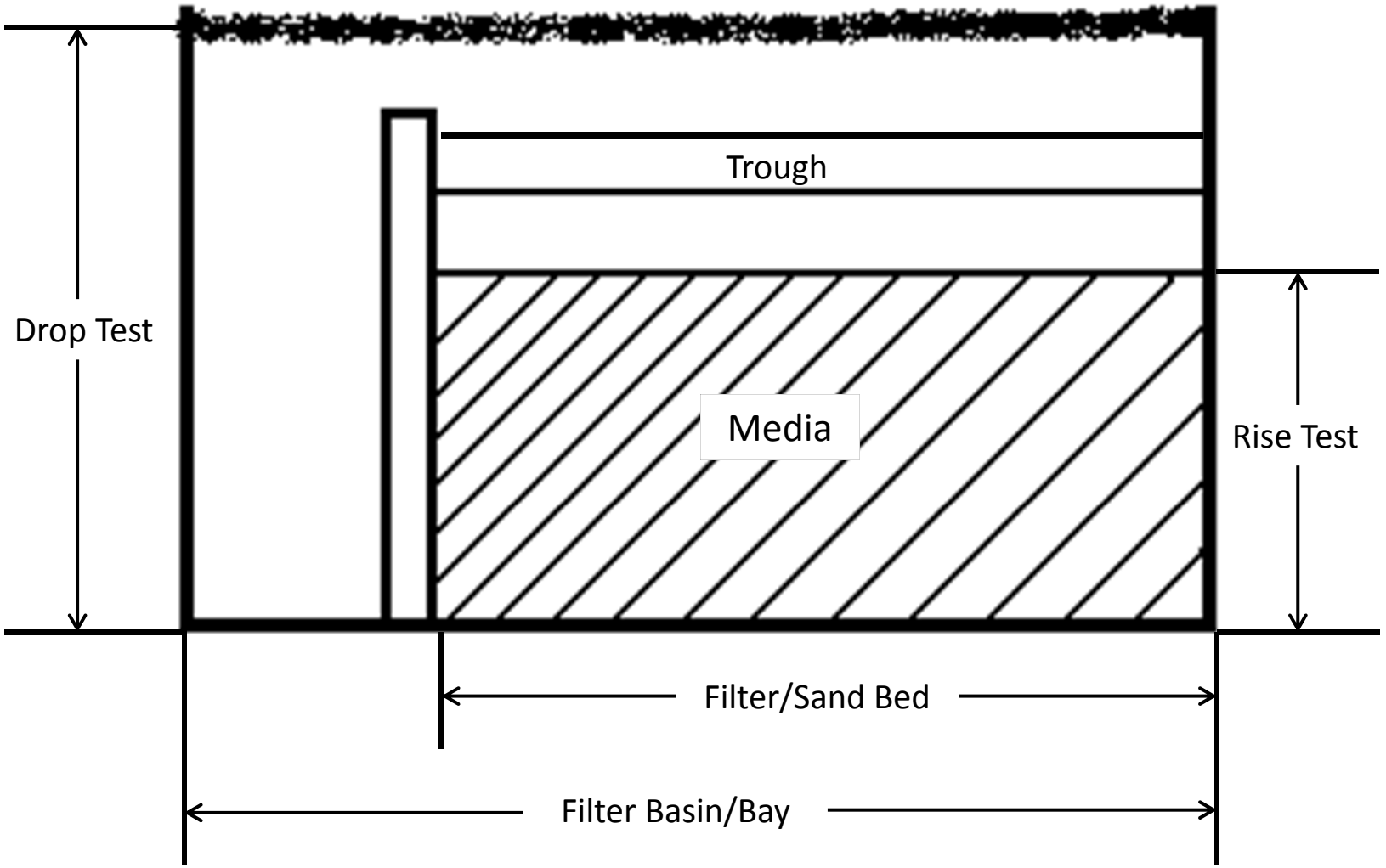
$$\% \text{ water used} = \frac{(\text{water used, gal})(100)}{\text{water produced, gal}}$$

$$= \frac{(35{,}000 \text{ gal})(100)}{3{,}780{,}000 \text{ gal}}$$

= 0.9 %

TDEC - Fleming Training Center 10

Drop Tests and Rise Tests



Filtration

1. The Cartersville WTP treats and average of 2.97 MGD. The water is split equally to each of 6 filters. Each filter basin measures 10 feet wide by 20 feet long and 22 feet deep. Each filter bed measures 8 ft by 17 ft by 15 ft deep.

a. Determine the daily flow to each of the filters in gallons per minute.

b. The influent line to filter 5 is closed while the effluent remains open. Using a hook gauge and a stop watch, it is noted that the water level in the filter drops 6 inches in 70 seconds. What is the filtration rate in gallons per minute?

c. What is the filtration rate in gallon per minute per filter per square foot of surface area?

d. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 20 seconds. What is the backwash rate in gallons per minute?

e. Calculate the filter backwash rate in gallons per minute per square foot.

f. Calculate the gallons of water used to backwash the filter if it was backwashed for 15 minutes.

g. During a filter run of 75 hours, the total volume of water filtered was 2.8 million gallons. Calculate the percent of the product water used for backwashing.

APPLIED MATH FOR WATER
FILTER MATH

BASICS

1. A filter basin and its sand bed measure 28 feet by 16 feet. Calculate its sand bed area in ft^2.

2. The same filter basin that measures 28 feet by 16 feet has the water drop 6 inches, what was volume in gallons of the drop test?

3. The filter drop test was timed. The test times were 68 seconds, 72 seconds and 71 seconds. What was the average time in minutes?

4. A filter measures 28 feet by 20 feet. The influent is closed and the effluent is opened and the water drops 6 inches in 2 minutes. What is the filter rate in gallons per minute?

5. A filter measures 28 feet by 20 feet. The influent is closed and the effluent is opened and the water drains down 6" in 2 minutes. What is the filter loading rate in gallons per minute per square foot?

6. A filter measures 26 feet by 15 feet. The influent line is shut and the water drops 2.6 inches per minute. Calculate the rate of filtration in MGD.

7. A filter measures 26 feet by 15 feet and has a filter media depth of 36 inches. Assuming a backwash rate of 15 gpm/ft^2 and 11 minutes of backwash required, how many gallons of water are required for each backwash?

8. The filter in Problem #7 filtered 13.95 MG during the last filter run. Based on the gallons produced and the gallons required to backwash the filter, calculate the percent of the product water used for backwashing.

USE THE FOLLOWING INFORMATION FOR PROBLEMS 9a – g.

9. The Randyville Water Plant treats an average of 5.18 MGD. The water is split equally to each of the 8 filters. Each filter basin measures 12 feet wide by 16 feet long and by 24 feet deep. Each filter bed measures 12 feet by 14 feet by 11 feet deep.

   a. Determine the daily flow to each of the filters in gallons per minute.

   b. The influent line to Filter 6 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 7 inches in 80 seconds. What is the filtration rate in gallons per minute?

   c. What is the filtration rate in gallons per minute per filter per square foot of surface area?

   d. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 7 inches in 15 seconds. What is the backwash rate in gallons per minute?

e. Calculate the filter backwash rate in gallons per minute per square foot.

f. Calculate the gallons of water used to backwash the filter if it was backwashed for 15 minutes.

g. During a filter run of 95 hours the total volume of water filtered was 3.80 million gallons. Calculate the percent of the product water used for backwashing.

USE THE FOLLOWING INFORMATION FOR PROBLEMS 10a – g.

10. The Chrisburg Water Plant treats an average of 7.2 MGD. The water is split equally to each of 8 filters. Each filter basin measures 12.5 feet wide by 16.5 feet long by 24 feet deep. Each filter bed measures 12.5 feet by 14 feet by 10 feet deep.

    a. Determine the daily flow to each of the filters.

b. The influent line to Filter 6 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 6 inches in 69 seconds on test 1, 6 inches in 67 seconds on test 2 and 6 inches in 70 seconds on test 3. What is the filtration rate in gallons per minute?

c. What is the filtration rate in gallons per minute per square foot of surface area?

d. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 13 seconds. What is the backwash rate in gallons per minute?

e. Calculate the filter backwash rate in gallons per minute per square foot.

f. Calculate the gallons of water used to backwash the filter if it was backwashed for 20 minutes.

g. During a filter run of 95 hours the total volume of water filtered was 3.74 million gallons. Calculate the percent of the product water used for backwashing.

11. Calculate the filtration rate in gpm/ft^2 for a filter with a sand area of 26 feet by 22 feet when the applied flow is 2.36 MGD.

12. Determine the filtration rate in gpm/ft^2 for a filter with a surface of 28 feet by 20 feet. With the influent valve closed, the water above the filter dropped 12 inches in 4 minutes.

13. A filter measures 26 feet by 15 feet. The influent line is shut and the water drops 2.6 inches per minute, calculate the rate of filtration in MGD.

14. The filter in Problem #13 has a filter media depth of 36 inches. Assuming a backwash rate of 15 gpm/ft^2 and 6 minutes of backwash, how many gallons of water is required for each backwash?

15. A filter plant has 6 filters, each measuring 20 feet X 15 feet. One filter is out of service. The other five filters are capable of filtering 500 GPM each. How many gallons per minute per square foot will each filter?

16. A filter is 30 feet X 20 feet. If, when the influent valve is closed, the water above the filter drops 3.7 inches per minute, what is the rate of filtration in MGD?

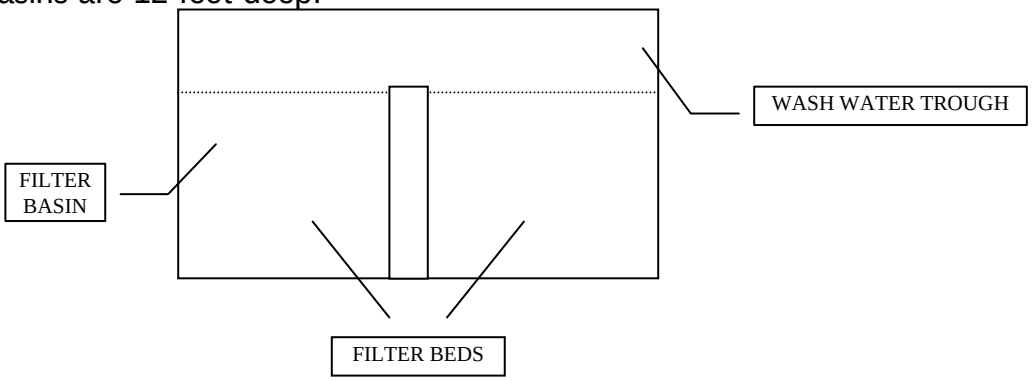
17. Determine the backwash pumping rate in gallons per minute for a filter 33 feet by 21 feet if the desired backwash rate is 17 GPM/ft^2.

18. Determine the volume of water in gallons required to backwash the filter in the previous problem if the filter is backwashed for 6 minutes.

19. During a filter run the total volume of water filtered was 14.65 million gallons. When the filter was backwashed, 72,560 gallons of water were used. Calculate the percent of the filtered water used for backwashing.

USE THE FOLLOWING INFORMATION FOR PROBLEMS 21a – 21g
(put your thinking cap on)

20. The Billyville Water Treatment Plant treats an average of 8.0 MGD. The water is split equally to each of four filters. Each filter basin measures 35 feet long by 19 feet wide and has a divider wall jutting out into the middle measuring 1 foot by 16 feet. Each filter basin contains two filter beds, each measuring 17 feet by 16 feet. The filter basins are 12 feet deep.



a. Determine the daily flow to each of the filters.

b. The influent line to Filter 1 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 6 inches in 93 seconds. What is the filtration rate in gallons per minute?

c. What is the filtration rate in gallons per minute per square foot of surface area?

d. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 19.5 seconds. What is the backwash rate in gallons per minute?

e. Calculate the filter backwash rate in gallons per minute per square foot.

f. Calculate the gallons of water used to backwash the filter if it was backwashed for 11 minutes.

g. During a filter run of 117 hours the total volume of water filtered was 8.78 million gallons. Calculate the percent of the product water used for backwashing.

Answers:

1. 448 ft^2
2. 1675.5 gal
3. 1.17 min
4. 1047.2 gpm
5. 1.87 gpm/ft^2
6. 0.91 MGD
7. 64,350 gallons
8. 0.46%
9. a. 450 gpm/filter
   b. 628 gpm
   c. 3.74 gpm/ft^2
   d. 2932 gpm
   e. 17.5 gpm/ft^2
   f. 43,980 gallons
   g. 1.2%
10. a. 0.9 MGD/filter
    b. 674 gpm
    c. 3.85 gpm/ft^2
    d. 3,020 gpm
    e. 17.3 gpm/ft^2
    f. 60,400 gallons
    g. 1.6%
11. 2.87 gpm/ft^2
12. 1.87 gpm/ft^2
13. 0.91 MGD
14. 35,100 gallons
15. 1.67 gpm/ft^2
16. 2.0 MGD
17. 11,781 gpm
18. 70,686 gallons
19. 0.5%
20. a. 2.0 MGD/filter
    b. 1565.97 gpm
    c. 2.9 gpm/ft^2
    d. 6260 gpm
    e. 11.5 gpm/ft^2
    f. 68,860 gal
    g. 0.78%

Section 11

Coagulation / Flocculation

Coagulation and Flocculation

Calculating dosages, conversions and feeder settings

Calculating Pounds/ Day

- A water plant treats 5.8 MGD. If the alum dose is 19 mg/L, how many pounds per day of alum will the operator feed?

lbs = (dose,mg/L)(volume,MG)(8.34 lb/gal)

= (19 mg/L)(5.8 MG)(8.34 lb/gal)

= 919 lbs/ day alum

One Step Further

- The average flow for a water plant is 12 MGD. Jar tests indicate that the best alum dose is 26 mg/L. What would be the setting in grams per minute?

$$\text{gram/min} = \frac{(\text{dose, mg/L})(\text{flow, gpd})(3.785\ \text{L/gal})}{(1440\ \text{min/day})(1000\ \text{mg/gram})}$$

$$= \frac{(26\ \text{mg/L})(12{,}000{,}000\ \text{gpd})(3.785\ \text{L/gal})}{(1440\ \text{min/day})(1000\ \text{mg/gram})}$$

= 820 grams/min

Dosage

- A water plant used 12 lbs of polymer to treat 0.5 MGD. What is the dosage in mg/L?

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

$$= \frac{12\ \text{lbs/day}}{(0.5\ \text{MGD})(8.34\ \text{lb/gal})}$$

= 2.9 mg/L

Dilutions

- Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of this would it take to make 55 gallons of a 1% solution?

$$(\text{Conc.}_1)(\text{Vol.}_1) = (\text{Conc.}_2)(\text{Vol.}_2)$$

$$(.08)(X\ \text{gal}) = (.01)(55\ \text{gal})$$

$$X\ \text{gal} = \frac{(.01)(55\ \text{gal})}{.08}$$

= 6.9 gal

Liquid Feeder Setting

- An operator wants to feed 11 mg/L of alum for a flow of 1.2 MGD. The alum contains 643 mg of dry chemical per milliliter of liquid. What would be the setting on the liquid alum feeder in mL/min?

$$\text{mL/min} = \frac{(\text{dose, mg/L})(\text{flow, gpd})(3.785\ \text{L/gal})}{(\text{chem. conc., mg/mL})(1440\ \text{min/day})}$$

$$= \frac{(11\ \text{mg/L})(1{,}200{,}000\ \text{gpd})(3.785\ \text{L/gal})}{(643\ \text{mg/mL})(1440\ \text{min/day})}$$

= 54 mL/min

Liquid Feeder Setting

- A water plant treats 10 MGD with 25 mg/L liquid alum. How many gallons per day will be used? The alum contains 5.35 lbs dry alum per gallon.

gpd = $\frac{\text{(chem. dose, mg/L)(flow, MGD)(8.34lbs/gal)}}{\text{chem. conc., lbs/gal}}$

= $\frac{\text{(25 mg/L)(10 MGD)(8.34lbs/gal)}}{\text{5.35 lbs/gal}}$

= 390 gal/day

Ferric Chloride

- A plant has just switched from alum to ferric chloride. Jar tests indicate that 9.3 mg/L should be fed to treat 5.0 MGD. How many mL/min should be fed if each mL of solution contains 594 mg dry chemical?

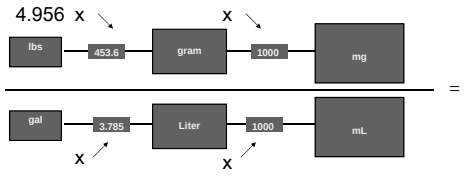
mL/min = $\frac{\text{(dose, mg/L)(flow, gpd)(3.785 L/gal)}}{\text{(chem. conc., mg/mL)(1440 min/day)}}$

= $\frac{\text{(9.3 mg/L)(5,000,000 gpd)(3.785 L/gal)}}{\text{(594mg/mL)(1440 min/day)}}$

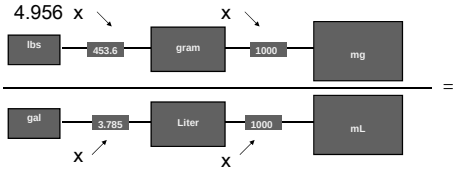
= 206 mL/min

lb/gal to mg/mL Conversion

- Ferric chloride contains 4.956 lbs dry chemical per gallon of liquid solution, how many mg/mL is this?



lb/gal to mg/mL Conversion



$\frac{(4.956)(453.8)(1000)}{(3.785)(1000)} = \frac{2,248,041.6}{3785}$ = 593.9 mg/mL

Coagulation/Flocculation

1. The average flow for a water plant is 5.2 MGD. A jar test indicates that the best alum dosage is 3.5 mg/L. How many pounds per day will the operator feed?

2. The average flow for a water plant 1,200,000 gallons per day. A jar test indicates that the best alum dosage is 1.8 mg/L. How many grams per minute should the feeder deliver?

3. A plant used 39 pounds of alum treating 3.7 MGD. Calculate the dose in mg/L.

4. Liquid polymer is supplied to a water treatment plant as a 9% solution. How many gallons of this liquid is required to make 150 gallons of 1.5% polymer solution?

5. Liquid alum delivered to a water treatment plant contains 795.4 milligrams of alum per milliliter of liquid solution. Jar test indicate that the best alum dose is 5 mg/L. Determine the setting on the liquid alum feeder in milliliters per minute if the flow is 2.8 MGD.

6. An operator has decided to switch from dry alum to liquid alum. If he feeds an average of 150 lbs of dry alum a day, how many gallons of liquid alum will he need to feed on average given the following information?

Alum, liquid: 49% concentration
10.7 lbs/gallon
5.4 lbs dry alum/gallon
1.335 specific gravity

APPLIED MATH FOR WATER
COAGULATION & FLOCCULATION

1. The average flow for a water plant is 3.25 MGD. A jar test indicates that the best alum dosage is 2.5 mg/L. How many pounds per day will the operator feed?

2. The average flow for a water plant is 13.5 MGD. The jar test indicates that the best alum dose is 1.8 mg/L. How many pounds per day will the operator feed?

3. Determine the setting on a dry alum feeder in pounds per day when the flow is 1.3 MGD. Jar tests indicate that the best alum dose is 12 mg/L.

4. The average flow for a water plant is 8.3 MGD. A jar test indicates that the best alum dosage is 2.2 mg/L. How many grams per minute should the feeder deliver?

5. The average daily flow for a water plant is 0.75 MGD. If the polymer dosage is kept at 1.8 mg/L, how many pounds of polymer will be used in 30 days?

6. The average flow for a water plant is 8,890 gpm. A jar test indicates that the best polymer dose is 3.1 mg/L. How many pounds will the plant feed in one week? (Assume the plant runs 24 hour/day, 7 days/week.)

7. A water treatment plant used 27 pounds of cationic polymer to treat 1.6 million gallons of water during a 24-hour period. What is the polymer dosage in mg/L?

8. A water plant fed 130 lbs of alum treating 1.3 MGD. Calculate the dose in mg/L.

9. A water plant fed 52 grams per minute of dry alum while treating 2.6 MGD. Calculate the mg/L dose.

10. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of this liquid polymer should be used to make 200 gallons of a 0.7% polymer solution?

11. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of this liquid polymer should be used to make 5 gallons of a 5% polymer solution?

12. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of liquid polymer should be used to make 55 gallons of a 0.5% polymer solution?

13. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of alum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 8 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute if the flow is 2.2 MGD.

14. You collect three 2-minute samples from an Alum dry feeder. What is the feed rate in mg/L when the flow rate is 2 MGD?

Sample 1 = 25 grams
Sample 2 = 22 grams
Sample 3 = 24 grams

15. A water plant is treating 8.2 MGD with 2.0 mg/L liquid alum. How many gpd of liquid alum will be required? The liquid alum contains 5.36 lbs dry alum/gallon.

16. A jar test indicates the 3.4 mg/L of liquid alum is required in treating 7.6 MGD. How many mL/min should the metering pump deliver? The liquid alum delivered to the plant contains 645 mg alum per mL of liquid solution.

17. A jar test indicates that 1.8 mg/L of liquid ferric chloride should be fed to treat 2,778 gpm of water. How many mL/min should be fed by a metering pump? Ferric chloride contains 4.59 lbs dry chemical per gallon of liquid solution.

18. An operator has decided to switch from dry alum to liquid alum. If he feeds an average of 100 lbs of dry alum a day, how many gallons of liquid alum will he need to feed on average given the following information:

Alum, liquid: 48.5% concentration
11.13 lbs/gallon
5.40 lbs dry alum/gallon
1.335 Specific Gravity

19. If an operator wants to switch from dry ferric chloride to liquid ferric chloride, how many gallons per day would he have to feed if he normally feeds 200 lbs of dry ferric daily? Plant flow rate is 4 MGD. What would be the feed rate in milliliters per minute?

Ferric Chloride: 39% concentration
11.76 lbs/gallon
4.59 dry lbs of $FeCl_2$/gallon
1.41 Specific Gravity

20. Based on the information provided below calculate the milligrams of alum per milliliter of solution. If jar test results indicate that the best dosage is 25 mg/L, what is the feed rate in mL/min? The plant flow rate is 6 MGD.

Alum, liquid 48.5% concentration
11.13 lbs/gallon
5.40 lbs dry alum/gallon
1.335 Specific Gravity

21. Based on the information provided below calculate the milligrams of ferric chloride per milliliter of solution. If jar test results indicate that the best dosage is 7 mg/L, what is the feed rate in mL/min? The plant flow rate is 6 MGD.

Ferric Chloride: 39% concentration
11.76 lbs/gallon
4.59 dry lbs of $FeCl_2$/gallon
1.41 Specific Gravity

ANSWERS:

1.	67.8 lbs/day	9.	7.6 mg/L	17.	34.4 mL/min
2.	202.7 lbs/day	10.	17.5 gallons	18.	18.5 gallons
3.	130 lbs/day	11.	3.1 gal	19.	43.6 gal/day
4.	48 grams/min	12.	3.4 gal		114.5 mL/min
5.	337.8 lbs	13.	72 mL/min	20.	647.14 mg/mL
6.	2,316.5 lbs	14.	2.25 mg/L		609.3 mL/min
7.	2 mg/L	15.	25.5 gal/day	21.	550.07 mg/mL
8.	12 mg/L	16.	105.3 mL/min		200.7 mL/min

APPLIED MATH FOR WATER
COAGULATION & FLOCCULATION PRACTICE QUIZ

1. The average flow for a water plant is 6.3 MGD. A jar test indicates that the best alum dosage is 19 mg/L. How many pounds per day will the operator feed?

2. Determine the setting on a dry alum feeder when the flow is 5.4 MGD. Jar tests indicate that the best alum dose is 8 mg/L. What would be the setting in grams per minute?

3. The average daily flow for a water plant is 7.5 MGD. Jar test results indicate the best polymer dosage is 1.8 mg/L. How many pounds of polymer will be used in 90 days?

4. A water treatment plant used 14 pounds of cationic polymer to treat 2.0 million gallons of water during a 24-hour period. What is the polymer dosage in mg/L?

5. A water plant fed 48.5 grams per minute while treating 2.2 MGD. Calculate the mg/L dose.

6. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of liquid polymer should be used to make 200 gallons of a 1.0% polymer solution?

7. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of alum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 15 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the flow is 7.2 MGD. There are 3.785 liters in one gallon.

8. A water plant is treating 1.8 MGD with 2.0 mg/L liquid alum. How many gpd of liquid alum will be required? The liquid alum contains 5.36 lbs dry alum/gallon.

9. A jar test indicates the 4.3 mg/L of liquid alum is required in treating 6.7 MGD. How many mL/min should the metering pump deliver? The liquid alum delivered to the plant contains 645 mg alum per mL of liquid solution.

10. An operator has decided to switch from dry alum to liquid alum. If he feeds 114 lbs of dry alum on average a day, how many gallons of liquid alum will he need to feed on average given the following information:

Alum, liquid	48.5% concentration
	11.13 lbs/gallon
	5.40 lbs dry alum/gallon
	1.335 Specific Gravity

11. Based on the information provided below calculate the milligrams of ferric chloride per milliliter of solution. If jar test results indicate that the best dosage is 21 mg/L, what is the feed rate in mL/min? The plant flow rate is 7.5 MGD.

Ferric Chloride	39% concentration
	11.76 lbs/gallon
	4.59 dry lbs/gallon
	1.41 Specific Gravity

ANSWERS:

1. 998.3 lbs/day
2. 113.5 grams/min
3. 10,133.1 lbs
4. 0.84 mg/L
5. 8.39 mg/L
6. 25 gal
7. 442 mL/min
8. 5.6 gpd
9. 117.4 mL/min
10. 21.1 gpd
11. 550.07 mg/mL; 752.6 mL/min

Section 12

Feeders

Feeder Math

1 TDEC - Fleming Training Center

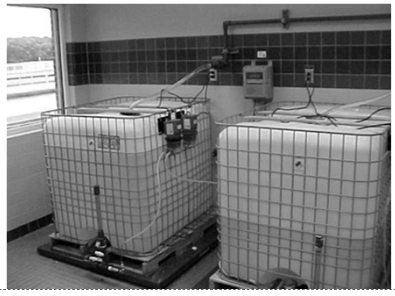
$KMnO_4$ Feeder System

- Take one minute sample and weigh grams:
  - convert to pounds per day = $\frac{(\text{grams/min weighed})(1440 \text{ min/day})}{454 \text{ grams/pound}}$ = lbs/day

2 TDEC - Fleming Training Center

Phosphate Feeder Room

- gallons per day = $\frac{(\text{mL/min})(1440 \text{ min/day})}{3785 \text{ mL/gallon}}$



Calibration Tubes

3 TDEC - Fleming Training Center

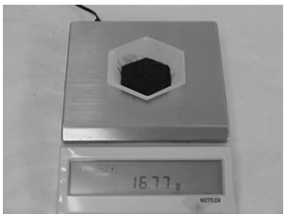
Calibrating mL's per Minute

- Minimum once per shift
- Don't forget to put valves back in correct position!

4 TDEC - Fleming Training Center

Dry Feeder Calibration

- If a dry feeder delivers 96 grams of chemical in 3 minutes, how many grams per minute does it deliver?
- $\frac{96 \text{ grams}}{3 \text{ min}} = 32 \text{ grams/min}$



Good idea to have top loading balance on hand

5 TDEC - Fleming Training Center

Dry Feeder Calibration

- To check the feed rate of a dry feeder, an operator collects 4 samples. Each sample is collected for 1 minute. What is the average feed rate?

Sample 1 : 17.6 grams Sample 3 : 17.5 grams

Sample 2 : 17.1 grams Sample 4 : 17.8 grams

$$\text{Average} = \frac{17.6 \text{ g} + 17.1 \text{ g} + 17.5 \text{ g} + 17.8 \text{ g}}{4}$$

$$\text{Average} = \frac{70 \text{ g}}{4} = 17.5 \text{ g}$$

6 TDEC - Fleming Training Center

Liquid Feeder Calibration

- A chemical feeder delivers 620 milliliters of liquid alum in 3 minutes. What is the average feed rate in mL/min?

$$\frac{\textbf{620 mL}}{\textbf{3 min}} = \textbf{206.7 mL/min}$$

7 TDEC - Fleming Training Center

Converting Feed Rate to Total Usage

Box Method

- When converting from one unit to another you must know:
  - Conversion factor
  - Whether to multiply or divide

TDEC - Fleming Training Center 8

Conversions

- Convert 32.5 grams per minute to pounds per hour.

$$\frac{32.5 \text{ grams}}{\text{min}} \times \frac{1 \text{ lb}}{454 \text{ grams}} \times \frac{60 \text{ min}}{1 \text{ hour}} = 4.3 \text{ lb/hr}$$

9 TDEC - Fleming Training Center

Conversions

- Convert 206.7 mL/min to gallons per hour.

$$\frac{206.7 \text{ mL}}{\text{min}} \times \frac{1 \text{ gal}}{3785 \text{ mL}} \times \frac{60 \text{ min}}{1 \text{ hour}} = 3.3 \text{ gal/hr}$$

10 TDEC - Fleming Training Center

Conversions

- Convert 165 gallons per day to mL/min.

$$\frac{165 \text{ gal}}{\text{day}} \times \frac{3785 \text{ mL}}{1 \text{ gal}} \times \frac{1 \text{ day}}{1440 \text{ min}} = 433.7 \text{ mL/min}$$

11 TDEC - Fleming Training Center

Dosage

- What is the dosage if a plant uses 103.1 lbs. of chemical to treat 11.5 MG?

$$\textbf{mg/L} = \frac{\text{chemical feed, lbs./day}}{\text{(MGD)(8.34 lbs./gal)}}$$

$$= \frac{103.1 \text{ lbs.}}{\text{(11.5 MGD)(8.34 lbs./gal)}}$$

$$= 1.07 \text{ mg/L}$$

12 TDEC - Fleming Training Center

Feeders

1. An operator collections 5 three-minute samples from a dry feeder. Based on the information given, determine the average grams per min.

