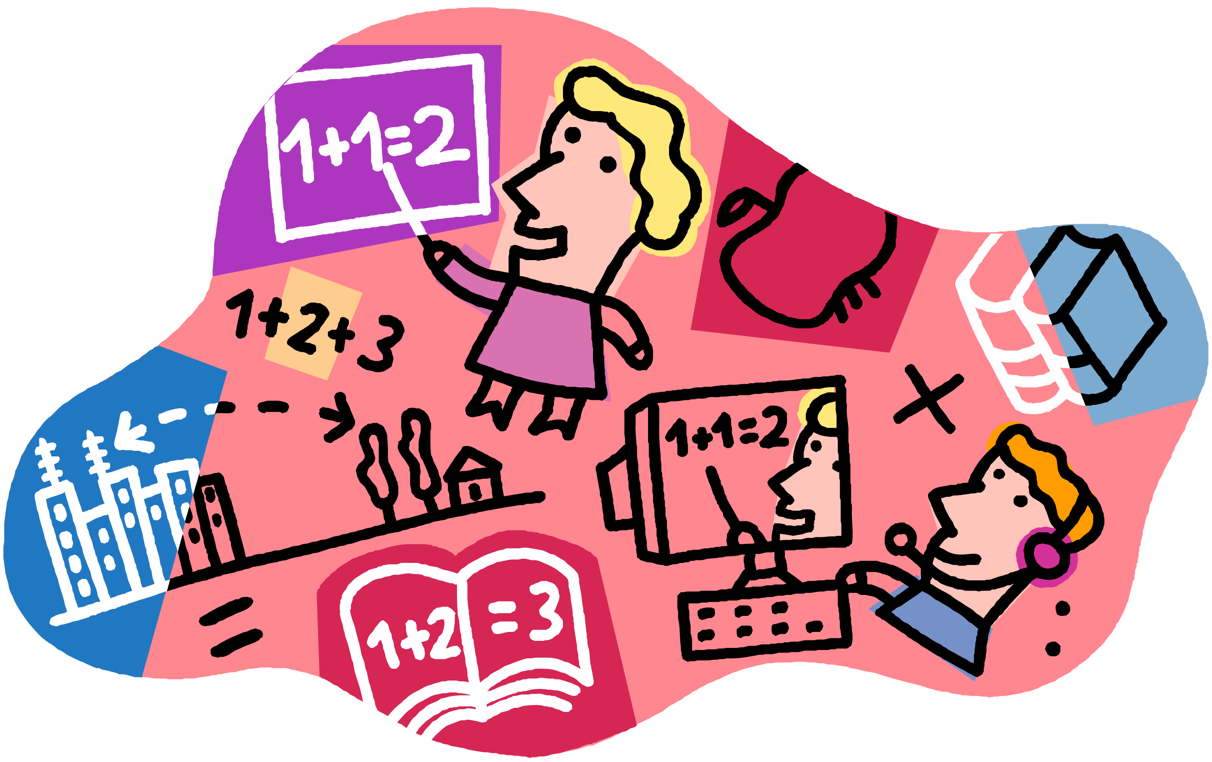
Applied Math for Wastewater Systems

Course #1201



Fleming Training Center
April 15-19, 2013

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Applied Math for Wastewater Treatment

Course#1201
April 15-19, 2012
Instructor: Shannon Pratt

<u>Monday, April 15</u>

8:30	Registration
8:45	Basic Math Review
10:30	Area and Volume Calculations Conversions
11:30	Lunch
12:45	Velocity and Flow

<u>Tuesday, April 16</u>

8:30	Activated Sludge
11:30	Lunch
12:45	Activated Sludge – continued
2:00	Wastewater Collection and Pre-Treatment

<u>Wednesday, April 17</u>

8:30	Sedimentation
11:30	Lunch
12:45	Horsepower and Efficiency

<u>Thursday, April 18</u>

8:30	Trickling Filters
10:00	Chemical Dosage
11:30	Lunch
12:45	Sludge Digestion and Dewatering

<u>Friday, April 19</u>

8:30	Laboratory Calculations
10:30	Metric System
11:15	Lunch
12:30	Exam and Course Evaluation

State of Tennessee

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Applied Math for Wastewater Systems

Section 1
Basic Math Review

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 (divided the numerator by the denominator).

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.

<u>Known</u>

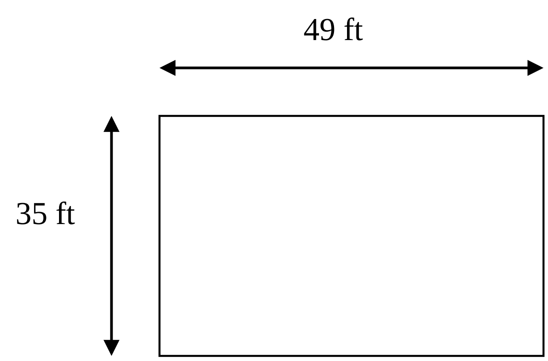
Length = 35 ft
Width = 49 ft

<u>Unknown</u>

Area = ?

A = (l)(w)

A = (35 ft)(49 ft)
A = 1715 ft^2

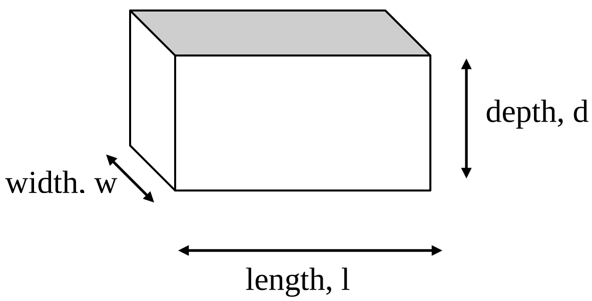


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

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	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

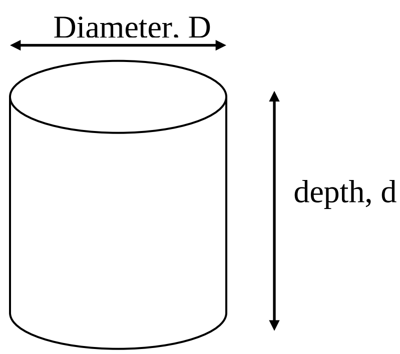
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



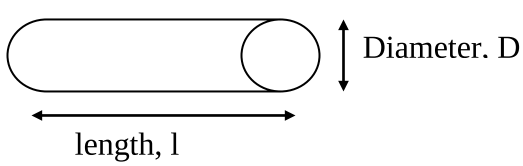
Volume = (l)(w)(d)

Cylindrical Tank



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

Portion of a Pipeline



Volume = (0.785) (D $)^2$ (l)

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

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

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

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

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

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

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

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

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

Finding x^2

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

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

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

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

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

Percent Practice Problems

Convert the following fractions to decimals:

1. $\frac{3}{4}$

2. $\frac{5}{8}$

3. $\frac{1}{4}$

4. $\frac{1}{2}$

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

<u>Basics – Finding x</u>

1.	1.8	8.	360	15.	2817
2.	5.7	9.	1649	16.	4903
3.	5.3	10.	244.7	17.	547,616
4.	5,976,990	11.	11	18.	117
5.	8256.6	12.	5	19.	508,000
6.	8.1	13.	7994	20.	0.35
7.	0.005	14.	590.4		

<u>Finding x^2</u>

21.	80	23.	40	25.	10.9
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 and Volume

1

Area, Volume and Conversions

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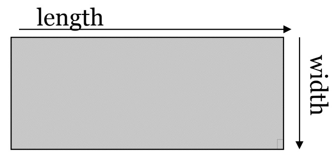
Area

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

Area Formulas

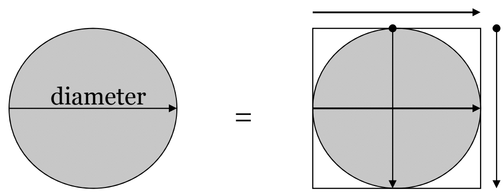
- Rectangle

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



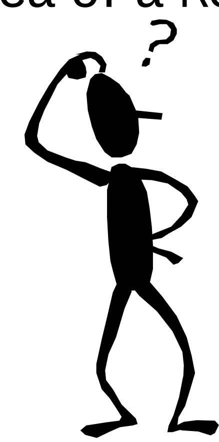
- Circle

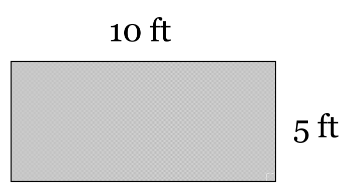
  A = $(0.785)(\text{diameter, ft})^2$



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

Area of a Rectangle





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

A = (10 ft)(5 ft)

A = 50 ft^2

5

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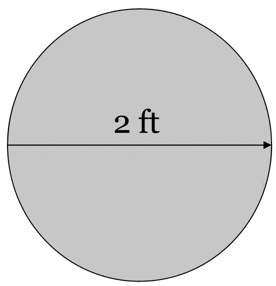
Area of a Circle



Diameter = 2 ft

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

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

$A = 3.14\ ft^2$

6

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Volume

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

  V = (l)(w)(d)

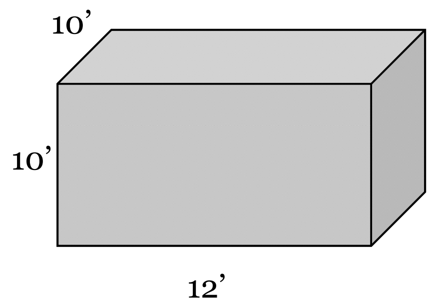
- Measured in:
  - Cubic inches
  - Cubic feet
  - Gallons
  - Acre-feet, etc.

Volume of a Rectangular Tank, ft^3

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

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

V = 1200 ft^3



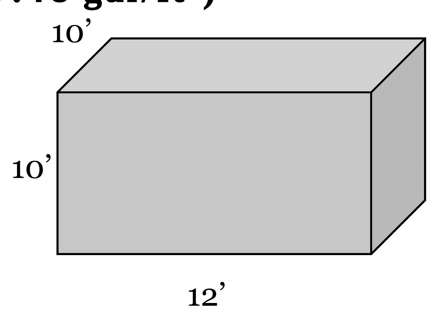
Volume of a Rectangular Tank, gal

V, ft^3 = 1200 ft^3

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

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

V, gal = 8976 gal

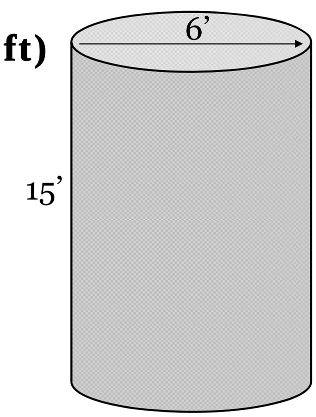


Volume of a Cylinder, ft^3

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

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

$V = 424\ ft^3$



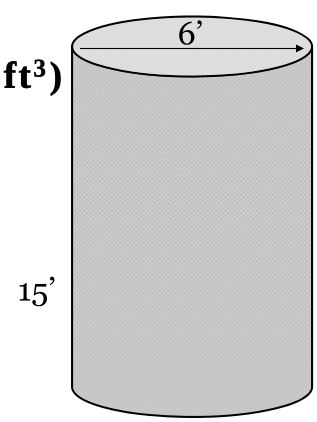
Volume of a Cylinder, gallons

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

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

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

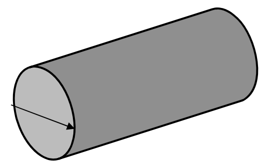
$V, gal = 3171.52\ gal$



Note

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

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



Diameter = 8 in

Conversions

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

Conversions

Conversion Factors

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

→ Multiply

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

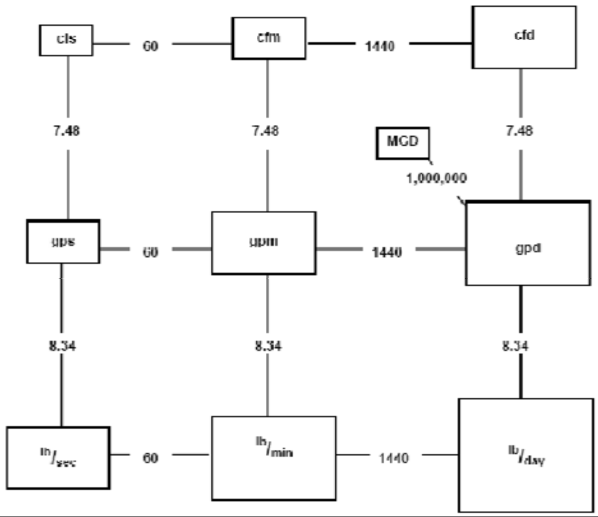
Conversions

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

¼ = 0.25 miles

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

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.

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' circular 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. How much does 1 ft^3 of water weigh (pounds)?

21. How many cubic yards of dirt is 700 ft^3?

22. 1050 ft^3 of dirt is being excavated, how many yd^3 is this?

23. A one-quarter mile segment of pipeline is being flushed, how many feet of pipeline is this?

24. How many feet of pipe is needed for 2 miles of new line?

25. A three-eights 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 are 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. 62.4 lbs
21. 25.9 yd^3
22. 38.9 yd^3
23. 1320 feet
24. 10,560 feet
25. 1,980 ft
26. 18,348 lbs

Section 3
Flow and Velocity

Velocity and Flow

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TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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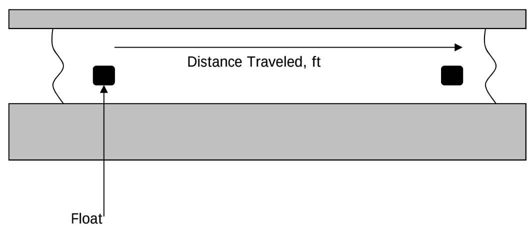
Velocity

- Distance per time
- Measured in:
  - Miles per hour
  - Feet per second
  - Feet per minute

TDEC - Fleming Training Center 2

Velocity Formulas

- Velocity, ft/sec = $\frac{\text{distance traveled, ft}}{\text{time, sec}}$
- Velocity, ft/min = $\frac{\text{distance traveled, ft}}{\text{time, min}}$



Velocity

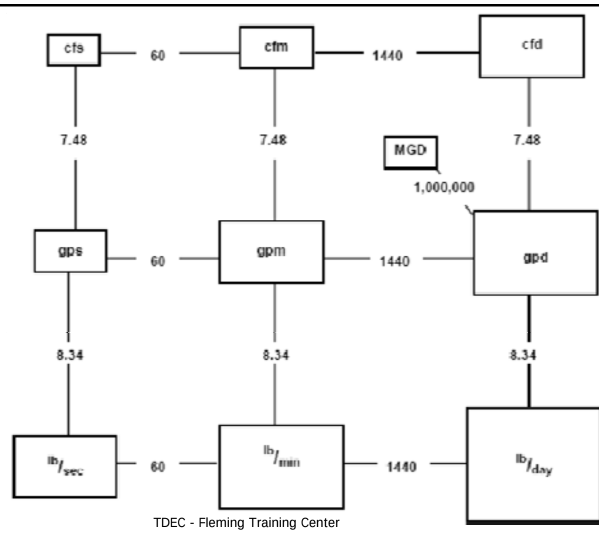
- A cork is placed in a channel and travels 400 feet in 2 minutes and 25 seconds. What is the velocity of the wastewater in the channel, ft/min?

- 25 seconds/60 = 0.4167
- Vel = $\frac{400 \text{ ft}}{2.4167 \text{ min}}$ = 165.5 ft/min

Flow Conversions – Box Method

Small to Big → multiply

Big to Small → divide



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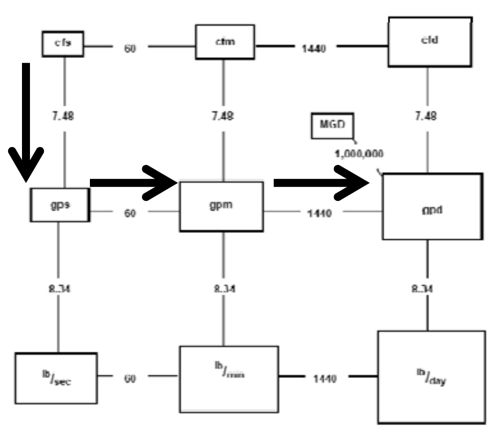
Flow Conversions – Box Method

- Express a flow of 2 ft^3/sec in terms of gal/day.
  - (2)(7.48)(60)(1440)
  - = 1,292,544 gpd



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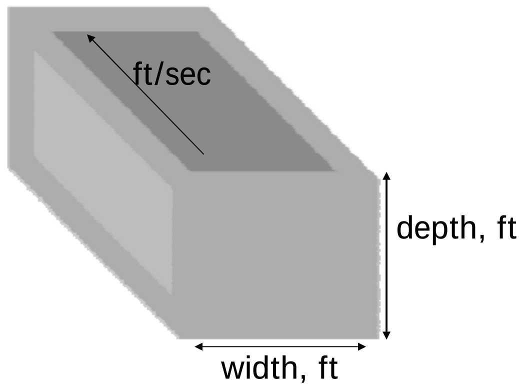
Flow in a Channel

- Q, ft^3/sec = (Area, ft^2)(Velocity, ft/sec)
- Q, ft^3/sec = (width, ft)(depth, ft)(velocity, ft/sec)



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Flow in a Channel

- A channel 36 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 1.2 ft/sec, what is the flow in the channel in ft^3/sec?

- Q = (3ft)(2 ft)(1.2 ft/sec)

  = 7.2 ft^3/sec

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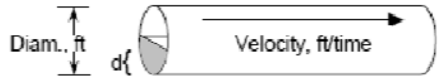
Flow in a Pipe Flowing Full

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

Flow in a Pipe Flowing Full

- The flow through a 10-inch diameter sewer is flowing full at 2.5 ft/sec. What is the flow rate in ft^3/sec and gal/day?
- Q = (0.785)(0.8333)(0.8333)(2.5) = 1.36 ft^3/sec
- (1.36 ft^3/sec)(7.48 gal/ft^3)(60 sec/min)(1440 min/day) = 880,699.5 gal/day



Flow in a Partially Full Pipe

- Q = (factor from d/D table)(Diameter, ft)^2(vel, fps)

depth/Diameter Table

0.01	0.0013	0.26	0.1623	0.51	0.4027	0.76	0.6404
0.02	0.0037	0.27	0.1711	0.52	0.4127	0.77	0.6489
0.03	0.0069	0.28	0.1800	0.53	0.4227	0.78	0.6573
0.04	0.0105	0.29	0.1890	0.54	0.4327	0.79	0.6655
0.05	0.0147	0.30	0.1982	0.55	0.4426	0.80	0.6736
0.06	0.0192	0.31	0.2074	0.56	0.4526	0.81	0.6813
0.07	0.0242	0.32	0.2167	0.57	0.4625	0.82	0.6893
0.08	0.0294	0.33	0.2260	0.58	0.4724	0.83	0.6969
0.09	0.0350	0.34	0.2355	0.59	0.4822	0.84	0.7043
0.10	0.0409	0.35	0.2450	0.60	0.4920	0.85	0.7115
0.11	0.0470	0.36	0.2546	0.61	0.5018	0.86	0.7186
0.12	0.0534	0.37	0.2642	0.62	0.5118	0.87	0.7254
0.13	0.0600	0.38	0.2739	0.63	0.5212	0.88	0.7320
0.14	0.0668	0.39	0.2836	0.64	0.5308	0.89	0.7384
0.15	0.0739	0.40	0.2934	0.65	0.5404	0.90	0.7445
0.16	0.0811	0.41	0.3032	0.66	0.5499	0.91	0.7504
0.17	0.0885	0.42	0.3130	0.67	0.5594	0.92	0.7560
0.18	0.0961	0.43	0.3229	0.68	0.5687	0.93	0.7612
0.19	0.1039	0.44	0.3328	0.69	0.5780	0.94	0.7662
0.20	0.1118	0.45	0.3428	0.70	0.5872	0.95	0.7707
0.21	0.1199	0.46	0.3527	0.71	0.5964	0.96	0.7749
0.22	0.1281	0.47	0.3627	0.72	0.6054	0.97	0.7785
0.23	0.1365	0.48	0.3727	0.73	0.6143	0.98	0.7816
0.24	0.1449	0.49	0.3827	0.74	0.6231	0.99	0.7841
0.25	0.1535	0.50	0.3927	0.75	0.6318	1.00	0.7854

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Flow in a Partially Full Pipe

- A 10-inch diameter pipeline has water flowing at a depth of 4 inches. What is the gal/min flow if the velocity of the wastewater is 3.1 fps?