Sample 1 = 37.8 grams
Sample 2 = 38.3 grams
Sample 3 = 35.6 grams

2. What is the average dose in mg/L for the feeder in the previous question if the plant treats 3.9 MGD?

APPLIED MATH FOR WATER
FEEDER MATH

1.a. An operator is checking the calibration on a chemical feeder. The feeder delivers 102 grams in 5 minutes. How many grams per minute does the feeder deliver?

1.b. How many pounds per day does the feeder deliver?

2.a. An operator checks the calibration of a dry feeder by catching samples and weighing them on a balance. Each catch lasts 1 minute. Calculate the average feed rate in grams per minute based on the following data:

Sample 1 weighs 37.0 grams
Sample 2 weighs 36.2 grams
Sample 3 weighs 39.4 grams
Sample 4 weighs 38.6 grams

2.b. How many pounds per hour is being fed?

3.a. An operator collects 3 two-minute samples from a dry feeder:

Sample 1 weighs 22.2 grams
Sample 2 weighs 24.0 grams
Sample 3 weighs 21.9 grams

What is the average grams per minute?

3.b. What is the average dose in mg/L for the feeder in question 3.a. if the plant treats 420,000 gpd?

4.a. An operator collects 5 two-minute samples from a dry feeder:

Sample 1 weighs 49.2 grams
Sample 2 weighs 44.0 grams
Sample 3 weighs 41.9 grams
Sample 4 weighs 48.3 grams
Sample 5 weighs 47.6 grams

What is the average grams per minute?

4.b. What is the average dose in mg/L if the plant treats 1,200,000 gpd?

5.a. A chemical feeder calibration is tested using a 1,000 ml graduated cylinder. The cylinder filled to 850 ml in a 3 minute test. What is the chemical feed rate in milliliters per minute?

5.b. What is the chemical feed rate in gallons per minute?

5.c. What is the chemical feed rate in gallons per day?

6.a. A chemical feeder draws a liquid chemical from a one-liter (1,000 ml) graduated cylinder for 30 seconds. At the end of 30 seconds, the graduated cylinder has 400 ml remaining. What is the chemical feed rate in milliliters per minute?

6.b. What is the chemical feed rate in gallons per minute?

6.c. What is the chemical feed rate in gallons per day?

7. A water plant treats 3.5 MGD with a dose of 2.2 mg/L $KMnO_4$. If the water plant uses 257 gallons of permanganate per day, how many ml/min must be pumped?

8.a. A water plant treats 8.5 MGD with a dose of 1.7 mg/L $KMnO_4$. How many gpd of permanganate must be used? ($KMnO_4$ was made up at 0.25 lbs per 1 gallon of water)

8.b. How many ml/min must be pumped?

8.c. If the water plant uses 3 potassium permanganate pumps, how many ml/min must be pumped by each?

9. $KMnO_4$ has been made according to the manufacturer recommendations (30 mg/mL). The water plant operators wants to dose 3.6 MGD with 2.0 mg/L KMnO4. How many ml/min must be delivered by the metering pump?

Answers:

1.a. 20.4 grams/min
1.b. 64.76 lbs/day
2.a. 37.8 grams/min
2.b. 5 lbs/hour
3.a. 11.35 grams/min
3.b. 10.3 mg/L
4.a. 23.1 grams/min
4.b. 7.3 mg/L
5.a. 283.3 ml/min
5.b. 0.0748 gal/min
5.c. 107.7 gpd

6.a. 1200 ml/min
6.b. 0.32 gal/min
6.c. 456.5 gpd
7. 675.5 ml/min
8.a. 482.052 gpd
8.b. 1267 ml/min
8.c. 422.3 ml/min
9. 630.83 ml/min

APPLIED MATH FOR WATER
FEEDER MATH PRACTICE QUIZ

1. An operator collects 3 two-minute samples from a dry feeder:
   Sample 1 weighs 47.3 grams
   Sample 2 weighs 44.8 grams
   Sample 3 weighs 42.4 grams
   The water plant is treating 4.5 MGD. What is the average dose in mg/L?

2. A chemical feeder feeds a liquid chemical to a 1000 mL graduated cylinder for 48 seconds. At the end of the 48 seconds, the graduated cylinder is completely full. What is the chemical feed rate for the metering pump in gallons per day?

3. A water plant used 167 gallons of a liquid chemical in one day. How many mL/min was pumped?

4. The operator measured the amount of dry chemical fed in one day as 114.5 lbs. How many grams/min should the dry feeder have delivered?

5. How many grams in one pound?

6. How many milliliters in one gallon?

7. How many milligrams in one pound?

8. How many liters in one gallon?

ANSWERS:

1. 1.9 mg/L
2. 475.6 gpd
3. 439 mL/min
4. 36.1 g/min
5. 453.6
6. 3,785
7. 453,600
8. 3.785

Section 13

Pre-treatment and Lab

Pretreatment

Algae Control

Iron and Manganese Control

Copper Sulfate

- Dosage depends on alkalinity and pH.
  - If methyl-orange alkalinity is < 50 mg/L as $CaCO_3$, a dosage of 0.3 mg/L is recommended, based on total lake volume.
  - If methyl-orange alkalinity is > 50 mg/L as $CaCO_3$, 1 mg/L for the upper 2 ft of the volume of the lake is recommended.

Copper Sulfate Problem

- If the methyl-orange alkalinity is 40 mg/L, how many pounds of copper sulfate will be required to treat a pond with a volume of 32 acre-ft?

Copper sulfate = (0.9 lbs/acre-ft)(volume, acre-ft)
= (0.9 lbs/acre-ft)(32 acre-ft)
= 28.8 lbs copper sulfate

Potassium Permanganate

- Potassium permanganate oxidizes iron and manganese, and may be helpful in controlling algae in reservoirs.

$KMnO_4$ Solutions

- I want to make a 3% solution of $KMnO_4$. What % by weight would 15 lbs. $KMnO_4$ in 55 gallons of water give me?

$$\%\ \text{by weight} = \frac{\text{Weight of chemical, lbs}}{\text{Weight of water, lbs + Weight of chemical, lbs}}$$

$$= \frac{15\ \text{lbs}}{(55\ \text{gal})(8.34\ \text{lbs/gal}) + 15\text{lbs}}$$

$$= \frac{15\ \text{lbs.}}{458.7\ \text{lbs.} + 15\text{lbs}} = \frac{15\text{lbs}}{473.7\ \text{lbs}} = 0.03 \text{ or } 3\%$$

Permanganate Dosage

- It takes 1.92 mg/L of $KMnO_4$ to oxidize 1 mg of manganese. How much $KMnO_4$ will be needed to treat 1.65 mg/L of manganese?

mg/L = (1.65 mg/L Mn)(1.92 mg/L $KMnO_4$)
= 3.17 mg/L $KMnO_4$

Laboratory Solutions

- You want to make up a standard solution of $KMnO_4$ for a jar test. How would you make a .01% solution from 10 mL of a 3.0% solution?

$(Concentration_1)(Volume_1) = (Concentration_2)(Volume_2)$

$(.03)(10mL) = (.0001)(x\ mL)$

$\frac{(.03)(10mL)}{(.0001)} = (x\ mL)$

$3000\ mL = x$

Laboratory Solutions

- How many mL of water should be added to 20 mL of a 5.0N solution to make a .8N solution?

$(Normality_1)(Volume_1) = (Normality_2)(Volume_2)$

$(5\ N)(20\ mL) = (.8\ N)(x\ mL)$

$x\ mL = \frac{(5\ N)(20\ mL)}{(.8N)} = \frac{100\ mL}{.8} = 125\ mL$

125 mL – 20 mL = 105 mL

Pre-treatment and Lab

1. A holding pond measures 550 feet by 1075 feet and has an average depth of 12 feet.

a. What is the volume of the pond in acre-feet?

b. What is the volume of the pond in million gallons?

c. If the Methyl Orange alkalinity is 21 mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

d. If the Methyl Orange alkalinity is 72 mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

2.a. Carus Chemicals recommends a 5% permanganate solution. If 2.0 lbs $KMnO_4$ is dissolved in 10 gallons of water, what is the % by weight?

b. To produce a 5% solution, how many pounds of $KMnO_4$ should be dissolved in a tank 4.0 feet in diameter and filled to a depth 4.5 feet?

c. Your raw water has 1.6 mg/L of iron. How much $KMnO_4$ should be used to treat the iron? Each 1.0 ppm requires 0.91 mg/L of $KMnO_4$.

d. Your raw water has 6.2 mg/L of manganese. How much $KMnO_4$ should be used to treat manganese? Each 1.0 ppm of manganese requires 1.92 mg/L $KMnO_4$.

e. Your raw water has 0.4 mg/L of iron and 3.4 mg/L of manganese. How much $KMnO_4$ should be used? (Each 1.0 ppm requires 0.91 mg/L of $KMnO_4$; each 1.0 ppm of manganese requires 1.92 mg/L $KMnO_4$)

f. Carus Chemicals recommends a 5% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallons of water. How many mg of $KMnO_4$ is there per mL of solution?

g. The water plant is treating 3.0 MGD and the operator has determined that the $KMnO_4$ dose should be 3.9 mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lb/gal)

Applied Math for Water Laboratory Solutions

1. A laboratory solution is made using 52 milligrams of Sodium Chloride (NaCl) dissolved in a 1 liter volumetric flask filled to the mark. What is the mg/L concentration of the solution?

2. If 33 lbs of a chemical is added to 148 lbs of water, what is the % strength by weight?

3. You need 1 liter of 0.1N HCl and you have 10N on hand. How many mL's of the 10N do you need to make 1 liter?

4. 250 mL of 3N NaOH is diluted to 1000mL. What is the new normality of the solution?

5. 500 mL of 10N NaOH is diluted to 1 liter. What is the new normality of the solution?

6. You are given 20 mL of 30N HCl. How many mL's of water should be added to make 1.1N HCl?

7. An operator needs a 0.1N solution in order to conduct an analysis. The operator has 1.5N solution on hand. How much (mL) of the 1.5N solution is needed to make 1 liter of 0.1N solution?

8. An operator needs a 0.1N solution in order to conduct an analysis. The operator has 2.0N solution on hand. How many milliliters of the 2.0N solution is needed to make 1 liter of 0.1N solution?

9. 450 mL of 5N NaOH is diluted to 1 liter. What is the new normality of the solution?

10. You are given 8 mL of 15N H_2SO_4. How much water (in mL) should be added to make 0.4N H_2SO_4?

11. An operator needs a 0.2N solution and has 2.5N on hand. How much (in mL) of the 2.5N solution is needed to make one-half liter of 0.2N solution?

Answers:

1. 52mg/L
2. 18.2%
3. 10 mL
4. 0.75N
5. 5N
6. 525.45 mL
7. 66.7 mL
8. 50 mL
9. 2.25N
10. 292 mL
11. 40 mL

Applied Math for Water Pretreatment

Copper Sulfate

1.a. A holding pond measures 400 feet by 1213 feet and has an average depth of 10.5 feet. What is the volume of the pond in acre-ft?

b. What is the volume of the pond in million gallons?

c. If the Methyl Orange alkalinity is 28mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

d. If the Methyl Orange alkalinity is 61mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

2.a. A holding pond measures 2400 feet by 576 feet and has an average depth of 8.75 feet. What is the volume of the pond in acre-ft?

b. What is the volume of the pond in million gallons?

c. If the Methyl Orange alkalinity is 44mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

d. If the Methyl Orange alkalinity is 82mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

3. For algae control of a reservoir, a dosage of 0.5 mg/L copper is desired. The reservoir has a volume of 20 MG. How many pounds of copper sulfate (25% available copper) will be required?

4. The desired copper sulfate dose in a reservoir is 5 mg/L. The reservoir has a volume of 62 acre-ft. How many lbs of copper sulfate (25% available copper) will be required?

5. A pond has an average length of 250 ft, an average width of 75 ft and an average depth of 10 ft. If the desired dose of copper sulfate is 0.8 lbs/ acre ft, how many pounds of copper Sulfate will be required?

Potassium Permanganate

1.a. Carus Chemicals recommends a 3% permanganate solution. If 2.5 lbs $KMnO_4$ is dissolved in 10 gallons of water, what is the % by weight?

b. To produce a 3% solution, how many pounds $KMnO_4$ should be dissolved in a tank 3.5 feet in diameter and filled to a depth of 4.25 feet?

c. Your raw water has 1.8mg/L of iron. How much $KMnO_4$ should be used to treat the iron? (Each 1.0 ppm of Iron requires 0.91mg/L of $KMnO_4$)

d. Your raw water has 6.6mg/L of manganese. How much $KMnO_4$ should be used to treat manganese? (Each 1.0 ppm of Manganese requires 1.92mg/L of $KMnO_4$)

e. Your raw water has 0.2mg/L of iron and 2.9mg/L of manganese. How much $KMnO_4$ should be used? (0.91mg/L $KMnO_4$ per 1.0 ppm Fe; 1.92mg/L $KMnO_4$ per 1.0 ppm Mn)

f. Carus Chemicals recommends a 3% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallon of water. How many mg $KMnO_4$ is there per mL of solution?

g. Carus Chemicals recommends a 3% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallon of water. If 55 gallons of $KMnO_4$ is made at this ratio, how many pounds of chemical are required?

h. The water plant is treating 2.0 MGD and the operator has determined that the $KMnO_4$ dose should be 4.6mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal)

i. The water plant is treating 11.2 MGD and the operator has determined that the $KMnO_4$ dose should be 2.3mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal)

j. Your raw water contains 0.7mg/L iron and 1.2mg/L manganese. You have determined to feed 0.4mg/L $KMnO_4$ to overcome a taste and odor problem caused by an algal bloom in addition to the amounts required to oxidize the iron and manganese. How many mL/min should the liquid feeder be set to feed in order to treat 9.1 MGD? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal; 0.91mg/L $KMnO_4$ per 1.0 ppm Fe; 1.92mg/L $KMnO_4$ per 1.0 ppm Mn)

2.a. Carus Chemicals recommends a 3% permanganate solution. If 25 lbs of $KMnO_4$ are dissolved in 100 gallons of water, what is the % by weight?

b. To produce a 3% solution, how many pounds $KMnO_4$ should be dissolved in a tank 3.5 feet in diameter and filled to a depth of 3.5 feet?

c. Your raw water has 2.8mg/L of iron. How much $KMnO_4$ should be used to treat the iron? (Each 1.0 ppm of Iron requires 0.91mg/L of $KMnO_4$)

d. Your raw water has 2.0mg/L of manganese. How much $KMnO_4$ should be used to treat the manganese? (Each 1.0 ppm of Manganese requires 1.92mg/L of $KMnO_4$)

e. Your raw water has 0.2mg/L of iron and 3.1mg/L of manganese. How much $KMnO_4$ should be used? (0.91mg/L $KMnO_4$ per 1.0 ppm Fe; 1.92mg/L $KMnO_4$ per 1.0 ppm Mn)

f. Carus Chemicals recommends a 3% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallon of water. How many mg $KMnO_4$ are there per 100mL of solution?

g. Carus Chemicals recommends a 3% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallon of water. If 67 gallons of $KMnO_4$ are made at this ratio, how many pounds of chemical are required?

h. The water plant is treating 14.5 MGD and the operator has determined that the $KMnO_4$ dose should be 3.9mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal.)

i. The water plant is treating 6.5 MGD and the operator has determined that the $KMnO_4$ dose should be 3.2mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal.)

j. Your raw water contains 2.2mg/L of iron and 0.7mg/L of manganese. You have determined to feed 0.5mg/L $KMnO_4$ to overcome a taste and odor problem caused by an algal bloom in addition to the amounts required to oxidize the iron and manganese. How many mL/min should the liquid feeders be set to feed in order to treat 5.4 MGD? The plant flow is split evenly between two separate flash mixers. The $KMnO_4$ is being introduced into each rapid mix by its own metering pump. ? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal; 0.91mg/L $KMnO_4$ per 1.0 ppm Fe; 1.92mg/L $KMnO_4$ per 1.0 ppm Mn)

Answers:

Copper sulfate

1.a. 117 ac-ft
b. 38.1 MG
c. 105.3 lbs
d. 60.1 lbs

2.a. 277.7 ac-ft
b. 90.5 MG
c. 250 lbs
d. 171.4 lbs
e.

3. 334 lbs
4. 3370 lbs
5. 3.44 lbs

Potassium permanganate

1.a. 2.91%
b. 78.9 lbs
c. 1.64mg/L
d. 12.67mg/L
e. 5.75mg/L
f. 29.96mg/mL
g. 13.75 lbs
h. 807 mL/min
i. 2260 mL/min
j. 2667 mL/min

2.a. 2.9%
b. 64.9 lbs
c. 2.55mg/L
d. 3.84mg/L
e. 6.13mg/L
f. 2996 mg
g. 16.76 lbs
h. 4961 mL/min
i. 1823 mL/min
j. 911 mL/min

Section 14

Softening

Softening

Lime-Soda Ash Process

1 TDEC - Fleming Training Center

Water Hardness

- Caused by minerals such as calcium and magnesium
- Expressed as mg/L $CaCO_3$

2 TDEC - Fleming Training Center

Water Hardness

- Some textbooks define hard water as water with a hardness greater than 100 mg/L
- High hardness can cause excessive scaling in hot water heaters, inhibit the cleaning action of soaps, and cause problems for industries

3 TDEC - Fleming Training Center

Total Hardness

- Total hardness = calcium hardness + magnesium hardness
- Total hardness = carbonate hardness + noncarbonate hardness

4 TDEC - Fleming Training Center

Alkalinity

- The capacity of water to neutralize acids
- Expressed as mg/L $CaCO_3$
- Composed of the carbonate, bicarbonate, and hydroxide content of the water

5 TDEC - Fleming Training Center

Alkalinity Calculations

- The phenolphthalein alkalinity on a water sample is 62 mg/L and the total alkalinity is 94 mg/L. What is the carbonate alkalinity?

P = 62 mg/L T = 94 mg/L
P is greater than 1/2 T
Carbonate alkalinity = 2T - 2P
= 2(94 mg/L) - 2(62 mg/L)
= 188 mg/L - 124 mg/L
= 64 mg/L

6 TDEC - Fleming Training Center

Alkalinity Calculations

- A water sample was determined to have a phenolphthalein alkalinity of 42 mg/L and a total alkalinity of 105 mg/L. What is the bicarbonate alkalinity?

P = 42 mg/L T = 105 mg/L
P is less than 1/2 T
bicarbonate alkalinity = T - 2P
= 105 mg/L - 2(42 mg/L)
= 105 mg/L - 84 mg/L
= 21 mg/L

7 TDEC - Fleming Training Center

Alkalinity Calculations

- A water sample was determined to have a phenolphthalein alkalinity of 42 mg/L and a total alkalinity of 105 mg/L. What is the carbonate alkalinity?

P = 42 mg/L T = 105 mg/L
P is less than 1/2 T
carbonate alkalinity = 2P
= 2(42 mg/L)
= 84 mg/L

8 TDEC - Fleming Training Center

Hardness Calculations

- If the total alkalinity on a sample is 78 mg/L and the total hardness is 86 mg/L, what is the carbonate hardness?

TA = 78 mg/L TH = 86 mg/L
TH is greater than TA
Carbonate hardness = TA
= 78 mg/L

9 TDEC - Fleming Training Center

Hardness Calculations

- If the total alkalinity on a sample is 78 mg/L and the total hardness is 86 mg/L, what is the noncarbonate hardness?

TA = 78 mg/L TH = 86 mg/L
TH is greater than TA
noncarbonate hardness = TH - TA
= 86 mg/L - 78 mg/L
= 8 mg/L

10 TDEC - Fleming Training Center

Alkalinity Titrations

- Use the following titration results to calculate the carbonate, bicarbonate, and hydroxide alkalinity:
  - 3.0 mL of 0.02N H_2SO_4 was used to reach a pH of 8.3, and a total of 12.5 mL was used to reach the Methyl-Orange endpoint in a 100 mL sample.

$$PA = \frac{A \times N \times 50{,}000}{\text{mL of sample}}$$

$$= \frac{(3.0\ \text{mL})(0.02\ \text{N})(50{,}000)}{100\ \text{mL}} = 30\ \text{mg/L}$$

11 TDEC - Fleming Training Center

Alkalinity Titrations

- Use the following titration results to calculate the carbonate, bicarbonate, and hydroxide alkalinity:
  - 3.0 mL of 0.02N H2SO4 was used to reach a pH of 8.3, and a total of 12.5 mL was used to reach the Methyl-Orange endpoint in a 100 mL sample.

$$TA = \frac{B \times N \times 50{,}000}{\text{mL of sample}}$$

$$= \frac{(12.5\ \text{mL})(0.02\ \text{N})(50{,}000)}{100\ \text{mL}} = 125\ \text{mg/L}$$

12 TDEC - Fleming Training Center

Alkalinity Titrations

PA = 30 mg/L TA = 125 mg/L

P is less than 1/2 T

bicarbonate alkalinity = T - 2P
= 125 mg/L - 2(30 mg/L)
= 125 mg/L - 60 mg/L
= 65 mg/L

13 TDEC - Fleming Training Center

Alkalinity Titrations

PA = 30 mg/L TA = 125 mg/L

P is less than 1/2 T

carbonate alkalinity = 2P
= 2(30 mg/L)
= 60 mg/L

hydroxide alkalinity = 0

14 TDEC - Fleming Training Center

Softening

- How many pounds of lime are required to treat 8.4 MGD with a dose of 16.5 mg/L? The lime is 85% pure.

$$\text{lbs/day} = \frac{(\text{dose, mg/L})(\text{flow, MGD})(8.34 \text{ lbs/gal})}{\%\text{ purity, as decimal}}$$

$$= \frac{(16.5 \text{ mg/L})(8.4 \text{ MGD})(8.34 \text{ lbs/gal})}{0.85}$$

= 1359.9 lbs/day

15 TDEC - Fleming Training Center

Softening

- How many pounds of soda ash are required to treat 8.4 MGD with a dose of 53 mg/L? The soda ash is 100% pure.

$$\text{lbs/day} = \frac{(\text{dose, mg/L})(\text{flow, MGD})(8.34 \text{ lbs/gal})}{\%\text{ purity, as decimal}}$$

$$= \frac{(53 \text{ mg/L})(8.4 \text{ MGD})(8.34 \text{ lbs/gal})}{1}$$

= 3713 lbs/day

16 TDEC - Fleming Training Center

Softening

1. On a water sample the total alkalinity was 75 mg/L and the total hardness was 99 mg/L. What are the carbonate and noncarbonate hardness concentrations in mg/L?

2. It takes 5.4 mL of 0.02 N H_2SO_4 to reach a pH of 8.3 and a total of 11.7 mL to reach the Methyl Orange end-point in a 100 mL sample. What is the carbonate, bicarbonate, and hydroxyl alkalinity in mg/L as $CaCO_3$?

3. How many pounds per day of quicklime are required to treat 4.2 MGD with a dose of 175 mg/L? The quicklime is 85% pure.

Applied Math for Water

Softening

1. On a water sample the total alkalinity was 98 mg/L and the total hardness was 112 mg/L. What is the carbonate and noncarbonate hardness concentrations in mg/L?

2. It takes 3.2 mL of 0.02 N H_2SO_4 to reach a pH of 8.3 and a total of 10.1 mL to reach the Methyl Orange end-point in a 100 mL sample. What is the carbonate, bicarbonate and hydroxyl alkalinity in mg/L as $CaCO_3$?

3. It takes 4.3 mL of 0.02 N H_2SO_4 to reach a pH of 8.3 and a total of 8.2 mL to reach the Methyl Orange end-point in a 100 mL sample. What is the carbonate, bicarbonate and hydroxyl alkalinity in mg/L as $CaCO_3$?

4. How many pounds/day of quicklime (CaO) is required to treat 6.4 MGD with a dose of 148 mg/L. The quicklime is 85% pure.

5. How many pounds/day of soda ash (Na_2CO_3) would be required to treat 7.3 MGD with a dose of 29.8 mg/L?

6. It has been calculated that 112.5 mg/L quicklime (CaO) and 38.6 mg/L soda ash (Na_2CO_3) are required in treating a certain water. The quicklime to be used is 92% pure; the soda ash is 100% pure, and the plant flow is 1.6 MGD. How many pounds per day of quicklime and soda ash should be used?

Answers:

1. 98 mg/L Carbonate hardness
   14 mg/L Noncarbonate hardness
2. Carbonate = 64 mg/L as $CaCO_3$
   Bicarbonate = 37 mg/L as $CaCO_3$
   Hydroxyl = 0 mg/L as $CaCO_3$
3. Carbonate = 78 mg/L as $CaCO_3$
   Bicarbonate = 0 mg/L as $CaCO_3$
   Hydroxyl = 4 mg/L as $CaCO_3$
4. 9,294 lbs/day
5. 1,814 lbs/day
6. 1,632 lbs/day quicklime
   515 lbs/day soda ash

Section 15

Temperature Conversions

Temperature Conversions

1. 215^{o}F to ^{o}C

2. 34^{o}C to ^{o}F

Temperature Conversions

Convert these temperatures:

Remember formulas on page 1 in your formula book
°C = 0.556(°F – 32)
°F = 1.8 (°C) + 32

1. 160°F to °C

2. 70°F to °C

3. 35°C to °F

4. 45.5°C to °F

Answers:
1. 71.1°C 2. 21.1°C 3. 95°F 4. 113.9°F

Section 16

Answers

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

$8.1 = (4.5)(x)$

$\frac{8.1}{4.5} = x$

$\boxed{1.8 = x}$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

$(0.0854865)(x) = 0.49$

$x = \frac{0.49}{0.0854865}$

$\boxed{x = 5.73}$

3. $\frac{233}{x} = 44$

$233 = (44)(x)$

$\frac{233}{44} = x$

$\boxed{5.29 = x}$

4. $940 = \frac{x}{(0.785)(90)(90)}$

$940 = \frac{x}{6358.5}$

$(940)(6358.5) = x$

$\boxed{5,976,990 = x}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

$x = \frac{4128.3}{0.5}$

$\boxed{x = 8256.6}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

$x = \frac{3800}{(56.5)(8.34)}$

$\boxed{x = 8.06}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

$x = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(114)}$

$\boxed{x = 0.005}$

8. $2^{\circ} = \frac{x}{180}$

$(2)(180) = x$

$\boxed{360 = x}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

$46 = \frac{(875.7)(x)}{31400}$

$(46)(31400) = (875.7)(x)$

$\frac{(46)(31400)}{875.7} = x$

$\boxed{1649.4 = x}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

$(2.4)(x) = (0.785)(5)(5)(4)(7.48)$

$x = \frac{(0.785)(5)(5)(4)(7.48)}{2.4}$

$\boxed{x = 245}$

11. $19{,}747 = (20)(12)(x)(7.48)$

$19.747 = (1795.2)(x)$

$\frac{19747}{1795.2} = x$

$10.99 = x$

12. $\frac{(15)(12)(1.25)(7.48)}{x} = 337$

$\frac{(15)(12)(1.25)(7.48)}{337} = x$

$4.99 = x$

13. $\frac{x}{(4.5)(8.34)} = 213$

$x = (213)(4.5)(8.34)$

$x = 7993.89$

14. $\frac{x}{246} = 2.4$

$x = (2.4)(246)$

$x = 590.4$

15. $6 = \frac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

$\frac{(6)(65)(1.3)(8.34)}{(0.18)(8.34)} = x$

$2817 = x$

16. $\frac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

$\frac{(3000)(3.6)(8.34)}{(0.785)(23.4)} = x$

$4903.5 = x$

17. $109 = \frac{x}{(0.785)(80)(80)}$

$(109)(0.785)(80)(80) = x$

$547616 = x$

18. $(x)(3.7)(8.34) = 3620$

$x = \frac{3620}{(3.7)(8.34)}$

$x = 117$

19. $2.5 = \frac{1{,}270{,}000}{x}$

$x = \frac{1270000}{2.5}$

$x = 508{,}000$

20. $0.59 = \frac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

$x = \frac{(170)(2.42)(8.34)}{(1980)(0.59)(8.34)}$

$x = \frac{3431.076}{9742.788}$

$x = 0.35$

Finding x^2

21. $(0.785)(D^2) = 5024$

$$\frac{D^2}{0.785} = \frac{5024}{0.785}$$
$$\sqrt{D^2} = \sqrt{6400}$$
$$D = 80$$

22. $(x^2)(10)(7.48) = 10{,}771.2$

$$(x^2)(74.8) = 10771.2$$
$$(x^2) = \frac{10771.2}{74.8}$$
$$\sqrt{x^2} = \sqrt{144}$$
$$x = 12$$

23. $51 = \frac{64{,}000}{(0.785)(D^2)}$

$$D^2 = \frac{64000}{(51)(0.785)}$$
$$\sqrt{D^2} = \sqrt{1598.6}$$
$$D = 39.98$$

24. $(0.785)(D^2) = 0.54$

$$D^2 = \frac{0.54}{0.785}$$
$$\sqrt{D^2} = \sqrt{0.6879}$$
$$D = 0.829$$

25. $2.1 = \frac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

$$2.1 = \frac{(88.077)(D^2)}{5024}$$
$$(2.1)(5024) = (88.077)(D^2)$$
$$\frac{(2.1)(5024)}{88.077} = D^2$$
$$\sqrt{119.786} = \sqrt{D^2}$$
$$10.94 = D$$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾ 0.75
2. ⅝ 0.625
3. ¼ 0.25
4. ½ 0.5

Convert the following percents to decimals:

5. 35% $\frac{35}{100}$ = 0.35
6. 99% $\frac{99}{100}$ = 0.99
7. 0.5% $\frac{0.5}{100}$ = 0.005
8. 30.6% $\frac{30.6}{100}$ = 0.306

Convert the following decimals to percents:

9. 0.65 (0.65)(100) = 65%
10. 0.125 (0.125)(100) = 12.5%
11. 1.0 (1.0)(100) = 100%
12. 0.05 (0.05)(100) = 5%

Calculate the following: "of" means multiply; "is" means equal to

13. 15% of 125 (0.15)(125) = 18.75
14. 22% of 450 (0.22)(450) = 99
15. 473 is what % of 2365? 473 = (%)(2365) → $\frac{473}{2365}$ = x
    0.2 = x
    (0.2)(100) = x
    20% = x
16. 1.3 is what % of 6.5? 1.3 = (x)(6.5)
    $\frac{1.3}{6.5}$ = x
    0.2 = x
    20% = x

APPLIED MATH FOR WATER
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.

$A = \text{length} * \text{width}$

$A = (45\,ft)(12\,ft) = 540\,ft^2$

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

$A = (90\,ft)(25\,ft)$

$A = 2250\,ft^2$

3. Calculate the cross-sectional area in ft^2 for a 2 ft diameter main that has just been laid.

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

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

$A = 3.14\,ft^2$

4. Calculate the cross-sectional area in ft^2 for a 24 inch diameter main that has just been laid. $\frac{24\,in \mid 1\,ft}{\mid 12\,in} = 2\,ft$

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

$A = 3.14\,ft^2$

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

$18/12 = 1.5\,ft$

$A = (0.785)(1.5\,ft)(1.5\,ft)$

$A = 1.77\,ft^2$

6. Calculate the cross-sectional area (in ft^2) for a 2 inch line that has just been laid.

$2/12 = 0.1667\,ft$

$A = (0.785)(0.1667\,ft)(0.1667\,ft)$

$A = 0.02\,ft^2$

Volume

7. Calculate the volume (in ft^3) of a tank that measures 10 ft by 10 ft by 10 ft.

$Vol = (L)(W)(d)$

$Vol = (10\,ft)(10\,ft)(10\,ft) = 1000\,ft^3$

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

$Vol = (22\,ft)(11\,ft)(5\,ft)$

$Vol = (1210\,ft^3)(7.48\,ft^3/gal)$

$Vol, gal = 9050.8\,gal$

9. Calculate the volume (in gallons) of water in a tank that is 254 feet long, 62 feet wide and 10 feet deep if the tank only contains 2 feet of water.

$Vol, gal = (254\,ft)(62\,ft)(2\,ft)(7.48\,ft^3/gal)$

$= 235{,}590.08\,gal$

10. 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. $8/12 = 0.6667\,ft$

$Vol, gal = (12\,ft)(5\,ft)(0.6667\,ft)(7.48\,ft^3/gal)$

$= 299.2\,gal$

11. Calculate the maximum volume of water in gallons for a kid's swimming pool that measures 6 feet across and can hold 18 inches of water. $18/12 = 1.5\,ft$

$Vol = (0.785)(D)^2(depth)$

$Vol = (0.785)(6\,ft)(6\,ft)(1.5\,ft)$

$Vol = (42.39\,ft^3)(7.48\,ft^3/gal) = 317.08\,gal$

12. How many gallons of water can a barrel hold if it measures 3.5 feet in diameter and can hold water to a depth of 4 feet?

$Vol, gal = (0.785)(3.5\,ft)(3.5\,ft)(4\,ft)(7.48\,ft^3/gal)$

$= 287.72\,gal$

13. 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? $30/12 = 2.5$ ft

$(0.25\ mi)(5280\ ft/mi) = 1320$ ft

$$vol, gal = (0.785)(2.5\ ft)(2.5\ ft)(1320\ ft)(7.48\ ft^3/gal)$$
$$= 48442.35\ gal$$

14. 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?

$(3,000,000\ gal)(0.05) = 150,000\ gal$

15. What is 5% of a 1.2 million gallon tank?

$(1.2\ MG)(0.05) = 0.06\ MG$

Conversions

16. How many seconds in one minute?

60 seconds

17. How many minutes in one hour?

60 minutes

18. How many minutes in one day?

$$\frac{1\ day}{1} \left| \frac{24\ hr}{1\ day} \right| \frac{60\ min}{24\ hr} = 1440\ min$$

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

$$\frac{3.6\ ft^3}{sec} \left| \frac{1\ gal}{7.48\ ft^3} \right. = 0.48\ gal$$

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

$$\frac{2.4\ ft^3}{sec} \left| \frac{60\ sec}{1\ min} \right| \frac{1\ gal}{7.48\ ft^3} = 19.25\ gal/min$$

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

$$\frac{6.31\ MG}{day} \left| \frac{1\ day}{24\ hr} \right| \frac{1\ hr}{60\ min} \left| \frac{1000000\ gal}{1\ MG} \right| = 4381.94\ gal/min$$

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

$$\frac{695\ gal}{min} \left| \frac{60\ min}{1\ hr} \right| \frac{24\ hr}{1\ day} \left| \frac{1\ MG}{1000000\ gal} \right| = 1.0008\ MGD$$

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

$$\frac{800\ gal}{} \left| \frac{8.34\ lb}{1\ gal} \right| = 6672\ lb$$

DON'T THINK TOO HARD ON THIS ONE...

24. If you double the size of a pipe, does it double the volume that can be carried? For example, if you have 1000 feet of 12 inch line and you replace it with a 24 inch line, does your volume double?

12 inch

$vol, gal = (0.785)(1ft)(1ft)(1000ft)(7.48)$

$= 5871.8\ gal$

24 inch

$vol, gal = (0.785)(2ft)(2ft)(1000ft)(7.48)$

$= 23487.2\ gal$

difference

$\frac{23487.2\ gal}{5871.8\ gal} = 4 \rightarrow$ no, it quadruples it!

APPLIED MATH FOR WATER
DENSITY & SPECIFIC GRAVITY

Density: Weight per unit volume.

2 ways to express density: $\frac{lb/gal}{lb/ft^3}$

Specific gravity: Density of any substance compared to a "standard density."

Standard density of water: 8.34 lb/gal

62.4 lb/ft^3

1. Find the specific gravity for rock granite if the density is 162 lbs/ft^3.

$$S.g. = \frac{density}{62.4\ lb/ft^3} = \frac{162\ lb/ft^3}{62.4\ lb/ft^3} = 2.6$$

2. Find the specific gravity for SAE 30 motor oil if the density is 56 lbs/ft^3.

$$S.g. = \frac{56\ lb/ft^3}{62.4\ lb/ft^3} = 0.9$$

3. Find the specific gravity of dry alum if the density is 65 lbs/ft^3.

$$S.g. = \frac{65\ lb/ft^3}{62.4\ lb/ft^3} = 1.04$$

4. Find the specific gravity for liquid alum that weighs 11.07 lbs/gal.

$$S.g. = \frac{11.07\ lb/gal}{8.34\ lb/gal} = 1.3$$

5. Find the specific gravity for fluorosilicic acid that weighs 10.5 lbs/gal.

$$S.g. = \frac{10.5\ lb/gal}{8.34\ lb/gal} = 1.3$$

6. Find the specific gravity for ferric sulfate that weighs 12.34 lbs/gal.

$$S.G. = \frac{12.34\ lb/gal}{8.34\ lb/gal} = 1.5$$

7. Find the density (lbs/ft^3) of a certain oil that has a S.G. of 0.92.

density = (specific gravity)(62.4 lb/ft^3)
= (0.92)(62.4 lb/ft^3
= 57.4 lb/ft^3

8. Find the density (lbs/gal) of ferric chloride that has a S.G. of 1.140.

density = (specific gravity)(8.34 lb/gal)
= (1.140)(8.34 lb/gal)
= 9.5 lb/gal

9. Find the density (lbs/gal) of caustic soda that has a S.G. of 1.530.

density = (1.530)(8.34 lb/gal)
= 12.8 lb/gal

10. Find the density (lbs/ft^3) of potassium permanganate that has a S.G. of 1.522.

density = (1.522)(62.4 lb/ft^3)
= 95.0 lb/ft^3

11. A tank holds 1,240 gallons of a certain liquid. The specific gravity is 0.93. How many pounds of liquid are in the tank?

density = (0.93)(8.34 lb/gal) = 7.7562 lb/gal
lb = (7.7562 lb/gal)(1240gal)
= 9617.69 lb

12. Pump rate desired: 25 gpm
Liquid weight: 74.9 lbs/ft^3
How many pounds of liquid can be pumped per day?

$$\frac{74.9\ lb}{ft^3} \left| \frac{1\ ft^3}{7.48\ gal} \right. = 10.013\ lb/gal$$

$$\frac{25\ gal}{min} \left| \frac{1440\ min}{day} \right| \frac{10.013\ lb}{gal} = 360{,}481.28\ lb/day$$

13. A certain pump delivers 23 gallons per minute.
    A. How many lbs of water does the pump deliver in 1 minute?
    B. How many lbs/min will the pump deliver if the liquid weighs 71.9 lbs/ft^3?

A) $\frac{23\text{ gal}}{1\text{ min}} \mid \frac{8.34\text{ lb}}{1\text{ gal}} = 191.82\text{ lb}$

B) $\frac{71.9\text{ lb}}{\text{ft}^3} \mid \frac{1\text{ ft}^3}{7.48\text{ gal}} = 9.6123\text{ lb/gal}$

$\frac{23\text{ gal}}{\text{min}} \mid \frac{9.6123\text{ lb}}{\text{gal}} = 221.08\text{ lb/min}$

14. A certain pump delivers 14 gallons per minute.
    A. How many lbs of water does the pump deliver in 24 hours?
    B. How many lbs/day will the pump deliver if the liquid weighs 8.1 lbs/gal?

A) $\frac{14\text{ gal}}{\text{min}} \mid \frac{1440\text{ min}}{\text{day}} \mid \frac{8.34\text{ lb}}{\text{gal}} = 168134.4\text{ lb/day}$

B) $\frac{14\text{ gal}}{\text{min}} \mid \frac{1440\text{ min}}{\text{day}} \mid \frac{8.1\text{ lb}}{\text{gal}} = 163296\text{ lb/day}$

15. Compare the density of chlorine gas with the density of air. Chlorine gas weighs 0.187 lbs/ft^3. (standard density of air = 0.075 lb/ft^3)

$\frac{0.187\text{ lb/ft}^3}{0.075\text{ lb/ft}^3} = 2.49$

Chlorine gas is 2.5 times heavier than air

ANSWERS:

1. 2.6
2. 0.9
3. 1.04
4. 1.33
5. 1.26
6. 1.48
7. 57.4 lbs/ft^3
8. 9.5 lbs/gal
9. 12.76 lbs/gal
10. 95 lbs/ft^3
11. 9,617.7 lbs
12. 360,481 lbs/day
13. a. 191.8 lbs/min
    b. 221 lbs/min
14. a. 168,134 lbs/day
    b. 163,296 lbs/day
15. 2.49

Velocity and Flow

1. A bobber is placed in a channel and travels 450 feet in 2 ½ minutes. What is the velocity of the water flowing in the channel in ft/min?

$$Vel = \frac{distance}{time}$$

$$vel = \frac{450\ ft}{2.5\ min} = 180\ ft/min$$

2. A channel 30 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 2.75 ft/sec, what is the flow in the channel in ft^3/sec? And gal/min?

$30\ in / 12\ in/ft = 2.5\ ft$

$Q = (width)(depth)(velocity)$

$= (2.5\ ft)(2\ ft)(2.7\ ft/sec)$

$= (13.75\ ft^3/sec)(60)(7.48)$

$= 6170\ gpm$

3. The flow through a 24 inch pipe is moving at a velocity of 5.4 ft/sec. What is the flow rate in gal/min? $24/12 = 2\ ft$

$Q = (0.785)(d, ft)^2(vel)$

$Q = (0.785)(2\ ft)(2\ ft)(5.4\ ft/sec)$

$Q = 16.956\ ft^3/sec$

$$\frac{16.956\ ft^3}{sec} \left| \frac{60\ sec}{1\ min} \right| \frac{7.48\ gal}{1\ ft^3} = 7609.85\ gal/min$$

Applied Math for Distribution
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?

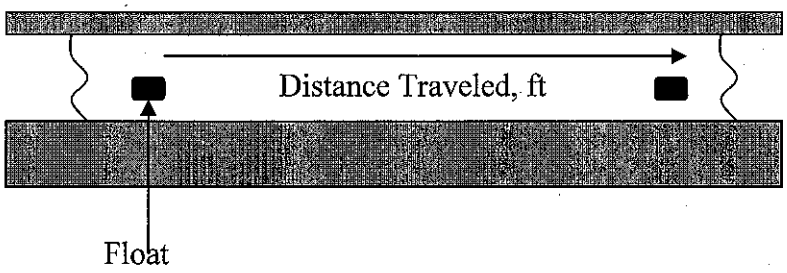
$$V = \frac{\text{distance}}{\text{time}} \qquad V = \frac{370\text{ ft}}{2\text{ min}} = 185\text{ ft/min}$$

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 = 2(60) + 14 = 134 sec

$$V = \frac{300\text{ ft}}{134\text{ sec}} = 2.24\text{ ft/sec}$$

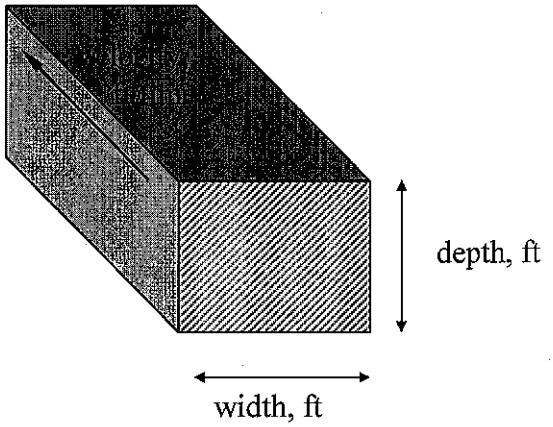
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min? 30 sec = 0.5 min

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



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

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



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

$A = (width)(depth)$

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? $48in = 4ft$

$Q = (4ft)(1.5ft)(2.8\ ft/sec)$

$Q = 16.8\ ft^3/sec$

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?

$Q = (3ft)(2.5ft)(120\ ft/min)$

$Q = 900\ ft^3/min \longrightarrow$ use flow chart to convert

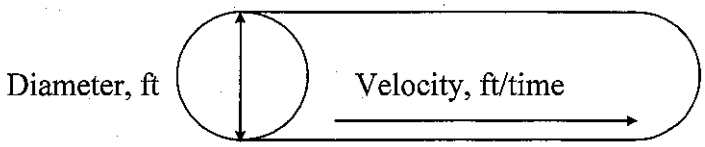
$Q = 9.69$ MGD

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?

$8.1\ ft^3/sec = (3ft)(depth)(1.5\ ft/sec)$

$\frac{8.1\ ft^3/sec}{(3ft)(1.5\ ft/sec)} = depth$

$1.8ft = depth$



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

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

Flow through a 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?

$Q = (0.785)(2ft)^2(3.2\,ft/sec)$

$Q = (0.785)(4ft^2)(3.2\,ft/sec)$

$Q = 10.05\,ft^3/sec$

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? $6\,in = 0.5ft$

$Q = (0.785)(0.5)(0.5)(3\,ft/sec)$

$Q = 0.59\,ft^3/sec$

9. 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?

$0.7\,ft^3/sec = (0.785)(D)^2(3.6\,ft/sec)$

$\frac{0.7\,ft^3/sec}{(0.785)(3.6\,ft/sec)} = D^2$

$\sqrt{0.2477\,ft^2} = \sqrt{D^2} \longrightarrow D = 0.50\,ft = 6\,in$

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

$\frac{8\,in \mid 1\,ft}{12\,in} = 0.6667\,ft$

$Q = (0.785)(0.6667\,ft)^2(3.4\,ft/sec)$

$Q = 1.1862\,ft^3/sec \longrightarrow$ use flow chart

$Q = 532.4\,gal/min$

APPLIED MATH FOR WATER
FLOW RATE

Q = AV

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

$A = (L)(W)$ $Q = (3ft)(2ft)(1.8\ ft/sec)$

$Q = 10.8\ ft^3/sec$

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min? 12 in = 1 ft

$A = (0.785)(D^2)$ $Q = (1ft)(1ft)(0.785)(110\ ft/min)$

$Q = 86.35\ ft^3/min$

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

$18/12 = 1.5ft$

$Q = (0.785)(1.5ft)(1.5ft)(182\ ft/min)$

$= 321.46\ ft^3/min$

$\frac{321.46\ ft^3}{min} \mid \frac{7.48\ gal}{ft^3} = 2404.50\ gal/min$

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe? 24/12 = 2 ft

$Q = (0.785)(2ft)(2ft)(212\ ft/min) = 665.68\ ft^3/min$

$\frac{665.68\ ft^3}{min} \mid \frac{1440\ min}{1\ day} \mid \frac{7.48\ gal}{ft^3} = 7,170,172.42\ gpd$

5. What would be the gpd flow rate for a 6" line flowing at 2 feet/second?

$6/12 = 0.5$ ft

$Q = (0.785)(0.5)(0.5)(2 ft/sec) = 0.3925 ft^3/sec$

$$\frac{0.3925 ft^3}{sec} \left| \frac{60 sec}{min} \right| \frac{1440 min}{day} \left| \frac{7.48 gal}{ft^3} \right| = 253661.76 gpd$$

6. A 36" water main has just been installed. If the main is flushed at 2.5 ft/second, how many gallons/minute of water should be flushed from the hydrant?

$36/12 = 3$ ft

$Q = (0.785)(3ft)(3ft)(2.5 ft/sec) = 17.6625 ft^3/sec$

$$\frac{17.6625 ft^3}{sec} \left| \frac{60 sec}{min} \right| \frac{7.48 gal}{ft^3} = 7926.93 gal/min$$

7. A 36" water main has just been installed. If the main is flowing at a velocity of 2 ft/second, how many MGD will the pipe deliver? $36/12 = 3$ ft

$Q = (0.785)(3ft)(3ft)(2 ft/sec) = 14.13 ft^3/sec$

$$\frac{14.13 ft^3}{sec} \left| \frac{60 sec}{min} \right| \frac{1440 min}{day} \left| \frac{7.48 gal}{ft^3} \right| \frac{1 MG}{1000000 gal} = 9.13 MGD$$

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe? $18/12 = 1.5$ ft

$$\frac{830 yds}{} \left| \frac{3 ft}{1 yd} \right. = 2490 ft$$

Vel = 2490 ft / 5 min

Vel = 498 ft/min

$Q = (0.785)(1.5ft)(1.5ft)(498 ft/min) = 879.5925 ft^3/min$

$$\frac{879.5925 ft^3}{min} \left| \frac{1440 min}{day} \right| \frac{7.48 gal}{ft^3} \left| \frac{= MG}{1000000 gal} \right. = 9.47 MGD$$

9. A water crew is flushing hydrants on a 12-inch diameter main. The pitot gage reads 560 gpm being flushed from the hydrant. What is the flushing velocity (in feet/min) through the pipe?

$Q = A * V$

$12/12 = 1\,ft$

$Q = 560\,gal/min \quad A = (0.785)(1ft)(1ft) = 0.785\,ft^2$

$$Q = \left(\frac{560\,gal}{min}\right)\left(\frac{7.48\,gal}{ft^3}\right) = 4188.8\,ft^3/min$$

$$4188.8\,ft^3/min = (0.785\,ft^2)(V)$$

$$\frac{4188.8\,ft^3/min}{0.785\,ft^2} = V \Rightarrow 5336.05\,ft/min$$

VELOCITY (OPEN CHANNEL)

10. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the flow velocity in <u>feet per minute in</u> the channel? (Assume that float is traveling at the average velocity of the water.)

$$Vel = \frac{distance}{time}$$

$$Vel = \frac{300\,ft}{2.5\,min} = 120\,ft/min$$

11. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in <u>feet per second?</u>

$$Vel = \frac{30\,ft}{20\,sec}$$

$$Vel = 1.5\,ft/sec$$

12. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the <u>cubic-feet-per-minute</u> flow rate in the channel?

$$Q = A * V$$

$$Q = (4ft)(2.3ft)(500ft/3min)$$

$$Q = 1533.33\,ft^3/min$$

AQUIFER FLOW

13. Geologic studies show that the water in an aquifer moves 25 feet in 60 days. What is the average velocity of the water in ft/day?

$$Vel = \frac{25\ ft}{60\ days} = 0.42\ ft/day$$

14. If the water in a water table aquifer moves 2 feet per day, how far will the water travel in 13 days?

$$\left(\frac{2\ ft}{day}\right)(13\ days) = 26\ ft$$

15. If the water in a water table aquifer moves 2.25 feet per day, how long will it take the water to move 61 feet?

$$(61\ ft)\left(\frac{day}{2.25\ ft}\right) = 27.11\ days$$

FLOW

16. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24" main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that one month? $24/12 = 2\ ft$

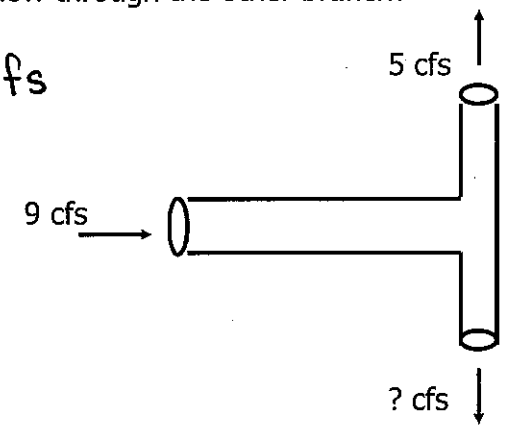
$$Q = (0.785)(2ft)(2ft)(2.9\ ft/sec) = 9.106\ ft^3/sec$$

$$\frac{9.106\ ft^3}{sec} \left| \frac{60\ sec}{min} \right| \frac{60\ min}{hr} \left| \frac{18\ hr}{day} \right| \frac{31\ day}{month} \left| \frac{7.48\ gal}{ft^3} \right| = \frac{1\ MG}{1000000\ gal}$$

$$= 136.83\ MG$$

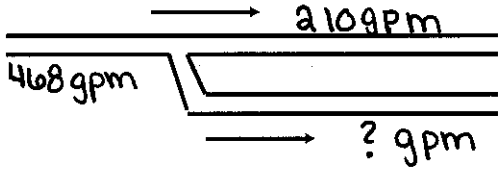
17. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?

$9\text{ cfs} - 5\text{ cfs} = 4\text{ cfs}$

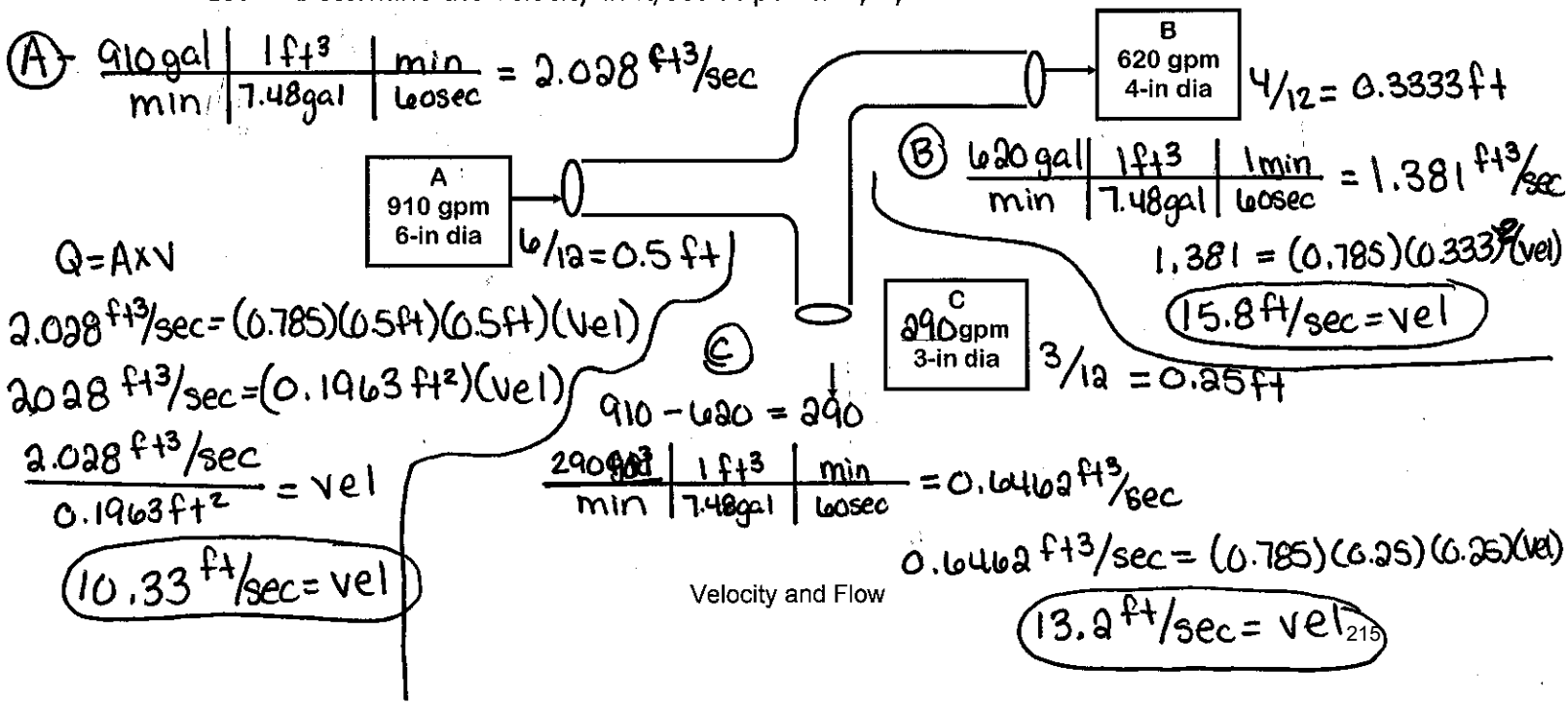


18. A water line has been run to a new subdivision. The flow through the main line is 468 gpm. The line splits into two lines (each serving half of the subdivision). If one line flows 210 gpm, what should be the flow from the other line?