- d/D = 4 inches of water ÷ 10-inch diameter
  = 4/10 = 0.4 ↝ 0.2934
- Q = (0.2934)(0.8333)(0.8333)(3.1) = 0.6316 ft^3/sec
- (0.6316 ft^3/sec)(7.48 gal/ft^3)(60 sec/min) = 408,169 gpm

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Applied Math for Wastewater
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 gpm	3. 396 ft^3/min
2. 8.7 ft^3/min	5. 2201 gpm	6. 3,931,200 gpd

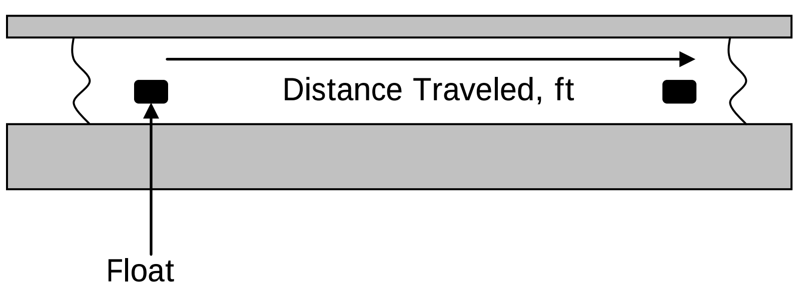
Applied Math for Wastewater
Flow and Velocity

Velocity

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

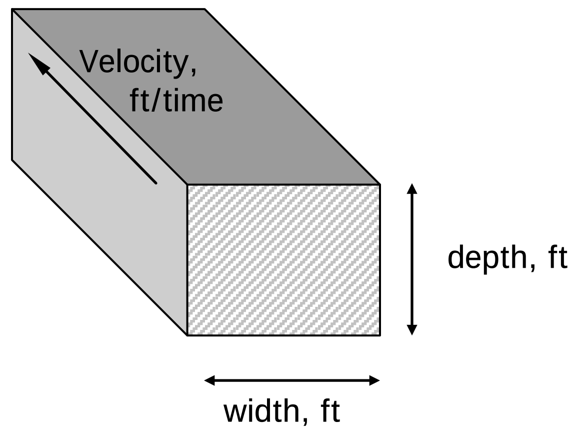
2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

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



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

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



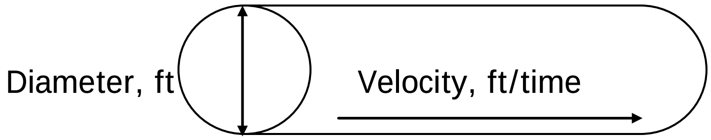
$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

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?



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

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

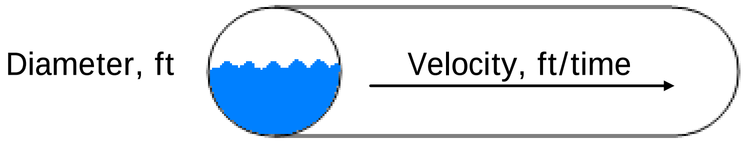
<u>Flow through full pipe</u>

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

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

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

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



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

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

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

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

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

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

Answers:

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

Applied Math for Wastewater
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” sewer needs to be cleaned. If the line is flushed at 2.5 ft/second, how many gallons/minute of water should be flushed from the hydrant?

7. A 36” pipe has just been installed. If the wastewater 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?

VELOCITY (OPEN CHANNEL)

9. 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.)

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

11. 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?

FLOW IN A PARTIALLY FULL PIPE

12. Wastewater is moving through an 18-inch sewer at a velocity of 3 ft/sec. If the wastewater is flowing at a depth of 6 inches, calculate the flow, gal/min.

13. Wastewater is moving through a 12-inch sewer at a velocity of 240 ft/min. If the water is flowing at a depth of 9 inches, what is the flow rate, MGD?

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. 120 ft/min
10. 1.5 ft/sec
11. 1533 cu ft/min
12. 685 gal/min
13. 1.63 MGD

Section 4
Collection and Pretreatment

Preliminary Treatment Math

Wet Well Capacity

1. A wet well is 13 feet long, 8 feet wide and 10 feet deep. What is the gallon capacity of the wet well?

2. The maximum capacity of a wet well is 4787 gal. If the wet well is 10 feet long and 8 feet wide, what is the maximum depth of water in the wet well in feet?

Wet Well Pumping Rate, gpm

3. A wet well is 12 feet by 10 feet. With no influent to the well, a pump lowers the water level 1.2 feet during a 4-minute pumping test. What is the pumping rate, gpm?

4. The water level in a well drops 18 inches during a 3-minute pumping test. If the wet well is 8 feet by 6 feet, what is the pumping rate in gpm?

Screenings Removed

5. A total of 55 gallons of screenings are removed from the wastewater flow during a 24-hour period. What is the screenings removal, cu.ft./day?

6. The flow at a treatment plant is 3.6 MGD. If the total of 55 cu.ft. screenings are removed during a 24-hour period, what is the screenings removal, cu.ft./MG?

Screenings Pit Capacity, days

7. A screening pit has a capacity of 400 cu.ft. If an average of 3.8 cu.ft of screenings are removed daily from the wastewater flow, in how many days will the pit be full?

8. A plant averages a screenings removal of 2.1 cu.ft./MG. If the average daily flow is 2.7 MGD, how many days will it take to fill a 290 cu.ft. screening pit?

Grit Removal, cu.ft./MG

9. A treatment plant removes 12 cu.ft. of grit in one day. How many cu.ft./MG of grit are removed if the plant flow was 8 MGD?

10. The total daily grit removal for a plant is 270 gallons. If the flow is 12.3 MGD, find the grit removal, cu.ft./MG.

Grit Channel Flow Rate

11. A grit channel 36 inches wide has water flowing to a depth of 1 ft. If the velocity of the wastewater is 1.1 ft/sec, what is the flow in the channel in cfs and gpm?

12. A grit channel is 3 feet wide, 50 feet long with water flowing to a depth of 18 inches. What is the fpm velocity through the channel if the flow is 220 gpm?

Answers:

1. 7,779.2 gal
2. 8 feet
3. 269 gpm
4. 179.5 gpm
5. 7.35 cu.ft./day
6. 15.3 cu.ft./MG
7. 105 days
8. 51 days
9. 1.5 cu.ft./MG
10. 2.9 cu.ft./MG
11. 1481 gpm
12. 6.5 fpm

Applied Math for Wastewater Treatment
Preliminary Treatment Math
Extra Problems

Screenings Pit Capacity

1. A screenings pit has a capacity of 600 cu.ft. If an average of 2.9 cu.ft. of screenings is removed daily from the wastewater flow, in how many days will the pit be full?

2. A screenings pit has a capacity of 9 cu. yards available for screenings. If the plant removes an average of 1.6 cu.ft. per day, in how many days will the pit be full?

3. A plant has been averaging a screenings removal of 2.6 cu.ft./MG. If the average daily flow is 2.9 MGD, how many days will it take to fill a screenings pit with an available capacity of 292 cu.ft.?

4. Suppose we want to use a screenings pit for 120 days. If the screenings removal rate is 3.5 cu.ft./day, what is the required screenings pit capacity in cu.ft.?

Grit Channel Velocity

5. A grit channel is 4 ft. wide, with water flowing to a depth of 18 inches. If the flow meter indicates a flow rate of 1820 gpm, what is the velocity of flow through the channel in feet/sec?

6. A stick in a grit channel travels 26 feet in 32 seconds. What is the estimated velocity in the channel in feet/sec.?

7. The total flow through both channels of a grit channel is 4.3 cfs. If each channel is 3 ft wide and water is flowing to a depth of 14 inches, what is the velocity of flow through the channel in fps?

8. A stick placed in a grit channel flows 36 feet in 32 seconds. What is the estimated velocity in the channel in feet/sec.?

9. The depth of water in a grit channel is 16 inches. The channel is 34 inches wide. If the flow meter indicates a flow of 1140 gpm, what is the velocity of flow through the channel in ft/sec.?

Grit Removal

10. A treatment plant removes 12 cu.ft. of grit in a day. If the plant flow is 8 MGD, what is the grit removal expressed in cu.ft./MG?

11. The total daily grit removal for a plant is 260 gallons. If the plant flow is 11.4 MGD, how many cu.ft. of grit are removed per million gallons of flow?

12. The average grit removal at a particular treatment plant is 3.1 cu.ft./MG. If the monthly average daily flow is 3.8 MGD, how many cubic yards of grit would be removed from the wastewater flow during one 30-day month?

13. The monthly average grit removal is 2.2 cubic feet per million gallons. If the average daily flow for the month is 4,230,000 gpd, how many cubic yards must be available for grit disposal if the disposal pit is to have a 90-day capacity?

14. A grit channel is 2.6 feet wide and has water flowing to a depth of 16 inches. If the velocity through the channel is 1.1 feet per second, what is the flow rate through the channel in cu.ft./sec.?

15. A grit channel 3-ft wide has water flowing at a velocity of 1.4 ft per second. If the depth of the water is 14 inches, what is the flow rate through the channel, in gal/day?

16. A grit channel 32 inches wide has water flowing to a depth of 10 inches. If the velocity of the water is 0.90 fps, what is the flow rate in the channel in cu.ft./sec?

Answers:

1. 207 days
2. 152 days
3. 39 days
4. 420 cu.ft.
5. 0.68 fps
6. 0.81 fps
7. 0.61 fps
8. 1.13 fps
9. 0.67 fps
10. 1.5 cu.ft./MG
11. 3.0 cu.ft./MG
12. 13.1 cu.yd./month
13. 31 cu.yd.
14. 3.8 cfs
15. 3,166,733 gpd
16. 2 cfs

Section 5
Sedimentation

Applied Math for Wastewater Treatment
Sedimentation

1. The flow to a circular clarifier is 3,940,000 gpd. If the clarifier is 75 ft in diameter and 12 feet deep, what is the clarifier detention time in hours? (Round to the nearest tenth.)

2. A circular clarifier has a diameter of 50 feet. If the primary clarifier influent flow is 2,260,000 gpd, what is the surface overflow rate in gpd/sq.ft.?

3. A rectangular clarifier has a total of 210 ft. of weir. What is the weir overflow rate in gpd/ft when the flow 3,728,000 gpd?

4. A secondary clarifier, 55-ft in diameter, receives a primary effluent flow of 1,887,000 gpd and a return sludge flow of 528,000 gpd. If the MLSS concentration is 2640 mg/L, what is the solids loading rate in lbs/day/sq.ft. on the clarifier? (Round to the nearest tenth.)

5. A circular primary clarifier has a diameter of 60 feet. If the influent flow to the clarifier is 2.62 MGD, what is the surface overflow rate in gpd/sq.ft.?

6. A secondary clarifier, 70 feet in diameter, receives a primary effluent flow of 2,740,000 gpd and a return sludge flow of 790,000 gpd. If the mixed liquor suspended solids concentration is 2815 mg/L, what is the solids loading rate in the clarifier in lbs/day/sq.ft.? (Round to the nearest tenth.)

7. The flow to a secondary clarifier is 5.1 MGD. If the influent BOD concentration is 216 mg/L and the effluent BOD concentration is 103 mg/L, how many lbs/day BOD are removed daily?

8. The flow to a sedimentation tank 80 feet long, 30 feet wide and 14 feet deep is 4.05 MGD. What is the detention time in the tank, in hours? (Round to the nearest tenth.)

Answers:

1. 2.4 hours
2. 1152 gpd/sq.ft.
3. 17,752 gpd/ft
4. 22.4 lbs/day/sq.ft.
5. 927 gpd/sq.ft.
6. 21.5 lbs/day/sq.ft.
7. 4806 lbs/day
8. 1.5 hrs

Applied Math for Wastewater Treatment
Sedimentation
Extra Problems

Detention Time, hours

1. The flow to a sedimentation tank is 70 ft long, 25 ft wide and 10 ft deep is 100,000 gph. What is the detention time in hours?

2. The flow to a sedimentation tank 90 ft long, 30 ft wide and 12 feet deep is 3.0 MGD. What is the detention time in the tank in hours?

3. A rectangular sedimentation basin is 70 feet long by 25 feet wide and has water to a depth of 10 feet. The flow to the basin is 2,220,000 gpd. Calculate the detention time in hours for the sedimentation basin.

4. A circular clarifier has a diameter of 80 feet and an average water depth of 12 feet. If the flow to the clarifier is 2,920,000 gpd, what is the detention time in hours?

5. A rectangular sedimentation basin is 60 ft long and 20 ft wide and contains water to a depth of 10 feet. If the flow to the basin is 1,520,000 gpd, what is the detention time in hours?

Weir Overflow Rate, gpd/ft

6. A rectangular clarifier has a total of 120 feet of weir. What is the weir overflow rate in gpd/ft when the flow is 1.5 MGD?

7. A circular clarifier receives a flow of 2.95 MGD. If the diameter of the weir is 70 ft, what is the weir overflow rate in gpd/ft?

8. A circular clarifier receives a flow of 2,520,000 gpd. If the diameter of the weir is 70 ft, what is the weir overflow rate in gpd/ft?

9. A rectangular sedimentation basin has a length of 50 ft and a width of 35 ft. If the flow to the basin is 1,890,000 gpd, what is the weir overflow rate in gpd/ft?

10. A circular clarifier receives a flow of 3.7 MGD. If the diameter of the weir is 70 ft, what is the weir overflow rate in gpd/ft?

Surface Overflow Rate, gpd/sq.ft.

11. A circular clarifier has a diameter of 55 ft. If the primary effluent flow is 2,075,000 gpd, what is the surface overflow rate in gpd/sq.ft.?

12. A sedimentation basin 70 ft by 15 ft receives a flow of 1.2 MGD. What is the surface overflow rate in gpd/sq.ft.?

13. The average flow to a secondary clarifier is 2580 gpm. What is the surface overflow rate, gpd/ft^2 if the secondary clarifier has a diameter of 70 ft?

14. A rectangular sedimentation basin is 60 ft long and 25 ft wide. When the flow is 510 gpm, what is the surface overflow in gpd/sq.ft.?

15. A circular clarifier has a diameter of 70 ft. If the flow to the clarifier is 1610 gpm, what is the surface overflow in gpd/sq.ft.?

Solids Loading Rate, lbs/day/sq.ft.

16. A circular secondary clarifier with a diameter of 100 ft treats a flow of 3.5 MGD inflow and 1.0 MGD return sludge flow. If the MLSS concentration is 4200 mg/L, what is the solids loading rate in lbs/day/sq.ft.?

17. A secondary clarifier handles a flow of 0.9 MGD and a suspended solids concentration of 3600 mg/L. The clarifier is 50 ft in diameter. Find the solids loading rate in lbs/day/sq.ft.

18. A secondary clarifier is 70 ft in diameter and receives a combined primary effluent and return activated sludge (RAS) flow of 3.60 MGD. If the MLSS concentration in the aerator is 2650 mg/L, what is the solids loading rate on the secondary clarifier in lbs/day/sq.ft.?

19. A secondary clarifier, 80 ft in diameter, receives a primary effluent flow of 3.10 MGD and a return activated sludge flow of 1.15 MGD. If the MLSS concentration is 2825 mg/L, what is the solids loading rate on the clarifier in lbs/day/sq.ft.?

20. A secondary clarifier, 60 ft in diameter, receives a primary effluent flow of 2,550,000 gpd and a return activated sludge flow of 800,000 gpd. If the MLSS concentration is 2210 mg/L, what is the solids loading rate on the clarifier in lbs/day/sq.ft.?

BOD and Suspended Solids Removed, lbs/day

21. If 110 mg/L suspended solids are removed by a primary clarifier, how many lbs/day suspended solids are removed when the flow is 6,150,000 gpd?

22. If 125 mg/L suspended solids are removed by a primary clarifier, how many lbs/day suspended solids are removed when the flow is 5.16 MGD?

23. The flow to a primary clarifier is 2,920,000 gpd. If the influent to the clarifier has a BOD concentration of 240 mg/L and the primary effluent has a 200 mg/L BOD, how many lbs/day BOD are removed by the clarifier?

24. The flow to a secondary clarifier is 4.44 MGD. If the influent BOD concentration is 200 mg/L and the effluent concentration is 110 mg/L, how many lbs of BOD are removed daily?

25. The flow to a primary clarifier is 980,000 gpd. If the influent to the clarifier has a suspended solids concentration of 320 mg/L and the primary clarifier effluent has a suspended solids concentration of 120 mg/L, how many lbs/day suspended solids are removed by the clarifier?

Unit Process Efficiency, %

26. The suspended solids entering a primary clarifier is 182 mg/L. If the suspended solids concentration in the primary clarifier effluent is 79 mg/L, what is the suspended solids removal efficiency of the primary clarifier?

27. The influent to a primary clarifier has a BOD content of 260 mg/L. If the primary clarifier effluent has a BOD concentration of 54 mg/L, what is the BOD removal efficiency?

28. The suspended solids entering a primary clarifier is 230 mg/L. If the suspended solids concentration in the primary clarifier effluent is 95 mg/L, what is the suspended solids removal efficiency of the primary clarifier?

29. The concentration of suspended solids entering a primary clarifier is 188 mg/L. If the concentration of suspended solids in the primary clarifier effluent is 77 mg/L, what is the suspended solids removal efficiency of the primary clarifier?

30. The influent to a primary clarifier has a BOD content of 280 mg/L. If the primary clarifier effluent has a BOD concentration of 60 mg/L, what is the BOD removal efficiency of the primary clarifier?

Answers:

1. 1.3 hrs
2. 1.9 hrs
3. 1.4 hrs
4. 3.7 hrs
5. 1.4 hrs
6. 12,500 gpd/ft
7. 13,421 gpd/ft
8. 11,465 gpd/ft
9. 11,118 gpd/ft
10. 16,833 gpd/ft
11. 874 gpd/ft^2
12. 1143 gpd/ft^2
13. 966 gpd/ft^2
14. 490 gpd/ft^2
15. 603 gpd/ ft^2
16. 20 lbs/day/ ft^2
17. 14 lbs/day/ ft^2
18. 21 lbs/day/ ft^2
19. 20 lbs/day/ ft^2
20. 22 lbs/day/ ft^2
21. 5642 lbs/day
22. 5379 lbs/day
23. 974 lbs/day
24. 3333 lbs/day
25. 1635 lbs/day
26. 56.6%
27. 79.2%
28. 58.7 %
29. 59.0%
30. 78.6%

Section 6
Trickling Filter Math

Applied Math for Wastewater Treatment
Trickling Filter Math

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

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

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

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

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

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

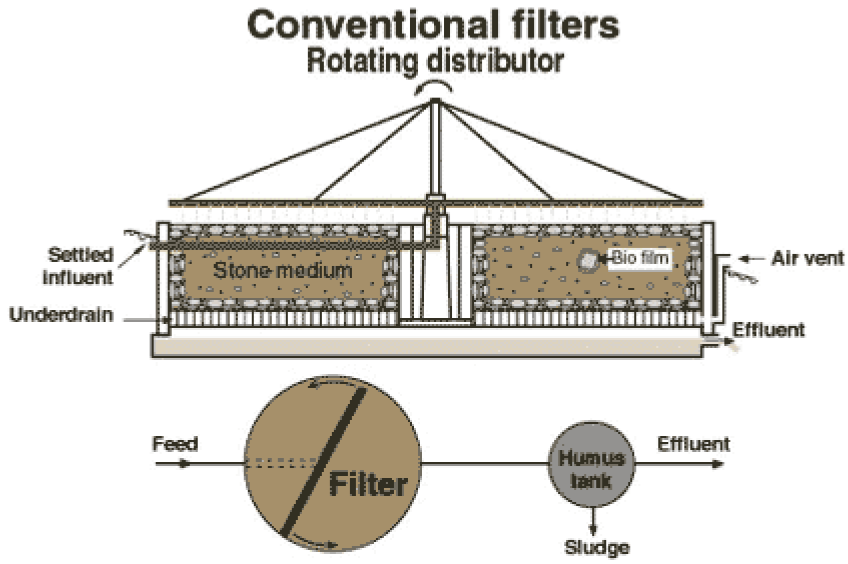
7. The suspended solids concentration entering a trickling filter is 210 mg/L. If the suspended solids concentration in the trickling filter effluent is 67 mg/L, what is the suspended solids removal efficiency of the trickling filter?

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

Answers:

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

Applied Math for Wastewater Treatment
Trickling Filter Math
Extra Problems



Hydraulic Loading Rate

1. A trickling filter 75 ft in diameter treats a primary clarifier effluent flow of 1.4 MGD. If the recirculated flow is 0.3 MGD, what is the hydraulic loading rate, gpd/sq ft?

2. The flow to a standard rate trickling filter is 450,000 gpd. If the trickling filter is 80 ft in diameter and 5 ft deep, what is the hydraulic loading rate?

3. A trickling filter, 80 ft in diameter, treats a primary effluent flow of 660,000 gpd. If the recirculated flow to the trickling filter is 120,000 gpd, what is the hydraulic loading rate on the trickling filter in gpd/ft^2?

4. A high-rate trickling filter receives a flow of 2360 gpm. If the filter has a diameter of 90 ft, what is the hydraulic loading on the filter in gpd/ft^2?

5. A trickling filter receives a flow of 2200 gpm with a BOD concentration of 125 mg/L. If the filter is 95 feet in diameter, what is the hydraulic loading rate, gpd/sq ft?