$468\text{ gpm} - 210\text{ gpm} = 258\text{ gpm}$



19. Determine the velocity in ft/sec at points A, B, & C.



Sedimentation

1. The flow to a sedimentation tank is 200,000 gpd. If the tank is 50 feet long and 30 feet wide, what is the surface overflow rate in gpd/ft^2?

$$SOR = \frac{\text{flow, gpd}}{\text{area, ft}^2}$$

$$= \frac{200000\ \text{gpd}}{(50\ \text{ft})(30\ \text{ft})} = 133.33\ \text{gpd/ft}^2$$

2. A tank has a length of 75 ft and 25 ft wide. What is the weir length around the basin in feet?

$$\text{Weir length} = (2)(\text{length}) + (2)(\text{width})$$
$$= (2)(75\ \text{ft}) + (2)(25\ \text{ft})$$
$$= 150\ \text{ft} + 50\ \text{ft} = 200\ \text{ft}$$

3. A clarifier has a diameter of 90 feet. What is the length of the weir around the clarifier in feet?

$$\text{weir length} = (3.14)(\text{diameter})$$
$$= (3.14)(90\ \text{ft})$$
$$= 282.6\ \text{ft}$$

4. The diameter of weir in a circular clarifier is 105 feet. What is the weir overflow rate in gpd/ft if the flow over the weir is 1.83 MGD?

$$WOR = \frac{\text{flow, gpd}}{\text{weir length, ft}}$$

$$= \frac{1{,}830{,}000\ \text{gpd}}{(3.14)(105\ \text{ft})}$$

$$= 5550.5\ \text{gpd/ft}$$

5. A clarifier is 45 feet long, 30 feet long and 10 feet deep. If the daily flow is 3.5 MGD, what is the detention time (in minutes) in the basin?

$$DT, \text{hr} = \frac{(\text{vol, gal})(24\ \text{hr/day})}{\text{flow, gpd}}$$

$$\text{vol} = (45)(10)(30)(7.48) = 100980\ \text{gal}$$

$$= \frac{(100980\ \text{gal})(24\ \text{hr/day})}{3500000\ \text{gpd}}$$

$$= (0.6924\ \text{hr})(60\ \text{min/hr}) = 41.55\ \text{min}$$

Applied Math for Water

Sedimentation and Detention Time

Surface Overflow Rates (SOR)

1. A tank has a length of 100 feet, a width of 25 feet and a depth of 15 feet. What is the surface area in ft^2?

$$A = (L, ft)(W, ft)$$
$$A = (100\,ft)(25\,ft)$$
$$A = 2500\,ft^2$$

2. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the surface area of the clarifier in ft^2?

$$A = (0.785)(d, ft)^2$$
$$A = (0.785)(82\,ft)(82\,ft)$$
$$A = 5671.63\,ft^2$$

3. The flow to a sedimentation tank is 3.05 MGD. If the tank is 80 feet long and 20 feet wide, what is the surface overflow rate in gallons per day per square foot?

$$SOR = \frac{flow, gal/day}{area, ft^2}$$
$$= \frac{3{,}050{,}000\,gpd}{(80\,ft)(20\,ft)}$$
$$= 1906.25\,gpd/ft^2$$

4. The flow to a sedimentation tank is 50,000 gpd. If the tank is 55 feet long and 15 feet wide, what is the surface overflow rate (gpd/ft^2)?

$$SOR = \frac{50{,}000\,gpd}{(55\,ft)(15\,ft)}$$
$$= 60.61\,gpd/ft^2$$

5. A sedimentation tank is 90 feet long and 40 feet wide and receives a flow of 5.04 MGD. Calculate the SOR in gpd/ft^2.

$$SOR = \frac{5040000\ gpd}{(90ft)(40ft)}$$

$$= 1400\ gpd/ft^2$$

6. A circular clarifier has a diameter of 80 feet. If the flow to the clarifier is 3.8 MGD, what is the surface overflow rate (gpd/ft^2)?

$$SOR = \frac{3800000\ gpd}{(0.785)(80ft)(80ft)}$$

$$= 756.37\ gpd/ft^2$$

7. A clarifier has a flow rate of 4,600 gpm and a diameter of 75 feet. What is the surface overflow rate in gpd/ft^2?

$$\frac{4600\ gal}{min} \left| \frac{1440\ min}{day} \right. = 6624000\ gpd$$

$$SOR = \frac{6624000\ gpd}{(0.785)(75ft)(75ft)}$$

$$= 1500.13\ gpd/ft^2$$

8. A clarifier with a diameter of 55 feet receives a flow of 2.075 MGD. What is the surface overflow rate (gpd/ft^2)?

$$SOR = \frac{2075000\ gpd}{(0.785)(55ft)(55ft)}$$

$$= 873.82\ gpd/ft^2$$

9. What is the gpd/ft^2 overflow to a circular clarifier that has the following:
Diameter: 70 feet
Flow: 1,950 gpm

$$\frac{1950\ gal}{min} \left| \frac{1440\ min}{day} \right. = 2808000\ gpd$$

$$SOR = \frac{2808000\ gpd}{(0.785)(70ft)(70ft)} = 730.01\ gpd/ft^2$$

10. A rectangular clarifier receives a flow of 5.4 MGD. The length of the clarifier is 99 feet 7 inches and the width is 78 feet 6 inches. What is the SOR in gpd/ft^2?

$$\frac{7\text{ in} \mid \text{ft}}{12\text{in}} = 0.5833\text{ft} \qquad \frac{6\text{in} \mid \text{ft}}{12\text{in}} = 0.5\text{ft}$$

$$SOR = \frac{5400000\text{ gpd}}{(99.5833\text{ft})(78.5\text{ft})} = 690.78\ \text{gpd/ft}^2$$

Weir Overflow Rates (WOR)

11. A tank has a length of 100 feet, a width of 25 feet, and a depth of 15 feet. What is the weir length around the basin in feet?

$$\text{Weir length} = 2(\text{Weir length}) + 2(\text{Weir width})$$

$$\text{Weir} = 2(100\text{ ft}) + 2(25\text{ ft}) = 200\text{ ft} + 50\text{ ft}$$
$$= 250\text{ ft}$$

12. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the length of the weir around the clarifier in ft?

$$\text{Weir length} = (3.14)(\text{Weir diameter})$$
$$= (3.14)(82\text{ft})$$
$$= 257.48\text{ft}$$

13. A sedimentation tank has a total of 150 feet of weir over which the water flows. What is the weir overflow rate in gallons per day per foot of weir when the flow is 1.7 MGD?

$$WOR = \frac{\text{flow, gpd}}{\text{Weir length, ft}}$$

$$= \frac{1,700,000\text{ gpd}}{150\text{ ft}}$$
$$= 11,333.33\ \text{gpd/ft}$$

14. The diameter of the weir in a circular clarifier is 85 feet. What is the weir overflow rate (gpd/ft) if the flow over the weir is 2.24 MGD?

$$WOR = \frac{2224000\text{gpd}}{85\text{ft}}$$

$$= 26164.71\ \text{gpd/ft}$$

15. A sedimentation tank has a total of 200 feet of weir which the water flows over. What is the weir overflow rate (gpd/ft) when the flow is 2.2 MGD?

$$WOR = \frac{2{,}200{,}000\ gpd}{800\ ft}$$

$$= 11{,}000\ gpd/ft$$

16. The diameter of the weir in a circular clarifier is 125 feet. The flow is 6.33 MGD. What is the weir overflow rate (gpd/ft)?

$$WOR = \frac{6{,}330{,}000\ gpd}{(3.14)(125\ ft)}$$

$$= 16127.399\ gpd/ft$$

17. A tank has a diameter of 49.4 feet. What is the gallons/day per foot of weir overflow when the tank receives 1,953,000 gpd?

$$WOR = \frac{1{,}953{,}000\ gpd}{(3.14)(49.4\ ft)}$$

$$= 12590.589\ gpd/ft$$

18. The flow rate to a particular clarifier is 528 gpm and the tank has a length of 30 feet and a width of 17.5 feet. What is the gpd/ft of weir?

$$\frac{528\ gal}{min} \left| \frac{1440\ min}{day} \right. = 760320\ gpd$$

$$WOR = \frac{760320\ gpd}{2(30\ ft) + 2(17.5\ ft)}$$

$$= 8003.37\ gpd/ft$$

19. The weir in a basin measures 30 feet by 15 feet. What is the weir overflow rate (gpd/ft) when the flow is 1,098,000 gpd?

$$WOR = \frac{1{,}098{,}000\ gpd}{2(30\ ft) + 2(15\ ft)}$$

$$= 12200\ gpd/ft$$

20. What is the weir overflow rate of a clarifier that is 50 feet 4 inches by 44 feet 3 inches and has an influent flow of 1.87 MGD? $4/12 = 0.3333ft$ $3/12 = 0.25ft$

$$WOR = \frac{1870000gpd}{2(50.3333ft)+2(44.25ft)}$$

$$= 9885.47\ gpd/ft$$

Detention Time

21. A tank has a length of 100 feet, a width of 25 feet and a depth of 15 feet. What is the volume in gallons?

$$Vol, gal = (L, ft)(W, ft)(D, ft)(7.48\ gal/ft^3)$$

$$= (100ft)(25ft)(15ft)(7.48\ gal/ft^3)$$

$$= 280,500\ gal$$

22. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the volume of the clarifier in gallons?

$$Vol, gal = (0.785)(diameter, ft)^2(Depth, ft)(7.48 gal/ft^3)$$

$$= (0.785)(82ft)(82ft)(12ft)(7.48\ gal/ft^3)$$

$$= 473783.80\ gal$$

23. A circular clarifier handles a flow of 0.9 MGD. The clarifier is 50 feet in diameter and 8 feet deep. What is the detention time in hours?

$$DT = \frac{(Vol, gal)(24\ hr/d)}{flow, gpd}$$

$$= \frac{(0.785)(50ft)(50ft)(8ft)(7.48 gal/ft^3)(24hr/d)}{900,000\ gpd} = 3.13\ hrs$$

24. A clarifier is 70 feet long, 25 feet wide and 10 feet deep. If the daily flow is 2,780,000 gpd, what is the detention time (in hours) in the basin?

$$DT = \frac{(70ft)(25ft)(10ft)(7.48 gal/ft^3)(24hr/d)}{2780000gpd}$$

$$= 1.13\ hrs$$

25. What is the detention time in hours of a circular clarifier that receives a flow of 3,300 gpm and the clarifier is 65 feet in diameter and 12 feet deep?

$$DT = \frac{(0.785)(65ft)(65ft)(12ft)(7.48)(24)}{4752000gpd}$$

$$\frac{3300gal}{min} \left| \frac{1440min}{day} \right. = 4752000\ gpd$$

$$= 1.50\ hrs$$

26. A sedimentation tank is 60 feet long, 12 feet wide and has water to a depth of 12 feet. If the flow to the tank is 21,600 gph, what is the detention time in hours?

$$DT = \frac{(60ft)(12ft)(12ft)(7.48 gal/ft^3)(24 hr/d)}{518400 gpd}$$

$$\frac{21600 gal}{hr} \mid \frac{24 hr}{day} = 518400 gpd$$

$$= 2.99 hr$$

27. A circular clarifier receives a flow of 920 gpm. If it has a diameter of 55 feet and a water depth of 7 feet, what is the detention time in hours?

$$DT = \frac{(55ft)(55ft)(0.785)(7ft)(7.48 gal/ft^3)(24 hr/d)}{1324800 gpd} \cdot \frac{920 gal}{min} \mid \frac{1440 min}{day} = 1324800 gpd$$

$$= 2.25 hr$$

28. A clear well is 70 feet long, 20 feet wide and has a water to a depth of 8 feet. If the daily flow is 698 gpm, what is the detention time in minutes?

$$DT, hr = \frac{(70ft)(20ft)(8ft)(7.48 gal/ft^3)(24 hr/d)}{1005120 gpd} \quad \frac{698 gal}{min} \mid \frac{1440 min}{day} = 1005120 gpd$$

$$= (2.00 hr)\left(\frac{60 min}{hr}\right) = 120 min$$

Answers:

1. 2500 ft^2
2. 5278 ft^2
3. 1906 gpd/ft^2
4. 60.6 gpd/ft^2
5. 1400 gpd/ft^2
6. 756 gpd/ft^2
7. 1500 gpd/ft^2
8. 874 gpd/ft^2
9. 730 gpd/ft^2
10. 691 gpd/ft^2
11. 250 ft
12. 257.5 ft
13. 11333 gpd/ft
14. 8393 gpd/ft
15. 11,000 gpd/ft
16. 16,127 gpd/ft
17. 12,591 gpd/ft
18. 8003 gpd/ft
19. 12,200 gpd/ft
20. 9885 gpd/ft
21. 280,500 gal
22. 473,784 gal
23. 3.13 hr
24. 1.13 hr
25. 1.5 hr
26. 3.0 hrs
27. 2.25 hrs
28. 120 min

Applied Math for Water
Sedimentation Practice Quiz

1. The flow to a sedimentation tank is 3.85 MGD. If the tank is 70 feet long and 35 feet wide, what is the surface overflow rate (gpd/ft^2)?

$$SOR = \frac{3850000\ gpd}{(70ft)(35ft)}$$

$$= 1571.43\ gpd/ft^2$$

2. The diameter of the weir in a circular clarifier is 110 feet. The flow is 5.75 MGD. What is the weir overflow rate (gpd/ft)?

$$WOR = \frac{5750000\ gpd}{(3.14)(110ft)}$$

$$= 16647.37\ gpd/ft$$

3. A rectangular clarifier handles a flow of 3.28 MGD. The clarifier is 60 feet long, 40 feet wide and 25 feet deep. What is the detention time in <u>minutes</u>?

$$DT = \frac{(60ft)(40ft)(25ft)(7.48\ gal/ft^3)(24\ hr/day)(60\ min/hr)}{3280000\ gpd}$$

$$= 197.03\ min$$

4. A circular clarifier receives a flow of 3,472.2 gpm. What is the detention time in the clarifier (in hours)? The clarifier has a diameter of 62.5 feet and a depth of 21 feet.

$$DT = \frac{(0.785)(62.5\,ft)(62.5\,ft)(21\,ft)(7.48\,gal/ft^3)(24\,hr/d)}{(3{,}472.2\,gal/min)(1440\,min/day)}$$

$$= 2.31 \text{ hours}$$

Answers:

1. 1571 gpd/ft^2
2. 16,647 gpd/ft
3. 197 min
4. 2.3 hours

Pumps

1. A pump must pump 4,500 gpm against a total head of 75 feet. What horsepower will be required to do the work?

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

$$\frac{(4500 gpm)(75 ft)}{3960} = 85 hp$$

2. If a pump is to deliver 325 gpm of water against a total head of 75 feet, and the pump has an efficiency of 87%, what horsepower must be supplied to the pump?

$$BHP = \frac{(flow, gpm)(head, ft)}{(3960)(pump\ eff)}$$

$$= \frac{(325 gpm)(75 ft)}{(3960)(0.87)} = 7 hp$$

3. The manual indicates that the output of a certain motor is 40 hp. How much horsepower must be supplied to the motor if the motor is 95% efficient?

$$mHP = \frac{BHP}{motor\ eff.}$$

$$= \frac{40 hp}{0.95} = 42.1 hp$$

4. The water horsepower was calculated to be 20 hp. If the motor supplies the pump with 23 hp, what must be the efficiency of the pump?

$$pump\ eff = \frac{water\ hp}{brake\ hp} * 100$$

$$= \frac{20 hp}{23 hp} * 100$$

$$= 86.96\%$$

5. What is the overall efficiency if 40 hp is supplied to the motor and 26 hp of work is accomplished?

$$\text{Overall eff} = \frac{\text{water hp}}{\text{motor hp}} * 100$$

$$= \frac{26\ \text{hp}}{40\ \text{hp}} * 100 = 65\%$$

6. Given that 30 kilowatts (kW) power is supplied to a motor and the brake horsepower is 31 hp, what is the efficiency of the motor?

$$31\ \text{KW} / 0.746\ \text{KW/hp} = 41.555\ \text{hp}$$

$$\text{motor eff} = \frac{31\ \text{hp}}{41.555\ \text{hp}} * 100 = 74.6\%$$

7. A pump is discharging 1200 gpm against a head of 55 feet. The wire-water-efficiency is 75 percent. If the cost of power is $0.038/kW hr, what is the cost of the power consumed during a run of 105 hours?

$$\text{mHP} = \frac{(\text{flow, gpm})(\text{head, ft})}{(3960)(\text{pump eff})(\text{motor eff})} = \frac{(1200\text{gpm})(55\text{ft})}{(3960)(0.75)} = 22.2\ \text{hp}$$

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

$$= (22.22\text{hp})(0.746\ \text{KW/hp})(\$0.038/\text{KW-hr})$$

$$= (\$0.63/\text{hr})(105\ \text{hr}) = \$66.14$$

8. What is the horsepower for a motor that is rated at 55 amps and 440 volts?

$$\text{hp} = \frac{(\text{volts})(\text{amps})}{746\ \text{watt/hp}}$$

$$= \frac{(440)(55)}{746\ \text{W/hp}}$$

$$= 32.4\ \text{hp}$$

9. Determine the power factor for a system that uses 4971 watts and pulls 12 amps at 440 volts.

$$p.f. = \frac{\text{watts}}{(\text{volts})(\text{amps})}$$

$$= \frac{4971}{(440)(12)} = 0.94$$

10. If a single-phase motor pulls 15 amps at 220 volts and has a power factor of 1.2, how many kilowatts of power does it use?

$$KW = \frac{(\text{volts})(\text{amps})(p.f.)}{1000\ W/KW}$$

$$= \frac{(220)(15)(1.2)}{1000}$$

$$= 3.96\ KW$$

11. How many watts of power does a three-phase motor use if it pulls 30 amps at 440 volts and has a power factor of 0.93?

$$\text{watts} = (\text{volts})(\text{amps})(p.f.)(1.732)$$

$$= (440)(30)(0.93)(1.732)$$

$$= 21262.03\ \text{watts}$$

APPLIED MATH FOR WATER TREATMENT
PUMP HORSEPOWER/EFFICIENCY/COST/MOTORS

HORSEPOWER

1. A pump must pump 3,000 gpm against a total head of 25 feet. What horsepower (water horsepower) will be required to do the work?

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

$$= \frac{(3000gpm)(25ft)}{3960} = 18.94\ hp$$

2. A flow of 555 gpm must be pumped against a head of 40 feet. What is the horsepower required?

$$WHP = \frac{(555gpm)(40ft)}{3960}$$

$$= 5.61\ hp$$

3. Suppose a pump is pumping a total head of 76.2 feet. If 900 gpm is to be pumped, what is the water horsepower requirement?

$$WHP = \frac{(900gpm)(76.2ft)}{3960}$$

$$= 17.32\ hp$$

4. Suppose a pump is pumping against a total head of 46 feet. If 850 gpm is to be pumped, what is the horsepower requirement?

$$WHP = \frac{(850gpm)(46ft)}{3960}$$

$$= 9.87\ hp$$

5. A pump is delivering a flow of 835 gpm against a total head of 35.6 feet. What is the water horsepower?

$$WHP = \frac{(835gpm)(35.6ft)}{3960}$$

$$= 7.51\ hp$$

6. What is the water horsepower of a pump that is producing 1,523 gpm against a head of 65 feet?

$$WHP = \frac{(1523\,gpm)(65\,ft)}{3960}$$

$$= 25.0\,hp$$

EFFICIENCY

7. If a pump is to deliver 360 gpm of water against a total head of 95 feet, and the pump has an efficiency of 85 percent, what horsepower must be supplied to the pump?

$$BHP = \frac{(flow,\,gpm)(head,\,ft)}{(3960)(Pump\ eff.)}$$

$$= \frac{(360\,gpm)(95\,ft)}{(3960)(0.85)} = 10.16\,hp$$

8. If a pump is to deliver 450 gpm of water against a total head of 90 feet, and the pump has an efficiency of 70 percent, what horsepower must be supplied to the pump?

$$BHP = \frac{(450\,gpm)(90\,ft)}{(3960)(0.70)}$$

$$= 14.61\,hp$$

9. The motor nameplate indicated that the output of a certain motor is 35 hp. How much horsepower must be supplied to the motor, if the motor is 90% efficient?

$$MHP = \frac{BHP}{motor\ eff}$$

$$= \frac{35hp}{0.90} = 38.89\,hp$$

10. The motor nameplate indicated that the output of a certain motor is 20 hp. How much horsepower must be supplied to the motor if the motor is 90 percent efficient?

$$MHP = \frac{20hp}{0.90}$$

$$= 22.22\,hp$$

11. You have calculated that a certain pumping job will require 9 whp. If the pump is 80 percent efficient and the motor is 72 percent efficient, what motor horsepower will be required?

$$MHP = \frac{BHP}{\text{motor eff}} \qquad BHP = \frac{WHP}{\text{pump eff}}$$

$$= \frac{11.25\,hp}{0.72} = \boxed{15.63\,hp} \qquad = \frac{9\,hp}{0.80} = 11.25\,hp$$

12. You have calculated that a certain pumping job will require 6 whp. If the pump is 80 percent efficient and the motor is 90 percent efficient, what motor horsepower will be required?

$$BHP = \frac{6\,hp}{0.8} \qquad MHP = \frac{7.5\,hp}{0.90}$$

$$= 7.5\,hp \qquad = \boxed{8.3\,hp}$$

13. Based on the gallons per minute to be pumped and the total head the pump must pump against, the water horsepower requirement was calculated to be 18.5 whp. If the motor supplies the pump with 21 hp, what must be the efficiency of the pump?

$$\text{Pump eff} = \frac{WHP}{BHP} * 100$$

$$= \frac{18.5\,hp}{21\,hp} * 100 = 88.1\%$$

14. What is the overall efficiency if an electric power equivalent to 35 hp is supplied to the motor and 18.5 hp of work is accomplished?

$$\text{Overall eff} = \frac{WHP}{MHP} * 100 =$$

$$= \frac{18.5\,hp}{35\,hp} * 100 = 58.9\%$$

15. Suppose that 31 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 19 bhp, what is the efficiency of the motor?

$$\frac{31\,KW \mid 1\,HP}{\mid 0.746\,KW} = 41.555\,HP$$

$$\text{Motor eff} = \frac{BHP}{MHP} * 100$$

$$= \frac{19\,bhp}{41.555\,hp} * 100$$

$$= 45.72\%$$

16. Suppose that 10 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 12 bhp, what is the efficiency of the motor?

$$\text{motor eff} = \frac{12\,hp}{13.4048\,hp} * 100$$

$$= 89.5\%$$

$$10\,KW \left| \frac{1\,hp}{0.746\,KW} \right. = 13.4048\,hp$$

PUMPING COST

17. The motor horsepower required for a particular pumping job is 39 hp. If your power cost is $0.08/kW hr, what is the cost of operating the motor for one hour?

$$\text{Cost, \$/hr} = (MHP)(0.746\,KW/hp)(\text{Cost, \$/KW-hr})$$

$$= (39\,hp)(0.746\,KW/hp)(\$0.08/KW\text{-}hr)$$

$$= \$2.33/hr$$

18. The motor horsepower required for a particular pumping job is 30 hp. If your power cost is $0.05/kW hr, what is the cost of operating the motor for one hour?

$$\text{cost} = (30\,hp)(0.746\,KW/hp)(\$0.05/KW\text{-}hr)$$

$$= \$1.12/hr$$

19. You have calculated that the minimum motor horsepower requirement for a particular pumping problem is 25 mhp. If the cost of power is $0.025/kW hr, what is the power cost in operating the pump for 14 hours?

$$\text{cost} = (25hp)(0.746\,KW/hp)(\$0.025/KW\text{-}hr)$$

$$= (\$0.47/hr)(14\,hr)$$

$$= \$6.53$$

20. A pump is discharging 1100 gpm against a head of 65 feet. The wire-to-water efficiency is 70 percent. If the cost of power is $0.025/kW hr, what is the cost of the power consumed during a week in which the pump runs 80 hours?

$$MHP = \frac{(1100\ gpm)(65\ ft)}{(3960)(0.70)} = 25.7936\ hp$$

$$Cost = (25.7936 hp)(0.746\ kw/hp)(0.025/kw\text{-}hr)$$
$$= (\$0.48/hr)(80 hrs)$$
$$= \$38.48$$

21. Given a brake horsepower of 18.5, a motor efficiency of 88 percent and a cost of $0.015/kW hr, determine the daily power cost for operating a pump.

$$MHP = \frac{18.5 hp}{0.88} = 21.0227 hp$$

$$Cost = (21.0227 hp)(0.746\ kw/hp)(\$0.015/kw\text{-}hr)$$
$$= (\$0.24/hr)(24\ hr/day)$$
$$= \$5.65/day$$

22. A pump is discharging 1500 gpm against a head of 80 feet. The wire-to-water efficiency is 68 percent. If the cost of power is $0.035/kW hr, what is the cost of the power consumed during a week in which the pump runs 90 hours?

$$MHP = \frac{(1500\ gpm)(80\ ft)}{(3960)(0.68)} = 44.5633 hp$$

$$Cost = (44.5633 hp)(0.746\ kw/hp)(\$0.035/kw\text{-}hr)$$
$$= (\$1.16/hr)(90\ hr)$$
$$= \$104.72$$

MOTORS

23. What would be the horsepower on a motor that is rated at 36 amps and 440 volts?

$$HP = \frac{(volts)(amps)}{746\ watts/hp}$$

$$= \frac{(440)(36)}{746} = 21.23 hp$$

24. What would be the horsepower on a motor that is rated at 12 amps and 440 volts?

$$HP = \frac{(440)(12)}{746}$$

$$= 7.08 hp$$

25. What would be the horsepower on a motor that is rated at 16 amps and 440 volts?

$$HP = \frac{(440)(16)}{746}$$

$$= 9.44 hp$$

26. How many watts of power does a single-phase motor use if it pulls 12 amps at 110 volts and has a power factor of 1?

$$Watts = (volts)(amps)(power\ factor)$$

$$= (110 volts)(12 amps)(1)$$

$$= 1320 watts$$

27. How many watts of power does a single-phase motor use if it pulls 12 amps at 220 volts and has a power factor of 0.8?

$$Watts = (220 volts)(12 amps)(0.8)$$

$$= 2112 watts$$

28. How many watts of power does a single-phase motor use if it pulls 12 amps at 110 volts and has a power factor of 0.3?

$$Watts = (110 volts)(12 amps)(0.3)$$

$$= 396 watts$$

29. How many watts of power does a three-phase motor use if it pulls 20 amps at 440 volts and has a power factor of 0.85?

$$\text{Watts} = (\text{volts})(\text{amps})(\text{power factor})(1.732)$$
$$= (440)(20)(0.85)(1.732)$$
$$= 12{,}955.36 \text{ watts}$$

30. How many watts of power does a three-phase motor use if it pulls 40 amps at 440 volts and has a power factor of 0.9?

$$\text{watts} = (440)(40)(0.9)(1.732)$$
$$= 27434.88 \text{ watts}$$

31. How many kilowatts of power does a three-phase motor use if it pulls 20 amps at 440 volts and has a power factor of 0.85?

$$KW = \frac{(\text{volts})(\text{amps})(\text{pf})(1.732)}{1000 \text{ Watt/KW}}$$
$$= \frac{(440)(20)(0.85)(1.732)}{1000} = 12.96 \text{ KW}$$

32. What is the power factor on a system that uses 3872 watts and pulls 11 amps at 440 volts?

$$\text{power factor} = \frac{\text{watts}}{(\text{volts})(\text{amps})}$$
$$= \frac{3872}{(440)(11)} = 0.8$$

33. What is the power factor on a system that uses 3960 watts and pulls 10 amps at 440 volts?

$$\text{power factor} = \frac{3960}{(440)(10)}$$
$$= 0.9$$

APPLIED MATH FOR WATER TREATMENT
PUMP RATES PROBLEMS

1. During a 60-minute pumping test, 9,456 gallons are pumped into a tank that has a length of 10 feet, width of 8 feet, and depth of 6 feet. The tank was empty before the pumping test was started. What is the GPM rate?