Organic Loading Rate (OLR)

6. A trickling filter 80 ft in diameter with a media depth of 4 ft receives a primary effluent flow of 1.85 MGD with a BOD concentration of 110 mg/L. What is the organic loading rate, lbs BOD/day/1000 cu ft?

7. An 80 ft diameter trickling filter with a media depth of 7 ft receives a flow of 2,180,000 gpd. If the BOD concentration of the primary effluent is 139 mg/L, find the organic loading rate.

8. A trickling filter, 100 ft in diameter with a media depth of 6 ft, receives a flow of 1,400,000 gpd. If the BOD concentration of the primary effluent is 210 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 ft^3?

9. A 90-ft diameter trickling filter with a media depth of 7 ft receives a primary effluent flow of 3,400,000 gpd with a BOD of 111 mg/L. What is the organic loading on the trickling filter in lbs BOD/day/1000 ft^3?

10. Calculate OLR for the following trickling filter:

Diameter: 75 ft
Media depth: 5 ft
Flow: 315 gpm
Influent BOD: 210 mg/L

BOD & Suspended Solids Removal

11. If 110 mg/L suspended solids are removed by a trickling filter, how many pounds per day suspended solids are removed when the flow is 4.2 MGD?

12. A trickling filter receives a flow of 4,900,000 gpd. If the BOD concentration entering the trickling filter is 160 mg/l and the effluent contains 30 mg/L, how many pounds of BOD are removed daily?

13. If 122 mg/L suspended solids are removed by a trickling filter, how many lbs/day suspended solids are removed when the flow is 3,240,000 gpd?

14. The flow to a trickling filter is 1.82 MGD. If the primary effluent has a BOD concentration of 250 mg/L and the trickling filter effluent has a BOD concentration of 74 mg/L, how many lbs of BOD are removed?

15. If 182 mg/L of BOD are removed from a trickling filter when the flow to the trickling filter is 2,920,000 gpd, how many lbs/day BOD are removed?

Unit Process Efficiency

16. The suspended solids entering a trickling filter is 135 mg/L. If the suspended solids in the effluent is 28 mg/L, what is the suspended solids removal efficiency, %? If the flow to the filter is 1.5 cfs, calculate lbs/day suspended solids removed.

17. The suspended solids concentration entering a trickling filter is 149 mg/L. If the suspended solids concentration in the trickling filter effluent is 48 mg/L, what is the suspended solids removal efficiency of the trickling filter?

18. The influent to a primary clarifier has a BOD content of 261 mg/L. The trickling filter effluent BOD is 22 mg/L. What is the BOD removal efficiency of the treatment plant?

19. The concentration of suspended solids entering a trickling filter if 201 mg/L. If the concentration of suspended solids in the trickling filter effluent is 22 mg/L, what is the suspended solids removal efficiency of the trickling filter?

20. The concentration of suspended solids entering a trickling filter is 111 mg/L. If 88 mg/L suspended solids are removed from the trickling filter, what is the suspended solids removal efficiency of the trickling filter?

ANSWERS:

1. 385 gpd/ft^2
2. 89.6 gpd/ft^2
3. 155 gpd/ft^2
4. 534 gpd/ft^2
5. 447 gpd/ft^2
6. 84.5 lbs BOD/day/1000 ft^3
7. 71.9 lbs BOD/day/1000 ft^3
8. 52.1 lbs BOD/day/1000 ft^3
9. 70.7 lbs BOD/day/1000 ft^3
10. 36 lbs BOD/day/1000 ft^3
11. 3853 lbs/day SS Removed
12. 5313 lbs/day BOD Removed
13. 3297 lbs/day SS Removed
14. 2671 lbs/day BOD Removed
15. 4432 lbs/day BOD Removed
16. 79%; 865 lbs/day SS Removed
17. 67.8%
18. 91.6%
19. 89.1%
20. 79.3%

Section 7
Activated Sludge

Applied Math for Wastewater Treatment
Activated Sludge

BOD or COD Loading, lbs/day

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

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

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

Food to Microorganism Ratio

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

Mean Cell Residence Time (MCRT), days

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

Wasting Rates

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

Applied Math for Wastewater Treatment
Activated Sludge

BOD or COD Loading, lbs/day

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

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

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

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

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

Food to Microorganism Ratio

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

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

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

Mean Cell Residence Time (MCRT), days

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

9. Determine MCRT given the following information:

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

Wasting Rates

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

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

Answers:

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

Applied Math for Wastewater Treatment
Activated Sludge
Extra Problems

BOD or COD Loading, lbs/day

1. The flow to an aeration basin is 880,000 gpd. If the BOD content of the wastewater entering the aeration basin is 240 mg/L, what is the lbs/day BOD loading?

2. The flow to the aeration basin is 2980 gpm. If the COD concentration of the wastewater is 160 mg/L, how many lbs of COD are applied to the aeration basin daily?

3. The BOD content of the wastewater entering an aeration basin is 165 mg/L. If the flow to the aeration basin is 3,240,000 gpd, what is the lbs/day BOD loading?

4. The daily flow to an aeration basin is 4,880,000 gpd. If the COD concentration of the influent wastewater is 150 mg/L, how many lbs of COD are applied to the aeration basin daily?

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

5. If the mixed liquor suspended solids concentration is 2110 mg/L and the aeration basin has a volume of 460,000 gallons, how many lbs of suspended solids are in the aeration basin?

6. The aeration basin of a conventional activated sludge plant has a mixed liquor volatile suspended solids (MLVSS) concentration of 2420 mg/L. If the aeration basin is 90 ft long by 50 ft wide and has wastewater to a depth of 16 ft, how many lbs of MLVSS are under aeration?

7. The aeration basin of a conventional activated sludge plant has a mixed liquor volatile suspended solids (MLVSS) concentration of 2410 mg/L. If the aeration basin is 80 ft long by 40 ft wide and has wastewater to a depth of 16 ft, how many lbs of MLVSS are under aeration?

8. An aeration basin is 110 ft long, 30 ft wide and has wastewater to a depth of 16 ft. If the aeration basin of this conventional activated sludge plant has a mixed liquor suspended solids (MLSS) concentration of 2740 mg/L, how many lbs of MLSS are under aeration?

9. An aeration basin is 110 ft long, 50 ft wide and has wastewater to a depth of 16 ft. If the mixed liquor suspended solids (MLSS) concentration in the aeration basin is 2470 mg/L with a volatile solids content of 73%, how many lbs of MLVSS are under aeration?

Food to Microorganism Ratio

10. An activated sludge aeration basin receives a primary effluent flow of 2.72 MGD with a BOD concentration of 198 mg/L. The mixed liquor volatile suspended solids (MLVSS) concentration is 2610 mg/L and the aeration basin volume is 480,000 gallons. What is the current F/M ratio?

11. An activated sludge aeration basin receives a primary effluent flow of 3,350,000 gpd with a BOD of 148 mg/L. The mixed liquor volatile suspended solids (MLVSS) concentration is 2510 mg/L and the aeration basin volume is 490,000 gallons. What is the F/M ratio?

12. The flow to a 195,000 gallon oxidation ditch is 320,000 gpd. The BOD concentration of the wastewater is 180 mg/L. If the mixed liquor suspended solids (MLSS) concentration is 2540 mg/L with a volatile solids content of 72%, what is the F/M ratio?

13. The desired F/M ratio at an extended aeration activated sludge plant is 0.7 lb BOD/lb MLVSS. If the primary effluent flow is 3.3 MGD and has a BOD of 181 mg/L, how many pounds of MLVSS should be maintained in the aeration basin?

14. The desired F/M ratio at a particular activated sludge plant is 0.4 lbs BOD/lb MLVSS. If the primary effluent flow is 2,510,000 gpd and has a BOD concentration of 141 mg/L, how many lbs of MLVSS should be maintained in the aeration basin?

Mean Cell Residence Time (MCRT), days

15. An activated sludge system has a total of 29,100 lbs of MLSS. The concentration of suspended solids leaving the final clarifier in the effluent is calculated to be 400 lbs/day. Suspended solids wasted from the clarifier are 2920 lbs/day. What is the MCRT in days?

16. Determine the MCRT given the following data: aeration basin volume, 1,500,000 gallons; mixed liquor suspended solids, 2710 mg/L; final clarifier, 106,000 gallons; waste activated sludge, 5870 mg/L; WAS pumping rate, 72,000 gpd; plant flow, 3.3 MGD; secondary effluent SS, 25 mg/L; average clarifier core SS, 1940 mg/L.

17. An aeration basin has a volume of 460,000 gallons. The final clarifier has a volume of 178,000 gallons. The MLSS concentration in the aeration basin is 2222 mg/L. If 1610 lbs/day suspended solids are wasted and 240 lbs/day suspended solids are in the secondary effluent, what is the MCRT for the activated sludge system?

18. Determine MCRT given the following information:

Aeration Basin = 350,000 gal	MLSS = 2910 mg/L
Final Clarifier = 125,000 gal	S.E. SS = 16 mg/L
Flow = 1,400,000 gpd	WAS = 6210 mg/L
WAS Pump Rate = 27,000 gpd	

Wasting Rates

19. Using Constant F/M Ratio: The desired F/M ratio for an activated sludge system is 0.5 lbs BOD/lb MLVSS. It has been calculated that 3400 lbs of BOD enter the aeration basin daily. If the volatile solids content of the MLSS is 69%, how many lbs MLSS are desired in the aeration basin?

20. Using Constant MCRT: The desired MCRT for an activated sludge plant is 9 days. The secondary effluent flow is 3,220,000 gpd with a suspended solids content of 23 mg/L. There is a total of 32,400 lbs SS in the system. How many lbs/day WAS SS must be wasted to maintain the desired MCRT?

21. Given the following data, determine the lbs/day suspended solids to be wasted:

Aeration Tank Volume = 1.2 MG	Desired F/M = 0.4
Influent Flow = 3,100,000 gpd	MLSS = 2200 mg/L
BOD = 110 mg/L	%VS = 68%

Answers:

1. 1761 lbs BOD/day
2. 5726 lbs COD/day
3. 4459 lbs BOD/day
4. 6105 lbs COD/day
5. 8095 lbs MLSS
6. 10,870 lbs MLVSS
7. 7698 lbs MLVSS
8. 9025 lbs MLSS
9. 9899 lbs MLVSS
10. 0.43
11. 0.40
12. 0.16
13. 7116 lbs MLVSS
14. 7379 lbs MLVSS
15. 8.8 days
16. 8.5 days
17. 6.4 days
18. 7.3 days
19. 9855 lbs MLSS desired
20. 2982 lbs MLSS to waste
21. 11,562 lbs MLSS to waste

Section 8
Pumps

Horsepower and Efficiency

Applied Math For Pumps And Motors

TDEC - Fleming Training Center 1

Understanding Work and 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

TDEC - Fleming Training Center 2

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

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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.

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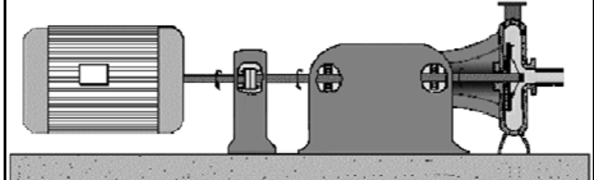

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Computing Water Horsepower

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

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

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

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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 = $\frac{(3000 \text{ gpm})(25 \text{ head in ft})}{3960}$

  = 18.94

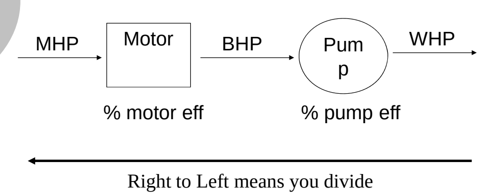
Brake Horsepower

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

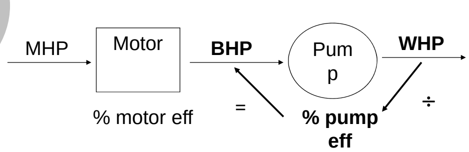
Motor Horsepower

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

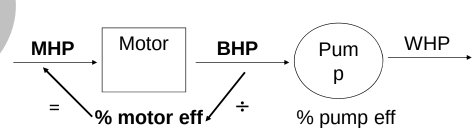
Pumps



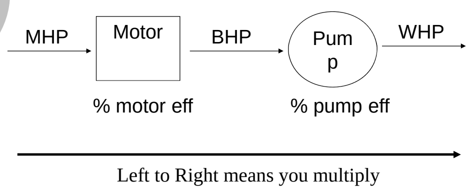
Pumps - BHP



Pumps - MHP



Pumps



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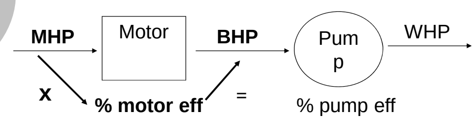
Pumps - BHP



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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.

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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

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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.

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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.***

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Determining Pumping Costs

What was your electric bill last month?

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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

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Determining Pumping Costs

- For example, if you have a pumping job which 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

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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)

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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 which pulls 100 amps would have a power wattage of 22,000 watts. What would be the horsepower of this motor?
- $$\text{HP} = \frac{(\text{volts})(\text{amps})}{746\ \text{watts/hp}} = \frac{(220)(100)}{746} = 29\text{hp}$$

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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)
- $$\text{kW, Single Phase} = \frac{(\text{volts})(\text{amps})(\text{power factor})}{1{,}000\ \text{Watts/kilowatt}}$$
- $$\text{kW, Three Phase} = \frac{(\text{volts})(\text{amps})(\text{power factor})(1.732)}{1{,}000\ \text{Watts/kilowatt}}$$

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

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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 = $\frac{\text{watts}}{(\text{volts})(\text{amps})}$
- The power factor might be on the data plate, but will always be in the manual

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Amperes Single and Three Phase

- $\text{amps}_{\text{Single Phase}} = \frac{(746)(\text{horsepower})}{(\text{volts})(\%\text{eff.})(\text{power factor})}$
- $\text{amps}_{\text{Three Phase}} = \frac{(746)(\text{horsepower})}{(1.732)(\text{volts})(\%\text{eff.})(\text{power factor})}$

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Applied Math for Wastewater
Pump Horsepower & Efficiency

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

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

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

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

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

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

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

ANSWERS

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

Applied Math for Wastewater
Pump Horsepower/Efficiency/Cost/Motors
Extra Problems

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

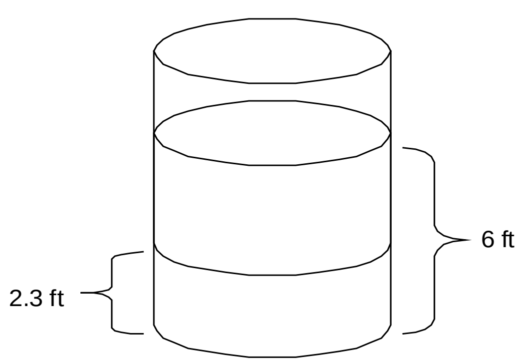
MOTORS
23. 21.2 hp
24. 7.1 hp
25. 9.4 hp
26. 1,320 watts
27. 2,112 watts
28. 396 watts
29. 12,955.4 watts
30. 27,434.9 watts
31. 13 kW
32. 0.8
33. 0.9

Applied Math for Wastewater
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?

ANSWERS

1. 157.6 gpm
2. 122.7 gpm
3. 452.6 gpm
4. 111 gpm
5. 356.2 gpm
6. 188.7 gpm

Section 9
Chemical Dosage

Applied Math for Wastewater Treatment
Chemical Dosage

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

Chemical Feed Rate (Full Strength), lbs/day

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

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

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

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

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

Chlorine Dose, Demand and Residual, mg/L

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

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

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

Chemical Dosage, mg/L

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

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

Hypochlorination

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

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

Answers:

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

Applied Math for Wastewater Treatment
Chemical Dosage

Chemical Feed Rate (Full Strength), lbs/day

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

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

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

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

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

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

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

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

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

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

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

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

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

Chlorine Dose, Demand and Residual, mg/L

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

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

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

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

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

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

Chemical Dosage, mg/L

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

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

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

Hypochlorination

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

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

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

<u>Use the following information for problems 25 – 28:</u>
At 8:00 a.m. on Monday morning a chlorine cylinder weighs 83 pounds. At 8:00 a.m. on Tuesday morning the same cylinder weighs 69 pounds.

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

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

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

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

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

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

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

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

Answers:

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

Section 10
Sludge Digestion

Applied Math for Wastewater Treatment
Sludge Digestion

- Typical Aerobic Digester
    - Detention time greater than 20 days
    - Volatile solids loading = 0.1 – 0.3 lbs VS/day/ft^3
    - DO = 1.0
    - pH = 5.9 – 7.7

- Typical Anaerobic Digester
    - Detention time = 30 – 60 days
    - Heated = 90-95ºF
    - Volatile solids loading = 0.04 – 0.1 lbs VS/day/ft^3
    - pH = 6.8 – 7.2

Volatile Solids to the Digester, lbs/day

1. If a 8,250 lbs/day of solids with a volatile solids content of 68% are sent to the digester, how many lbs/day volatile solids are sent to the digester?

2. A total of 3600 gpd of sludge is pumped to the digester. If the sludge has a 5.7% solids content with 71% volatile solids, how many lbs/day volatile solids are pumped to the digester?

Digester Loading Rate, lbs VS added/day/ft^3

3. What is the digester loading if a digester, 45 feet in diameter with a liquid level of 20 feet, receives 82,500 lbs/day of sludge with 5.8% solids and 69% volatile solids?

4. A digester, 40-ft in diameter with a liquid level of 18 ft receives 26,400 gpd of sludge with 5.7% solids and 71% volatile solids. What is the digester loading in lbs VS added/day/ft^3?

Volatile Acids/Alkalinity Ratio

- VA/Alk ratio is an indicator of progress of digestion and the balance between the two stage process of anaerobic digestion
  - First stage – facultative, acid forming organisms convert complex organic matter to volatile (organic) acids
  - Second stage – anaerobic methane-forming organisms convert the acids to odorless end products of methane gas and carbon dioxide
- Normally less than 0.1, acceptable range is 0.1 – 0.2
  - Increase indicates possible excess feeding of raw sludge to the digester or removal of too much digested sludge
  - pH decreases at less than or equal to 0.8

5. The volatile acids concentration of the sludge in an anaerobic digester is 170 mg/L. If the measured alkalinity is 2150 mg/L, what is the VA/Alkalinity ratio?

Percent Volatile Solids Reduction

- Aerobic digester = 40-50%
- Anaerobic digester = 40-60%

6. The raw sludge to a digester has a volatile solids content of 69%. The digested sludge volatile solids content is 53%. What is the percent volatile solids reduction?

7. The digested sludge volatile solids content is 52%. The raw sludge to the digester has a volatile solids content of 67%. What is the percent volatile solids reduction?

Volatile Solids Destroyed, lbs VS/day/ft^3

- Measure of digester effectiveness

8. A flow of 3750 gpd sludge is pumped to a 35,000-ft^3 digester. The solids concentration of the sludge is 6.3% with a volatile solids content of 68%. If the volatile solids reduction during digestion is 54%, how many lbs/day volatile solids are destroyed per ft^3 of digester capacity?

9. A 50-ft diameter digester receives a sludge flow of 2800 gpd with a solids content of 5.8% and a volatile solids concentration of 70%. The volatile solids reduction during digestion is 54%. The digester operates at a level of 20 ft. What is the lbs/day volatile solids reduction per cu ft of digester capacity? Assume the sludge weighs 8.34 lbs/day.

Digester Gas Production, ft^3 Gas Produced / lb VS destroyed

- Indicator of the progress of digestion
- Normal range is 12 – 18 ft^3 gas produced / lb VS destroyed
- Sharp increase indicates presence of high organic content of sludge

10. The anaerobic digester at a treatment plant receives a total of 10,500 gpd of raw sludge. This sludge has a solids content of 5.3% of which 64% is volatile. If the digester yields a volatile solids reduction of 61% and the average digester gas production is 22,300 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

11. A total of 2060 lbs of volatile solids are pumped to the digester daily. If the percent reduction of volatile solids due to digestion is 57% and the average gas production for the day is 19,150 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

Digestion Time, days

- Flow through the digester

12. An aerobic digester 40-ft in diameter has a side water depth of 12 ft. The sludge flow to the digester is 8200 gpd. Calculate the hydraulic detention time in days.

13. A 50-ft aerobic digester has a side water depth of 10 feet. The sludge flow to the digester is 9500 gpd. Calculate the digestion time in days.

Answers:

1. 5610 lbs/day
2. 1215 lbs/day
3. 0.10
4. 0.39
5. 0.08
6. 49.3%
7. 46.6%
8. 0.021 lbs/day/ft^3
9. 0.013 lbs/day/ft^3
10. 12.3ft^3/lb VS destroyed
11. 16.3ft^3/lb VS destroyed
12. 13.7 days
13. 15.5 days

Applied Math for Wastewater Treatment
Sludge Digestion
Extra Problems

Digester Loading Rate, lbs VS added/day/ft^3

1. A digester 50 ft in diameter with a water depth of 22 ft receives 86,100 lbs of raw sludge per day. If the sludge contains 5% solids and 70% is volatile solids, what is the digester loading in lbs VS added/day/ft^3?

2. What is the digester loading in lbs VS added/day/ft^3 if a digester that is 40 ft in diameter with a liquid level of 22 ft receives 28,500 gpd of sludge with 5.6% solids and 72% volatile solids? Assume the sludge weighs 8.34 lbs/gal.

3. A digester that is 50 ft in diameter with a liquid level of 20 ft receives 36,220 gpd of sludge with 5.6% solids and 68% volatile solids. What is the digester loading in lbs VS added/day/ft^3? Assume the sludge weighs 8.34 lbs/gal.

4. A digester that is 50 ft in diameter with a liquid level of 18 ft receives 16,200 gpd of sludge with 5.1% solids and 72% volatile solids. What is the digester loading in lbs VS added/day/ft^3?

Volatile Acids/Alkalinity Ratio

5. The volatile acids concentration of the sludge in an anaerobic digester is 174 mg/L. If the measured alkalinity is 2220 mg/L, what is the VA/Alkalinity ratio?

6. The volatile acids concentration of the sludge in an anaerobic digester is 160 mg/L. If the measured alkalinity is 2510 mg/L, what is the VA/Alkalinity ratio?

7. The measured alkalinity is 2410 mg/L. If the volatile acids concentration of the sludge in an anaerobic digester is 144 mg/L, what is the VA/Alkalinity ratio?

8. The measured alkalinity is 2620 mg/L. If the volatile acids concentration of the sludge in an anaerobic digester is 178 mg/L, what is the VA/Alkalinity ratio?

Lime Neutralization

9. To neutralize a sour digester, 1 mg/L of lime is added for every mg/L of volatile acids in the digester sludge. If the digester sludge contains 244,000 gallons of sludge with a volatile acid level of 2280 mg/L, how many lbs of lime should be added?

10. To neutralize a sour digester, 1 mg/L of lime is added for every mg/L of volatile acids in the digester sludge. If the digester sludge contains 200,000 gallons of sludge with a volatile acid level of 2010 mg/L, how many lbs of lime should be added?

11. A digester contains 234,000 gallons of sludge with a volatile acid level of 2540 mg/L. To neutralize a sour digester, 1 mg/L of lime is added for every mg/L of volatile acids in the digester sludge. How many lbs of lime should be added?

12. A digester sludge is found to have a volatile acids content of 2410 mg/L. If the digester volume is 182,000 gallons, how many lbs of lime will be required for neutralization?

Percent Volatile Solids Reduction

13. Sludge entering a digester has a volatile solids content of 68%. Sludge leaving the digester has a volatile solids content of 52%. What is the percent volatile solids reduction?

14. Sludge leaving a digester has a volatile solids content of 54%. Sludge entering the digester has a volatile solids content of 70%. What is the percent volatile solids reduction?

15. The raw sludge to a digester has a volatile solids content of 70%. The digested sludge volatile solids content is 55%. What is the percent volatile solids reduction?

16. The volatile solids content of a digested sludge is 54%. The raw sludge to a digester has a volatile solids content of 69%. What is the percent volatile solids reduction?

Volatile Solids Destroyed, lbs VS/day/ft^3

17. A flow of 3800 gpd sludge is pumped to a 36,500 ft^3 digester. The solids concentration of the sludge is 6.3% with a volatile solids content of 73%. If the volatile solids reduction during digestion is 57%, how many lbs/day volatile solids are destroyed/ft^3 of digester capacity? Assume the sludge weighs 8.34 lbs/gal.

18. A flow of 4520 gpd sludge is pumped to a 34,000 ft^3 digester. The solids concentration of the sludge is 7% with a volatile solids content of 69%. If the volatile solids reduction during digestion is 54%, how many lbs/day volatile solids are destroyed/ft^3 of digester capacity? Assume the sludge weighs 8.34 lbs/gal.

19. A 50-ft diameter digester receives a sludge flow of 2600 gpd with a solids content of 5.6% and a volatile solids concentration of 72%. The volatile solids reduction during digestion is 52%. The digester operates at a level of 18 ft. What is the lbs/day volatile solids reduction/ft^3 of digester capacity? Assume the sludge weighs 8.34 lbs/gal.

20. The sludge flow to a 40-ft diameter digester is 2800 gpd with a solids concentration of 6.1% and a volatile solids concentration of 65%. The digester is operated at a depth of 17 ft. If the volatile solids reduction during digestion is 56%, what is the lbs/day volatile solids reduction per 1000 ft^3 of digester capacity? Assume the sludge weighs 8.34 lbs/gal.

Digester Gas Production, ft^3 Gas Produced / lb VS destroyed

21. A digester gas meter reading indicates that, on average, 6600 ft^3 of gas are produced per day. If 500 lbs/day volatile solids are destroyed, what is the digester gas production in ft^3/lb VS destroyed?

22. A total of 2110 lbs of volatile solids are pumped to the digester daily. If the percent reduction of volatile solids due to digestion is 59% and the average gas production for the day is 19,330 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

23. A total of 582 lbs/day of volatiles solids are destroyed. If a digester gas meter reading indicates that 8710 ft^3 of gas are produced per day, on average, what is the digester gas production in ft^3/lb VS destroyed daily?

24. The percent reduction of volatile solids due to digestion is 54% and the average gas production for the day is 26,100 ft^3. If 3320 lbs of volatile solids are pumped to the digester daily, what is the gas production in ft^3/lb VS destroyed daily?

Digestion Time, days

25. An aerobic digester 40-ft in diameter has a side water depth of 10 ft. The sludge flow to the digester is 8250 gpd. Calculate the hydraulic detention time in days.

26. A 40-ft aerobic digester has a side water depth of 12 feet. The sludge flow to the digester is 9100 gpd. Calculate the digestion time in days.

27. An aerobic digester is 80 ft long by 25 ft wide and has a side water depth of 12 ft. The sludge flow to the digester is 7800 gpd, what is the hydraulic digestion time, in days?

28. An aerobic digester is 90 ft long by 20 ft wide and has a side water depth of 10 ft. The sludge flow to the digester is 7600 gpd, what is the hydraulic digestion time, in days?

Answers:

1. 0.07 lbs VS added/day/ft^3
2. 0.35 lbs VS added/day/ft^3
3. 0.29 lbs VS added/day/ft^3
4. 0.14 lbs VS added/day/ft^3
5. 0.078
6. 0.064
7. 0.060
8. 0.068
9. 4640 lbs
10. 3353 lbs
11. 4957 lbs
12. 3658 lbs
13. 49.0%
14. 49.7%
15. 47.6%
16. 47.3%
17. 0.023 lbs VS/day/ft^3
18. 0.029 lbs VS/day/ft^3
19. 0.013 lbs VS/day/ft^3
20. 24.3 lbs VS/day/1000 ft^3
21. 13.2 ft^3/ lb VS destroyed
22. 15.5 ft^3/ lb VS destroyed
23. 15.0 ft^3/ lb VS destroyed
24. 14.6 ft^3/ lb VS destroyed
25. 11.4 days
26. 12.4 days
27. 23 days
28. 17.7 days

Section 11
Laboratory

Applied Math for Wastewater Treatment
Geometric Mean

<u>Geometric Mean Using a Texas Instrument TI-30Xa</u>

<u>Example:</u>
60 100 0 0

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

Step 1: 1/n → 1 divided by the number of test results. For our example above, there are four test results.

- 1 ÷ 4 = 0.25 (write this number down, you will use it in Step 3)

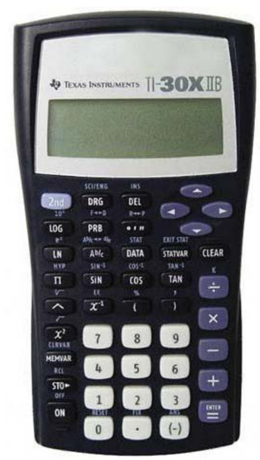
Step 2: Multiply all of the test results together and punch the = button on the calculator. Remember to count 0 as a 1.

- 60 x 100 x 1 x 1 = 6000 (Do Not clear out your calculator)

Step 3: Punch the y^x button and then type in the number from Step 1, then punch =.

- 6000 y^x 0.25 = 8.8011

<u>Geometric Mean Using a Texas Instrument TI-30Xa</u>



<u>Example:</u>
60 100 0 0

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

Step 1: 1/n → 1 divided by the number of test results. For our example above, there are four test results.

- 1 ÷ 4 = 0.25 (write this number down, you will use it in Step 3)

Step 2: Multiply all of the test results together and punch the = button on the calculator. Remember to count 0 as a 1.

- 60 x 100 x 1 x 1 = 6000 (Do Not clear out your calculator)

Step 3: Punch the ^ button, then type in the number from Step 1, & then punch =.

- 6000 y^x 0.25 = 8.8011

Applied Math for Wastewater Treatment
Laboratory

Bacteriological, fecal coliform and *E. coli*

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

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

Solutions

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

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

Settleable Solids (Imhoff Cone)

5. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 16.5 mL/L and the settleable solids of the effluent are 0.6 mL/L.

6. The settleable solids of the raw wastewater is 18 mL/L. If the settleable solids of the clarifier is 0.9 mL/L, what is the settleable solids removal efficiency of the clarifier?

7. The settleable solids of the raw wastewater is 20 mL/L. If the settleable solids of the clarifier is 0.8 mL/L, what is the settleable solids removal efficiency of the clarifier?

Settleability

8. The settleability test is conducted on a sample of MLSS. What is the percent settleable solids if 410 mL settle in the 2000-mL graduate?

9. A 2000-mL sample of activated sludge is poured into the 2000-mL graduate. If the settled sludge is measured as 315 mL, what is the percent settleable solids?

10. The settleability test is conducted on a sample of MLSS. What is the percent settleable solids if 390 mL settle in the 2000-mL graduate?

Suspended Solids and Volatile Suspended Solids

11. Given the following information regarding a primary effluent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 50 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	25.6715 g	25.6701 g
Weight of Dish (Tare Wt.)	25.6670 g	25.6670 g

12. Given the following information regarding a primary effluent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 25 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	36.1544 g	36.1500 g
Weight of Dish (Tare Wt.)	36.1477 g	36.1477 g

SVI and SDI

- Values normally fall in the range of 50-150
- A rise indicates young bulky sludge
- A decrease below the range of 50-150 indicates old sludge
- A good settling quality of activated sludge is a low SVI around 50-80

13. The settleability test indicates that after 30 minutes, there are 215 mL of suspended solids in the 1-liter graduate cylinder. If the MLSS concentration in the aeration tank is 2180 mg/L, what is the sludge volume index?

14. The activated sludge settleability test indicates 380 mL settling in the 2-liter graduate cylinder. If the MLSS concentration in the aeration tank is 2260 mg/L, what is the sludge volume index?

15. The MLSS concentration in the aeration tank is 2050 mg/L. If the activated sludge settleability test indicates 219 mL settled in the one-liter graduated cylinder, what is the sludge density index?

Biochemical Oxygen Demand, BOD

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

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

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

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

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

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

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

Alkalinity

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

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

Oxygen Uptake Rate

21. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake rate, mg/L/hr.

Elapsed Time, min	DO, mg/L
0	7.9
1	6.8
2	6.1
3	5.3
4	4.6
5	3.9

Temperature

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

23. Convert 56º F to degrees Celsius.

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

Answers:

1. 21
2. 26
3. 53.6 mL
4. 160 mL
5. 96.4%
6. 95%
7. 96%
8. 20.5%
9. 15.8%
10. 19.5%
11. 90 mg/L SS; 31.1% VSS
12. 268 mg/L SS; 65.7% VSS
13. 98.6 mL/g
14. 84.1 mL/g
15. 0.936
16. 150 mg/L
17. 123 mg/L
18. 200 mg/L
19. 240 mg/L
20. 101 mg/L
21. 44mg/L/hr
22. 22.2ºC
23. 13.3ºC
24. 71.6ºF

Applied Math for Wastewater Treatment
Laboratory
Extra Problems

Bacteriological, fecal coliform and *E. coli*

1. Determine the geometric mean for the following samples:

   Sample #1 = 20.0 mg/L
   Sample #2 = 20.0 mg/L
   Sample #3 = 210.0 mg/L
   Sample #4 = 3,500.0 mg/L

2. Determine the geometric mean for the following samples:

   Sample #1 = 45.0 mg/L
   Sample #2 = 61.0 mg/L
   Sample #3 = 98.0 mg/L
   Sample #4 = 150.0 mg/L

3. Determine the bacteria colonies/100 mL for a 25 mL sample that had 50 colonies grow on the membrane filter for fecal coliforms.

4. Determine the bacteria colonies/100 mL when a membrane filtration test was performed for *E. coli*, after 24-hours of incubation, 57 colonies were counted. The sample volume used was 75 mL.

Solutions

5. How many mL of 0.2N NaOH will react with 500 mL of 0.01N HCl?

6. A 2-liter volume of 0.05N HCl solution is to be prepared. How many mL of 9N HCl must be diluted with water to prepare the desired volume?

7. It takes 8.2 mL of a solution of HCl to neutralize 10 mL of 4N NaOH. What is the concentration of the HCl solution?

Settleable Solids (Imhoff Cone)

8. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 16.5 mL/L and the settleable solids of the effluent are 0.6 mL/L.

9. The settleable solids of the raw wastewater is 18 mg/L. If the settleable solids of the clarifier is 0.9 mL/L, what is the settleable solids removal efficiency of the clarifier?

10. The settleable solids of the raw wastewater is 20mg/L. If the settleable solids of the clarifier is 0.8 mL/L, what is the settleable solids removal efficiency of the clarifier?

Settleability

11. A settleability test is conducted on a sample of MLSS. What is the percent settleable solids if 440 mL settle in a 2000-mL graduated cylinder?

12. A 2000-mL sample of activated sludge is taken. If the settled sludge is measured as 320 mL, what is the percent settleable solids?

13. A settleability test is conducted on a sample of MLSS. What is the percent settleable solids if 410 mL settle in a 2000-mL graduated cylinder?

Total Solids and Volatile Solids

14. Given the following information regarding a primary effluent sample, calculate (a) the percent total solids and (b) the percent volatile suspended solids of the sample.

	Sludge (Total Sample)	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	85.78 g	26.27 g	24.31 g
Weight of Dish (Tare Wt.)	21.50 g	21.50 g	21.50 g

15. Given the following information regarding a primary effluent sample, calculate (a) the percent total solids and (b) the percent volatile suspended solids of the sample.

	Sludge (Total Sample)	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	75.48 g	22.67 g	21.45 g
Weight of Dish (Tare Wt.)	20.80 g	20.80 g	20.80 g

Suspended Solids and Volatile Suspended Solids

16. Given the following information regarding a primary effluent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 50 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	25.6818 g	25.6802 g
Weight of Dish (Tare Wt.)	25.6715 g	25.6715 g

17. Given the following information regarding a treatment plant influent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 25 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	36.1588 g	36.1543 g
Weight of Dish (Tare Wt.)	36.1496 g	36.1496 g

18. Given the following information regarding a treatment plant influent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 25 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	28.3196 g	28.3082 g
Weight of Dish (Tare Wt.)	28.2981 g	28.2981 g

SVI and SDI

19. After 30 minutes, a settleability test resulted in 220 mL of settleable solids in a 1-liter graduated cylinder. If the MLSS concentration in the aeration tank is 2210mg/L, what is the sludge volume index?

20. An activated sludge settleability test resulted in 410 mL settling in a 2-liter graduated cylinder. If the MLSS concentration in the aeration tank is 2310 mg/L, what is the sludge volume index?

21. The MLSS concentration in an aeration tank is 2110 mg/L. If the activated sludge settleability test indicates that 222 mL settled in a 1-liter graduated cylinder, what is the sludge density index?

22. Activated sludge in an aeration tank is found to have a concentration of MLSS of 2140 mg/L. If the settleability test results in 186 mL settleable solids in a 1-liter graduated cylinder after 30 minutes, what is the sludge density index?

23. After 30 minutes, a settleability test resulted in 215 mL of settleable solids in a 1-liter graduated cylinder. If the MLSS concentration in the aeration tank is 2510 mg/L, what is the sludge volume index?

Biochemical Oxygen Demand, BOD

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

    Sample Volume = 7 mL
    BOD Bottle Volume = 300 mL
    Initial DO of Diluted Sample = 8 mg/L
    Final DO of Diluted Sample = 3.7 mg/L

25. Results from a BOD test are provided. Calculate the BOD of the sample after 5 days:

    Sample Volume = 12 mL
    BOD Bottle Volume = 300 mL
    Initial DO of Diluted Sample = 8.7 mg/L
    Final DO of Diluted Sample = 4.4 mg/L

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

March 23 – 190 mg/L
March 24 – 198 mg/L
March 25 – 205 mg/L
March 26 – 202 mg/L
March 27 – 210 mg/L
March 28 – 201 mg/L
March 29 – 197 mg/L

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

April 10 – 220 mg/L
April 11 – 315 mg/L
April 12 – 265 mg/L
April 13 – 198 mg/L
April 14 – 112 mg/L
April 15 – 255 mg/L
April 16 – 279 mg/L

Alkalinity

28. Alkalinity titration on a 100-mL sample resulted in 5.1 mL of 0.02N H_2SO_4 to drop the pH from 7.8 to 4.5.

29. To drop the pH from 7.7 to 4.5 on a 100-mL sample 12.3 mL of 0.02N H_2SO_4 was used to determine the alkalinity.

Oxygen Uptake Rate

30. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake rate, mg/L/hr.

Elapsed Time, min	DO, mg/L
0	8.2
1	7.3
2	6.7
3	6.5
4	6.3
5	6.2

31. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake rate, mg/L/hr.

Elapsed Time, min	DO, mg/L
0	8.5
1	7.8
2	7.3
3	6.7
4	6.1
5	5.3

Temperature

32. The influent to a treatment plant has a temperature of 70ºF. What is this temperature expressed in degrees Celsius?

33. Convert 60ºF to degrees Celsius.

34. The effluent of a treatment plant is 24ºC. What is this temperature expressed in degrees Fahrenheit?

35. What is 16ºC expressed in terms of degrees Fahrenheit?

Answers:

1. 131 mg/L
2. 79.7 mg/L
3. 200 cfu
4. 76 cfu
5. 25 mL
6. 11.1 mL
7. 4.9N
8. 96.4%
9. 95.0%
10. 96.0%
11. 22.0%
12. 16.0%
13. 20.5%
14. 7.4% TS; 41.1% VS
15. 3.4% TS; 65.2% VS
16. 206 mg/L SS; 15.5% VSS
17. 368 mg/L SS; 48.9% VSS
18. 860 mg/L SS; 53.0% VSS
19. 99.5 mL/g
20. 88.7 mL/g
21. 0.95
22. 1.15
23. 85.7 mL/g
24. 184.3 mg/L
25. 107.5 mg/L
26. 200 mg/L
27. 235 mg/L
28. 51 mg/L
29. 123 mg/L
30. 10 mg/L/hr
31. 40 mg/L/hr
32. 21.1ºC
33. 15.6ºC
34. 75.2ºF
35. 60.8ºF

Section 12
Metric System

Metric System

Applied Math for Wastewater

Is the English System Easier?

12 inches = 1 foot
3 feet = 1 yard
5280 feet = 1 mile
2 pints = 1 quart
4 quarts = 1 gallon
16 ounces = 1 pound
32 fluid ounces = 1 quart

- A foot determined by the size of a person's foot, there wasn't a standard
- Confusing numbers, nothing repeats

History

- By the eighteenth century, dozens of different units of measurement were commonly used throughout the world
- Length, for example, could be measured in feet, inches, miles, spans, cubits, hands, furlongs, palms, rods, chains, leagues, and more
- The lack of common standards led to a lot of confusion and significant inefficiencies in trade between countries

History

- At the end of the century, the French government sought to alleviate this problem by devising a system of measurement that could be used throughout the world
- In 1790, the French National Assembly commissioned the Academy of Science to design a simple decimal-based system of units; the system they devised is known as the metric system

History

- In 1960, the metric system was officially named the Système International d'Unités (or SI for short) and is now used in nearly every country in the world except the United States
- The metric system is almost always used in scientific measurement

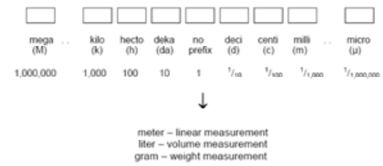
Metric System Simplicity

- There is only one unit of measurement for each type of quantity measured
  - Length
  - Mass
  - Volume
- The three most common base units are the meter, gram, and liter

Metric System Simplicity

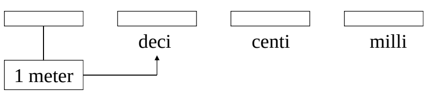
- The meter is a unit of length equal to 3.28 feet
- The gram is a unit of mass equal to approximately 0.0022 pounds
- The liter is a unit of volume equal to 1.05 quarts.
- So volume is always measured in liters, whether you are measuring how much water you need for a chlorine test or how much water is in your clarifier or sedimentation basin.