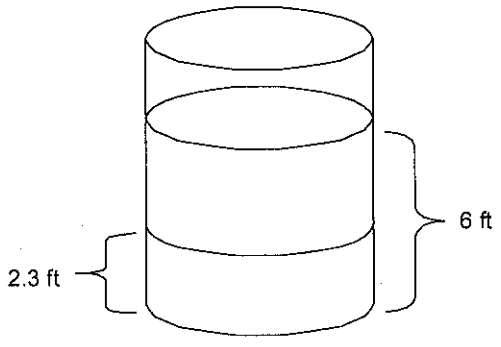
$$gal/min = \frac{9456\ gal}{60\ min} = 157.6\ gpm$$

2. During a 30-minute pumping test, 3680 gallons are pumped into a tank, which has a diameter of 10 ft. The water level before the pumping test was 3 ft. What is the GPM rate?

$$gal/min = \frac{3680\ gal}{30\ min}$$

$$= 122.67\ gpm$$

3. A 50-ft diameter tank has water to a depth of 6 feet. The inlet valve is closed and a 2-hour pumping test is begun. If the water level in the tank at the end of the test is 2.3 feet, what is the pumping rate in gallons per minute?



$$Vol = (0.785)(50ft)(50ft)(6-2.3ft)$$
$$= (7261.25\ ft^3)(7.48\ gal/ft^3)$$
$$= \frac{54314.15\ gal}{120\ min}$$
$$gal/min = 452.62\ gpm$$

4. A tank has a length of 12 feet, a depth of 12 feet, a width of 12 feet, and has water to a depth of 10 feet. If the tank can be emptied in 1 hour 37 minutes, what is the pumping rate in gallons per minute?

$$Vol,gal = (12ft)(12ft)(10ft)(7.48 gal/ft^3)$$

$$= \frac{10771.2 gal}{97 min}$$

$$gal/min = 111.04 gpm$$

5. During a pumping test, water was pumped into an empty tank 10 feet by 10 feet by 5 feet deep. The tank completely filled with water in 10 minutes 30 seconds. Calculate the pumping rate in GPM.

$$Vol,gal = (10ft)(10ft)(5ft)(7.48 gal/ft^3)$$

$$= \frac{3740 gal}{10.5 min}$$

$$gal/min = 356.19 gpm$$

6. During a 60 minute pumping test, 11,321 gallons are pumped into a tank that has a length of 15 feet, a width of 10 feet and a depth of 8 feet. The tank was empty before the pumping test was started. What is the GPM rate?

$$gal/min = \frac{11321 gal}{60 min}$$

$$= 188.68 gpm$$

7. A wet well is 15 feet long and 12 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 1.25 feet during a 5-minute pumping test, what is the gpm pumping rate?

$$Vol = (15ft)(12ft)(1.25ft)(7.48 gal/ft^3)$$

$$= \frac{1683\ gal}{5\ min}$$

$$gal/min = 336.6\ gpm$$

8. A pump is discharged into a 55-gallon barrel. If it takes 35 seconds to fill the barrel, what is the pumping rate in GPM? $35/60 = 0.5833\ min$

$$gal/min = \frac{55\ gal}{0.5833\ min}$$

$$= 94.29\ gpm$$

9. A pump is rated at 300 gpm. A pump test is conducted for 3 minutes. What is the actual gpm pumping rate if the wet well is 10 feet long and 8 feet wide and the water level drops 1.33 feet during the pump test?

$$Vol, gal = (10ft)(8ft)(1.33ft)(7.48 gal/ft^3)$$

$$= \frac{795.872\ gal}{3\ min}$$

$$gal/min = 265.29\ gpm$$

10. During a pumping test, 12,600 gallons are pumped into a tank. If the pump is rated at 210 gpm, how many minutes did it take to fill the tank?

$$210\ gal/min = \frac{12600\ gal}{x} \Longrightarrow x = \frac{12600\ gal}{210\ gpm}$$

Pumps

$$x = 60\ min$$

11. If a tank 12 feet long, 12 feet wide, 12 feet deep, and holding water to a depth of 8 feet can be emptied at a pumping rate of 575 gpm, how many minutes will it take to remove all the water?

$$575\ gal/min = \frac{(12ft)(12ft)(8ft)(7.48\ gal/ft^3}{X\ min}$$

$$X = \frac{8616.96\ gal}{575\ gpm}$$

$$X = 14.99\ min$$

ANSWERS

1. 157.6 gpm
2. 122.7 gpm
3. 452.6 gpm
4. 111 gpm
5. 356.2 gpm
6. 188.7 gpm
7. 336.6 gpm
8. 94.3 gpm
9. 265.3 gpm
10. 60 minutes
11. 15 minutes

Applied Math for Water Treatment
Pump Math
Extra Problems

1. The brake horsepower of a pump is 22 hp. If the water horsepower is 17 hp, what is the efficiency of the pump?

$$\text{pump eff} = \frac{17\text{ hp}}{22\text{ hp}} * 100$$

$$77.3\%$$

2. If the motor horsepower is 50 hp and the brake horsepower is 43 hp, what is the percent efficiency of the motor?

$$\text{motor eff} = \frac{43\text{ hp}}{50\text{ hp}} * 100$$

$$= 86\%$$

3. The motor horsepower is 25 hp. If the motor is 89% efficient, what is the brake horsepower?

$$0.89 = \frac{BHP}{25\text{ hp}}$$

$$(0.89)(25\text{ hp}) = BHP$$
$$22.25 = BHP$$

4. A total of 50 hp is supplied to a motor. If the wire-to-water efficiency of the pump and motor is 62%, what will the Whp be?

$$WHP = (50\text{ hp})(0.62)$$

$$= 31\text{ hp}$$

5. The brake horsepower is 34.4 hp. If the motor is 86% efficient, what is the motor horsepower?

$$MHP = \frac{34.4\text{ hp}}{0.86}$$

$$= 40\text{ hp}$$

6. A pump must pump 1500 gpm against a total head of 40 ft. What horsepower is required for this work?

$$WHP = \frac{(1500gpm)(40ft)}{3960}$$

$$= 15.15hp$$

7. If 20 hp is supplied to a motor (Mhp), what is the Bhp and Whp if the motor is 85% efficient and the pump is 80% efficient?

$$BHP = (20hp)(0.85) = 17hp$$

$$WHP = (17hp)(0.80) = 13.6hp$$

8. A total of 35 hp is required for a particular pumping application. If the pump efficiency is 85%, what is the brake horsepower required?

$$BHP = \frac{35hp}{0.85}$$

$$= 41.18hp$$

9. The motor horsepower requirement has been calculated to be 45 hp. How many kilowatts electric power does this represent? (Remember, 1 hp = 746 watts)

$$\frac{45hp}{} \left| \frac{746watts}{1hp} \right| \frac{1KW}{1000watts} = 33.57KW$$

10. The motor horsepower requirement has been calculated to be 75 hp. During the week, the pump is in operation a total of 144 hours. If the electricity cost is $0.06125 per kW-hr, what would be the power cost that week for the pumping?

$$Cost = (75hp)(0.746^{KW}/_{hp})(0.06125/_{KW\text{-}hr})$$

$$= (\$3.43/hr)(144hr)$$

$$= \$493.48$$

5. 77%
6. 86%
7. 22.25 Bhp
8. 31 Whp

5. 40 Mhp
6. 15 Whp
7. 17 Bhp, 13.6 Whp
8. 41.2 Bhp

9. 33.57 kW
10. $493.48

Disinfection

1. A treatment plant wants to have 1.4 mg/L residual chlorine in the distribution system. Due to a main break the demand has climbed to 0.8 mg/L. What is the required dose?

$$\text{dose} = \text{demand} + \text{residual}$$
$$= 1.4\ \text{mg/L} + 0.8\ \text{mg/L}$$
$$= 2.2\ \text{mg/L}$$

2. A city has a combined residual of 0.5 mg/L and a free residual of 1.8 mg/L. What is the total residual in mg/L?

$$\text{total} = \text{combined} + \text{residual}$$
$$= 0.5\ \text{mg/L} + 1.8\ \text{mg/L}$$
$$= 2.3\ \text{mg/L}$$

3. A water plant treats 4.3 MGD. If the chlorine dose needs to be 4.5 mg/L, what is the chlorine feed requirement in lb/day?

p.7

$$\text{lb/day} = (\text{dose, mg/L})(\text{flow, MGD})(8.34\ \text{lb/gal})$$
$$= (4.5\ \text{mg/L})(4.3\ \text{MGD})(8.34\ \text{lb/gal})$$
$$= 161.38\ \text{lb}$$

4. Determine the chlorine dose in mg/L if 17 lbs of chlorine are fed while treating 1.3 MGD of water.

p.7

$$\text{dose, mg/L} = \frac{\text{feed rate, lb/day}}{(\text{flow, MGD})(8.34\ \text{lb/gal})}$$
$$= \frac{17\ \text{lb}}{(1.3\ \text{MGD})(8.34)} = 1.57\ \text{mg/L}$$

5. How many pounds of 65% available HTH is needed to make 4 gallons of a 7% solution?

p.13

$$\text{HTH, lbs} = \frac{(\text{des. cl})(\text{des. vol})(8.34\ \text{lb/gal})}{\%\ \text{HTH}}$$
$$= \frac{(0.07)(4\ \text{gal})(8.34\ \text{lb/gal})}{0.65}$$
$$= 3.59\ \text{lb}$$

6. How many gallons of bleach (12.5% available chlorine) will it take to make a 5 % solution when added to enough water to make 50 gallons of hypochlorite?

$$\text{bleach, gal} = \frac{(\text{des. cl})(\text{des. vol})}{\%\ \text{bleach}}$$

$$\frac{(0.05)(50\ \text{gal})}{0.125} = 20\ \text{gal}$$

7. A water plant has just switched from sodium hypochlorite to chlorine gas. If they used an average of 32 gal/day of 15% sodium hypochlorite (bleach), how many pounds per day will they use of Cl_2?

$$\text{chlorine} = (\text{avail cl})(\text{vol})(8.34\ \text{lb/gal})$$
$$= (0.15)(32\ \text{gal})(8.34\ \text{lb/gal})$$
$$= 40.03\ \text{lb}$$

8. A chlorine cylinder weighs 150 pounds. Twenty four hours later the same cylinder weighs 103 pounds. What is the chlorinator feed rate in lb/day?

$$150\ \text{lb} - 103\ \text{lb} = 47\ \text{lb/day}$$

a. Estimate the chlorine dose in mg/L for the chlorinator. The flow totalizer reads 13, 597,405 gallons and 15, 078,687 gallons 24 hrs later.

$$15078687\ \text{gal} - 13597405\ \text{gal} = 1{,}481{,}282\ \text{gal}$$

$$\text{dose, mg/L} = \frac{47\ \text{lb/day}}{(1.481\ \text{MGD})(8.34)} = 3.81\ \text{mg/L}$$

b. If the setting on chlorinator does not change, how many pounds of chlorine will be left in the cylinder **2** days later?

$$(47\ \text{lb/day})(2\ \text{day}) = 94\ \text{lb}$$
$$103\ \text{lb} - 97\ \text{lb} = 6\ \text{lb}$$

c. How many 150lb cylinders will this plant need in a month (with 30 days)?

$$(47\ \text{lb/day})(30\ \text{days}) = 1410\ \text{lb}$$

$$\frac{1410\ \text{lb}}{150\ \text{lb/cylinder}} = 9.4 \Rightarrow 10\ \text{cylinders}$$

APPLIED MATH FOR WATER
DISINFECTION MATH

pg. 12

DOSE & DEMAND

1. A water system has a chlorine demand of 4.1 mg/L and wants to have a 1.1 mg/L residual. What would be the dose?

demand = dose - residual

4.1 mg/L = dose - 1.1 mg/L

4.1 mg/L + 1.1 mg/L = dose

5.2 mg/L = dose

2. A city wants to have 1.4 mg/L chlorine in the distribution system. Due to a main break the demand has climbed to 1.0 mg/L. What is the residual?

demand = dose - residual

1.0 mg/L = 1.4 mg/L - residual

1.4 mg/L - 1.0 mg/L = residual

0.4 mg/L =

3. A system just had a main break. The chlorine level of 3.3 mg/L has dropped to 0.3 mg/L. What is the chlorine demand?

demand = 3.3 mg/L - 0.3 mg/L

= 3.0 mg/L

4. A city doses the water to have a residual of 1.9 mg/L. The demand has risen because of a main break to 1.8 mg/L. What is the free residual?

residual = dose - demand

= 1.9 - 1.8

= 0.1 mg/L

5. A city has a combined residual of 0.2 mg/L and a free residual of 1.7 mg/L. What is the total residual in mg/L?

total residual = combined + free

= 0.2 mg/L + 1.7 mg/L

= 1.9 mg/L

6. The total residual in a clearwell is 2.7 mg/L. If the free residual is 2.5, what is the combined residual?

$2.7\ mg/L = combined + 2.5\ mg/L$

$2.7 - 2.5 = combined$

$0.2\ mg/L = combined$

7. The total residual in a the clearwell is 2.5 mg/L. If the free residual is 2.2mg/L, what is the combined residual?

$2.5\ mg/L = combined + 2.2\ mg/L$

$2.5 - 2.2 = combined$

$0.3\ mg/L = combined$

DOSAGE

pg. 7

8. A water plant treats 7.5 MGD. If the chlorine dose needs to be 3 mg/L, what is the chlorine requirement in pounds per day?

$feed\ rate, lb/day = (dose)(flow)(8.34\ lb/gal)$

$= (3\ mg/L)(7.5\ MGD)(8.34\ lb/gal)$

$= 187.65\ lb/day$

9. If the water plant treats 1.8 MGD and wants to dose the water with 2.8 mg/L of chlorine, what would be the lbs/day feed rate?

$lb/day = (2.8\ mg/L)(1.8\ MGD)(8.34\ lb/gal)$

$= 42.03\ lb/day$

10. How many pounds per day of chlorine are required to treat 14 million gallons of water with 3.3 mg/L of chlorine gas? Cl_2 = 100% purity

$$lb/day = \frac{(3.3\ mg/L)(14\ MGD)(8.34\ lb/gal)}{1}$$

$= 385.31\ lb/day$

11. Determine the chlorine dose in mg/L if 13 pounds of chlorine are fed while treating 968,000 gallons of water.

$$\text{dosage, mg/L} = \frac{\text{feed rate}}{(\text{flow})(8.34\ \text{lb/gal})}$$

$$= \frac{13\ \text{lb/d}}{(0.968\ \text{MG})(8.34)} = 1.61\ \text{mg/L}$$

12. Determine the chlorine dose in mg/L if 28 lbs/day is fed for a flow of 1,750,000 gpd.

$$\text{mg/L} = \frac{28\ \text{lb/day}}{(1.75\ \text{MGD})(8.34\ \text{lb/gal})}$$

$$= 1.92\ \text{mg/L}$$

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

$$\text{mg/L} = \frac{93\ \text{lb/day}}{(3.7008\ \text{MGD})(8.34\ \text{lb/gal})}$$

$$= 3.01\ \text{mg/L}$$

$$\frac{2570\ \text{gal}}{\text{min}} \left| \frac{1440\ \text{min}}{\text{day}} \right| \frac{1\ \text{MG}}{1000000\ \text{gal}}$$

$$= 3.7008\ \text{MGD}$$

14. What should the setting be on a chlorinator in lbs/24 hours if a pump usually delivers 600gpm and the desired chlorine dosage is 4mg/L?

$$\text{lb/day} = (4\ \text{mg/L})(0.864\ \text{MGD})(8.34)$$

$$= 28.82\ \text{lb/day}$$

$$\frac{600\ \text{gal}}{\text{min}} \left| \frac{1440\ \text{min}}{\text{day}} \right| \frac{1\ \text{MG}}{1000000\ \text{gal}}$$

$$= 0.864\ \text{MGD}$$

15. 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.

$$\text{dose, mg/L} = \frac{31.5\ \text{lb/day}}{(1.6\ \text{MGD})(8.34)} = 2.36\ \text{mg/L}$$

$$\text{demand} = 2.36\ \text{mg/L} - 1.85\ \text{mg/L}$$

$$= 0.51\ \text{mg/L}$$

USE THE FOLLOWING INFORMATION FOR PROBLEMS 16 – 19:

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.

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

$83\,lb - 69\,lb = 14\,lb/day$

17. 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.)

$13,528,924 - 12,982,083 = 546,841\,gal/day$

$$dose = \frac{14\,lb/day}{(0.546841\,gpd)(8.34\,lb/gal)}$$

$= 3.07\,mg/L$

18. 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.?

$(14\,lb/day)(3\,days) = 42\,lbs$

$69\,lb - 42\,lb = 27\,lb$

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

$(14\,lb/day)(30\,days) = 420\,lbs$

$$\frac{420\,lb}{150\,lb/cylinder} = 2.8 \Rightarrow 3\ cylinders$$

USE THE FOLLOWING INFORMATION FOR PROBLEMS 20 – 22:

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.

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

$298\,lb - 216\,lb = 82\,lb/8\,hr = (10.25\,lb/hr)(24\,hr/day)$

$= 246\,lb/day$

21. 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?

$$298\,lb - 246\,lb = 52\,lb$$

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

$$(246\,lb/day)(31\,days) = 7626\,lb$$

$$\frac{7626\,lb}{2000\,lb/cylinder} = 3.813 \Rightarrow 4\ cylinders$$

HYPOCHLORINATION

pg. 13

23. How many pounds of 65% available chlorine HTH is needed to make 1 gallon of 10% solution?

$$HTH, lb = \frac{(desired\ Cl)(desired\ vol)(8.34\,lb/gal)}{HTH\ avail\ Cl}$$

$$= \frac{(0.10)(1\,gal)(8.34\,lb/gal)}{0.65}$$

$$= 1.28\,lb$$

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

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

$$= 11.55\,lb$$

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

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

$$= 0.38\,lb$$

26. How many gallons of bleach (15% available chlorine) will it take to make a 4% solution when added to enough water to make 50 gallons of hypochlorite?

$$\text{bleach, gal} = \frac{(\text{des. chlorine})(\text{des volume, gal})}{\text{avail chlorine}}$$

$$= \frac{(0.04)(50\text{ gal})}{0.15} = 13.33\text{ gal}$$

27. 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?

$$\text{HTH, lbs} = \frac{(0.02)(15\text{gal})(8.34\text{ lb/gal})}{0.65}$$

$$= 3.85\text{ lbs}$$

28. How many gallons of bleach (5.25% available chlorine) will it take to make a 2% solution when added to enough water to make 8 gallons of hypochlorite?

$$\text{bleach, gal} = \frac{(0.02)(8\text{gal})}{0.0525}$$

$$= 3.05\text{gal}$$

29. Water from a well is being treated by a hypochlorinator. If the hypochlorinator is set at a pumping rate of 25 gallons per day and uses a 2% available chlorine solution, what is the chlorine dose in mg/L if the pump delivers 140 gpm?

$$\text{dose, mg/L} = \frac{(\text{bleach fed})(\text{avail chlorine})}{\text{flow}}$$

$$\frac{140\text{ gal}}{\text{min}} \left| \frac{1440\text{ min}}{\text{day}} \right| \frac{1\text{MG}}{1000000\text{gal}}$$

$$= \frac{(25\text{gpd})(0.02)}{0.2016\text{MGD}}$$

$$= 2.48\text{ mg/L}$$

30. A water plant has just switched from sodium hypochlorite to chlorine gas. If they used an average of 26 gal/day of 15% sodium hypochlorite, how many pounds per day will they use of Cl_2?

$$\text{Chlorine, lb} = (\text{avail chlorine})(\text{bleach vol})(8.34\text{ lb/gal})$$

$$= (0.15)(26\text{gal/day})(8.34\text{ lb/gal})$$

$$= 32.53\text{ lb}$$

31. A water plant has run out of calcium hypochlorite for disinfecting a storage tank. If they needed 55 pounds of HTH, how many gallons of 15% sodium hypochlorite will they need?

$$\text{bleach, gal} = \frac{(\text{HTH avail Chlorine})(\text{HTH, lb})}{(\text{bleach avail Chlorine})(8.34\ \text{lb/gal})}$$

$$= \frac{(0.65)(55\text{lb})}{(0.15)(8.34\ \text{lb/gal})}$$

$$= 28.58\ \text{gal}$$

USE THE FOLLOWING INFORMATION TO ANSWER #32 – 34:

A section of pipe 250 feet long and 10 inches in diameter is filled with water. You need to disinfect it with a chlorine dose of 50 mg/L. $10/12 = 0.8333\text{ft}$

$$\text{Vol, gal} = (0.785)(0.8333)(0.8333)(250)(7.48) = 1019.4097\ \text{gal}$$

32. How many pounds of chlorine gas will be required?

$$\text{Chem fed, lbs} = (\text{dose})(\text{vol})(8.34\ \text{lb/gal})$$

$$= (50\ \text{mg/L})(0.001019\ \text{MG})(8.34\ \text{lb/gal})$$

$$= 0.43\ \text{lbs}$$

33. How many pounds of 65% available HTH will be required?

$$\text{Chem fed, lbs} = \frac{(\text{dose})(\text{vol})(8.34)}{\%\ \text{Cl}}$$

$$= \frac{(50\ \text{mg/L})(0.001019\ \text{MG})(8.34\ \text{lb/gal})}{0.65}$$

$$= 0.65\ \text{lb HTH}$$

34. How many gallons of 5.25% available bleach will be required?

$$\text{feed rate, gal/day} = \frac{(\text{Cl dose})(\text{flow})}{\text{avail Cl}}$$

$$= \frac{(50\ \text{mg/L})(0.001019\ \text{MG})}{0.0525} = 0.97\ \text{gal/day}$$

35. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 3 to disinfect the tank. This method requires you to make up a 50 mg/L available chlorine solution that will fill approximately 5% of the tank volume. The tank holds 3 MG. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to meet the above mentioned requirements?

$$\text{Vol} = 0.05 * 3000000\ \text{gal} = 150{,}000\ \text{gal}$$

$$\text{HTH, lbs} = \frac{(50\ \text{mg/L})(0.15\ \text{MG})(8.34\ \text{lb/gal})}{0.65}$$

$$= 96.231\text{bs HTH}$$

36. How many gallons of water <u>and</u> lbs of HTH 65% available chlorine will have to be added to disinfect a tank that holds 100,000 gallons using the above mentioned requirements?

$$Vol,gal = 0.05 * 100.000gal = 5000\,gal$$

$$HTH,lbs = \frac{(50mg/L)(0.005MG)(8.34\,lb/gal)}{0.65}$$

$$= 3.21\,lbs$$

Answers:

1. 5.2 mg/L
2. 0.4 mg/L
3. 3.0 mg/L
4. 0.1 mg/L
5. 1.9 mg/L
6. 0.2 mg/L
7. 0.3 mg/L
8. 188 lbs/day
9. 42 lbs/day
10. 385 lbs/day
11. 1.61 mg/L
12. 1.92 mg/L
13. 3.01 mg/L
14. 29 lbs/24hr
15. 0.51 mg/L
16. 14 lbs/day
17. 3.07 mg/L
18. 27 lbs
19. 3 cylinders
20. 246 lbs/day
21. 52 lbs
22. 4 cylinders
23. 1.28 lbs
24. 11.5 lbs
25. 0.38 lbs
26. 13.3 gallons bleach
27. 3.8 lbs
28. 3 gallons
29. 2.48 mg/L
30. 32.5 lbs
31. 28.6 gal
32. 0.43 lbs
33. 0.65 lbs
34. 0.97 gallons
35. 150,000 gallons, 96.2 lbs
36. 5000 gallons, 3.2 lbs

Fluoridation

1. A water plant produces 1,750 gpm and the town wants to have a 0.8 mg/L of fluoride in the finished water. If fluorosilicic acid is used, what would be the fluoride feed rate in lb/day?

$$\frac{1750\ gal}{min}\left|\frac{60\ min}{1\ day}\right|\frac{1\ MG}{1000000\ gal} = 0.105\ MGD$$

$$\text{feed rate, lb/day} = \frac{(dose)(flow, MGD)(8.34\ lb/gal)}{(AFI)(purity)}$$

$$= \frac{(0.8\ mg/L)(0.105\ MGD)(8.34\ lb/gal)}{(0.23)(0.792)} = 3.85\ lb/day$$

2. A water plant produces 2750 gpm. What would be the fluoride feed rate from a saturator in gpm to obtain 0.7 mg/L in the water?

$$\text{rate, gpm} = \frac{(dose)(flow, gpm)}{18000\ mg/L}$$

$$= \frac{(0.7\ mg/L)(2750\ gpm)}{18000\ mg/L} = 0.11\ gpm$$

3. A plant uses 90 lb of sodium fluorosilicate in treating 9.6 MGD. What is the calculated dosage in mg/L?

$$\text{dose, mg/L} = \frac{(FI, lbs)(AFI)(Purity)}{(flow, MGD)(8.34)}$$

$$= \frac{(90\ lb)(0.985)(0.1607)}{(9.6\ MGD)(8.34)}$$

$$= 0.67\ mg/L$$

4. The fluoride for a plant's raw water source was measured to be 0.2 mg/L. If the city wants the finished water to contain the recommended amount of 0.7 mg/L, what mg/L of fluoride should the water plant dose?

$$FI = 0.7\ mg/L - 0.2\ mg/L = 0.5\ mg/L$$

Applied Math for Water
Fluoride

Feed Rates

1.a. A water plant produces 2,000 gpm, and the city wants to have 1.1mg/L of fluoride in the finished water. If sodium fluorosilicate were used, what would the fluoride feed rate be in lbs/day?

$$\text{feed rate, lb/day} = \frac{(\text{dose})(\text{flow, MGD})(8.34\ \text{lb/gal})}{(\text{AFI})(\text{purity})}$$

$$\frac{2000\ \text{gal}}{\text{min}} \left| \frac{1440\ \text{min}}{\text{day}} \right| \frac{1\ \text{MG}}{1000000\ \text{gal}} = 2.88\ \text{MGD}$$

$$= \frac{(1.1\ \text{mg/L})(2.88\ \text{MGD})(8.34\ \text{lb/gal})}{(0.985)(0.607)} = 44.19\ \text{lb/day}$$

1.b. Give that there are 453.6 grams in a pound, what would the fluoride feed rate for the previous problem be in gram/min?

$$\frac{44.19\ \text{lb}}{\text{day}} \left| \frac{1\ \text{day}}{1440\ \text{min}} \right| \frac{453.6\ \text{g}}{1\ \text{lb}} = 13.9\ \text{g/min}$$

2. A water plant has a daily average production of 695 gpm, and the city wants to have a 1.0mg/L fluoride in the finished water. The natural fluoride level is less than 0.1mg/L. Find the fluoride feed rate in lbs/day using sodium fluorosilicate.

$$\text{lb/day} = \frac{(1.0\ \text{mg/L})(1.0008\ \text{MGD})(8.34)}{(0.607)(0.985)}$$

$$\frac{695\ \text{gal}}{\text{min}} \left| \frac{1440\ \text{min}}{\text{day}} \right| \frac{1\ \text{MG}}{1000000\ \text{gal}} = 1.0008\ \text{MGD}$$

$$= 13.96\ \text{lb/day}$$

3. If it is known that the plant rate is 4,000 gpm and the dosage needed is 0.8mg/L, what is the fluoride feed rate in lbs/min using fluorosilicic acid?

$$\text{lb/min} = \frac{(\text{dose})(\text{flow})(8.34\ \text{lb/gal})}{(1000000)(\text{AFI})(\text{purity})}$$

$$= \frac{(0.8\ \text{mg/L})(4000\ \text{gpm})(8.34\ \text{lb/gal})}{(1000000)(0.798)(0.93)} = 0.15\ \text{lb/min}$$

4. What is the fluoride feed rate in lbs/day using <u>fluorosilicic acid</u> if the plant rate is 1.0 MGD, the natural fluoride content is 0.2mg/L, and the desired fluoride content is 1.2mg/L? dose = 1.2 mg/L - 0.2 mg/L = 1.0 mg/L

$$lb/day = \frac{(1.0\ mg/L)(1.0\ MGD)(8.34\ lb/gal)}{(0.792)(0.23)}$$

$$= 45.78\ lb/day$$

5. If a small water plant wishes to use <u>sodium fluorosilicate</u> in a dry feeder and the water plant has a flow of 180 gpm, what would the fluoride feed rate be in lbs/min? Assume 0.1mg/L natural fluoride and 1.0mg/L is the desired concentration in the finished water. dose = 1.0 - 0.1 = 0.9 mg/L

$$lb/min = \frac{(0.9\ mg/L)(180\ gpm)(8.34\ lb/gal)}{(1000000)(0.607)(0.985)}$$

$$= 0.002\ lb/min$$

Sodium Fluoride Feed Rates for Saturator

6. A water plant produces 1.0 MGD. What would the fluoride feed rate be from a saturator in gpd to obtain 1.0mg/L in the water?

$$gal/min = \frac{(dose)(flow)}{18000\ mg/L}$$

$$\frac{1\ MGD}{day} \left| \frac{1\ day}{1440\ min} \right| \frac{1000000\ gal}{1\ MG} = 694.44\ gpm$$

$$= \frac{(1.0\ mg/L)(694.44\ gpm)}{18000\ mg/L}$$

$$= 0.03858\ gpm$$

$$\frac{0.03858\ gal}{min} \left| \frac{1440\ min}{day} \right. = 55.56\ gpd$$

7. A small water plant has a daily production rate of 180 gpm and the natural fluoride level is 0.1mg/L. If 1.0mg/L fluoride is desired in the water, what feed rate in mL/min of sodium fluoride from a saturator must be maintained?

dose = 1.0 - 0.1 = 0.9 mg/L

$$gal/min = \frac{(0.9\ mg/L)(180\ gpm)}{18000\ mg/L} = 0.009\ gpm$$

$$\frac{0.009\ gal}{min} \left| \frac{3.785\ L}{gal} \right| \frac{1000\ mL}{1\ L} = 34.07\ mL/min$$

Calculated Dosages

8. A plant uses 65lbs of sodium fluorosilicate in treating 5,540,000 gallons of water in one day. What is the calculated dosage in mg/L?

$$mg/L = \frac{(fluoride)(AF)(purity)}{(flow)(8.34)}$$

$$= \frac{(65lbs)(0.607)(0.985)}{(5.54MGD)(8.34)} = 0.84\ mg/L$$

9. A plant uses 26lbs of sodium fluorosilicate to treat 1,756,000 gallons of water. What is the calculated dosage for this plant in mg/L?

$$mg/L = \frac{(26lbs)(0.607)(0.985)}{(1.756MGD)(8.34)}$$

$$= 1.06\ mg/L$$

10. A water plant has an actual production rate of 0.8MGD. If 10lbs of sodium fluorosilicate was fed in one day, what is the calculated dosage in mg/L?

$$mg/L = \frac{(10lb)(0.607)(0.985)}{(0.8MGD)(8.34)}$$

$$= 0.90\ mg/L$$

11. A plant uses 43lbs of fluorosilicic acid in treating 1,226,000 gallons of water. What is the calculated dosage in mg/L?

$$mg/L = \frac{(43lb)(0.792)(0.23)}{(1.226MG)(8.34)}$$

$$= 0.77\ mg/L$$

12. A plant uses 898lbs of fluorosilicic acid in treatment of 17,058,000 gallons of water. What is the calculated dosage in mg/L?

$$mg/L = \frac{(898lb)(0.792)(0.23)}{(17.058MG)(8.34)}$$

$$= 1.15\ mg/L$$

13. A water plant uses a total of 2,800lbs of fluorosilicic acid at 28% purity during 4 days to fluoridate 52 million gallons of water. What would be the calculated dosage in mg/L?

$$mg/L = \frac{(2800lb)(0.28)(0.792)}{(52MG)(8.34)}$$

$$= 1.43 mg/L$$

14. A water plant feeds sodium fluoride in a dry feeder. They use 5.5lbs of the chemical to fluoridate 240,000 gallons of water. What is the calculated dosage in mg/L?

$$mg/L = \frac{(5.5lb)(0.452)(0.98)}{(0.24MG)(8.34)}$$

$$= 1.22 mg/L$$

15. A plant uses 10 gallons of sodium fluoride from a saturator in treating 200,000 gallons of water. What is the calculated dosage in mg/L?

$$mg/L = \frac{(sol'n\ fed)(18000mg/L)}{flow, gpd}$$

$$= \frac{(10gal)(18000mg/L)}{200,000gpd}$$

$$= 0.9 mg/L$$

16. A plant uses 19 gallons of solution from its saturator in treating 360,000 gallons of water. What is the calculated dosage in mg/L?

$$mg/L = \frac{(19gal)(18000mg/L)}{360,000gpd}$$

$$= 0.95 mg/L$$

17. A small water plant uses sodium fluoride from a saturator at a rate of 1.0 gpd and the plant treats 4500gpd. What is the calculated dosage in mg/L?

$$mg/L = \frac{(1gal)(18000mg/L)}{4500gpd} = 4 mg/L$$

Applied Math for Water

Fluoride Practice Quiz

1. A water plant has a daily average production of 1,736 gpm and the city wants to have a 1.0 mg/L fluoride level in the finished water. How many lbs/day of sodium fluorosilicate would be required to reach this dosage?

$$lb/day = \frac{(1\,mg/L)(2.5\,MGD)(8.34\,lb/gal)}{(0.607)(0.985)}$$

$$= 34.87\,lb/day$$

$$\frac{1736\,gal}{min}\left|\frac{1440\,min}{day}\right|\frac{1\,MG}{1000000\,gal} = 2.50\,MGD$$

2. What is the fluoride feed rate in lbs/day using fluorosilic acid if the plant rate is 1.0 MGD, the natural fluoride level is 0.3 mg/L, and the desired fluoride level is 1.2 mg/L?

$$lb/day = \frac{(0.9\,mg/L)(1\,MGD)(8.34\,lb/gal)}{(0.792)(0.23)}$$

$$= 41.21\,lb/day$$

$dose = 1.2 - 0.3 = 0.9\ mg/L$

3. A small water plant wishes to use sodium fluoride in a dry feeder and the water plant has a capacity (flow) of 220 gpm, what would the fluoride feed rate be in grams/min? Assume a 0.1 mg/L natural fluoride and 1.0 mg/L is desired in the drinking water.