- All units can be converted into smaller or larger units by moving a decimal point



Conversions

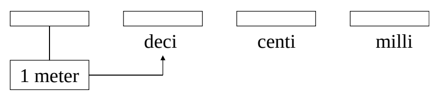
- Convert 1 meter to decimeters (dm)



- Converting from meters to decimeters requires moving one place to the right, therefore, move the decimal point from its present position one place to the right as well.

Conversions

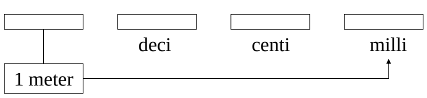
- Convert 1 meter to decimeters (dm)



- 1.0 meter = 10 decimeters

Conversions

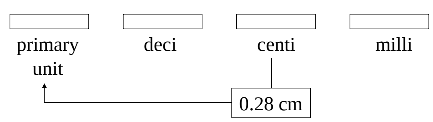
- Convert 1 gram to milligrams (mg)



- 1.000 gram = 1000 milligrams

Conversions

- Convert 0.28 cm to meters



- 0.28 cm = 0.0028 meter

Applied Math for Wastewater
Metric Conversions

1. 1 m = __________ cm
2. 1 g = __________ mg
3. 1 kg = __________ g
4. 1 cm = __________ mm
5. 10 cm = __________ mm
6. 50 cm = __________ mm
7. 8 km = __________ m
8. 19 km = __________ m
9. 29 L = __________ mL
10. 83 m = __________ mm
11. 1.8 cm = __________ mm
12. 2.5 mg = __________ g
13. 2.6 km = __________ m
14. 8.5 km = __________ m
15. 80 mL = __________ L
16. 150 mm = __________ cm
17. 5000 m = __________ km
18. 1300 g = __________ kg
19. 17 mm = __________ cm
20. 125 mm = __________ cm
21. 170 L = __________ mL
22. 155 m = __________ km

23. A particular pipe is delivered in sections 5 meters long. How many sections are required to span a distance of 1 kilometer?

24. You need to measure 34.6 milligrams of a chemical to make a solution. If the display on the scale only shows grams, what will the reading be?

25. During your last visit to the doctor, the nurse told you that you weighed 98 kilograms. Assuming that a nickel weighs approximately 5 grams, how many nickels would it take to equal your weight? If that were true, then how much is your weight worth in nickels?

26. Your favorite coffee mug at work holds about ½ a liter. If you average about 8 milliliters each time you take a sip, how many sips does it take to get to the bottom of your mug?

Answers:

1. 100 cm
2. 1000 mg
3. 1000 g
4. 10 mm
5. 100 mm
6. 500 mm
7. 8000 m
8. 19,000 m
9. 29,000 mL
10. 83,000 mm
11. 18 mm
12. 0.0025 g
13. 2600 m
14. 8500 m
15. 0.08 L
16. 15 cm
17. 5 km
18. 1.3 kg
19. 1.7 cm
20. 12.5 cm
21. 170,000 mL
22. 0.155 km
23. 200 sections
24. 0.0346 g
25. 19,600 nickels, $980
26. 62.5 sips

Section 13
Answers

Solving for the Unknown

Basics – finding x

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

$8.1 = (4.5)(x)$

$\frac{8.1}{4.5} = x$

$1.8 = x$

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

$(0.0854865)(x) = 0.49$

$x = \frac{0.49}{0.0854865}$

$= 5.7$

Flip Flop

only when x is on bottom

3. $\frac{233}{x} = \frac{44}{1}$

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

$5.3 = x$

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

$\frac{940}{1} = \frac{x}{6358.5}$

$(940)(6358.5) = x$

$5,976,990 = x$

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

$x = \frac{4128.3}{0.5} = 8256.6$

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

$x = \frac{3800}{(56.5)(8.34)} = \frac{3800}{471.21} = 8.1$

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

$114 = \frac{2205.93}{(3846.5)(x)}$

$x = \frac{2205.93}{(3846.5)(114)} = \frac{2205.93}{438501} = 0.005$

8. $\frac{2}{1} = \frac{x}{180}$

$(2)(180) = x$

$360 = x$

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

$\frac{46}{1} = \frac{(875.7)(x)}{31400}$

$(46)(31400) = (875.7)(x)$

$\frac{1444400}{875.7} = x = 1649$

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

$2.4 = \frac{587.18}{x}$

$x = \frac{587.18}{2.4} = 244.7$

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

19,747 = (1795.2)(x)

$\frac{19{,}747}{1795.2} = x$

11 = x

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

$\frac{1683}{x} = 337$

$\frac{1683}{337} = x$

5 = x

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

$\frac{x}{37.53} = 213$

x = (213)(37.53)

= **7994**

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

x = (2.4)(246)

x = 590.4

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

$6 = \frac{(x)(1.5012)}{704.73}$

(6)(704.73) = (x)(1.5012)

$\frac{4228.38}{1.5012} = x$

2817 = x

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

$\frac{90072}{(0.785)(x)} = 23.4$

$\frac{90072}{(0.785)(23.4)} = \frac{90072}{18.369} =$ **4903**

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

$109 = \frac{x}{5024}$

(109)(5024) = x

547,616 = x

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

(x)(30.858) = 3620

$x = \frac{3620}{30.858}$

x = 117

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

$x = \frac{1{,}270{,}000}{2.5}$

x = 508,000

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

$0.59 = \frac{(3431.076)}{(x)(16513.2)}$

$x = \frac{(3431.076)}{(0.59)(16513.2)}$

$= \frac{3431.076}{9742.788}$

= 0.35

Finding x^2

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

$$D^2 = \frac{5024}{0.785} = 6400$$

$$D = \sqrt{6400} = \boxed{80}$$

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

$$(x^2)(74.8) = 10{,}771.2$$

$$x^2 = \frac{10{,}771.2}{74.8} = 144$$

$$x = \sqrt{144} = \boxed{12}$$

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

$$D^2 = \frac{64{,}000}{(0.785)(51)} = \frac{64{,}000}{40.035} = 1598.6012$$

$$D = \sqrt{1598.6012} = \boxed{39.98 \approx 40}$$

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

$$D^2 = \frac{0.54}{0.785} = 0.687898$$

$$D = \sqrt{0.687898} = \boxed{0.83}$$

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

$$\frac{2.1}{1} = \frac{(88.077)(D^2)}{5024}$$

$$(2.1)(5024) = (88.077)(D^2)$$

$$\frac{10550.4}{88.077} = D^2$$

$$119.786 = D^2$$

$$D = \sqrt{119.786} = \boxed{10.9}$$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾ $\frac{3}{4} = 0.75$
2. ⅝ $\frac{5}{8} = 0.625$
3. ¼ $\frac{1}{4} = 0.25$
4. ½ $\frac{1}{2} = 0.5$

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? $473 = (x)(2365) \rightarrow \frac{473}{2365} = x \rightarrow 0.2 = x = 20\%$ (decimal form)
16. 1.3 is what % of 6.5? $1.3 = (x)(6.5) \rightarrow \frac{1.3}{6.5} = x \rightarrow 0.2 = x$
    $20\% = x$

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.

$$A = (\text{length})(\text{width})$$
$$= (45\,ft)(12\,ft)$$
$$= 540\,ft^2$$

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.

$$A = (90\,ft)(25\,ft)$$
$$= 2250\,ft^2$$

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

$$A = (0.785)(\text{Diameter})^2$$
$$= (0.785)(2\,ft)^2$$
$$= 3.14\,ft^2$$

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

$$\frac{24\,in}{} \left| \frac{1\,ft}{12\,in} \right. = 2\,ft$$

$$A = (0.785)(2\,ft)^2$$
$$= 3.14\,ft^2$$

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

$$\frac{2\,in}{} \left| \frac{1\,ft}{12\,in} \right. = 0.1667\,ft$$

$$A = (0.785)(0.1667\,ft)^2$$
$$= 0.02\,ft^2$$

VOLUME

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

$$V = (\text{length})(\text{width})(\text{depth})$$
$$= (10\,ft)(10\,ft)(10\,ft)$$
$$= 1000\,ft^3$$

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

$$V = (22\,ft)(11\,ft)(5\,ft)$$
$$= 1210\,ft^3 \times \frac{7.48\,gal}{1\,ft^3}$$
$$= 9050.8\,gal$$

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.

$$V = (254\,ft)(62\,ft)(2\,ft)(7.48\,gal/ft^3)$$
$$= 235590\,gal$$

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.

$$\frac{8\,in}{} \times \frac{1\,ft}{12\,in} = 0.66667\,ft$$
$$V = (12\,ft)(6\,ft)(0.66667\,ft)(7.48\,gal/ft^3)$$
$$= 359.04\,gal$$

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.

$$\frac{18\,in}{} \times \frac{1\,ft}{12\,in} = 1.5\,ft$$
$$Vol. = (0.785)(D)^2(\text{depth})$$
$$= (0.785)(6\,ft)^2(1.5\,ft)(7.48\,gal/ft^3)$$
$$= 317\,gal$$

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?

$$V = (0.785)(3.5\,ft)^2(4\,ft)(7.48\,gal/ft^3)$$
$$= 287.7\,gal$$

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?

$\frac{30 \text{ in} \mid 1 \text{ ft}}{\mid 12 \text{ in}} = 2.5 \text{ ft}$

$\frac{0.25 \text{ mi} \mid 5280 \text{ ft}}{\mid 1 \text{ mi}} = 1320 \text{ ft}$

$V = (0.785)(2.5 \text{ ft})^2(1320 \text{ ft})(7.48 \text{ gal/ft}^3)$

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

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?

$\frac{10 \text{ in} \mid 1 \text{ ft}}{\mid 12 \text{ in}} = 0.8333 \text{ ft}$

$V = (0.785)(0.8333 \text{ ft})^2(5{,}000 \text{ ft})(7.48 \text{ gal/ft}^3)$

$= 20388 \text{ gal} = 0.02 \text{ MG}$

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?

5% of 3 MG ⇒ $(0.05)(3 \text{ MG}) = 0.15 \text{ MG}$

$= 150{,}000 \text{ gal}$

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

$(0.05)(1.2 \text{ MG}) = 0.06 \text{ MG}$ or $60{,}000 \text{ gal}$

CONVERSIONS

16. How many seconds in 1 minute? 60 sec/min

17. How many minutes in 1 hour? 60 min/hr

18. How many hours in 1 day? 24 hr/d

19. How many minutes in 1 day? 1440 min/d

20. How much does 1 ft^3 of water weigh (pounds)?

$$\frac{1\ ft^3}{} \bigg| \frac{7.48\ gal}{1\ ft^3} \bigg| \frac{8.34\ lbs}{1\ gal} = 62.4\ lbs$$

21. How many cubic yards of dirt is 700 ft^3?

$$\frac{700\ ft^3}{} \bigg| \frac{1\ yd^3}{27\ ft^3} = 25.9\ yd^3$$

22. 1050 ft^3 of dirt is being excavated, how many yd^3 is this?

$$\frac{1050\ ft^3}{} \bigg| \frac{1\ yd^3}{27\ ft^3} = 38.9\ yd^3$$

23. A one-quarter mile segment of pipeline is being flushed, how many feet of pipeline is this?

$$\frac{0.25\ mi}{} \bigg| \frac{5280\ ft}{1\ mi} = 1320\ ft$$

24. How many feet of pipe is needed for 2 miles of new line?

$$\frac{2\ mi}{} \bigg| \frac{5280\ ft}{1\ mi} = 10,560\ ft$$

25. A three-eights mile segment of pipeline is to be repaired. How many feet of pipeline is this? $3/8 = 0.375$

$$\frac{0.375\ mi}{} \bigg| \frac{5280\ ft}{1\ mi} = 1980\ ft$$

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

$$\frac{2,200\ gal}{} \bigg| \frac{8.34\ lbs}{1\ gal} = 18,348\ lbs$$

Applied Math for Distribution
Flow Conversions

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

$$\frac{5\ \text{ft}^3}{\text{sec}} \times \frac{7.48\ \text{gal}}{1\ \text{ft}^3} \times \frac{60\ \text{sec}}{1\ \text{min}} = \boxed{2244\ \text{gpm}}$$

2. What is 38 gps expressed as gpd?

$$\frac{38\ \text{gal}}{\text{sec}} \times \frac{60\ \text{sec}}{1\ \text{min}} \times \frac{1440\ \text{min}}{1\ \text{d}} = \boxed{3{,}283{,}200\ \text{gpd}}$$

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

$$\frac{4{,}270{,}000\ \text{gal}}{\text{day}} \times \frac{1\ \text{ft}^3}{7.48\ \text{gal}} \times \frac{1\ \text{d}}{1440\ \text{min}} = \boxed{396\ \text{ft}^3/\text{min}}$$

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

$$\frac{5.6\ \text{MG}}{\text{D}} \times \frac{1{,}000{,}000\ \text{gal}}{1\ \text{MG}} \times \frac{1\ \text{ft}^3}{7.48\ \text{gal}} \times \frac{1\ \text{d}}{1440\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = \boxed{8.7\ \text{ft}^3/\text{sec}}$$

5. Express 423,690 cfd as gpm.

$$\frac{423{,}690\ \text{ft}^3}{\text{d}} \times \frac{7.48\ \text{gal}}{1\ \text{ft}^3} \times \frac{1\ \text{d}}{1440\ \text{min}} = \boxed{2201\ \text{gpm}}$$

6. Convert 2730 gpm to gpd.

$$\frac{2730\ \text{gal}}{\text{min}} \times \frac{1440\ \text{min}}{\text{d}} = \boxed{3{,}931{,}200\ \text{gal/d}}$$

Applied Math for Collections
Flow and Velocity

Velocity

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

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

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

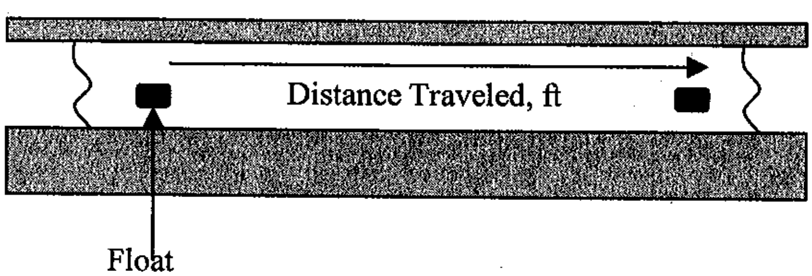
means we need time in seconds!!

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

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

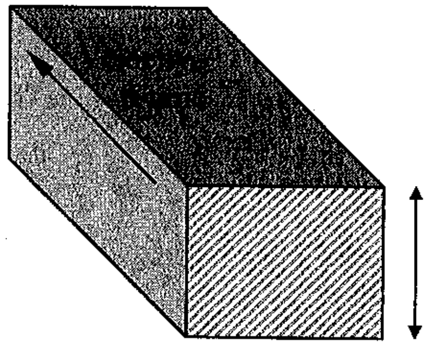
need time in minutes

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



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

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



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

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?

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

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

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

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

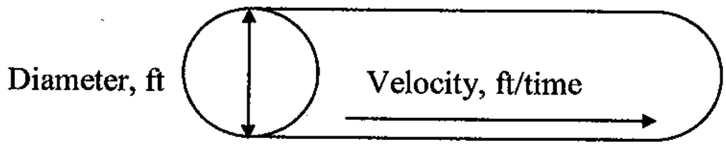
$Q = (3 ft)(2.5 ft)(120 ft/min) = \boxed{900\ ft^3/min}$

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

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

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

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



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

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

Flow through full pipe

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

D=2 ft
vel= 3.2 ft/sec

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

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

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

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

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

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

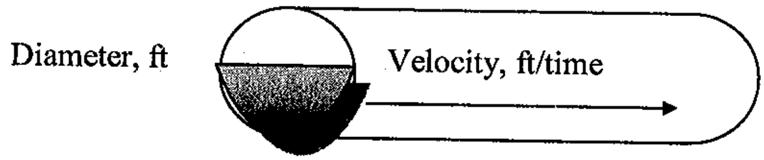
$Q = (0.785)(0.6667 ft)(0.6667 ft)(3.4 ft/sec)$
$= (1.1862\ ft^3/sec)(60)(7.48) = \boxed{532\ gpm}$

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

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

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

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



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

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

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

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

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

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

$d/D = 6/12 = 0.5$ → 0.3927 on chart

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

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

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

$d/D = 5/10 = 0.5$ → 0.3927 on chart

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

D = 8 in = 0.6667 ft
d = 5 in

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

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

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

Applied Math for Collection
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?

w = 3 ft
d = 2 ft
vel = 1.8 fps

$Q = (w)(d)(vel)$
$= (3\text{ ft})(2\text{ ft})(1.8\text{ fps})$
$= 10.8\ ft^3/sec$

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?

D = 12 in = 1 ft
vel = 110 ft/min

$Q = (0.785)(D, ft)(D, ft)(vel)$
$= (0.785)(1\text{ ft})(1\text{ ft})(110\text{ ft/min})$
$= 86.4\ ft^3/min$

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?

D = 18 in = 1.5 ft
vel = 182 fpm

$Q = (0.785)(1.5\text{ ft})(1.5\text{ ft})(182\text{ fpm})$
$= (321.4575\ ft^3/min)(7.48) = 2404.5$ gpm

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

D = 24 in = 2 ft
vel = 212 ft/min

$Q = (0.785)(2\text{ ft})(2\text{ ft})(212\text{ ft/min})$
$= (665.68\ ft^3/min)(1440)(7.48)$
$= 7{,}170{,}172$ gpd

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

D = 6 in = 0.5 ft
vel = 2 ft/sec

$Q = (0.785)(0.5\text{ ft})(0.5\text{ ft})(2\text{ ft/sec})$
$= (0.3925\ ft^3/sec)(60)(1440)(7.48)$
$= 253{,}662$ gpd

6. A 36" sewer needs to be cleaned. If the line is flushed at 2.5 ft/second, how many gallons/minute of water should be flushed from the hydrant?

D = 36 in = 3 ft
vel = 2.5 fps

$Q = (0.785)(3\,ft)(3\,ft)(2.5\,fps)$
$= (17.6625\,ft^3/sec)(60)(7.48)$
$= \boxed{7927\,gpm}$

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

D = 36 in = 3 ft
vel = 2 ft/sec

$Q = (0.785)(3\,ft)(3\,ft)(2\,ft/sec)$
$= \frac{(14.13\,ft^3/sec)(60)(1440)(7.48)}{1{,}000{,}000}$
$= \boxed{9.13\,MGD}$

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?

can give velocity

D = 18 in = 1.5 ft
dist = (830 yd)(3 ft/yd) = 2490 ft
time = 5 min
$vel = \frac{2490\,ft}{5\,min} = 498\,ft/min$

$Q = (0.785)(1.5\,ft)(1.5\,ft)(498\,ft/min)$
$= \frac{(879.5925\,ft^3/min)(1440)(7.48)}{1{,}000{,}000}$
$= \boxed{9.5\,MGD}$

VELOCITY (OPEN CHANNEL)

9. 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.)

$vel = \frac{dist.}{time} = \frac{300\,ft}{2.5\,min} = \boxed{120\,ft/min}$

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

$$vel = \frac{30 ft}{20 sec} = \boxed{1.5 ft/sec}$$

11. 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?

w = 4 ft
d = 2.3 ft
time = 3 min
dist = 500 ft

$$vel = \frac{500 ft}{3 min} = 166.6667 ft/min$$

$$Q = (4 ft)(2.3 ft)(166.6667 ft/min) = \boxed{1533.3333 ft^3/min}$$

FLOW IN A PARTIALLY FULL PIPE

12. Wastewater is moving through an 18-inch sewer at a velocity of 3 ft/sec. If the wastewater is flowing at a depth of 6 inches, calculate the flow, gal/min.

D = 18 in = 1.5 ft
vel = 3 fps
d = 6 in

$$d/D = 6/18 = 0.33 \Rightarrow 0.2260$$

$$Q = (0.2260)(1.5 ft)(1.5 ft)(3 fps)$$
$$= (1.5255 ft^3/sec)(60)(7.48)$$
$$= \boxed{685 gpm}$$

13. Wastewater is moving through a 12-inch sewer at a velocity of 240 ft/min. If the water is flowing at a depth of 9 inches, what is the flow rate, MGD?

D = 12 in = 1 ft
vel = 240 fpm
d = 9 in

$$d/D = 9/12 = 0.75 \Rightarrow 0.6318$$

$$Q = (0.6318)(1 ft)(1 ft)(240 fpm)$$
$$= \frac{(151.632 ft^3/min)(1440)(7.48)}{1,000,000}$$
$$= \boxed{1.6 MGD}$$

Preliminary Treatment Math

Wet Well Capacity

1. A wet well is 13 feet long, 8 feet wide and 10 feet deep. What is the gallon capacity of the wet well?

$$\text{vol., gal} = (l)(w)(d)(7.48\text{ gal/ft}^3)$$
$$= (13\text{ ft})(8\text{ ft})(10\text{ ft})(7.48)$$
$$= \boxed{7{,}779.2\text{ gal}}$$

2. The maximum capacity of a wet well is 4787 gal. If the wet well is 10 feet long and 8 feet wide, what is the maximum depth of water in the wet well in feet?

$$4787\text{ gal} = (10\text{ ft})(8\text{ ft})(d)(7.48)$$
$$4787 = (d)(598.4)$$
$$\frac{4787}{598.4} = \boxed{8\text{ ft depth}}$$

Wet Well Pumping Rate, gpm

3. A wet well is 12 feet by 10 feet. With no influent to the well, a pump lowers the water level 1.2 feet during a 4-minute pumping test. What is the pumping rate, gpm?

$$\text{pump rate, gpm} = \frac{(l)(w)(d)(7.48\text{ gal/ft}^3)}{\text{time, min}}$$
$$= \frac{(12\text{ ft})(10\text{ ft})(1.2\text{ ft})(7.48)}{4\text{ min}}$$
$$= \boxed{269\text{ gpm}}$$

4. The water level in a well drops 18 inches during a 3-minute pumping test. If the wet well is 8 feet by 6 feet, what is the pumping rate in gpm?

$$\text{pump rate, gpm} = \frac{(8\text{ ft})(6\text{ ft})(1.5\text{ ft})(7.48)}{3\text{ min}}$$
$$= \boxed{179.5\text{ gpm}}$$

* Screens are used in pretreatment to remove large debris. Average of 0.5-12 ft³/MG is removed.

Screenings Removed

5. A total of 55 gallons of screenings are removed from the wastewater flow during a 24-hour period. What is the screenings removal, cu.ft./day?

$55/7.48 = 7.3529\ ft^3$

$$\text{Screenings Removed, } ft^3/day = \frac{\text{screenings, } ft^3}{Day} = \frac{7.3529\ ft^3}{1 d} = \boxed{7.35\ ft^3/d}$$

6. The flow at a treatment plant is 3.6 MGD. If the total of 55 cu.ft. screenings are removed during a 24-hour period, what is the screenings removal, cu.ft./MG?

$$\text{Screenings Removed, } ft^3/MG = \frac{\text{screenings, } ft^3/d}{\text{flow, MGD}} = \frac{55\ ft^3}{3.6\ MGD} = \boxed{15.3\ ft^3/MG}$$

Screenings Pit Capacity, days

7. A screening pit has a capacity of 400 cu.ft. If an average of 3.8 cu.ft of screenings are removed daily from the wastewater flow, in how many days will the pit be full?

$$\text{Screening Pit Capacity, days} = \frac{\text{Screening Pit Volume, } ft^3}{\text{Screenings Removed, } ft^3/d} = \frac{400\ ft^3}{3.8\ ft^3/d} = \boxed{105\ d}$$

8. A plant averages a screenings removal of 2.1 cu.ft./MG. If the average daily flow is 2.7 MGD, how many days will it take to fill a 290 cu.ft. screening pit?

$$2.1\ ft^3/MG = \frac{x}{2.7\ MGD}$$

$$(2.1)(2.7) = 5.67\ ft^3/d$$

$$\text{Pit capacity, days} = \frac{290\ ft^3}{5.67\ ft^3/d} = \boxed{51\ days}$$

*Sanitary WW systems normally average 1-4 ft^3 grit/MG.

Grit Removal, cu.ft./MG

9. A treatment plant removes 12 cu.ft. of grit in one day. How many cu.ft. of grit are removed if the plant flow was 8 MGD?

$$\text{Grit Removal, } ft^3/MG = \frac{\text{Grit Volume, } ft^3/d}{\text{flow, MGD}}$$

$$= \frac{12\ ft^3/d}{8\ MGD} = \boxed{1.5\ ft^3/MG}$$

10. The total daily grit removal for a plant is 270 gallons. If the flow is 12.3 MGD, find the grit removal, cu.ft./MG.

$$\frac{270}{7.48} = 36.0963\ ft^3/d$$

$$\text{Grit Removal, } ft^3/MG = \frac{36.0963\ ft^3/d}{12.3\ MGD}$$

$$= \boxed{2.9\ ft^3/MG}$$

Grit Channel Flow Rate

11. A grit channel 36 inches (~3 ft) wide has water flowing to a depth of 1 ft. If the velocity of the wastewater is 1.1 ft/sec, what is the flow in the channel in cfs and gpm?

$$Q_{cfs} = (w, ft)(d, ft)(vel, fps)$$

$$= (3ft)(1ft)(1.1\ fps)$$

$$= \boxed{3.3\ ft^3/sec}$$

$$(3.3)(7.48)(60) = \boxed{1481\ gpm}$$

12. A grit channel is 3 feet wide, 50 feet long with water flowing to a depth of 18 (~1.5 ft) inches. What is the fpm velocity through the channel if the flow is 220 gpm?

→ need flow in ft^3/min

$$\frac{220\ gpm}{7.48} = 29.4118\ ft^3/min$$

$$29.4118\ ft^3/min = (3ft)(1.5ft)(vel)$$

$$29.4118 = (4.5)(vel)$$

$$\frac{29.4118}{4.5} = vel$$

$$\boxed{6.5\ fpm = vel}$$

Applied Math for Wastewater Treatment
Preliminary Treatment Math
Extra Problems

Screenings Pit Capacity

1. A screenings pit has a capacity of 600 cu.ft. If an average of 2.9 cu.ft. of screenings is removed daily from the wastewater flow, in how many days will the pit be full?

   $$\text{days} = \frac{600 \text{ ft}^3}{2.9 \text{ ft}^3/\text{d}} = \boxed{207 \text{ days}}$$

2. A screenings pit has a capacity of 9 cu. yards available for screenings. If the plant removes an average of 1.6 cu.ft. per day, in how many days will the pit be full? $(9 \text{ cu.yd.})(27 \text{ ft}^3/\text{yd}^3) = 243 \text{ ft}^3$

   $$\text{days} = \frac{243 \text{ ft}^3}{1.6 \text{ ft}^3/\text{d}} = \boxed{152 \text{ days}}$$

3. A plant has been averaging a screenings removal of 2.6 cu.ft./MG. If the average daily flow is 2.9 MGD, how many days will it take to fill a screenings pit with an available capacity of 292 cu.ft.?

   $$2.6 \text{ ft}^3/\text{MG} = \frac{? \text{ ft}^3/\text{d}}{2.9 \text{ MGD}}$$

   $$(2.6)(2.9) = 7.54 \text{ ft}^3/\text{d}$$

   $$\text{days} = \frac{292 \text{ ft}^3}{7.54 \text{ ft}^3/\text{d}} = \boxed{39 \text{ days}}$$

4. Suppose we want to use a screenings pit for 120 days. If the screenings removal rate is 3.5 cu.ft./day, what is the required screenings pit capacity in cu.ft.?

   $$120 \text{ days} = \frac{? \text{ ft}^3}{3.5 \text{ ft}^3/\text{d}}$$

   $$(120)(3.5) = \boxed{420 \text{ ft}^3}$$

Grit Channel Velocity

~ 1.5ft

5. A grit channel is 4 ft. wide, with water flowing to a depth of 18 inches. If the flow meter indicates a flow rate of 1820 gpm, what is the velocity of flow through the channel in feet/sec? → need flow in ft³/sec

$\frac{1820}{(7.48)(60)} = 4.0553$ cfs

Q = (w, ft)(d, ft)(vel)

4.0553 cfs = (4ft)(1.5ft)(vel)

4.0553 = (6)(vel)

$\frac{4.0553}{6}$ = **0.68 ft/sec**

6. A stick in a grit channel travels 26 feet in 32 seconds. What is the estimated velocity in the channel in feet/sec.?

vel. = $\frac{26 ft}{32 sec}$

= **0.81fps**

7. The total flow through both channels of a grit channel is 4.3 cfs. If each channel is 3 ft wide and water is flowing to a depth of 14 inches, what is the velocity of flow through the channel in fps? ~ 1.1667 ft

4.3cfs = (2)(3 ft)(1.1667ft)(vel)

4.3 = (7)(vel)

$\frac{4.3}{7}$ = **0.61 fps**

8. A stick placed in a grit channel flows 36 feet in 32 seconds. What is the estimated velocity in the channel in feet/sec.?

vel = $\frac{36 ft}{32 sec}$

= **1.13 fps**

~ 1.333ft ~ 2.8333 ft

9. The depth of water in a grit channel is 16 inches. The channel is 34 inches wide. If the flow meter indicates a flow of 1140 gpm, what is the velocity of flow through the channel in ft/sec.? ~ 2.5401 ft³/sec

2.5401 ft³/sec = (1.3333 ft)(2.8333ft)(vel)

2.5401 = (3.7776)(vel)

$\frac{2.5401}{3.7776}$ = **0.67 fps**

Grit Removal

10. A treatment plant removes 12 cu.ft. of grit in a day. If the plant flow is 8 MGD, what is the grit removal expressed in cu.ft./MG?

$$\text{grit removal} = \frac{12\ ft^3/d}{8\ MGD}$$

$$= \boxed{1.5\ ft^3/MG}$$

11. The total daily grit removal for a plant is 260 gallons. If the plant flow is 11.4 MGD, how many cu.ft. of grit are removed per million gallons of flow?

$$\frac{260\ gal}{7.48} = 34.7594\ ft^3/d$$

$$\text{grit removal} = \frac{34.7594\ ft^3/d}{11.4\ MGD}$$

$$= \boxed{3.0\ ft^3/MG}$$

12. The average grit removal at a particular treatment plant is 3.1 cu.ft./MG. If the monthly average daily flow is 3.8 MGD, how many cubic yards of grit would be removed from the wastewater flow during one 30-day month?

$$3.1\ cu.ft./MG = \frac{?\ ft^3/d}{3.8\ MGD}$$

$$(3.1)(3.8) = 11.78\ ft^3/d \text{ screenings}$$

$$(11.78\ ft^3/d)(30d) = 353.4\ ft^3 \text{ screenings}$$

$$\frac{353.4\ ft^3}{27\ ft^3/yd^3} = \boxed{13.1\ yd^3/mo}$$

13. The monthly average grit removal is 2.2 cubic feet per million gallons. If the average daily flow for the month is 4,230,000 gpd, how many cubic yards must be available for grit disposal if the disposal pit is to have a 90-day capacity?

$$2.2\ ft^3/MG = \frac{?\ ft^3/d}{4.23\ MGD}$$

$$(2.2)(4.23) = 9.306\ ft^3/d$$

$$(9.306\ ft^3/d)(90d) = \frac{837.54\ ft^3}{27\ ft^3/yd^3} = \boxed{31\ yd^3}$$

14. A grit channel is 2.6 feet wide and has water flowing to a depth of 16 inches. ~ 1.3333 ft If the velocity through the channel is 1.1 feet per second, what is the flow rate through the channel in cu.ft./sec.?

$Q = (2.6 \text{ ft})(1.3333 \text{ ft})(1.1 \text{ fps})$

$= 3.8 \text{ ft}^3/\text{sec}$

15. A grit channel 3-ft wide has water flowing at a velocity of 1.4 ft per second. If the depth of the water is 14 inches, what is the flow rate through the channel, in gal/day? ~ 1.16667 ft

$Q = (3 \text{ ft})(1.16667 \text{ ft})(1.4 \text{ fps}) = 4.9 \text{ ft}^3/\text{sec}$

$(4.9 \text{ ft}^3/\text{sec})(7.48)(60)(1440) = 3,166,733 \text{ gpd}$

16. A grit channel 32 inches wide ~2.66667 ft has water flowing to a depth of 10 inches ~0.8333 ft. If the velocity of the water is 0.90 fps, what is the flow rate in the channel in cu.ft./sec?

$Q = (2.66667 \text{ ft})(0.8333 \text{ ft})(0.90 \text{ fps})$

$= 2 \text{ ft}^3/\text{sec}$

Applied Math for Wastewater Treatment
Sedimentation

1. The flow to a circular clarifier is 3,940,000 gpd. If the clarifier is 75 ft in diameter and 12 feet deep, what is the clarifier detention time in hours? (Round to the nearest tenth.)

$$\text{Detention Time, hrs} = \frac{(\text{Vol, gal})(24\ \text{hr/day})}{\text{Flow, gpd}}$$

$$\text{Vol.} = (0.785)(75\ \text{ft})^2(12\ \text{ft})(7.48) = 396346.5\ \text{gal}$$

$$= \frac{(396346.5\ \text{gal})(24)}{3{,}940{,}000\ \text{gpd}} = \boxed{2.4\ \text{hrs}}$$

2. A circular clarifier has a diameter of 50 feet. If the primary clarifier influent flow is 2,260,000 gpd, what is the surface overflow rate in gpd/sq.ft.?

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

$$= \frac{2{,}260{,}000\ \text{gpd}}{(0.785)(50\ \text{ft})^2} = \boxed{1151.6\ \text{gpd/ft}^2}$$

3. A rectangular clarifier has a total of 210 ft. of weir. What is the weir overflow rate in gpd/ft when the flow 3,728,000 gpd?

$$\text{WOR, gpd/ft} = \frac{\text{flow, gpd}}{(2)(l, \text{ft}) + (2)(w, \text{ft})} \quad \text{or} \quad \frac{\text{flow, gpd}}{\text{weir length, ft}}$$

$$= \frac{3{,}728{,}000\ \text{gpd}}{210\ \text{ft}} = 17{,}752\ \text{gpd/ft}$$

4. A secondary clarifier, 55-ft in diameter, receives a primary effluent flow of 1,887,000 gpd and a return sludge flow of 528,000 gpd. If the MLSS concentration is 2640 mg/L, what is the solids loading rate in lbs/day/sq.ft. on the clarifier? (Round to the nearest tenth.)

$$\text{SLR, lbs/day/ft}^2 = \frac{(\text{MLSS, mg/L})(\text{P.E.} + \text{RAS flow, MGD})(8.34)}{(0.785)(D, \text{ft})^2}$$

$$= \frac{(2640\ \text{mg/L})(\overbrace{1.887 + 0.528}^{2.415}\ \text{MGD})(8.34)}{(0.785)(55\ \text{ft})^2}$$

$$= \frac{53172.504\ \text{lbs/day}}{2374.625\ \text{ft}^2} = 22.4\ \text{lbs/day/ft}^2$$

5. A circular primary clarifier has a diameter of 60 feet. If the influent flow to the clarifier is 2.62 MGD, what is the surface overflow rate in gpd/sq.ft.?

$$SOR, gpd/ft^2 = \frac{2,620,000 \text{ gpd}}{(0.785)(60 ft)^2}$$

$$= \boxed{927 \text{ gpd}/ft^2}$$

6. A secondary clarifier, 70 feet in diameter, receives a primary effluent flow of 2,740,000 gpd and a return sludge flow of 790,000 gpd. If the mixed liquor suspended solids concentration is 2815 mg/L, what is the solids loading rate in the clarifier in lbs/day/sq.ft.? (Round to the nearest tenth.)

$$SLR, lbs/day/ft^2 = \frac{(2815 mg/L)(\overbrace{2.74 + 0.79}^{3.53} MGD)(8.34)}{(0.785)(70 ft)^2}$$

$$= \frac{82874.163 \text{ lbs/day}}{3846.5 ft^2} = \boxed{21.5 \text{ lbs/d}/ft^2}$$

7. The flow to a secondary clarifier is 5.1 MGD. If the influent BOD concentration is 216 mg/L and the effluent BOD concentration is 103, how many lbs/day BOD are removed daily?

Removed = Influent - Effluent = 216 mg/L - 103 mg/L = 113 mg/L

lbs/d = (Removed, mg/L)(Flow, MGD)(8.34)

$$= (113 mg/L)(5.1 MGD)(8.34) = \boxed{4806 \text{ lbs/d}}$$

8. The flow to a sedimentation tank 80 feet long, 30 feet wide and 14 feet deep is 4.05 MGD. What is the detention time in the tank, in hours? (Round to the nearest tenth.)

$$DT, hrs = \frac{(80 ft)(30 ft)(14 ft)(7.48)(24)}{4,050,000 \text{ gpd}}$$

$$= \boxed{1.5 \text{ hrs}}$$

Answers:

1. 2.4 hours
2. 1152 gpd/sq.ft.
3. 17,752 gpd/ft
4. 22.4 lbs/day/sq.ft.
5. 927 gpd/sq.ft.
6. 21.5 lbs/day/sq.ft.
7. 4806 lbs/day
8. 1.5 hrs

Applied Math for Wastewater Treatment
Sedimentation
Extra Problems

Detention Time, hours

1. The flow to a sedimentation tank is 70 ft long, 25 ft wide and 10 ft deep is 100,000 gph. What is the detention time in hours?

$$DT, hrs = \frac{(70 ft)(25 ft)(10 ft)(7.48)}{100,000 gph}$$

$$= \boxed{1.3 hrs}$$

2. The flow to a sedimentation tank 90 ft long, 30 ft wide and 12 feet deep is 3.0 MGD. What is the detention time in the tank in hours?

$$DT, hrs = \frac{(90 ft)(30 ft)(12 ft)(7.48)(24)}{3,000,000 gpd}$$

$$= \boxed{1.9 hrs}$$

3. A rectangular sedimentation basin is 70 feet long by 25 feet wide and has water to a depth of 10 feet. The flow to the basin is 2,220,000 gpd. Calculate the detention time in hours for the sedimentation basin.

$$DT, hrs = \frac{(70 ft)(25 ft)(10 ft)(7.48)(24)}{2,220,000 gpd}$$

$$= \boxed{1.4 hrs}$$

4. A circular clarifier has a diameter of 80 feet and an average water depth of 12 feet. If the flow to the clarifier is 2,920,000 gpd, what is the detention time in hours?

$$DT, hrs = \frac{(0.785)(80 ft)^2(12 ft)(7.48)(24)}{2,920,000 gpd}$$

$$= \boxed{3.7 hrs}$$

5. A rectangular sedimentation basin is 60 ft long and 20 ft wide and contains water to a depth of 10 feet. If the flow to the basin is 1,520,000 gpd, what is the detention time in hours?

$$DT, hrs = \frac{(60 ft)(20 ft)(10 ft)(7.48)(24)}{1,520,000 gpd}$$

$$= \boxed{1.4 hrs}$$

Weir Overflow Rate, gpd/ft

6. A rectangular clarifier has a total of 120 feet of weir. What is the weir overflow rate in gpd/ft when the flow is 1.5 MGD?

$$WOR, gpd/ft = \frac{1,500,000 gpd}{120 ft}$$

$$= \boxed{12,500 gpd/ft}$$

7. A circular clarifier receives a flow of 2.95 MGD. If the diameter of the weir is 70 ft, what is the weir overflow rate in gpd/ft?

$$WOR, gpd/ft = \frac{2,950,000 gpd}{(3.14)(70 ft)}$$

$$= \boxed{13,421 gpd/ft}$$

8. A circular clarifier receives a flow of 2,520,000 gpd. If the diameter of the weir is 70 ft, what is the weir overflow rate in gpd/ft?

$$WOR, gpd/ft = \frac{2,520,000 gpd}{(3.14)(70 ft)}$$

$$= \boxed{11,465 gpd/ft}$$

9. A rectangular sedimentation basin has a length of 50 ft and a width of 35 ft. If the flow to the basin is 1,890,000 gpd, what is the weir overflow rate in gpd/ft?

$$WOR, gpd/ft = \frac{1,890,000 gpd}{(2)(50 ft)+(2)(35 ft)} \quad (2)(50 ft)+(2)(35 ft) = 100 + 70 = 170$$

$$= \boxed{11,118 gpd/ft}$$

10. A circular clarifier receives a flow of 3.7 MGD. If the diameter of the weir is 70 ft, what is the weir overflow rate in gpd/ft?

$$WOR, gpd/ft = \frac{3{,}700{,}000 \text{ gpd}}{(3.14)(70 \text{ ft})}$$

$$= \boxed{16{,}833 \text{ gpd/ft}}$$

Surface Overflow Rate, gpd/sq.ft.

11. A circular clarifier has a diameter of 55 ft. If the primary effluent flow is 2,075,000 gpd, what is the surface overflow rate in gpd/sq.ft.?

$$SOR, gpd/ft^2 = \frac{2{,}075{,}000 \text{ gpd}}{(0.785)(55 \text{ ft})^2}$$

$$= \boxed{874 \text{ gpd/ft}^2}$$

12. A sedimentation basin 70 ft by 15 ft receives a flow of 1.2 MGD. What is the surface overflow rate in gpd/sq.ft.?

$$SOR, gpd/ft^2 = \frac{1{,}200{,}000 \text{ gpd}}{(70 \text{ ft})(15 \text{ ft})}$$

$$= \boxed{1143 \text{ gpd/ft}^2}$$

13. The average flow to a secondary clarifier is 2580 gpm. What is the surface overflow rate if the secondary clarifier has a diameter of 70 ft?