$dose = 1 - 0.1 = 0.9\,mg/L$

$$lb/day = \frac{(0.9\,mg/L)(0.3168\,MGD)(8.34\,lb/gal)}{(0.452)(0.985)}$$

$$= 5.34\,lb/day$$

$$\frac{220\,gal}{min}\left|\frac{1440\,min}{day}\right|\frac{1\,MG}{1000000\,gal} = 0.3168\,MGD$$

$$gram/min = \frac{(5.34\,lb/day)(453.6\,gram/lb)}{1440\,min/day}$$

$$= 1.68\,gram/min$$

4. A plant uses 69 lbs of sodium fluorosilicate in treating 4,950,000 gallons of water in one day. What is the calculated dosage in mg/L?

$$mg/L = \frac{(69\,lb)(0.607)(0.985)}{(4.95\,MGD)(8.34)}$$

$$= 1.0\,mg/L$$

5. A water plant produces 0.75 MGD. What would the fluoride feed rate from a sodium fluoride saturator be, in gph, to obtain 1.0 mg/L in the water?

$$gal/min = \frac{(1.0\,mg/L)(520.83\,gpm)}{18{,}000\,mg/L}$$

$$\frac{0.75\,MG}{day} \left| \frac{day}{1440\,min} \right| \frac{1{,}000{,}000\,gal}{MG} = 520.83\,gph$$

$$= 0.028935\,gpm$$

$$\frac{0.028935\,gal}{min} \left| \frac{60\,min}{hr} \right. = 1.74\,gal/hour$$

Answers:
1. 34.9 lbs/day
2. 41.2 lbs/day
3. 1.7 grams/min
4. 1.0 mg/L
5. 1.7 gph

Stabilization

1. Calculate the Langlier Index for a water sample based on the following information:

pH	=	7.8
temperature	=	20°C
TDS	=	100 mg/L
calcium	=	90 mg/L as $CaCO_3$ → 1.95
alkalinity	=	170 mg/L as $CaCO_3$ → 2.23

$pH_s = A + B - \log Ca - \log alk$

$= 2.04 + 9.75 - 1.95 - 2.23$

$= 7.61$

A = 2.04

B = 9.75

$LI = pH - pH_s$

$= 7.8 - 7.61$

$= 0.19 \rightarrow$ non-aggressive

2. Calculate the Aggressive Index for a water sample based on the following information:

total alkalinity	=	100 mg/L as $CaCO_3$
calcium	=	65 mg/L as $CaCO_3$
pH	=	7.2

$AI = pH + \log Ca + \log alk$

$= 7.2 + 2 + 1.81$

$= 11.01 \rightarrow$ moderately aggressive

Applied Math for Water

Stabilization Math

Langelier Index – Determine the LI and the corrosive characteristics:

1. Calculate the Langelier Index for the following information:

pH	=	7.65
temperature	=	15°C A = 2.12
TDS	=	200 mg/L B = 9.8
Calculation	=	80 mg/L as $CaCO_3$ = 1.90
Alkalinity	=	100 mg/L as $CaCO_3$ = 2.00

$pH_s = A + B - \log(Ca) - \log(alk)$

$= 2.12 + 9.8 - 1.9 - 2.0$

$= 8.02$

$LI = pH - pH_s$

$= 7.65 - 8.02$

$= -0.37 \Rightarrow$ moderately aggressive

2. Calculate the Langelier Index for the following information:

pH	=	7.4
temperature	=	20°C A = 2.04
TDS	=	200 mg/L B = 9.8
Calcium	=	80 mg/L as $CaCO_3$ = 1.90
Alkalinity	=	100 mg/L as $CaCO_3$ = 2.0

$pH_s = 2.04 + 9.8 - 1.90 - 2.00 = 7.94$

$LI = 7.4 - 7.94 = -0.54$

moderately aggressive

3. Calculate the Langelier Index for the following information:

pH	=	7.4
temperature	=	20°C A = 2.04
TDS	=	400 mg/L B = 9.86
Calcium	=	100 mg/L as $CaCO_3$ = 2.0
Alkalinity	=	100 mg/L as $CaCO_3$ = 2.0

$pH_s = 2.04 + 9.86 - 2.0 - 2.0 = 7.9$

$LI = 7.4 - 7.9 = -0.5$

moderately aggressive

4. Calculate the Langelier Index for the following information:

pH	=	7.0
temperature	=	15°C
TDS	=	200 mg/L
Calcium	=	10 mg/L as $CaCO_3$
Alkalinity	=	10 mg/L as $CaCO_3$

A = 2.12
B = 9.8
log Ca = 1.0
log Alk = 1.0

$pH_s = 2.12 + 9.8 - 1.0 - 1.0 = 9.92$

$LI = 7.0 - 9.92 = -2.92$

highly aggressive

5. Calculate the Langelier Index for the following information:

pH	=	7.6
temperature	=	25°C
TDS	=	400 mg/L
Calcium	=	150 mg/L as $CaCO_3$
Alkalinity	=	170 mg/L as $CaCO_3$

A = 1.98
B = 9.86
log Ca = 2.18
log alk = 2.23

$pH_s = 1.98 + 9.86 - 2.18 - 2.23 = 7.43$

$LI = 7.6 - 7.43 = 0.17$

non aggressive

6. Calculate the Langelier Index for the following information:

pH	=	8.6
temperature	=	15°C
TDS	=	200 mg/L
Calcium	=	50 mg/L as $CaCO_3$
Alkalinity	=	100 mg/L as $CaCO_3$

A = 2.12
B = 9.8
log Ca = 1.70
log alk = 2.00

$pH_s = 2.12 + 9.8 - 1.70 - 2 = 8.22$

$LI = 8.6 - 8.22 = 0.38$

non-aggressive

Aggressive Index – Determine the AI and the corrosive characteristics:

7. Calculate the aggressive index for the following information:

Total alkalinity	=	100 mg/L as $CaCO_3$	log alk = 2.0
Calcium	=	70 mg/L as $CaCO_3$	log Ca = 1.84
pH	=	7.6	

AI = pH + log Ca + log alk

= 7.6 + 1.84 + 2.0

= 11.44 moderately aggressive

8. Calculate the aggressive index for the following information:

Total alkalinity	=	270 mg/L as $CaCO_3$	log alk = 2.43
Calcium	=	200 mg/L as $CaCO_3$	log Ca = 2.30
pH	=	7.3	

AI = 7.3 + 2.43 + 2.30

= 12.03

non-aggressive

9. Calculate the aggressive index for the following information:

Total alkalinity	=	100 mg/L as $CaCO_3$	log alk = 2.00
Calcium	=	50 mg/L as $CaCO_3$	log Ca = 1.70
pH	=	7.2	

AI = 7.2 + 2.0 + 1.70

= 10.9

moderately aggressive

10. Calculate the aggressive index for the following information:

Total alkalinity	=	100 mg/L as $CaCO_3$	log alk = 2.0
Calcium	=	70 mg/L as $CaCO_3$	log Ca = 1.84
pH	=	7.2	

AI = 7.2 + 2.0 + 1.84

= 11.04 moderately aggressive

11. Calculate the aggressive index for the following information:

Total alkalinity	=	100 mg/L as $CaCO_3$	log alk = 2.0
Calcium	=	80 mg/L as $CaCO_3$	log Ca = 1.90
pH	=	7.1	

AI = 7.1 + 2.0 + 1.90

= 11

moderately aggressive

12. Calculate the aggressive index for the following information:

Total alkalinity	=	20 mg/L as $CaCO_3$	log alk = 1.3
Calcium	=	15 mg/L as $CaCO_3$	log Ca = 1.18
pH	=	7.0	

AI = 7.0 + 1.3 + 1.18

= 9.48

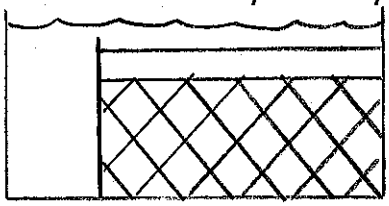
highly aggressive

Answers:

1. – 0.37 MA
2. – 0.55 MA
3. – 0.51 MA
4. – 2.92 HA
5. 0.17 NA
6. 0.38 NA
7. 11.45 MA
8. 12.03 NA
9. 10.9 MA
10. 11.05 MA
11. 11.0 MA
12. 9.48 HA

Filtration

1. The Cartersville WTP treats an average of 2.97 MGD. The water is split equally to each of 6 filters. Each filter basin measures 10 feet wide by 20 feet long and 22 feet deep. Each filter bed measures 8 ft by 17 ft by 15 ft deep.



a. Determine the daily flow to each of the filters in gallons per minute.

$$\frac{2{,}970{,}000\ \text{gpd}}{6\ \text{filters}} = 495{,}000\ \text{gpd/filter}$$

b. The influent line to filter 5 is closed while the effluent remains open. Using a hook gauge and a stop watch, it is noted that the water level in the filter drops 6 inches in 70 seconds. What is the filtration rate in gallons per minute?

$$\text{vol, gal} = (10\text{ft})(20\text{ft})(0.5\text{ft})(7.48) = 748\ \text{gal}$$

$$\text{time} = 70\text{s} / 60^{\text{s}}/\text{min} = 1.17\text{min}$$

$$\text{gpm} = \frac{748\ \text{gal}}{1.17\ \text{min}} = 641.1429\ \text{gal/min}$$

c. What is the filtration rate in gallon per minute per filter per square foot of surface area?

$$\text{basin area} = (10\text{ft})(20\text{ft}) = 300\ \text{ft}^2$$

$$\text{filter rate} = \frac{641.1429\ \text{gpm}}{300\ \text{ft}^2} = 2.1371\ \text{gpm/ft}^2$$

d. A hook gauge was used to determine the rate of rise in the filter bed during the backwash cycle. The water rose 6 inches in 20 seconds. What is the backwash rate in gallons per minute?

$$\text{vol, gal} = (8\text{ft})(17\text{ft})(0.5\text{ft})(7.48) = 508.64\ \text{gal}$$

$$\text{gpm} = \frac{508.64\ \text{gal}}{0.333\ \text{min}} = 1525.92\ \text{gal/min}$$

e. Calculate the filter backwash rate in gallons per minute per square foot.

$$\text{area} = (8\,ft)(17\,ft) = 136\,ft^2$$

$$gpm/ft^2 = \frac{1525.92\,gpm}{136\,ft^2} = 11.22\,gpm/ft^2$$

f. Calculate the gallons of water used to backwash the filter if it was backwashed for 15 minutes.

$$\text{backwash vol} = (\text{rate, } gpm/ft^2)(\text{time, min})(\text{filter area})$$

$$= (11.22\,gpm/ft^2)(15\,min)(136\,ft^2) = 22{,}888.80\,gal$$

g. During a filter run of 75 hours, the total volume of water filtered was 2.8 million gallons. Calculate the percent of the product water used for backwashing.

$$\%\,\text{backwash} = \frac{\text{backwash water}}{\text{filtered water}} * 100$$

$$= \frac{22888.80\,gal}{2800000\,gal} * 100$$

$$= 0.82\,\%$$

APPLIED MATH FOR WATER
FILTER MATH

BASICS

1. A filter basin and its sand bed measure 28 feet by 16 feet. Calculate its sand bed area in ft^2.

$$\text{sand bed area, } ft^2 = (\text{length, ft})(\text{width, ft})$$
$$= (28\,ft)(16\,ft)$$
$$= 448\,ft^2$$

2. The same filter basin that measures 28 feet by 16 feet has the water drop 6 inches, what was volume in gallons of the drop test? $6/12 = 0.5$

$$\text{Vol, gal} = (28\,ft)(16\,ft)(0.5\,ft)(7.48\,gal/ft^3)$$
$$= 1675.52\,gal$$

3. The filter drop test was timed. The test times were 68 seconds, 72 seconds and 71 seconds. What was the average time in minutes?

$$\text{avg} = \frac{68s + 72s + 71s}{3} = 70.3\,sec$$

$$70.3\,sec \left| \frac{1\,min}{60\,sec} \right. = 1.17\,min$$

4. A filter measures 28 feet by 20 feet. The influent is closed and the effluent is opened and the water drops 6 inches in 2 minutes. What is the filter rate in gallons per minute? $6/12 = 0.5\,ft$

$$\text{Vol, gal} = (28\,ft)(20\,ft)(0.5\,ft)(7.48\,gal/ft^3)$$
$$= \frac{2094.4\,gal}{2\,min}$$
$$gal/min = 1047.2\,gpm$$

5. A filter measures 28 feet by 20 feet. The influent is closed and the effluent is opened and the water drains down 6" in 2 minutes. What is the filter loading rate in gallons per minute per square foot?

$$\text{vol, gal} = (28\text{ft})(20\text{ft})(0.5\text{ft})(7.48\text{gal/ft}^3) = 2094.4\text{ gal}$$

$$\text{sand area, ft}^2 = (28\text{ft})(20\text{ft}) = 560\text{ ft}^2$$

$$\text{gpm} = \frac{2094.4\text{gal}}{2\text{min}} = 1047.2\text{gpm} \qquad \text{gpm/ft}^2 = \frac{1047.2\text{gpm}}{560\text{ft}^2} = 1.879\text{gpm/ft}^2$$

6. A filter measures 26 feet by 15 feet. The influent line is shut and the water drops 2.6 inches per minute. Calculate the rate of filtration in MGD.

$2.6/12 = 0.2167\text{ft}$

$$\text{gal/min} = \frac{(26\text{ft})(15\text{ft})(0.2167\text{ft})(7.48\text{gal/ft}^3)}{1\text{ min}} = 632.06\text{ gpm}$$

$$\frac{632.06\text{gal}}{\text{min}} \left| \frac{1440\text{min}}{\text{day}} \right| \frac{1\text{MG}}{1000000\text{gal}} = 0.91\text{MGD}$$

7. A filter measures 26 feet by 15 feet and has a filter media depth of 36 inches. Assuming a backwash rate of 15 gpm/ft^2 and 11 minutes of backwash required, how many gallons of water are required for each backwash?

$$\text{backwash vol, gal} = (\text{backwash rate})(\text{time})(\text{filter area})$$

$$= (15\text{gpm/ft}^2)(11\text{min})(26\text{ft})(15\text{ft})$$

$$= 64350\text{gal}$$

8. The filter in Problem #7 filtered 13.95 MG during the last filter run. Based on the gallons produced and the gallons required to backwash the filter, calculate the percent of the product water used for backwashing.

$$\%\text{ backwash} = \frac{64350\text{gal}}{13950000\text{gal}} * 100$$

$$= 0.46\%$$

USE THE FOLLOWING INFORMATION FOR PROBLEMS 9a – g.

9. The Randyville Water Plant treats an average of 5.18 MGD. The water is split equally to each of the 8 filters. Each filter basin measures 12 feet wide by 16 feet long and by 24 feet deep. Each filter bed measures 12 feet by 14 feet by 11 feet deep. $5.18\ MGD / 8\ filters = 0.6475\ MGD/filter$

a. Determine the daily flow to each of the filters in gallons per minute.

$$\frac{0.6475\ MG}{day} \left| \frac{day}{1440\ min} \right| \frac{1{,}000{,}000\ gal}{1\ MG} = 449.56\ gpm$$

b. The influent line to Filter 6 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 7 inches in 80 seconds. What is the filtration rate in gallons per minute? $7/12 = 0.5833$ ft

$$Vol, gal = (12ft)(16ft)(0.5833ft)(7.48\ gal/ft^3)$$

$$= \frac{837.76\ gal}{1.3333\ min} \qquad 80/60 = 1.33\ min$$

$$gal/min = 628.32\ gpm$$

c. What is the filtration rate in gallons per minute per filter per square foot of surface area?

$$Sand\ area, ft^2 = (12ft)(14ft) = 168\ ft^2$$

$$gpm/ft^2 = \frac{628.32\ gpm}{168\ ft^2} = 3.749\ gpm/ft^2$$

d. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 7 inches in 15 seconds. What is the backwash rate in gallons per minute? $7/12 = 0.5833\ ft$ $15/60 = 0.25\ min$

$$gal/min = \frac{(12ft)(14ft)(0.5833ft)(7.48)}{0.25\ min}$$

$$= 2932.16\ gpm$$

e. Calculate the filter backwash rate in gallons per minute per square foot.

$$gpm/ft^2 = \frac{2932.16\ gpm}{(12\ ft)(14\ ft)}$$

$$= 17.45\ gpm/ft^2$$

f. Calculate the gallons of water used to backwash the filter if it was backwashed for 15 minutes.

$$backwash_t vol = (17.45\ gpm/ft^2)(15\ min)(168\ ft^2)$$

$$= 43982.4\ gal$$

g. During a filter run of 95 hours the total volume of water filtered was 3.80 million gallons. Calculate the percent of the product water used for backwashing.

$$\%\ backwash = \frac{43982.4\ gal}{3800000\ gal} * 100$$

$$= 1.15\%$$

USE THE FOLLOWING INFORMATION FOR PROBLEMS 10a – g.

10. The Chrisburg Water Plant treats an average of 7.2 MGD. The water is split equally to each of 8 filters. Each filter basin measures 12.5 feet wide by 16.5 feet long by 24 feet deep. Each filter bed measures 12.5 feet by 14 feet by 10 feet deep.

a. Determine the daily flow to each of the filters.

$$\frac{7.2\ MGD}{8\ filters} = 0.9\ MGD/filter$$

b. The influent line to Filter 6 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 6 inches in 69 seconds on test 1, 6 inches in 67 seconds on test 2 and 6 inches in 70 seconds on test 3. What is the filtration rate in gallons per minute?

$$\text{Vol, gal} = (12.5\text{ft})(16.5\text{ft})(0.5\text{ft})(7.48) = 771.375\text{gal}$$

$$\text{avg time} = \frac{69\text{s} + 67\text{s} + 70\text{s}}{3} = 68.67\text{sec} / 60^{\text{sec}}/_{\text{min}} = 1.14\text{min}$$

$$\text{gal}/\text{min} = \frac{771.375\text{gal}}{1.14\text{min}} = 676.64\text{gpm}$$

c. What is the filtration rate in gallons per minute per square foot of surface area?

$$\text{gpm}/\text{ft}^2 = \frac{676.64\text{gpm}}{(12.5\text{ft})(14\text{ft})} = 3.86\,\text{gpm}/\text{ft}^2$$

d. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 13 seconds. What is the backwash rate in gallons per minute?

$13/60 = 0.2167$ min

$$\text{Vol, gal} = (12.5\text{ft})(14\text{ft})(0.5\text{ft})(7.48) = 654.5\text{gal}$$

$$\text{gal}/\text{min} = \frac{654.5\text{gal}}{0.2167\text{ min}}$$

$$= 3020.77\text{gpm}$$

e. Calculate the filter backwash rate in gallons per minute per square foot.

$$\text{gpm}/\text{ft}^2 = \frac{3020.77\text{gpm}}{(12.5\text{ft})(14\text{ft})}$$

$$= 17.26\,\text{gpm}/\text{ft}^2$$

f. Calculate the gallons of water used to backwash the filter if it was backwashed for 20 minutes.

$$\text{backwash vol} = (17.26\,\text{gpm}/\text{ft}^2)(20\text{ min})(12.5\text{ft})(14\text{ft})$$

$$= 60415.38\text{ gal}$$

g. During a filter run of 95 hours the total volume of water filtered was 3.74 million gallons. Calculate the percent of the product water used for backwashing.

$$\%\ \text{backwash} = \frac{60415.38\ \text{gal}}{3740000\ \text{gal}} * 100$$

$$= 1.61\%$$

11. Calculate the filtration rate in gpm/ft^2 for a filter with a sand area of 26 feet by 22 feet when the applied flow is 2.36 MGD.

$$\frac{2.36\ \text{MG}}{\text{day}} \left| \frac{1\ \text{day}}{1440\ \text{min}} \right| \frac{1000000\ \text{gal}}{1\ \text{MG}} = 1638.89\ \text{gpm}$$

$$\text{gpm/ft}^2 = \frac{1638.89\ \text{gpm}}{(26\text{ft})(22\text{ft})}$$

$$= 2.87\ \text{gpm/ft}^2$$

12. Determine the filtration rate in gpm/ft^2 for a filter with a surface of 28 feet by 20 feet. With the influent valve closed, the water above the filter dropped 12 inches in 4 minutes.

$$\text{vol, gal} = (28\text{ft})(20\text{ft})(1\text{ft})(7.48)$$

$$= \frac{4188.8\ \text{gal}}{4\ \text{min}}$$

$$\text{gal/min} = 1047.2\ \text{gpm}$$

$$\text{gpm/ft}^2 = \frac{1047.2\ \text{gpm}}{(28\text{ft})(20\text{ft})}$$

$$= 1.87\ \text{gpm/ft}^2$$

13. A filter measures 26 feet by 15 feet. The influent line is shut and the water drops 2.6 inches per minute, calculate the rate of filtration in MGD.

$2.6/12 = 0.2167\text{ft}$

$$\text{vol, gal} = (26\text{ft})(15\text{ft})(0.2167\text{ft})(7.48)$$

$$= 632.06\ \text{gal/min}$$

$$\frac{632.06\ \text{gal}}{\text{min}} \left| \frac{1440\ \text{min}}{\text{day}} \right| \frac{1\ \text{MG}}{1000000\ \text{gal}} = 0.91\ \text{MGD}$$

14. The filter in Problem #13 has a filter media depth of 36 inches. Assuming a backwash rate of 15 gpm/ft^2 and 6 minutes of backwash, how many gallons of water is required for each backwash?

$$\text{backwash, vol} = (15\ \text{gpm/ft}^2)(6\ \text{min})(26\text{ft})(15\text{ft})$$

$$= 35,100\ \text{gal}$$

15. A filter plant has 6 filters, each measuring 20 feet X 15 feet. One filter is out of service. The other five filters are capable of filtering 500 GPM each. How many gallons per minute per square foot will each filter?

$$gpm/ft^2 = \frac{500 gpm}{(20ft)(15ft)}$$

$$= 1.67 gpm/ft^2$$

16. A filter is 30 feet X 20 feet. If, when the influent valve is closed, the water above the filter drops 3.7 inches per minute, what is the rate of filtration in MGD?

$3.7/12 = 0.3083 ft$

$$gal/min = \frac{(30ft)(20ft)(0.3083ft)(7.48)}{1 min}$$

$$= 1383.8 gal/min$$

$$\frac{1383.8 gal}{min} \left| \frac{1440 min}{day} \right| \frac{1MG}{1000000 gal} = 1.99 MGD$$

17. Determine the backwash pumping rate in gallons per minute for a filter 33 feet by 21 feet if the desired backwash rate is 17 GPM/ft^2.

$$gpm = (17 gpm/ft^2)(33ft)(21ft)$$

$$= 11,781 gpm$$

18. Determine the volume of water in gallons required to backwash the filter in the previous problem if the filter is backwashed for 6 minutes.

$$backwash\ vol = (17 gpm/ft^2)(6 min)(33ft)(21ft)$$

$$= 70,686 gal$$

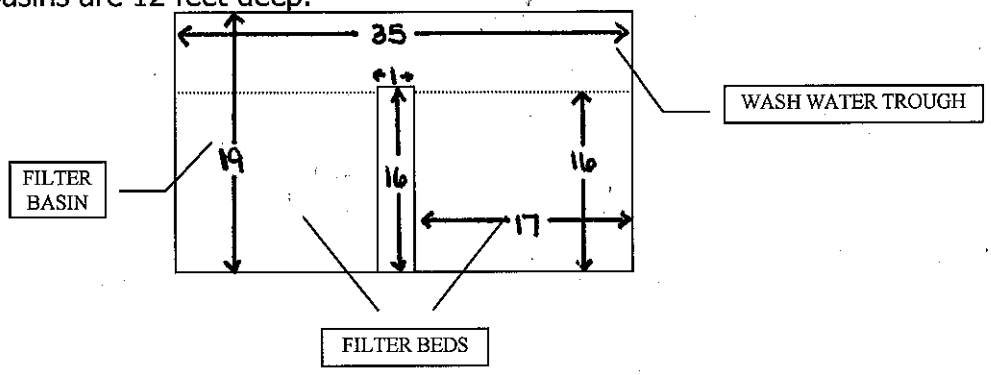
19. During a filter run the total volume of water filtered was 14.65 million gallons. When the filter was backwashed, 72,560 gallons of water were used. Calculate the percent of the filtered water used for backwashing.

$$\%\ \text{backwash} = \frac{72560\ \text{gal}}{14650000\ \text{gal}} * 100$$

$$= 0.49\%$$

USE THE FOLLOWING INFORMATION FOR PROBLEMS 21a – 21g
(put your thinking cap on)

20. The Billyville Water Treatment Plant treats an average of 8.0 MGD. The water is split equally to each of four filters. Each filter basin measures 35 feet long by 19 feet wide and has a divider wall jutting out into the middle measuring 1 foot by 16 feet. Each filter basin contains two filter beds, each measuring 17 feet by 16 feet. The filter basins are 12 feet deep.



a. Determine the daily flow to each of the filters.

$$\frac{8\ \text{MGD}}{4\ \text{filters}} = 2.0\ \text{MGD/filter}$$

b. The influent line to Filter 1 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 6 inches in 93 seconds. What is the filtration rate in gallons per minute? $6/12 = 0.5\ \text{ft}$

$$\text{filter area} = [(35\text{ft})(19\text{ft}) - (1\text{ft})(16\text{ft})] = 649\ \text{ft}^2$$

$93/60 = 1.55\ \text{min}$

$$\text{vol, gal} = (649\ \text{ft}^2)(0.5\text{ft})(7.48)$$

$$= \frac{2427.26\ \text{gal}}{1.55\ \text{min}}$$

$$\text{gal/min} = 1565.97\ \text{gpm}$$

c. What is the filtration rate in gallons per minute per square foot of surface area?

$$gpm/ft^2 = \frac{1565.97\ gpm}{(2)(17ft)(16ft)}$$

$$= 2.889 gpm/ft^2$$

d. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 19.5 seconds. What is the backwash rate in gallons per minute?