$(2580)(1440) = 3{,}715{,}200$ gpd

$$SOR, gpd/ft^2 = \frac{3{,}715{,}200 \text{ gpd}}{(0.785)(70 \text{ ft})^2}$$

$$= \boxed{966 \text{ gpd/ft}^2}$$

14. A rectangular sedimentation basin is 60 ft long and 25 ft wide. When the flow is 510 gpm, what is the surface overflow in gpd/sq.ft.? $(510)(1440) = 734{,}400$ gpd

$$SOR, gpd/ft^2 = \frac{734{,}400 \text{ gpd}}{(60 \text{ ft})(25 \text{ ft})}$$

$$= \boxed{490 \text{ gpd/ft}^2}$$

15. A circular clarifier has a diameter of 70 ft. If the flow to the clarifier is 1610 gpm, what is the surface overflow in gpd/sq.ft.? $(1610)(1440) = 2{,}318{,}400$ gpd

$$SOR, gpd/ft^2 = \frac{2{,}318{,}400 \text{ gpd}}{(0.785)(70 \text{ ft})^2}$$

$$= \boxed{603 \text{ gpd/ft}^2}$$

Solids Loading Rate, lbs/day/sq.ft.

16. A circular secondary clarifier with a diameter of 100 ft treats a flow of 3.5 MGD inflow and 1.0 MGD return sludge flow. If the MLSS concentration is 4200 mg/L, what is the solids loading rate in lbs/day/sq.ft.?

$$SLR, lbs/day/ft^2 = \frac{(4200 \text{ mg/L})(3.5 + 1.0 \text{ MGD})(8.34)}{(0.785)(100 \text{ ft})^2}$$

$$= \frac{157626 \text{ lbs/d}}{7850 \text{ ft}^2} = \boxed{20 \text{ lbs/d/ft}^2}$$

17. A secondary clarifier handles a flow of 0.9 MGD and a suspended solids concentration of 3600 mg/L. The clarifier is 50 ft in diameter. Find the solids loading rate in lbs/day/sq.ft.

$$SLR, lbs/d/ft^2 = \frac{(3600 \text{ mg/L})(0.9 \text{ MGD})(8.34)}{(0.785)(50 \text{ ft})^2}$$

$$= \frac{27021.6 \text{ lbs/d}}{1962.5 \text{ ft}^2} = \boxed{13.8 \text{ lbs/d/ft}^2}$$

18. A secondary clarifier is 70 ft in diameter and receives a combined primary effluent and return activated sludge (RAS) flow of 3.60 MGD. If the MLSS concentration in the aerator is 2650 mg/L, what is the solids loading rate on the secondary clarifier in lbs/day/sq.ft.?

$$SLR, lbs/d/ft^2 = \frac{(2650 \text{ mg/L})(3.60 \text{ MGD})(8.34)}{(0.785)(70 \text{ ft})^2}$$

$$= \frac{79563.6 \text{ lbs/d}}{3846.5}$$

$$= \boxed{20.7 \text{ lbs/d/ft}^2}$$

19. A secondary clarifier, 80 ft in diameter, receives a primary effluent flow of 3.10 MGD and a return activated sludge flow of 1.15 MGD. If the MLSS concentration is 2825 mg/L, what is the solids loading rate on the clarifier in lbs/day/sq.ft.?

$$SLR, lbs/d/ft^2 = \frac{(2825\ mg/L)(3.1 + 1.15\ MGD)(8.34)}{(0.785)(80\ ft)^2}$$

$$= \frac{100132.125\ lbs/d}{5024\ ft^2} = \boxed{19.9\ lbs/d/ft^2}$$

20. A secondary clarifier, 60 ft in diameter, receives a primary effluent flow of 2,550,000 gpd and a return activated sludge flow of 800,000 gpd. If the MLSS concentration is 2210 mg/L, what is the solids loading rate on the clarifier in lbs/day/sq.ft.?

$$SLR, lbs/d/ft^2 = \frac{(2210\ mg/L)(2.55 + 0.8\ MGD)(8.34)}{(0.785)(60\ ft)^2}$$

$$= \frac{61745.19\ lbs/d}{2826\ ft^2} = \boxed{21.8\ lbs/d/ft^2}$$

BOD and Suspended Solids Removed, lbs/day

21. If 110 mg/L suspended solids are removed by a primary clarifier, how many lbs/day suspended solids are removed when the flow is 6,150,000 gpd?

$$Removed, lbs/d = (110\ mg/L)(6.15\ MGD)(8.34)$$

$$= \boxed{5642\ lbs/d}$$

22. If 125 mg/L suspended solids are removed by a primary clarifier, how many lbs/day suspended solids are removed when the flow is 5.16 MGD?

$$Removed, lbs/d = (125\ mg/L)(5.16\ MGD)(8.34)$$

$$= \boxed{5379\ lbs/d}$$

23. The flow to a primary clarifier is 2,920,000 gpd. If the influent to the clarifier has a BOD concentration of 240 mg/L and the primary effluent has a 200 mg/L BOD, how many lbs/day BOD are removed by the clarifier?

Removed = 240 mg/L - 200 mg/L = 40 mg/L

lbs/d = (40 mg/L)(2.92 MGD)(8.34) = **974 lbs/d**

24. The flow to a secondary clarifier is 4.44 MGD. If the influent BOD concentration is 200 mg/L and the effluent concentration is 110 mg/L, how many lbs of BOD are removed daily?

Removed = 200 mg/L - 110 mg/L = 90 mg/L

lbs/d = (90 mg/L)(4.44 MGD)(8.34) = **3333 lbs/d**

25. The flow to a primary clarifier is 980,000 gpd. If the influent to the clarifier has a suspended solids concentration of 320 mg/L and the primary clarifier effluent has a suspended solids concentration of 120 mg/L, how many lbs/day suspended solids are removed by the clarifier?

Removed = 320 mg/L - 120 mg/L = 200 mg/L

lbs/d = (200 mg/L)(0.98 MGD)(8.34) = **1635 lbs/d**

Unit Process Efficiency, %

26. The suspended solids entering a primary clarifier is 182 (In) mg/L. If the suspended solids concentration in the primary clarifier effluent is 79 (out) mg/L, what is the suspended solids removal efficiency of the primary clarifier?

$$\text{Efficiency} = \left(\frac{\text{in} - \text{out}}{\text{in}}\right)(100)$$

$$= \left(\frac{182-79}{182}\right)(100)$$

$$= \left(\frac{103}{182}\right)(100) = \boxed{56.6\%}$$

27. The influent to a primary clarifier has a BOD content of 260 mg/L. If the primary clarifier effluent has a BOD concentration of 54 mg/L, what is the BOD removal efficiency?

In / Out

$$\% = \frac{260-54}{260} = \frac{206}{260} \times 100 = 79.2\%$$

28. The suspended solids entering a primary clarifier is 230 mg/L. If the suspended solids concentration in the primary clarifier effluent is 95 mg/L, what is the suspended solids removal efficiency of the primary clarifier?

IN / out

$$\% = \frac{230-95}{230} = \frac{135}{230} \times 100 = 58.7\%$$

29. The concentration of suspended solids entering a primary clarifier is 188 mg/L. If the concentration of suspended solids in the primary clarifier effluent is 77 mg/L, what is the suspended solids removal efficiency of the primary clarifier?

In / out

$$\% = \frac{188-77}{188} = \frac{111}{188} \times 100 = 59.0\%$$

30. The influent to a primary clarifier has a BOD content of 280 mg/L. If the primary clarifier effluent has a BOD concentration of 60 mg/L, what is the BOD removal efficiency of the primary clarifier?

In / Out

$$\% = \frac{280-60}{280} = \frac{220}{280} \times 100 = 78.6\%$$

Applied Math for Wastewater Treatment
Trickling Filter Math

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

$$HLR, gpd/ft^2 = \frac{P.E.Q + Recirc.Q, gpd}{Area, ft^2}$$

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

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

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

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

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

$$OLR, lbs/d/1000 ft^3 = \frac{(BOD, mg/L)(Q, MGD)(8.34)}{\left[\frac{(0.785)(D, ft)^2(d, ft)}{1000}\right]}$$

$$= \frac{(160 mg/L)(1.2 MGD)(8.34)}{\left[\frac{(0.785)(85 ft)^2(5 ft)}{1000}\right]} = \frac{1601.28}{28.3581} = \boxed{56.5 \text{ lbs/d/1000 ft}^3}$$

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

$$OLR = \frac{(110 mg/L)(3.24 MGD)(8.34)}{\left[\frac{(0.785)(80 ft)^2(6 ft)}{1000}\right]} = \frac{2972.376 \text{ lbs/d}}{30.144 \text{ 1000 ft}^3} = \boxed{98.6 \text{ lbs/d/1000 ft}^3}$$

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

$$lbs/d = (Removed, mg/L)(Flow, MGD)(8.34)$$

$$= (113 mg/L)(2.668 MGD)(8.34)$$

$$= \boxed{2514\ lbs/d}$$

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

$$lbs/d = (177 mg/L)(2.840 MGD)(8.34)$$

$$= \boxed{4192\ lbs/d}$$

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

$$Efficiency, \% = \left(\frac{in - out}{in}\right)(100)$$

$$= \left(\frac{210-67}{210}\right)(100) = \left(\frac{143}{210}\right)(100) = \boxed{68.1\%}$$

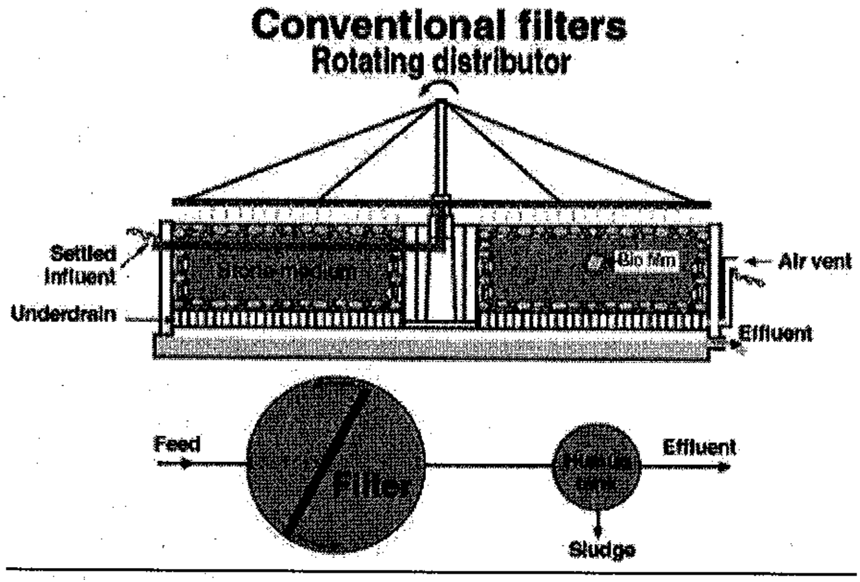
8. The influent to a primary clarifier has a BOD content of 252 (in) mg/L. The trickling filter effluent BOD is 20 (out) mg/L. What is the BOD removal efficiency of the treatment plant?

$$\% = \frac{252-20}{252} = \left(\frac{232}{252}\right)(100) = \boxed{92.1\%}$$

Answers:

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

Applied Math for Wastewater Treatment
Trickling Filter Math
Extra Problems



Hydraulic Loading Rate

1. A trickling filter 75 ft in diameter treats a primary clarifier effluent flow of 1.4 MGD. If the recirculated flow is 0.3 MGD, what is the hydraulic loading rate, gpd/sq ft?

$$HLR = \frac{1{,}400{,}000 + 300{,}000 \text{ gpd}}{(0.785)(75 \text{ ft})^2}$$

$$= \boxed{385 \text{ gpd/ft}^2}$$

2. The flow to a standard rate trickling filter is 450,000 gpd. If the trickling filter is 80 ft in diameter and 5 ft deep, what is the hydraulic loading rate?

$$HLR = \frac{450{,}000 \text{ gpd}}{(0.785)(80 \text{ ft})^2}$$

$$= \boxed{89.6 \text{ gpd/ft}^2}$$

3. A trickling filter, 80 ft in diameter, treats a primary effluent flow of 660,000 gpd. If the recirculated flow to the trickling filter is 120,000 gpd, what is the hydraulic loading rate on the trickling filter in gpd/ft^2?

$$HLR = \frac{660{,}000\,gpd + 120{,}000\,gpd}{(0.785)(80\,ft)^2}$$

$$= \boxed{155\ gpd/ft^2}$$

4. A high-rate trickling filter receives a flow of 2360 gpm. If the filter has a diameter of 90 ft, what is the hydraulic loading on the filter in gpd/ft^2?

$$(2360)(1440) = 3{,}398{,}400\,gpd$$

$$HLR = \frac{3{,}398{,}400\,gpd}{(0.785)(90\,ft)^2} = \boxed{534\ gpd/ft^2}$$

5. A trickling filter receives a flow of 2200 gpm with a BOD concentration of 125 mg/L. If the filter is 95 feet in diameter, what is the hydraulic loading rate, gpd/sq ft?

$$(2200)(1440) = 3{,}168{,}000\,gpd$$

$$HLR = \frac{3{,}168{,}000\,gpd}{(0.785)(95\,ft)^2} = \boxed{447\ gpd/ft^2}$$

Organic Loading Rate (OLR)

6. A trickling filter 80 ft in diameter with a media depth of 4 ft receives a primary effluent flow of 1.85 MGD with a BOD concentration of 110 mg/L. What is the organic loading rate, lbs BOD/day/1000 cu ft?

$$OLR = \frac{(110\,mg/L)(1.85\,MGD)(8.34)}{\left[\frac{(0.785)(80\,ft)^2(4\,ft)}{1000}\right]} = \frac{1697.19\,lbs/d}{20.096\,1000\,ft^3}$$

$$= \boxed{84.5\ lbs/d/1000\,ft^3}$$

7. An 80 ft diameter trickling filter with a media depth of 7 ft receives a flow of 2,180,000 gpd. If the BOD concentration of the primary effluent is 139 mg/L, find the organic loading rate.

$$OLR = \frac{(139\,mg/L)(2.18\,MGD)(8.34)}{\left[\frac{(0.785)(80\,ft)^2(7\,ft)}{1000}\right]} = \frac{2527.1868\,lbs/d}{35.168\,1000\,ft^3} = \boxed{71.9\ lbs/d/1000\,ft^3}$$

8. A trickling filter, 100 ft in diameter with a media depth of 6 ft, receives a flow of 1,400,000 gpd. If the BOD concentration of the primary effluent is 210 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 ft^3?

$$OLR = \frac{(210\,mg/L)(1.4\,MGD)(8.34)}{\left[\frac{(0.785)(100ft)^2(6ft)}{1000}\right]} = \frac{2451.96\text{ lbs/d}}{47.1\text{ 1000ft}^3} = \boxed{52.1\text{ lbs/d/1000 ft}^3}$$

9. A 90-ft diameter trickling filter with a media depth of 7 ft receives a primary effluent flow of 3,400,000 gpd with a BOD of 111 mg/L. What is the organic loading on the trickling filter in lbs BOD/day/1000 ft^3?

$$OLR = \frac{(111\,mg/L)(3.4\,MGD)(8.34)}{\left[\frac{(0.785)(90ft)^2(7ft)}{1000}\right]} = \frac{3147.516\text{ lbs/d}}{44.5095\text{ 1000ft}^3} = \boxed{70.7\text{ lbs/d/1000ft}^3}$$

10. Calculate OLR for the following trickling filter:

Diameter: 75 ft
Media depth: 5 ft

Flow: (315 gpm)(1440) = 453,600 gpd
Influent BOD: 210 mg/L

$$OLR = \frac{(210\,mg/L)(0.4536\,MGD)(8.34)}{\left[\frac{(0.785)(75ft)^2(5ft)}{1000}\right]} = \frac{794.43504\text{ lbs/d}}{22.078125\text{ 1000ft}^3}$$

$$= \boxed{36.0\text{ lbs/d/1000 ft}^3}$$

BOD & Suspended Solids Removal

11. If 110 mg/L suspended solids are removed by a trickling filter, how many pounds per day suspended solids are removed when the flow is 4.2 MGD?

$$lbs/d = (110\,mg/L)(4.2\,MGD)(8.34)$$

$$= \boxed{3853\text{ lbs/d}}$$

12. A trickling filter receives a flow of 4,900,000 gpd. If the BOD concentration entering the trickling filter is 160 mg/l and the effluent contains 30 mg/L, how many pounds of BOD are removed daily? Removed = 160 mg/L − 30 mg/L = 130 mg/L

$$lbs/d = (130\,mg/L)(4.9\,MGD)(8.34)$$

$$= \boxed{5313\text{ lbs/d}}$$

13. If 122 mg/L suspended solids are removed by a trickling filter, how many lbs/day suspended solids are removed when the flow is 3,240,000 gpd?

lbs/d = (122 mg/L)(3.24 MGD)(8.34)

= **3297 lbs/d**

14. The flow to a trickling filter is 1.82 MGD. If the primary effluent has a BOD concentration of 250 mg/L and the trickling filter effluent has a BOD concentration of 74 mg/L, how many lbs of BOD are removed?

Removed = 250 mg/L − 74 mg/L = 176 mg/L

lbs/d = (176 mg/L)(1.82 MGD)(8.34)

= **2671 lbs/d**

15. If 182 mg/L of BOD are removed from a trickling filter when the flow to the trickling filter is 2,920,000 gpd, how many lbs/day BOD are removed?

lbs/d = (182 mg/L)(2.92 MGD)(8.34)

= **4432 lbs/d**

Unit Process Efficiency

16. The suspended solids entering a trickling filter is 135 mg/L. If the suspended solids in the effluent is 28 mg/L, what is the suspended solids removal efficiency, %? If the flow to the filter is 1.5 cfs, calculate lbs/day suspended solids removed.

$$\% = \frac{135-28}{135} \times 100 = \boxed{79.3\%} \quad (135-28 = 107)$$

(1.5 cfs)(7.48)(60)(1440) = 969,408 gpd

lbs/d = (107 mg/L)(0.969408 MGD)(8.34) = **865 lbs/d**

17. The suspended solids concentration entering a trickling filter is 149 mg/L. If the suspended solids concentration in the trickling filter effluent is 48 mg/L, what is the suspended solids removal efficiency of the trickling filter?

$$\% = \frac{149-48}{149} \times 100 = \frac{101}{149} \times 100 = \boxed{67.8\%}$$

18. The influent to a primary clarifier has a BOD content of 261 mg/L. The trickling filter effluent BOD is 22 mg/L. What is the BOD removal efficiency of the treatment plant?

$$\% = \frac{261-22}{261} \times 100 = \frac{239}{261} \times 100 = \boxed{91.6\%}$$

19. The concentration of suspended solids entering a trickling filter if 201 mg/L. If the concentration of suspended solids in the trickling filter effluent is 22 mg/L, what is the suspended solids removal efficiency of the trickling filter?

$$\% = \frac{201-22}{201} \times 100 = \frac{179}{201} \times 100 = \boxed{89.1\%}$$

20. The concentration of suspended solids entering a trickling filter is 111 mg/L. If 88 mg/L suspended solids are removed from the trickling filter, what is the suspended solids removal efficiency of the trickling filter?

$$\% \; \frac{88}{111} \times 100 = \boxed{79.3\%}$$

Applied Math for Wastewater Treatment
Activated Sludge

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

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

   lbs BOD/day = (BOD, mg/L)(Flow, MGD)(8.34)
   = (225 mg/L)(0.85 MG)(8.34)
   = **1595 lbs/d**

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

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

   lbs COD/day = (COD, mg/L)(Flow, MGD)(8.34)
   = (155 mg/L)(1.728 MGD)(8.34)
   = **2234 lbs/d**

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

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

   aerator volume, gal = (120 ft)(45 ft)(12 ft)(7.48) = 484,704 gal

   MLSS, lbs = (MLSS, mg/L)(Aer. Vol, MG)(8.34)
   = (2150 mg/L)(0.484704 MG)(8.34)
   = **8691 lbs MLSS**

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

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

$$= (2300\text{ mg/L})(0.2\text{ MG})(8.34)(0.72)$$

$$= \boxed{2762\text{ lbs MLVSS}}$$

Food to Microorganism Ratio

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

$$F/M = \frac{(\text{BOD or COD, mg/L})(\text{Flow, MGD})(8.34)}{(\text{MLVSS, mg/L})(\text{Aer. Vol., MG})(8.34)}$$

$$= \frac{(180\text{ mg/L})(1.6\text{ MGD})(8.34)}{(2200\text{ mg/L})(0.42\text{ MG})(8.34)} = \frac{2401.92}{7706.16} = \boxed{0.31}$$

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

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

$$= \frac{517.497}{2902.9455} = \boxed{0.18}$$

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

$$\text{Desired MLVSS, lbs} = \frac{\text{BOD or COD, lbs}}{\text{Desired F/M ratio}}$$

$$= \frac{(172\text{ mg/L})(3.0\text{ MGD})(8.34)}{0.5}$$

$$= \boxed{8607\text{ lbs}}$$

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

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

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

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

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

9. Determine MCRT given the following information:

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

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

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

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

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

Wasting Rates

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

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

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

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

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

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

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

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

Answers:

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

Applied Math for Wastewater Treatment
Activated Sludge
Extra Problems

BOD or COD Loading, lbs/day

1. The flow to an aeration basin is 880,000 gpd. If the BOD content of the wastewater entering the aeration basin is 240 mg/L, what is the lbs/day BOD loading?

   lbs/d = (240 mg/L)(0.88 MGD)(8.34)

   = 1761 lbs/d

2. The flow to the aeration basin is 2980 gpm. If the COD concentration of the wastewater is 160 mg/L, how many lbs of COD are applied to the aeration basin daily?