$6/12 = 0.5\ ft$

$19.5/60 = 0.325\ min$

$$Vol, gal = (2)(17ft)(16ft)(0.5ft)(7.48)$$

$$= \frac{2034.56 gal}{0.325 min}$$

$$gal/min = 6260.18 gpm$$

e. Calculate the filter backwash rate in gallons per minute per square foot.

$$gpm/ft^2 = \frac{6260.18 gpm}{(2)(17ft)(16ft)}$$

$$= 11.519 gpm/ft^2$$

f. Calculate the gallons of water used to backwash the filter if it was backwashed for 11 minutes.

$$backwash\ vol = (11.519 gpm/ft^2)(11 min)(2)(17ft)(16ft)$$

$$= 68,862.03 gal$$

g. During a filter run of 117 hours the total volume of water filtered was 8.78 million gallons. Calculate the percent of the product water used for backwashing.

$$\% backwash = \frac{68862.03 gal}{8780000 gal} * 100$$

$$= 0.78\%$$

Coagulation/Flocculation

p.5 1. The average flow for a water plant is 5.2 MGD. A jar test indicates that the best alum dosage is 3.5 mg/L. How many pounds per day will the operator feed?

$$\text{lb/day} = (\text{dose})(\text{flow})(8.34\ \text{lb/gal})$$
$$= (3.5\ \text{mg/L})(5.2\ \text{MGD})(8.34\ \text{lb/gal})$$
$$= 151.79\ \text{lb/day}$$

pg.11 2. The average flow for a water plant 1,200,000 gallons per day. A jar test indicates that the best alum dosage is 1.8 mg/L. How many grams per minute should the feeder deliver?

$$\text{gram/min} = \frac{(\text{dose})(\text{flow})(3.785\ \text{L/gal})}{(1440\ \text{min/day})(1000\ \text{mg/g})}$$
$$= \frac{(1.8\ \text{mg/L})(1200000\ \text{gpd})(3.785)}{(1440)(1000)} = 5.689\ \text{/min}$$

pg.5 3. A plant used 39 pounds of alum treating 3.7 MGD. Calculate the dose in mg/L.

$$\text{dose, mg/L} = \frac{\text{feed rate, lb/day}}{(\text{flow})(8.34\ \text{lb/gal})}$$
$$= \frac{39\ \text{lb}}{(3.7\ \text{MGD})(8.34\ \text{lb/gal})}$$
$$= 1.26\ \text{mg/L}$$

4. Liquid polymer is supplied to a water treatment plant as a 9% solution. How many gallons of this liquid is required to make 150 gallons of 1.5% polymer solution?

$$C_1V_1 = C_2V_2$$
$$(0.09)(V_1) = (0.015)(150\ \text{gal})$$
$$V_1 = \frac{(0.015)(150\ \text{gal})}{0.09}$$
$$V_1 = 25\ \text{gal}$$

pg. 11

5. Liquid alum delivered to a water treatment plant contains 795.4 milligrams of alum per milliliter of liquid solution. Jar test indicate that the best alum dose is 5 mg/L. Determine the setting on the liquid alum feeder in milliliters per minute if the flow is 2.8 MGD.

$$mL/min = \frac{(dose)(flow, gpd)(3.785\ L/gal)}{(conc, mg/mL)(1440\ min/day)}$$

$$= \frac{(5\ mg/L)(2800000\ gpd)(3.785)}{(795.4\ mg/mL)(1440)} = 46.26\ mL/min$$

6. An operator has decided to switch from dry alum to liquid alum. If he feeds an average of 150 lbs of dry alum a day, how many gallons of liquid alum will he need to feed on average given the following information?

$$\frac{150\ lb}{5.4\ lb\ alum} \left| \frac{gal}{} \right.$$

$$= 27.78\ gal$$

Alum, liquid:
49% concentration
10.7 lbs/gallon weight
(5.4 lbs dry alum/gallon) conc.
1.335 specific gravity

APPLIED MATH FOR WATER COAGULATION & FLOCCULATION

pg.5

1. The average flow for a water plant is 3.25 MGD. A jar test indicates that the best alum dosage is 2.5 mg/L. How many pounds per day will the operator feed?

$$lb/day = (dose)(flow)(8.34\ lb/gal)$$
$$= (2.5\ mg/L)(3.25\ MGD)(8.34\ lb/gal)$$
$$= 67.76\ lb/day$$

2. The average flow for a water plant is 13.5 MGD. The jar test indicates that the best alum dose is 1.8 mg/L. How many pounds per day will the operator feed?

$$lb/day = (1.8\ mg/L)(13.5\ MGD)(8.34\ lb/gal)$$
$$= 202.66\ lb/day$$

3. Determine the setting on a dry alum feeder in pounds per day when the flow is 1.3 MGD. Jar tests indicate that the best alum dose is 12 mg/L.

$$lb/day = (12\ mg/L)(1.3\ MGD)(8.34\ lb/gal)$$
$$= 130.10\ lb/day$$

pg.11

4. The average flow for a water plant is 8.3 MGD. A jar test indicates that the best alum dosage is 2.2 mg/L. How many grams per minute should the feeder deliver?

$$gram/min = \frac{(dose)(flow)(3.785\ L/gal)}{(1440\ min/day)(1000\ mg/g)}$$
$$= \frac{(2.2\ mg/L)(8300000\ gpd)(3.785\ L/gal)}{(1440\ m/d)(1000\ mg/g)}$$
$$= 48\ gram/min$$

5. The average daily flow for a water plant is 0.75 MGD. If the polymer dosage is kept at 1.8 mg/L, how many pounds of polymer will be used in 30 days?

$$lb/day = (1.8\ mg/L)(0.75\ MGD)(8.34\ lb/gal)$$
$$= (11.259\ lb/day)(30\ days)$$
$$= 337.77\ lb$$

6. The average flow for a water plant is 8,890 gpm. A jar test indicates that the best polymer dose is 3.1 mg/L. How many pounds will the plant feed in one week? (Assume the plant runs 24 hour/day, 7 days/week.)

$$\frac{8890\ gal}{min} \left| \frac{1440\ min}{day} \right| \frac{1\ MG}{1000000\ gal}$$
$$= 12.8016\ MGD$$

$$lb/day = (3.1\ mg/L)(12.8016\ MGD)(8.34)$$
$$= (330.97\ lb/day)(7\ days/wk)$$
$$= 2316.81\ lb/week$$

pg. 5

7. A water treatment plant used 27 pounds of cationic polymer to treat 1.6 million gallons of water during a 24-hour period. What is the polymer dosage in mg/L?

$$mg/L = \frac{feed\ rate}{(flow)(8.34)}$$
$$= \frac{27\ lb/day}{(1.6\ MGD)(8.34\ lb/gal)}$$
$$= 2.02\ mg/L$$

8. A water plant fed 130 lbs of alum treating 1.3 MGD. Calculate the dose in mg/L.

$$mg/L = \frac{130\ lb/day}{(1.3\ MGD)(8.34\ lb/gal)}$$
$$= 11.99\ mg/L$$

pg. 5

9. A water plant fed 52 grams per minute of dry alum while treating 2.6 MGD. Calculate the mg/L dose.

$$mg/L = \frac{(\text{feed rate, g/min})(1000\ mg/g)}{(\text{flow, gpm})(3.785\ l/gal)}$$

$$= \frac{(52\ g/min)(1000\ mg/g)}{(1805.55\ gpm)(3.785\ l/gal)}$$

$$= 7.61\ mg/L$$

$$\frac{2.6\ MG}{day} \left| \frac{day}{1440\ min} \right| \frac{1000000\ gal}{1\ MG} = 1805.55\ gpm$$

pg. 7

10. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of this liquid polymer should be used to make 200 gallons of a 0.7% polymer solution?

$$C_1V_1 = C_2V_2$$

$$(0.08)(V_1) = (0.007)(200\ gal)$$

$$V_1 = \frac{(0.007)(200\ gal)}{0.08}$$

$$= 17.5\ gal$$

11. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of this liquid polymer should be used to make 5 gallons of a 5% polymer solution?

$$(C_1)(V_1) = (C_2)(V_2)$$

$$(0.08)(V_1) = (0.05)(5\ gal)$$

$$V_1 = \frac{(0.05)(5\ gal)}{0.08}$$

$$= 3.13\ gal$$

12. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of liquid polymer should be used to make 55 gallons of a 0.5% polymer solution?

$$(0.08)(V_1) = (0.005)(55\ gal)$$

$$V_1 = \frac{(0.005)(55\ gal)}{0.08}$$

$$V_1 = 3.44\ gal$$

13. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of alum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 8 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute if the flow is 2.2 MGD.

$$mL/min = \frac{(dose\ mg/L)(flow, gpd)(3.785\ L/gal)}{(conc, mg/mL)(1440\ min/day)}$$

$$= \frac{(8\ mg/L)(2200000\ gpd)(3.785\ L/gal)}{(642.3\ mg/mL)(1440\ min/day)}$$

$$= 72.02\ mL/min$$

pg. 5

14. You collect three 2-minute samples from an Alum dry feeder. What is the feed rate in mg/L when the flow rate is 2 MGD?

$$mg/L = \frac{(feed\ rate)(1000\ mg/g)}{(flow)(3.785\ L/gal)}$$

$$= \frac{(23.67\ g/2\ min)(1000\ mg/g)}{(1388.89\ gpm)(3.785\ L/gal)}$$

$$= 2.25\ mg/L$$

Sample 1 = 25 grams
Sample 2 = 22 grams
Sample 3 = 24 grams

$$\frac{25g + 22g + 24g}{3} = 23.67g$$

$$\frac{2\ MG}{day} \left| \frac{day}{1440\ min} \right| \frac{1000000\ gal}{1\ MG}$$

$$= 1388.89\ gpm$$

pg. 11

15. A water plant is treating 8.2 MGD with 2.0 mg/L liquid alum. How many gpd of liquid alum will be required? The liquid alum contains 5.36 lbs dry alum/gallon.

$$gal/day = \frac{(dose)(flow)(8.34\ lb/gal)}{conc.\ lb/gal}$$

$$= \frac{(2.0\ mg/L)(8.2\ MGD)(8.34\ lb/gal)}{5.36\ lb/gal}$$

$$= 25.52\ gal/day$$

16. A jar test indicates the 3.4 mg/L of liquid alum is required in treating 7.6 MGD. How many mL/min should the metering pump deliver? The liquid alum delivered to the plant contains 645 mg alum per mL of liquid solution.

$$mL/min = \frac{(3.4\ mg/L)(7600000\ gal/day)(3.785\ L/gal)}{(645\ mg/mL)(1440\ min/day)}$$

$$= 105.30\ mL/min$$

17. A jar test indicates that 1.8 mg/L of liquid ferric chloride should be fed to treat 2,778 gpm of water. How many mL/min should be fed by a metering pump? Ferric chloride contains 4.59 lbs dry chemical per gallon of liquid solution.

$$mL/min = \frac{(1.8\ mg/L)(4000320\ gpd)(3.785)}{(550.07\ mg/mL)(1440\ min/d)}$$

$$= 34.41\ mL/min$$

$$\frac{2778\ gal}{min} \left| \frac{1440\ min}{day} \right. = 4000320\ gpd$$

$$\frac{4.59\ lb}{gal} \left| \frac{1\ gal}{3785\ mL} \right| \frac{453.69}{lb} \left| \frac{1000\ mg}{1\ g} \right. = 550.07\ mg/mL$$

18. An operator has decided to switch from dry alum to liquid alum. If he feeds an average of 100 lbs of dry alum a day, how many gallons of liquid alum will he need to feed on average given the following information:

$$\frac{100\ lb\ dry\ alum}{5.4\ lb\ alum} \left| \frac{1\ gal}{} \right.$$

$$= 18.52\ gal$$

Alum, liquid:
48.5% concentration
11.13 lbs/gallon
5.40 lbs dry alum/gallon
1.335 Specific Gravity

19. If an operator wants to switch from dry ferric chloride to liquid ferric chloride, how many gallons per day would he have to feed if he normally feeds 200 lbs of dry ferric daily? Plant flow rate is 4 MGD. What would be the feed rate in milliliters per minute?

$$\frac{200\ lb\ ferric}{4.59\ dry\ ferric} \left| \frac{1\ gal}{} \right.$$

$$= 43.57\ gal/day$$

Ferric Chloride:
39% concentration
11.76 lbs/gallon
4.59 dry lbs of $FeCl_2$/gallon
1.41 Specific Gravity

$$\frac{43.57\ gal}{day} \left| \frac{1\ day}{1440\ min} \right| \frac{3785\ mL}{1\ gal} = \boxed{114.53\ mL/min}$$

OR

$$mg/L = \frac{200\ lb/day}{(4\ MGD)(8.34)}$$

$$= 5.9952\ mg/L$$

$$4.59\ lb/gal = 550.07\ mg/mL \qquad mL/min = \frac{(5.9952)(4000)(3.785)}{(550.07)(1440)}$$

$$= \boxed{114.59\ mL/min}$$

20. Based on the information provided below calculate the milligrams of alum per milliliter of solution. If jar test results indicate that the best dosage is 25 mg/L, what is the feed rate in mL/min? The plant flow rate is 6 MGD.

$$\frac{5.4\ lb}{gal} \left| \frac{1\ gal}{3785\ mL} \right| \frac{453.69}{1\ lb} \left| \frac{1000\ mg}{1\ g} \right| = 647.14\ mg/mL$$

48.5% concentration
11.13 lbs/gallon
5.40 lbs dry alum/gallon
1.335 Specific Gravity

$$mL/min = \frac{(25\ mg/L)(1{,}000{,}000\ gpd)(3.785\ L/gal)}{(647.14\ mg/mL)(1440\ min/day)}$$

$$= 609.25\ mL/min$$

21. Based on the information provided below calculate the milligrams of ferric chloride per milliliter of solution. If jar test results indicate that the best dosage is 7 mg/L, what is the feed rate in mL/min? The plant flow rate is 6 MGD.

$$\frac{4.59\ lb}{gal} \left| \frac{1\ gal}{3785\ mL} \right| \frac{453.69}{1\ lb} \left| \frac{1000\ mg}{1\ g} \right| = 550.07\ mg/mL$$

39% concentration
11.76 lbs/gallon
4.59 dry lbs of $FeCl_2$/gallon
1.41 Specific Gravity

$$mL/min = \frac{(7\ mg/L)(1{,}000{,}000\ gpd)(3.785\ L/gal)}{(550.07\ mg/mL)(1440\ min/day)}$$

$$= 800.69\ mL/min$$

ANSWERS:

1.	67.8 lbs/day	9.	7.6 mg/L	17.	34.4 mL/min
2.	202.7 lbs/day	10.	17.5 gallons	18.	18.5 gallons
3.	130 lbs/day	11.	3.1 gal	19.	43.6 gal/day
4.	48 grams/min	12.	3.4 gal		114.5 mL/min
5.	337.8 lbs	13.	72 mL/min	20.	647.14 mg/mL
6.	2,316.5 lbs	14.	2.25 mg/L		609.3 mL/min
7.	2 mg/L	15.	25.5 gal/day	21.	550.07 mg/mL
8.	12 mg/L	16.	105.3 mL/min		200.7 mL/min

APPLIED MATH FOR WATER
COAGULATION & FLOCCULATION PRACTICE QUIZ

1. The average flow for a water plant is 6.3 MGD. A jar test indicates that the best alum dosage is 19 mg/L. How many pounds per day will the operator feed?

$$lb/day = (19\,mg/L)(6.3\,MGD)(8.34\,lb/gal)$$

$$= 998.3\,lb/day$$

2. Determine the setting on a dry alum feeder when the flow is 5.4 MGD. Jar tests indicate that the best alum dose is 8 mg/L. What would be the setting in grams per minute?

$$gram/min = \frac{(8\,mg/L)(5400000\,gpd)(3.785\,L/gal)}{(1440\,min/day)(1000\,mg/g)}$$

$$= 113.55\,g/min$$

3. The average daily flow for a water plant is 7.5 MGD. Jar test results indicate the best polymer dosage is 1.8 mg/L. How many pounds of polymer will be used in 90 days?

$$lb/day = (1.8\,mg/L)(7.5\,MGD)(8.34\,lb/gal)$$

$$= (112.59\,lb/day)(90\,days)$$

$$= 10133.1\,lbs$$

4. A water treatment plant used 14 pounds of cationic polymer to treat 2.0 million gallons of water during a 24-hour period. What is the polymer dosage in mg/L?

$$mg/L = \frac{14\,lb/day}{(2.0\,MGD)(8.34\,lb/gal)}$$

$$= 0.84\,mg/L$$

5. A water plant fed 48.5 grams per minute while treating 2.2 MGD. Calculate the mg/L dose.

$$\frac{2.2\,MG}{day}\left|\frac{day}{1440\,min}\right|\frac{1000000\,gal}{MG} = 1527.78\,gpm$$

$$mg/L = \frac{(48.5\,g/min)(1000\,mg/g)}{(1527.78\,gpm)(3.785\,l/gal)}$$

$$= 8.39\,mg/L$$

6. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of liquid polymer should be used to make 200 gallons of a 1.0% polymer solution?

$$C_1V_1 = C_2V_2$$

$$(0.08)(V_1) = (0.01)(200\,gal)$$

$$V_1 = \frac{(0.01)(200\,gal)}{0.08}$$

$$= 25\,gal$$

7. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of alum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 15 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the flow is 7.2 MGD. There are 3.785 liters in one gallon.

$$mL/min = \frac{(15\,mg/L)(7200000\,gpd)(3.785\,l/gal)}{(642.3\,mg/mL)(1440\,min/day)}$$

$$= 441.97\,mL/min$$

8. A water plant is treating 1.8 MGD with 2.0 mg/L liquid alum. How many gpd of liquid alum will be required? The liquid alum contains 5.36 lbs dry alum/gallon.

$$gal/day = \frac{(2.0\,mg/L)(1.8\,MGD)(8.34\,lb/gal)}{5.36\,lb/gal}$$

$$= 5.6\,gpd$$

9. A jar test indicates the 4.3 mg/L of liquid alum is required in treating 6.7 MGD. How many mL/min should the metering pump deliver? The liquid alum delivered to the plant contains 645 mg alum per mL of liquid solution.

$$mL/min = \frac{(4.3\,mg/L)(6700000\,gpd)(3.785)}{(645\,mg/mL)(1440\,min/day)}$$

$$= 117.41\,mL/min$$

10. An operator has decided to switch from dry alum to liquid alum. If he feeds 114 lbs of dry alum on average a day, how many gallons of liquid alum will he need to feed on average given the following information:

Alum, liquid
48.5% concentration
11.13 lbs/gallon
5.40 lbs dry alum/gallon
1.335 Specific Gravity

$$\frac{114\,lb\,alum \mid gal}{5.4\,lb}$$

$$= 21.11\,gal$$

11. Based on the information provided below calculate the milligrams of ferric chloride per milliliter of solution. If jar test results indicate that the best dosage is 21 mg/L, what is the feed rate in mL/min? The plant flow rate is 7.5 MGD.

$$\frac{4.59\,lb}{gal} \mid \frac{1\,gal}{3785\,mL} \mid \frac{453.69}{1\,lb} \mid \frac{1000\,mg}{1\,g}$$

$$= 550.07\,mg/mL$$

39% concentration
11.76 lbs/gallon
4.59 dry lbs/gallon
1.41 Specific Gravity

$$mL/min = \frac{(21\,mg/L)(7500000\,gpd)(3.785\,L/gal)}{(550.07\,mg/mL)(1440\,min/day)}$$

$$= 752.6\,mL/min$$

ANSWERS:

1. 998.3 lbs/day
2. 113.5 grams/min
3. 10,133.1 lbs
4. 0.84 mg/L
5. 8.39 mg/L
6. 25 gal
7. 442 mL/min
8. 5.6 gpd
9. 117.4 mL/min
10. 21.1 gpd
11. 550.07 mg/mL; 752.6 mL/min

Feeders

1. An operator collections 5 three-minute samples from a dry feeder. Based on the information given, determine the average grams per min.

Sample 1 = 37.8 grams
Sample 2 = 38.3 grams
Sample 3 = 35.6 grams

$$\text{avg.} = \frac{37.89 + 38.39 + 35.69}{3}$$

$$= 37.233\text{g}$$

$$\text{gram/min} = \frac{37.23339}{5\text{ min}} = 7.459/\text{min}$$

Pg. 5

2. What is the average dose in mg/L for the feeder in the previous question if the plant treats 3.9 MGD?

$$\frac{3900000\text{ gal}}{\text{day}} \left| \frac{\text{day}}{60\text{ min}} \right. = 65{,}000\text{ gpm}$$

$$\text{dose, mg/L} = \frac{(\text{feed rate, g/min})(1000\text{ mg/g})}{(\text{flow, gpm})(3.785\text{ L/gal})}$$

$$= \frac{(7.459/\text{min})(1000\text{ mg/g})}{(65{,}000\text{ gpm})(3.785\text{ L/gal})}$$

$$= 0.03\text{ mg/L}$$

APPLIED MATH FOR WATER
FEEDER MATH

1.a. An operator is checking the calibration on a chemical feeder. The feeder delivers 102 grams in 5 minutes. How many grams per minute does the feeder deliver?

$$\text{gram/min} = \frac{102 \text{ grams}}{5 \text{ min}}$$

$$= 20.4 \text{ g/min}$$

1.b. How many pounds per day does the feeder deliver?

$$\frac{20.4 \text{ g}}{\text{min}} \left| \frac{1440 \text{ min}}{\text{day}} \right| \frac{1 \text{ lb}}{453.6 \text{ g}} = 64.76 \text{ lb/day}$$

2.a. An operator checks the calibration of a dry feeder by catching samples and weighing them on a balance. Each catch lasts 1 minute. Calculate the average feed rate in grams per minute based on the following data:

Sample 1 weighs 37.0 grams
Sample 2 weighs 36.2 grams
Sample 3 weighs 39.4 grams
Sample 4 weighs 38.6 grams

$$\text{avg} = \frac{37.0 \text{ g} + 36.2 \text{ g} + 39.4 \text{ g} + 38.6 \text{ g}}{4} = 37.8 \text{ g}$$

$$\text{gram/min} = \frac{37.8 \text{ g}}{1 \text{ min}} = 37.8 \text{ g/min}$$

2.b. How many pounds per hour is being fed?

$$\frac{37.8 \text{ g}}{\text{min}} \left| \frac{60 \text{ min}}{\text{hr}} \right| \frac{1 \text{ lb}}{453.6 \text{ g}}$$

$$= 5 \text{ lb/hr}$$

3.a. An operator collects 3 two-minute samples from a dry feeder:

Sample 1 weighs 22.2 grams
Sample 2 weighs 24.0 grams
Sample 3 weighs 21.9 grams

What is the average grams per minute?

$$\text{avg} = \frac{22.2 \text{ g} + 24.0 \text{ g} + 21.9 \text{ g}}{3} = 22.7 \text{ g}$$

$$\text{gram/min} = \frac{22.7 \text{ gram}}{2 \text{ min}} = 11.35 \text{ g/min}$$

3.b. What is the average dose in mg/L for the feeder in question 3.a. if the plant treats 420,000 gpd?

$$\frac{420000\,gal}{day}\left|\frac{1\,day}{1440\,min}\right. = 291.67\,gpm$$

$$mg/L = \frac{(11.359/min)(1000\,mg/g)}{(291.67\,gpm)(3.785\,l/gal)}$$

$$= 10.28\,mg/L$$

4.a. An operator collects 5 two-minute samples from a dry feeder:

Sample 1 weighs 49.2 grams
Sample 2 weighs 44.0 grams
Sample 3 weighs 41.9 grams
Sample 4 weighs 48.3 grams
Sample 5 weighs 47.6 grams

What is the average grams per minute?

$$avg = \frac{49.2g + 44.0g + 41.9g + 48.3g + 47.6g}{5} = 46.2\,g$$

$$gram/min = \frac{46.2\,g}{2\,min} = 23.1\,g/min$$

4.b. What is the average dose in mg/L if the plant treats 1,200,000 gpd?

$$\frac{1200000\,gal}{day}\left|\frac{1\,day}{1440\,min}\right. = 833.33\,gpm$$

$$mg/L = \frac{(23.1\,g/min)(1000\,mg/g)}{(833.33\,gpm)(3.785\,l/gal)}$$

$$= 7.32\,mg/L$$

5.a. A chemical feeder calibration is tested using a 1,000 ml graduated cylinder. The cylinder filled to 850 ml in a 3 minute test. What is the chemical feed rate in milliliters per minute?

$$mL/min = \frac{850\,mL}{3\,min}$$

$$= 283.33\,mL/min$$

5.b. What is the chemical feed rate in gallons per minute?

$$\frac{283.33\,mL}{min}\left|\frac{1L}{1000mL}\right|\frac{1\,gal}{3.785L}$$

$$= 0.075\,gal/min$$

5.c. What is the chemical feed rate in gallons per day?

$$\frac{0.075\ gal}{min} \left| \frac{1440\ min}{1\ day} \right.$$

$$= 107.79\ gpd$$

6.a. A chemical feeder draws a liquid chemical from a one-liter (1,000 ml) graduated cylinder for 30 seconds. At the end of 30 seconds, the graduated cylinder has 400 ml remaining. What is the chemical feed rate in milliliters per minute?

$$mL/min = \frac{600\ mL}{0.5\ min}$$

$$= 1200\ mL/min$$

$30/60 = 0.5\ min$

$1000\ mL - 400\ mL = 600\ mL$

6.b. What is the chemical feed rate in gallons per minute?

$$\frac{1200\ mL}{min} \left| \frac{gal}{3785\ mL} \right. = 0.317\ gpm$$

6.c. What is the chemical feed rate in gallons per day?

$$\frac{0.317\ gal}{min} \left| \frac{1440\ min}{day} \right. = 456.54\ gpd$$

7. A water plant treats 3.5 MGD with a dose of 2.2 mg/L $KMnO_4$. If the water plant uses 257 gallons of permanganate per day, how many ml/min must be pumped?

$$\frac{257\ gal}{day} \left| \frac{1\ day}{1440\ min} \right| \frac{3785\ mL}{1\ gal}$$

$$= 675.52\ mL/min$$

8.a. A water plant treats 8.5 MGD with a dose of 1.7 mg/L $KMnO_4$. How many gpd of permanganate must be used? ($KMnO_4$ was made up at 0.25 lbs per 1 gallon of water)

$$gal/day = \frac{(1.7\ mg/L)(8.5\ MG/D)(8.34\ lb/gal)}{0.25\ lb/gal}$$

$$= 482.05\ gpd$$

8.b. How many ml/min must be pumped?

$$\frac{482.05\text{gal}}{\text{day}} \left| \frac{1\text{ day}}{1440\text{ min}} \right| \frac{3785\text{mL}}{1\text{ gal}}$$

$$= 1267.06\ \text{mL/min}$$

8.c. If the water plant uses 3 potassium permanganate pumps, how many ml/min must be pumped by each?

$$\frac{1267.06\ \text{mL/min}}{3\text{ pumps}} =$$

$$= 422.35\ \text{mL/min per pump}$$

9. $KMnO_4$ has been made according to the manufacturer recommendations (30 mg/mL). The water plant operators wants to dose 3.6 MGD with 2.0 mg/L KMnO4. How many ml/min must be delivered by the metering pump?

$$\text{mL/min} = \frac{(2.0\ \text{mg/L})(3600000\ \text{gpd})(3.785)}{(30\ \text{mg/mL})(1440)}$$

$$= 630.83\ \text{mL/min}$$

Answers:

1.a. 20.4 grams/min
1.b. 64.76 lbs/day
2.a. 37.8 grams/min
2.b. 5 lbs/hour
3.a. 11.35 grams/min
3.b. 10.3 mg/L
4.a. 23.1 grams/min
4.b. 7.3 mg/L
5.a. 283.3 ml/min
5.b. 0.0748 gal/min
5.c. 107.7 gpd

APPLIED MATH FOR WATER
FEEDER MATH PRACTICE QUIZ

1. An operator collects 3 two-minute samples from a dry feeder:
   Sample 1 weighs 47.3 grams
   Sample 2 weighs 44.8 grams
   Sample 3 weighs 42.4 grams
   The water plant is treating 4.5 MGD. What is the average dose in mg/L?

$$\text{avg} = \frac{47.3g + 44.8g + 42.4g}{3} = \frac{44.83g}{2\text{ min}} = 22.4\ g/\text{min}$$

$$mg/L = \frac{(22.4\ g/\text{min})(1000\ mg/g)}{(3125\text{ gpm})(3.785\ L/\text{gal})}$$

$$\frac{4.5\text{ MG}}{\text{day}} \left| \frac{1\text{ day}}{1440\text{ min}} \right| \frac{1000000\text{ gal}}{\text{MG}} = 3125\text{ gpm}$$

$$= 1.90\ mg/L$$

2. A chemical feeder feeds a liquid chemical to a 1000 mL graduated cylinder for 48 seconds. At the end of the 48 seconds, the graduated cylinder is completely full. What is the chemical feed rate for the metering pump in gallons per day?

$$mL/\text{min} = \frac{1000\text{ mL}}{0.8\text{ min}} = 1250\ mL/\text{min} \qquad 48/60 = 0.8\text{ min}$$

$$\frac{1250\text{ mL}}{\text{min}} \left| \frac{1440\text{ min}}{\text{day}} \right| \frac{1\text{ gal}}{3785\text{ mL}}$$

$$= 475.56\text{ gpm}$$

3. A water plant used 167 gallons of a liquid chemical in one day. How many mL/min was pumped?

$$\frac{167\text{ gal}}{\text{day}} \left| \frac{1\text{ day}}{1440\text{ min}} \right| \frac{3785\text{ mL}}{1\text{ gal}}$$

$$= 438.95\ mL/\text{min}$$

4. The operator measured the amount of dry chemical fed in one day as 114.5 lbs. How many grams/min should the dry feeder have delivered?

$$\frac{114.5\ \text{lb}}{\text{day}} \left| \frac{1\ \text{day}}{1440\ \text{min}} \right| \frac{453.6\ \text{g}}{1\ \text{lb}}$$

=

5. How many grams in one pound?

453.6 g/lb

6. How many milliliters in one gallon?

3785 mL/gal

7. How many milligrams in one pound?

$$\frac{1\ \text{lb}}{1\ \text{lb}} \left| \frac{453.6\ \text{g}}{1\ \text{g}} \right| \frac{1000\ \text{mg}}{1\ \text{g}} = 453600$$

8. How many liters in one gallon?

3.785 L/gal

ANSWERS:

1. 1.9 mg/L
2. 475.6 gpd
3. 439 mL/min
4. 36.1 g/min
5. 453.6
6. 3,785
7. 453,600
8. 3.785

Pre-treatment and Lab

1. A holding pond measures 550 feet by 1075 feet and has an average depth of 12 feet.

a. What is the volume of the pond in acre-feet?

$$\text{pond vol, ac-ft} = \frac{(\text{length})(\text{width})(\text{depth})}{43560\ ft^2/ac}$$

$$= \frac{(550\ ft)(1075\ ft)(12\ ft)}{43560\ ft^2/ac} = 162.88\ ac\text{-}ft$$

b. What is the volume of the pond in million gallons?

$$\text{Vol, gal} = (\text{vol, ac-ft})(43560\ ft^2/ac)(7.48\ gal/ft^2)$$

$$= (162.8788\ ac\text{-}ft)(43560)(7.48) = 53070600\ gal$$

$$\text{Vol, MG} = (53070600\ gal)/1000000\ gal/MG = 53.07\ MG$$

c. If the Methyl Orange alkalinity is 21 mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

$21 < 50$

$$\text{lbs} = (0.9\ lb/ac\text{-}ft)(\text{vol, ac-ft})$$

$$= (0.9\ lb/ac\text{-}ft)(162.8788\ ac\text{-}ft)$$

$$= 146.59\ lbs$$

d. If the Methyl Orange alkalinity is 72 mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

$72 > 50$

$$A = \frac{(550ft)(1075ft)}{43560\ ft^2/ac} = 13.57\ ac.$$

$$\text{lbs} = (\text{surface area, ac})(5.4\ lb/ac)$$

$$= (13.57\ ac)(5.4\ lb/ac)$$

$$= 73.30\ lb$$

2.a. Carus Chemicals recommends a 5% permanganate solution. If 2.0 lbs $KMnO_4$ is dissolved in 10 gallons of water, what is the % by weight? $\frac{10\ gal \mid 8.34\ lb}{\mid\ gal} = 83.4\ lb$

$$\%\ by\ weight = \frac{wt\ chem}{wt\ water + wt\ chemicals} * 100$$

$$= \frac{2.0\ lb}{83.4\ lb + 2.0\ lb} * 100 = 2.34\ \%$$

b. To produce a 5% solution, how many pounds of $KMnO_4$ should be dissolved in a tank 4.0 feet in diameter and filled to a depth 4.5 feet? $Vol, gal = (0.785)(4)(4)(45)(7.48) = 422.7696\ gal$

$$lbs = \frac{(Vol * 8.34\ lb/gal)(des\ conc.)}{100\% - des\ conc}$$

$$= \frac{(422.7696\ gal * 8.34)(0.05)}{0.95} = 185.57\ lb$$

c. Your raw water has 1.6 mg/L of iron. How much $KMnO_4$ should be used to treat the iron? Each 1.0 ppm requires 0.91 mg/L of $KMnO_4$.

$$\frac{1.6\ mg/L \mid 0.91\ mg/L}{\mid\ 1\ ppm\ Fe} = 1.456\ mg/L$$

d. Your raw water has 6.2 mg/L of manganese. How much $KMnO_4$ should be used to treat manganese? Each 1.0 ppm of manganese requires 1.92 mg/L $KMnO_4$.

$$KMnO_4, mg/L = (6.2\ mg/L)(1.92\ mg/L) = 11.904\ mg/L$$

e. Your raw water has 0.4 mg/L of iron and 3.4 mg/L of manganese. How much $KMnO_4$ should be used? (Each 1.0 ppm requires 0.91 mg/L of $KMnO_4$; each 1.0 ppm of manganese requires 1.92 mg/L $KMnO_4$)

$$mg/L_{Fe} = (0.4\ mg/L)(0.91) = 0.364\ mg/L$$

$$mg/L_{Mn} = (3.4\ mg/L)(1.92) = 6.528\ mg/L$$

$$total = 0.364\ mg/L + 6.528\ mg/L = 6.892\ mg/L\ KMnO_4$$

f. Carus Chemicals recommends a 5% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallons of water. How many mg of $KMnO_4$ is there per mL of solution?

$$\frac{0.25\,lb}{gal}\left|\frac{1\,gal}{3785\,mL}\right|\frac{453.6\,g}{1\,lb}\left|\frac{1000\,mg}{1\,g}\right. = 29.96\,mg/mL$$

g. The water plant is treating 3.0 MGD and the operator has determined that the $KMnO_4$ dose should be 3.9 mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lb/gal)

$$mL/min = \frac{(dose)(flow,gpd)(3.785\,L/gal)}{(conc,mg/mL)(1440\,min/day)}$$

$$= \frac{(3.9\,mg/L)(3900000\,gpd)(3.785\,L/gal)}{(29.96\,mg/mL)(1440\,min/day)}$$

$$= 1334.41\,mL/min$$

Applied Math for Water Laboratory Solutions

1. A laboratory solution is made using 52 milligrams of Sodium Chloride (NaCl) dissolved in a 1 liter volumetric flask filled to the mark. What is the mg/L concentration of the solution?

$$mg/L = \frac{52\ mg}{1\ L}$$

$$= 52\ mg/L$$

2. If 33 lbs of a chemical is added to 148 lbs of water, what is the % strength by weight?

$$\%\ strength = \frac{wt\ chem}{wt\ water + wt\ chem} * 100$$

$$= \frac{33\ lb}{148\ lb + 33\ lb} * 100 = 18.23\%$$

3. You need 1 liter of 0.1N HCl and you have 10N on hand. How many mL's of the 10N do you need to make 1 liter?

$$N_1V_1 = N_2V_2$$

$$(0.1\ N)(1000mL) = (10N)(V_2)$$

$$\frac{(0.1N)(1000mL)}{10N} = V_2 \Longrightarrow 10\ mL$$

4. 250 mL of 3N NaOH is diluted to 1000mL. What is the new normality of the solution?

$$(250mL)(3N) = (N_2)(1000mL)$$

$$\frac{(250mL)(3N)}{1000mL} = N_2$$

$$0.75\ N = N_2$$

5. 500 mL of 10N NaOH is diluted to 1 liter. What is the new normality of the solution?

$$(500mL)(10N) = (1000mL)(N_2)$$

$$\frac{(500mL)(10N)}{1000mL} = N_2$$

$$5N = N_2$$

6. You are given 20 mL of 30N HCl. How many mL's of water should be added to make 1.1N HCl?

$$(20\,mL)(30\,N) = (V_2)(1.1\,N)$$

$$\frac{(20\,mL)(30\,N)}{1.1\,N} = V_2$$

$$545.45\,mL = V_2$$

7. An operator needs a 0.1N solution in order to conduct an analysis. The operator has 1.5N solution on hand. How much (mL) of the 1.5N solution is needed to make 1 liter of 0.1N solution?

$$(1000\,mL)(0.1\,N) = (V_2)(1.5\,N)$$

$$\frac{(1000\,mL)(0.1\,N)}{1.5\,N} = V_2$$

$$66.67\,mL = V_2$$

8. An operator needs a 0.1N solution in order to conduct an analysis. The operator has 2.0N solution on hand. How many milliliters of the 2.0N solution is needed to make 1 liter of 0.1N solution?

$$(1000\,mL)(0.1\,N) = (V_2)(2.0\,N)$$

$$\frac{(1000\,mL)(0.1\,N)}{2.0\,N} = V_2$$

$$50\,mL = V_2$$

9. 450 mL of 5N NaOH is diluted to 1 liter. What is the new normality of the solution?

$$(450\,mL)(5\,N) = (1000\,mL)(N_2)$$

$$\frac{(450\,mL)(5\,N)}{1000\,mL} = N_2$$

$$2.25\,N = N_2$$

10. You are given 8 mL of 15N H_2SO_4. How much water (in mL) should be added to make 0.4N H_2SO_4?

$$(8\,mL)(15\,N) = (V_2)(0.4\,N)$$

$$\frac{(8\,mL)(15\,N)}{0.4\,N} = V_2$$

$$300\,mL = V_2$$

11. An operator needs a 0.2N solution and has 2.5N on hand. How much (in mL) of the 2.5N solution is needed to make one-half liter of 0.2N solution?

$$(500\,mL)(2.5\,N) = (V_2)(0.2\,N)$$

$$\frac{(500\,mL)(2.5\,N)}{0.2\,N} = 6250\,mL = V_2$$

Applied Math for Water Pretreatment

Copper Sulfate

1.a. A holding pond measures 400 feet by 1213 feet and has an average depth of 10.5 feet. What is the volume of the pond in acre-ft?

$$\text{Area, ac} = \frac{(L, ft)(W, ft)}{43560\ ft^2/ac} =$$

$$= \frac{(400\ ft)(1213\ ft)}{43560\ ft^2/ac} = 11.14\ ac$$

$$\text{Vol, ac-ft} = (11.1387\ ac)(10.5\ ft) = \boxed{116.96\ ac\text{-}ft}$$

b. What is the volume of the pond in million gallons?

$$\text{Vol, gal} = (\text{Vol, ac-ft})(43{,}560\ ft^2/ac)(7.48\ gal/ft^3)$$

$$= (116.96\ ac\text{-}ft)(43{,}560\ ft^2/ac)(7.48\ gal/ft^3)$$

$$= 38107608\ gal\ /1000000\ gal/mG = \boxed{38.11\ mG}$$

c. If the Methyl Orange alkalinity is 28mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

alk < 50mg/L

$$\text{copper sulfate, lbs} = (0.9\ lb/ac\text{-}ft)(\text{Vol, ac-ft})$$

$$= (0.9\ lb/ac\text{-}ft)(116.9559\ ac\text{-}ft)$$

$$= 105.26\ lb$$

d. If the Methyl Orange alkalinity is 61mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

alk > 50mg/L

$$\text{copper sulfate, lbs} = (\text{area, ac})(5.4\ lb/ac)$$

$$= (11.1387\ ac)(5.4\ lb/ac)$$

$$= 60.14\ lb$$

$$A = \frac{(400ft)(1213ft)}{43560\ ft^2/acre} = 11.13\ ac$$

2.a. A holding pond measures 2400 feet by 576 feet and has an average depth of 8.75 feet. What is the volume of the pond in acre-ft?

$$\text{Area, ac-ft} = \frac{(L)(W)(D)}{43560\ ft^2/ac}$$

$$= \frac{(2400ft)(576ft)(8.75ft)}{43{,}560\ ft^2/ac}$$

$$= 277.69\ ac\text{-}ft$$

b. What is the volume of the pond in million gallons?

$$Vol, gal = (277.69\ ac\text{-}ft)(43{,}560\ ft^2/ac)(7.48\ gal/ft^3)$$
$$= 90478080\ gal\ /\ 1000000\ gal/MG$$
$$= 90.48\ MG$$

c. If the Methyl Orange alkalinity is 44mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

alk < 50mg/L

$$lbs = (0.9\ lb/ac\text{-}ft)(277.69\ ac\text{-}ft)$$
$$= 249.92\ lb$$

d. If the Methyl Orange alkalinity is 82mg/L, how many pounds of copper sulfate will be required to treat the water for algal problems?

alk > 50mg/L

$$lbs = (31.74\ ac)(5.4\ lb/ac)$$
$$= 171.37\ lbs$$

$$A = \frac{(2400\ ft)(576\ ft)}{43560\ ft^2/ac}$$
$$= 31.74\ ac$$

3. For algae control of a reservoir, a dosage of 0.5 mg/L copper is desired. The reservoir has a volume of 20 MG. How many pounds of copper sulfate (25% available copper) will be required?

$$lb = \frac{(dose)(volume)(8.34\ lb/gal)}{\%\ copper}$$
$$= \frac{(0.5\ mg/L)(20\ MG)(8.34)}{0.25} = 333.6\ lb$$

4. The desired copper sulfate dose in a reservoir is 5 mg/L. The reservoir has a volume of 62 acre-ft. How many lbs of copper sulfate (25% available copper) will be required?

$$lbs = \frac{(5\ mg/L)(20.20\ MG)(8.34)}{0.25}$$
$$= 3369.59\ lbs$$

$$\frac{62\ ac\text{-}ft \mid 325828.8\ gal \mid 1\ MG}{\mid 1\ ac\text{-}ft \mid 1000000\ gal}$$
$$= 20.20\ MG$$

5. A pond has an average length of 250 ft, an average width of 75 ft and an average depth of 10 ft. If the desired dose of copper sulfate is 0.8 lbs/ acre ft, how many pounds of copper Sulfate will be required?

$$Vol, ac\text{-}ft = \frac{(250\ ft)(75\ ft)(10\ ft)}{43560\ ft^2/ac} = 4.3\ ac\text{-}ft$$

$$lbs = \frac{4.3\ ac\text{-}ft \mid 0.8\ lb}{\mid ac\text{-}ft}$$
$$= 3.44\ lb$$

Potassium Permanganate

1.a. Carus Chemicals recommends a 3% permanganate solution. If 2.5 lbs $KMnO_4$ is dissolved in 10 gallons of water, what is the % by weight?

$$\frac{10\text{gal}}{1} \left| \frac{8.34\text{lb}}{\text{gal}} \right. = 83.4\text{ lbs}$$

$$\%\text{ strength} = \frac{2.5\text{ lb}}{83.4\text{ lb} + 2.5\text{ lb}} * 100$$

$$= 2.91\%$$

b. To produce a 3% solution, how many pounds $KMnO_4$ should be dissolved in a tank 3.5 feet in diameter and filled to a depth of 4.25 feet?

$$\text{vol, gal} = (0.785)(3.5)(3.5)(4.25)(7.48)$$
$$= 305.70\text{ gal}$$

$$\text{Chem, lbs} = \frac{(\text{water vol} * 8.34)(\text{des conc.})}{(1 - \text{des conc})}$$

$$= \frac{(305.70\text{gal} * 8.34)(0.03)}{1 - 0.03}$$

$$= 78.85\text{ lb}$$

c. Your raw water has 1.8mg/L of iron. How much $KMnO_4$ should be used to treat the iron? (Each 1.0 ppm of Iron requires 0.91mg/L of $KMnO_4$)

$$\frac{1.8\text{ mg/L iron}}{1} \left| \frac{0.91\text{ mg/L } KMnO_4}{1\text{ ppm Fe}} \right.$$

$$= 1.64\text{ mg/L}$$

d. Your raw water has 6.6mg/L of manganese. How much $KMnO_4$ should be used to treat manganese? (Each 1.0 ppm of Manganese requires 1.92mg/L of $KMnO_4$)

$$\text{mg/L } KMnO_4 = (6.6)(1.92)$$

$$= 12.67\text{ mg/L}$$

e. Your raw water has 0.2mg/L of iron and 2.9mg/L of manganese. How much $KMnO_4$ should be used? (0.91mg/L $KMnO_4$ per 1.0 ppm Fe; 1.92mg/L $KMnO_4$ per 1.0 ppm Mn)

$$\text{mg/L } KMnO_4 = (0.2\text{mg/L Fe})(0.91\text{mg/L}) = 0.182\text{ mg/L}$$

$$\text{mg/L } KMnO_4 = (2.9\text{mg/L Mn})(1.92\text{mg/L}) = 5.568\text{ mg/L}$$

$$0.182 + 5.568 = 5.75\text{ mg/L}$$

f. Carus Chemicals recommends a 3% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallon of water. How many mg $KMnO_4$ is there per mL of solution?

$$\frac{0.25\text{ lb}}{\text{gal}} \left| \frac{1\text{gal}}{3785\text{mL}} \right| \frac{453.69}{1\text{ lb}} \left| \frac{1000\text{mg}}{1\text{g}} \right. = 30\text{ mg/mL}$$

g. Carus Chemicals recommends a 3% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallon of water. If 55 gallons of $KMnO_4$ is made at this ratio, how many pounds of chemical are required?

$$lbs = \frac{0.25 lb}{gal} \Big| \frac{55 gal}{}$$

$$= 13.75 lbs$$

h. The water plant is treating 2.0 MGD and the operator has determined that the $KMnO_4$ dose should be 4.6mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal)

pg. 11

$$\frac{0.25 lb}{gal} \Big| \frac{1 gal}{3785 mL} \Big| \frac{453600 mg}{lb} = 29.96 \frac{mg}{mL}$$

$$mL/min = \frac{(4.6 mg/L)(2000000 gpd)(3.785 L/gal)}{(29.96 mg/mL)(1440 min/day)}$$

$$= 807.13 mL/min$$

i. The water plant is treating 11.2 MGD and the operator has determined that the $KMnO_4$ dose should be 2.3mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal)

$$mL/min = \frac{(2.3 mg/L)(11200000 gpd)(3.785 L/gal)}{(29.96 mg/mL)(1440 min/day)}$$

$$= 2259.97 mL/min$$

j. Your raw water contains 0.7mg/L iron and 1.2mg/L manganese. You have determined to feed 0.4mg/L $KMnO_4$ to overcome a taste and odor problem caused by an algal bloom in addition to the amounts required to oxidize the iron and manganese. How many mL/min should the liquid feeder be set to feed in order to treat 9.1 MGD? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal; 0.91mg/L $KMnO_4$ per 1.0 ppm Fe; 1.92mg/L $KMnO_4$ per 1.0 ppm Mn)

Fe $(0.7 mg/L\ Fe)(0.91 mg/L) = 0.637 mg/L$

Mn $(1.2 mg/L\ Mn)(1.92 mg/L) = 2.304$

Total $= 0.637 mg/L + 2.304 mg/L + 0.4 mg/L = 3.341 mg/L$

$$mL/min = \frac{(3.341 mg/L)(9100000 gpd)(3.785 L/gal)}{(29.96 mg/mL)(1440 min/day)}$$

$$= 2667.35 mL/min$$

2.a. Carus Chemicals recommends a 3% permanganate solution. If 25 lbs of $KMnO_4$ are dissolved in 100 gallons of water, what is the % by weight?

$$\frac{100\ gal}{} \left| \frac{8.34\ lb}{gal} \right. = 834\ lb$$

$$\%\ strength = \frac{25\ lb}{834\ lb + 25\ lb} * 100$$

$$= 2.91\%$$

b. To produce a 3% solution, how many pounds $KMnO_4$ should be dissolved in a tank 3.5 feet in diameter and filled to a depth of 3.5 feet?

$$Vol, gal = (0.785)(3.5)(3.5)(3.5)(7.48) = 251.75 gal$$

$$lbs = \frac{(251.75\ gal * 8.34)(0.03)}{(1-0.03)}$$

$$= 64.94\ lb$$

c. Your raw water has 2.8mg/L of iron. How much $KMnO_4$ should be used to treat the iron? (Each 1.0 ppm of Iron requires 0.91mg/L of $KMnO_4$)

$$(2.8\ mg/L)(0.91\ mg/L)$$

$$= 2.55\ mg/L$$

d. Your raw water has 2.0mg/L of manganese. How much $KMnO_4$ should be used to treat the manganese? (Each 1.0 ppm of Manganese requires 1.92mg/L of $KMnO_4$)

$$(2.0\ mg/L)(1.92\ mg/L)$$

$$= 3.84\ mg/L$$

e. Your raw water has 0.2mg/L of iron and 3.1mg/L of manganese. How much $KMnO_4$ should be used? (0.91mg/L $KMnO_4$ per 1.0 ppm Fe; 1.92mg/L $KMnO_4$ per 1.0 ppm Mn)

Fe $(0.2\ mg/L)(0.91\ mg/L) = 0.182\ mg/L$

Mn $(3.1\ mg/L)(1.92\ mg/L) = 5.952\ mg/L$

$$Total = (0.182\ mg/L + 5.952\ mg/L) = 6.134\ mg/L$$

f. Carus Chemicals recommends a 3% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallon of water. How many mg $KMnO_4$ are there per 100mL of solution?

$$\frac{0.25\ lb}{gal} \left| \frac{1\ gal}{3785\ mL} \right| \frac{453.6\ g}{1\ lb} \left| \frac{1000\ mg}{1\ g} \right. = 29.96\ mg/mL$$

$$(29.96\ mg/mL)(100\ mL) = 2996\ mg\ KMnO_4$$

g. Carus Chemicals recommends a 3% permanganate solution mixed at a ratio of 0.25 lbs per 1 gallon of water. If 67 gallons of $KMnO_4$ are made at this ratio, how many pounds of chemical are required?

$$(0.25\,lb/gal)(67\,gal)$$

$$= 16.75\,lb$$

h. The water plant is treating 14.5 MGD and the operator has determined that the $KMnO_4$ dose should be 3.9mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal.)

$$mL/min = \frac{(3.9\,mg/L)(14500000\,gpd)(3.785\,L/gal)}{(29.96\,mg/mL)(1440\,min/day)}$$

$$= 4961.29\,mL/min$$

i. The water plant is treating 6.5 MGD and the operator has determined that the $KMnO_4$ dose should be 3.2mg/L. How many mL/min must be pumped to obtain this dose? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal.)

$$mL/min = \frac{(3.2\,mg/L)(6500000\,gpd)(3.785\,L/gal)}{(29.96\,mg/mL)(1440\,min/day)}$$

$$= 2224.02\,mL/min$$

j. Your raw water contains 2.2mg/L of iron and 0.7mg/L of manganese. You have determined to feed 0.5mg/L $KMnO_4$ to overcome a taste and odor problem caused by an algal bloom in addition to the amounts required to oxidize the iron and manganese. How many mL/min should the liquid feeders be set to feed in order to treat 5.4 MGD? The plant flow is split evenly between two separate flash mixers. The $KMnO_4$ is being introduced into each rapid mix by its own metering pump. ? (The $KMnO_4$ was made at the recommended 0.25 lbs/gal; 0.91mg/L $KMnO_4$ per 1.0 ppm Fe; 1.92mg/L $KMnO_4$ per 1.0 ppm Mn)

Fe $(2.2\,mg/L)(0.91\,mg/L) = 2.002\,mg/L$

Mn $(0.7\,mg/L)(1.92\,mg/L) = 1.344\,mg/L$

Total $= 2.002\,mg/L + 1.344\,mg/L + 0.5\,mg/L = 3.846\,mg/L$

flow $= 5.4\,MGD / 2\,mixers = 2.7\,MGD$

$$mL/min = \frac{(3.846\,mg/L)(2700000\,gpd)(3.785\,L/gal)}{(29.96\,mg/mL)(1440\,min/day)}$$

$$= 911.03\,mL/min$$

Softening

1. On a water sample the total alkalinity was 75 mg/L and the total hardness was 99 mg/L. What are the carbonate and noncarbonate hardness concentrations in mg/L? TH = 99 TA = 75 so TH > TA

noncarbonate = TH − TA = 99 mg/L − 75 mg/L = 24 mg/L

carbonate = TA = 75 mg/L

2. It takes 5.4 mL of 0.02 N H_2SO_4 to reach a pH of 8.3 and a total of 11.7 mL to reach the Methyl Orange end-point in a 100 mL sample. What is the carbonate, bicarbonate, and hydroxyl alkalinity in mg/L as $CaCO_3$? P < ½ T

$$P = \frac{(A)(N)(50000)}{\text{sample vol}} \qquad T = \frac{(B)(N)(50000)}{\text{sample vol}}$$

B → T − (2)(P) = 9 mg/L

$$P = \frac{(5.4\text{mL})(0.02\text{N})(50000)}{100\text{ mL}} \qquad T = \frac{(11.7\text{ mg/L})(0.02)(50000)}{100\text{ mL}}$$

C → (2)(P) = 108 mg/L

H → 0 mg/L

P = 54 mg/L T = 117

3. How many pounds per day of quicklime are required to treat 4.2 MGD with a dose of 175 mg/L? The quicklime is 85% pure.

$$\text{lb/day} = \frac{(\text{dose})(\text{flow, MGD})(8.34\text{ lb/gal})}{\text{chem. purity}}$$

$$= \frac{(175\text{ mg/L})(4.2\text{ MGD})(8.34)}{0.85}$$

$$= 7211.65\text{ lb/day}$$

Applied Math for Water

Softening

pg. 14

1. On a water sample the total alkalinity was 98 mg/L and the total hardness was 112 mg/L. What is the carbonate and noncarbonate hardness concentrations in mg/L?

TA = 98 mg/L ; TH = 112 mg/L, so TH > TA

noncarbonate TH-TA = 112-98
= 14 mg/L

carbonate TA = 98 mg/L

pg. 15

2. It takes 3.2 mL of 0.02 N H_2SO_4 to reach a pH of 8.3 and a total of 10.1 mL to reach the Methyl Orange end-point in a 100 mL sample. What is the carbonate, bicarbonate and hydroxyl alkalinity in mg/L as $CaCO_3$?

P is less than 1/2 T

$$\text{Phenol alk} = \frac{(A)(N)(50{,}000)}{\text{Sample Vol, mL}} = \frac{(3.2\text{mL})(0.02N)(50000)}{100\text{ mL}} = 32\text{mg/L}$$

bicarbonate → T-2P = (101)(2)(32) = 37 mg/L

carbonate → (2)P = (2)(32) = 64 mg/L

hydroxide = 0

$$\text{Total alk} = \frac{(B)(N)(50000)}{\text{sample vol}} = \frac{(10.1\text{mL})(0.02)(50000)}{100\text{mL}} = 101\text{mg/L}$$

3. It takes 4.3 mL of 0.02 N H_2SO_4 to reach a pH of 8.3 and a total of 8.2 mL to reach the Methyl Orange end-point in a 100 mL sample. What is the carbonate, bicarbonate and hydroxyl alkalinity in mg/L as $CaCO_3$?

$$P_A = \frac{(4.3\text{mL})(0.02N)(50000)}{100\text{ mL}} = 43\text{ mg/L} \qquad T_A = \frac{(8.2\text{mL})(0.02N)(50000)}{100\text{ mL}} = 82\text{mg/L}$$

P_A is greater than 1/2 T_A

bicarbonate = 0 hydroxide = (2)(P)-T = (2)(43) - 82 = 4 mg/L

carbonate = (2)(T)-(2)(P) = (2)(82) - (2)(43) = 78 mg/L

pg. 14

4. How many pounds/day of quicklime (CaO) is required to treat 6.4 MGD with a dose of 148 mg/L. The quicklime is 85% pure.

$$\text{lb/day} = \frac{(\text{dose})(\text{flow, MGD})(8.34\text{ lb/gal})}{\%\text{ purity}}$$

$$= \frac{(148\text{mg/L})(6.4\text{MGD})(8.34\text{ lb/gal})}{0.85}$$

$$= 9293.7\text{ lb/day}$$

5. How many pounds/day of soda ash (Na_2CO_3) would be required to treat 7.3 MGD with a dose of 29.8 mg/L?

$$lb/day = \frac{(29.8\ mg/L)(7.3\ MGD)(8.34\ lb/gal)}{}$$

$$= 1814.28\ lb/day$$

6. It has been calculated that 112.5 mg/L quicklime (CaO) and 38.6 mg/L soda ash (Na_2CO_3) are required in treating a certain water. The quicklime to be used is 92% pure; the soda ash is 100% pure, and the plant flow is 1.6 MGD. How many pounds per day of quicklime and soda ash should be used?

$$lb/day_{quicklime} = \frac{(112.5\ mg/L)(1.6\ MGD)(8.34\ lb/gal)}{0.92} = 1631.74\ lb/day$$

$$lb/day_{soda\ ash} = \frac{(38.6\ mg/L)(1.6\ MGD)(8.34\ lb/gal)}{1} = 515.08\ lb/day$$

Answers:

1. 98 mg/L Carbonate hardness
   14 mg/L Noncarbonate hardness
2. Carbonate = 64 mg/L as $CaCO_3$
   Bicarbonate = 37 mg/L as $CaCO_3$
   Hydroxyl = 0 mg/L as $CaCO_3$
3. Carbonate = 78 mg/L as $CaCO_3$
   Bicarbonate = 0 mg/L as $CaCO_3$
   Hydroxyl = 4 mg/L as $CaCO_3$
4. 9,294 lbs/day
5. 1,814 lbs/day
6. 1,632 lbs/day quicklime
   515 lbs/day soda ash

Temperature Conversions

1. 215°F to °C

$$°C = (0.556)(F - 32)$$
$$= (0.556)(215 - 32)$$
$$= (0.556)(183) = 101.75°C$$

2. 34°C to °F

$$°F = (1.8)(°C) + 32$$
$$= (1.8)(34) + 32$$
$$= 61.2 + 32$$
$$= 93.2°F$$

Temperature Conversions

Convert these temperatures:

Remember formulas on page 1 in your formula book
°C = 0.556(°F – 32)
°F = 1.8 (°C) + 32

1. 160°F to °C

°C = 0.556 (160 - 32)

= 71.2°C

2. 70°F to °C

°C = 0.556 (70 - 32)

= 21.1°C

3. 35°C to °F

°F = 1.8(35) + 32

= 95° F

4. 45.5°C to °F

°F = 1.8(45.5) + 32

= 113.9°F

Answers:
1. 71.1°C 2. 21.1°C 3. 95°F 4. 113.9°F