   $\frac{(2980)(1440)}{1,000,000} = 4.2912$ MGD

   lbs/d = (160 mg/L)(4.2912 MGD)(8.34) = 5726 lbs/d

3. The BOD content of the wastewater entering an aeration basin is 165 mg/L. If the flow to the aeration basin is 3,240,000 gpd, what is the lbs/day BOD loading?

   lbs/d = (165 mg/L)(3.24 MGD)(8.34)

   = 4459 lbs/d

4. The daily flow to an aeration basin is 4,880,000 gpd. If the COD concentration of the influent wastewater is 150 mg/L, how many lbs of COD are applied to the aeration basin daily?

   lbs/d = (150 mg/L)(4.88 MGD)(8.34)

   = 6105 lbs/d

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

5. If the mixed liquor suspended solids concentration is 2110 mg/L and the aeration basin has a volume of 460,000 gallons, how many lbs of suspended solids are in the aeration basin?

$$\text{lbs} = (2110 \text{ lbs})(0.46 \text{ MG})(8.34)$$

$$= \boxed{8095 \text{ lbs}}$$

6. The aeration basin of a conventional activated sludge plant has a mixed liquor volatile suspended solids (MLVSS) concentration of 2420 mg/L. If the aeration basin is 90 ft long by 50 ft wide and has wastewater to a depth of 16 ft, how many lbs of MLVSS are under aeration?

$$\text{vol.} = \frac{(90 \text{ ft})(50 \text{ ft})(16 \text{ ft})(7.48)}{1{,}000{,}000} = 0.53856 \text{ MG}$$

$$\text{lbs} = (2420 \text{ mg/L})(0.53856 \text{ MG})(8.34) = \boxed{10{,}870 \text{ lbs}}$$

7. The aeration basin of a conventional activated sludge plant has a mixed liquor volatile suspended solids (MLVSS) concentration of 2410 mg/L. If the aeration basin is 80 ft long by 40 ft wide and has wastewater to a depth of 16 ft, how many lbs of MLVSS are under aeration?

$$\text{vol.} = \frac{(80 \text{ ft})(40 \text{ ft})(16 \text{ ft})(7.48)}{1{,}000{,}000} = 0.382976 \text{ MG}$$

$$\text{lbs} = (2410 \text{ mg/L})(0.382976 \text{ MG})(8.34) = \boxed{7698 \text{ lbs}}$$

8. An aeration basin is 110 ft long, 30 ft wide and has wastewater to a depth of 16 ft. If the aeration basin of this conventional activated sludge plant has a mixed liquor suspended solids (MLSS) concentration of 2740 mg/L, how many lbs of MLSS are under aeration?

$$\text{vol.} = \frac{(110 \text{ ft})(30 \text{ ft})(16 \text{ ft})(7.48)}{1{,}000{,}000} = 0.394944 \text{ lbs}$$

$$\text{lbs} = (2740 \text{ mg/L})(0.394944 \text{ lbs})(8.34) = \boxed{9025 \text{ lbs}}$$

9. An aeration basin is 110 ft long, 50 ft wide and has wastewater to a depth of 16 ft. If the mixed liquor suspended solids (MLSS) concentration in the aeration basin is 2470 mg/L with a volatile solids content of 73%, how many lbs of MLVSS are under aeration?

$$\text{Vol} = \frac{(110\text{ ft})(50\text{ ft})(16\text{ ft})(7.48)}{1{,}000{,}000} = 0.65824 \text{ MG}$$

$$\text{lbs} = \underbrace{(2470\text{ mg/L})(0.73)}_{\text{gives you mg/L MLVSS}}(0.65824)(8.34) = \boxed{9899\text{ lbs}}$$

Food to Microorganism Ratio

10. An activated sludge aeration basin receives a primary effluent flow of 2.72 MGD with a BOD concentration of 198 mg/L. The mixed liquor volatile suspended solids (MLVSS) concentration is 2610 mg/L and the aeration basin volume is 480,000 gallons. What is the current F/M ratio?

$$F/M = \frac{(198\text{ mg/L})(2.72\text{ MGD})(8.34)}{(2610\text{ mg/L})(0.48\text{ MG})(8.34)}$$

$$= \frac{4491.5904\text{ lbs/d BOD}}{10448.352\text{ lbs MLVSS}} = \boxed{0.43}$$

11. An activated sludge aeration basin receives a primary effluent flow of 3,350,000 gpd with a BOD of 148 mg/L. The mixed liquor volatile suspended solids (MLVSS) concentration is 2510 mg/L and the aeration basin volume is 490,000 gallons. What is the F/M ratio?

$$F/M = \frac{(148\text{ mg/L})(3.35\text{ MGD})(8.34)}{(2510\text{ mg/L})(0.49\text{ MG})(8.34)}$$

$$= \frac{4134.972\text{ lbs/d BOD}}{10257.366\text{ lbs MLVSS}} = \boxed{0.40}$$

12. The flow to a 195,000 gallon oxidation ditch is 320,000 gpd. The BOD concentration of the wastewater is 180 mg/L. If the mixed liquor suspended solids (MLSS) concentration is 2540 mg/L with a volatile solids content of 72%, what is the F/M ratio?

$$F/M = \frac{(180 \text{ mg/L})(0.32 \text{ MGD})(8.34)}{(2540 \text{ mg/L})(0.72)(0.195 \text{ MG})(8.34)}$$

$$= \frac{480.384 \text{ lbs/d BOD}}{2974.17744 \text{ lbs MLVSS}} = \boxed{0.16}$$

13. The desired F/M ratio at an extended aeration activated sludge plant is 0.7 lb BOD/lb MLVSS. If the primary effluent flow is 3.3 MGD and has a BOD of 181 mg/L, how many pounds of MLVSS should be maintained in the aeration basin?

$$\text{Desired MLVSS, lbs} = \frac{(181 \text{ mg/L})(3.3 \text{ MGD})(8.34)}{0.7}$$

$$= \boxed{7116 \text{ lbs MLVSS}}$$

14. The desired F/M ratio at a particular activated sludge plant is 0.4 lbs BOD/lb MLVSS. If the primary effluent flow is 2,510,000 gpd and has a BOD concentration of 141 mg/L, how many lbs of MLVSS should be maintained in the aeration basin?

$$\text{Desired MLVSS, lbs} = \frac{(141 \text{ mg/L})(2.51 \text{ MGD})(8.34)}{0.4}$$

$$= \boxed{7379 \text{ MLVSS lbs}}$$

Mean Cell Residence Time (MCRT), days

15. An activated sludge system has a total of 29,100 lbs ~~of MLSS~~ in system of MLSS. The concentration of suspended solids leaving the final clarifier in the effluent is calculated to be 400 lbs/day. Suspended solids wasted from the clarifier are 2920 lbs/day. What is the MCRT in days? leaving

$$\text{MCRT, days} = \frac{29{,}100 \text{ lbs}}{400 \text{ lbs/d} + 2920 \text{ lbs/d}}$$

$$= \frac{29{,}100 \text{ lbs}}{3320 \text{ lbs/d}} = \boxed{8.8 \text{ days}}$$

16. Determine the MCRT given the following data: aeration basin volume, 1,500,000 gallons; mixed liquor suspended solids, 2710 mg/L; final clarifier, 106,000 gallons; waste activated sludge, 5870 mg/L; WAS pumping rate, 72,000 gpd; plant flow, 3.3 MGD; secondary effluent SS, 25 mg/L; average clarifier core SS, 1940 mg/L.

Aer. Basin = 1,500,000 gal
Clarifier = 106,000 gal
WAS Pump = 72,000 gpd
Plant Flow = 3.3 MGD

MLSS = 2710 mg/L
WAS = 5870 mg/L
SE SS = 25 mg/L
CC SS = 1940 mg/L

★ Use 5th MCRT Formula ★

$$MCRT = \frac{(2710)(1.5)(8.34) + (1940)(0.106)(8.34)}{(5870)(0.072)(8.34) + (25)(3.3)(8.34)}$$

$$= \frac{33,902.1 + 1715.0376}{3524.8176 + 688.05} = \frac{35617.1376}{4212.8676} = \boxed{8.5 \text{ days}}$$

17. An aeration basin has a volume of 460,000 gallons. The final clarifier has a volume of 178,000 gallons. The MLSS concentration in the aeration basin is 2222 mg/L. If 1610 lbs/day suspended solids are wasted and 240 lbs/day suspended solids are in the secondary effluent, what is the MCRT for the activated sludge system?

Aer. Basin = 460,000 gal
Clarifier = 178,000 gal
MLSS = 2222 mg/L

SS wasted = 1610 lbs/d
SE SS = 240 lbs/d

★ Use top of 4th MCRT formula & bottom of 2nd formula ★

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

$$= \frac{(2222\ mg/L)(\overbrace{0.460 + 0.178}^{0.638}\ MG)(8.34)}{1610 + 240\ lbs/d}$$

$$= \frac{11823.08424\ lbs}{1850\ lbs/d} = \boxed{6.4 \text{ days}}$$

18. Determine MCRT given the following information:

Aeration Basin = 350,000 gal
Final Clarifier = 125,000 gal
Flow = 1,400,000 gpd
WAS Pump Rate = 27,000 gpd

MLSS = 2910 mg/L
S.E. SS = 16 mg/L
WAS = 6210 mg/L

★ Use 4th MCRT formula ★

$$MCRT = \frac{(2910\ mg/L)\overbrace{(0.35+0.125\ MG)}^{0.475}(8.34)}{(6210\ mg/L)(0.027\ MGD)(8.34)+(16\ mg/L)(1.4\ MGD)(8.34)}$$

$$= \frac{11527.965\ lbs}{1398.3678+186.816} = \frac{11527.965}{1585.1838} = \boxed{7.3\ d}$$

Wasting Rates

19. Using Constant F/M Ratio: The desired F/M ratio for an activated sludge system is 0.5 lbs BOD/lb MLVSS. It has been calculated that 3400 lbs of BOD enter the aeration basin daily. If the volatile solids content of the MLSS is 69%, how many lbs MLSS are desired in the aeration basin?

$$\text{Desired MLVSS, lbs} = \frac{3400\ lbs\ BOD}{0.5} = 6800\ lbs$$

$$\text{Desired MLSS, lbs} = \frac{6800\ lbs}{0.69} = \boxed{9855\ lbs}$$

20. Using Constant MCRT: The desired MCRT for an activated sludge plant is 9 days. The secondary effluent flow is 3,220,000 gpd with a suspended solids content of 23 mg/L. There is a total of 32,400 lbs SS in the system. How many lbs/day WAS SS must be wasted to maintain the desired MCRT?

$$\text{WAS, lbs/d} = \frac{32{,}400\ lbs}{9\ days} - (23\ mg/L)(3.22\ MGD)(8.34)$$

$$= 3600\ lbs/d - 617.6604\ lbs/d$$

$$= \boxed{2982\ lbs/d}$$

21. Given the following data, determine the lbs/day suspended solids to be wasted:

Aeration Tank Volume = 1.2 MG
Influent Flow = 3,100,000 gpd
BOD = 110 mg/L
Desired F/M = 0.4
MLSS = 2200 mg/L
%VS = 68%

Desired MLVSS, lbs/d = $\frac{(110 \text{ mg/L})(3.1 \text{ MGD})(8.34)}{0.4}$

= 7109.85 lbs

Desired MLSS, = $\frac{7109.85}{0.68}$ = 10455.66176 lbs

Actual MLSS = (2200 mg/L)(1.2 MG)(8.34) = 22017.6 lbs

MLSS to Waste = 22017.6 − 10455.6 = 11,562 lbs MLSS to waste

Answers:

1. 1761 lbs BOD/day
2. 5726 lbs COD/day
3. 4459 lbs BOD/day
4. 6105 lbs COD/day
5. 8095 lbs MLSS
6. 10,870 lbs MLVSS
7. 7698 lbs MLVSS
8. 9025 lbs MLSS
9. 9899 lbs MLVSS
10. 0.43
11. 0.40
12. 0.16
13. 7116 lbs MLVSS
14. 7379 lbs MLVSS
15. 8.8 days
16. 8.5 days
17. 6.4 days
18. 7.3 days
19. 9855 lbs MLSS desired
20. 2982 lbs MLSS to waste
21. ~~3977~~ lbs MLSS to waste
    11,562

Applied Math for Wastewater
Pump Horsepower & Efficiency
Practice Quiz

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

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

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

$$= \boxed{46\text{ hp}}$$

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

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

$$= \boxed{12.2\text{ hp}}$$

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

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

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

$$= \boxed{20.8\text{ hp}}$$

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

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

OR

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

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

$$\text{\% Eff., overall} = \frac{\text{W hp}}{\text{M hp}} \times 100$$

$$= \frac{16.3\text{ hp}}{36\text{ hp}} \times 100$$

$$= \boxed{45\%}$$

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

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

$$\text{M hp} = \frac{(1250)(71)}{(3960)(0.82)} = 27.33\text{ hp}$$

$$= (27.33\text{ hp})(0.746)(\$0.028)(126\text{ hr})$$

$$= \boxed{\$71.93}$$

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

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

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

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

ANSWERS

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

Applied Math for Wastewater
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?

$$Whp = \frac{(3{,}000\text{ gpm})(25\text{ ft})}{3960}$$

$$= \boxed{18.9\text{ hp}}$$

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

$$Whp = \frac{(555\text{ gpm})(40\text{ ft})}{3960}$$

$$= \boxed{5.6\text{ hp}}$$

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?

$$Whp = \frac{(900\text{ gpm})(76.2\text{ ft})}{3960}$$

$$= \boxed{17.3\text{ hp}}$$

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?

$$Whp = \frac{(850\text{ gpm})(46\text{ ft})}{3960}$$

$$= \boxed{9.9\text{ hp}}$$

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

$$Whp = \frac{(835\text{ gpm})(35.6\text{ ft})}{3960}$$

$$= \boxed{7.5\text{ hp}}$$

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

$$Whp = \frac{(1523 \text{ gpm})(65 \text{ ft})}{3960}$$

$$= \boxed{25 \text{ hp}}$$

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?

$$Bhp = \frac{(360 \text{ gpm})(95 \text{ ft})}{(3960)(0.85)}$$

$$= \boxed{10.2 \text{ hp}}$$

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?

$$Bhp = \frac{(450 \text{ gpm})(90 \text{ ft})}{(3960)(0.70)}$$

$$= \boxed{14.6 \text{ hp}}$$

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?

Bhp

$$Mhp = \frac{35 \text{ hp}}{0.90}$$

$$= \boxed{38.9 \text{ hp}}$$

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?

$$Mhp = \frac{20 \text{ hp}}{0.90}$$

$$= \boxed{22.2 \text{ hp}}$$

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?

$$\text{M hp} = \frac{\text{Whp}}{(\text{motor eff.})(\text{pump eff.})} = \frac{9}{(0.80)(0.72)} = \boxed{15.6 \text{ hp}}$$

OR

$$\text{Bhp} = \frac{\text{Whp}}{\text{pump eff}} = \frac{9}{0.8} = 11.25$$

$$\text{Mhp} = \frac{\text{Bhp}}{\text{motor eff}} = \frac{11.25}{0.72} = \boxed{15.6 \text{ hp}}$$

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?

$$\text{Mhp} = \frac{6 \text{ hp}}{(0.80)(0.90)} = \boxed{8.3 \text{ hp}}$$

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?

$$\%\text{pump eff.} = \frac{\text{Whp}}{\text{Bhp}} = \frac{18.5 \text{ hp}}{21 \text{ hp}} = 0.88 \times 100 = \boxed{88\%}$$

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?

$$\%\text{eff., overall} = \frac{\text{Whp}}{\text{Mhp}} = \frac{18.5 \text{ hp}}{35 \text{ hp}} = 0.529 = \boxed{52.9\%}$$

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?

$$\frac{31 \text{ kW} \,|\, 1 \text{ hp}}{|\, 0.746 \text{ kW}} = 41.55 \text{ Mhp}$$

$$\%\text{motor eff.} = \frac{\text{Bhp}}{\text{Mhp}} = \frac{19 \text{ hp}}{41.55 \text{ hp}} = 0.457 = \boxed{45.7\%}$$

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?

$$\frac{10\text{ kW} \mid 1\text{ hp}}{\mid 0.746\text{ kW}} = 13.40\text{ hp}$$

$$\%\text{ motor eff.} = \frac{12\text{ hp}}{13.4\text{ hp}} = 0.8952 = \boxed{89.5\%}$$

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?

$$\text{pump cost, \$/hr} = (\text{mhp})(0.746)(\text{cost, \$/kW-hr})$$
$$= (39\text{ hp})(0.746)(\$0.08)$$
$$= \boxed{\$2.33/\text{hr}}$$

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?

$$\text{pump cost, \$/hr} = (30\text{ hp})(0.746)(\$0.05)$$
$$= \boxed{\$1.12/\text{hr}}$$

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?

$$\text{pump cost, \$/hr} = (25\text{ hp})(0.746)(\$0.025)$$
$$= \$0.47/\text{hr}$$
$$@\ 14\text{ hrs} \Rightarrow (\$0.47/\text{hr})(14\text{ hrs})$$
$$= \boxed{\$6.53}$$

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?

$$Mhp = \frac{(1100\ gpm)(65\ ft)}{(3960)(0.70)} = 25.79\ hp$$

$$cost, \$/hr = (25.79\ hp)(0.746)(\$0.025) = \$0.48/hr$$

$$@\ 80\ hrs \Rightarrow (\$0.48/hr)(80\ hrs) = \boxed{\$38.48}$$

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.

$$Mhp = \frac{18.5\ hp}{0.88} = 21.02\ hp$$

$$cost, \$/hr = (21.02\ hp)(0.746)(\$0.015) = \$0.24/hr$$

$$@\ 24\ hrs \Rightarrow (\$0.24/hr)(24\ hrs) = \boxed{\$5.65/d}$$

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?

$$Mhp = \frac{(1500\ gpm)(80\ ft)}{(3960)(0.68)} = 44.56\ hp$$

$$cost, \$/hr = (44.56\ hp)(0.746)(\$0.035) = \$1.16/hr$$

$$@\ 90\ hrs \Rightarrow (\$1.16/hr)(90\ hrs) = \boxed{\$104.72}$$

MOTORS

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

$$hp = \frac{(440\ volts)(36\ amps)}{746} = \boxed{21.2\ hp}$$

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

$$hp = \frac{(440 \text{ volts})(12 \text{ amps})}{746}$$

$$= \boxed{7.1 \text{ hp}}$$

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

$$hp = \frac{(440 \text{ volts})(16 \text{ amps})}{746}$$

$$= \boxed{9.4 \text{ hp}}$$

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?

$$\text{watts} = (\text{volts})(\text{amps})(\text{power factor})$$

$$= (110 \text{ volts})(12 \text{ amps})(1 \text{ pf})$$

$$= \boxed{1320 \text{ watts}}$$

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?

$$\text{watts} = (220 \text{ volts})(12 \text{ amps})(0.8 \text{ pf})$$

$$= \boxed{2112 \text{ watts}}$$

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?

$$\text{watts} = (110 \text{ volts})(12 \text{ amps})(0.3 \text{pf})$$

$$= \boxed{396 \text{ watts}}$$

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?

$$\text{watts, three-phase} = (\text{volts})(\text{amps})(\text{pf})(1.732)$$

$$= (440 \text{ volts})(20 \text{ amps})(0.85 \text{ pf})(1.732)$$

$$= \boxed{12955 \text{ watts}}$$

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?

$$\text{watts, three-phase} = (440 \text{ volts})(40 \text{ amps})(0.9 \text{ pf})(1.732)$$

$$= \boxed{27{,}435 \text{ watts}}$$

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?

$$\text{kW} = \frac{(440 \text{ volts})(20 \text{ amps})(0.85 \text{ pf})(1.732)}{1000}$$

$$= \boxed{13 \text{ kW}}$$

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

$$\text{power factor} = \frac{\text{watts}}{(\text{volts})(\text{amps})}$$

$$= \frac{3872 \text{ watts}}{(440 \text{ volts})(11 \text{ amps})} = \boxed{0.8}$$

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

$$\text{power factor} = \frac{3960 \text{ watts}}{(440 \text{ volts})(10 \text{ amps})} = \boxed{0.9}$$

Applied Math for Wastewater
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?

$$\text{Pump Rate, gpm} = \frac{\text{volume, gal}}{\text{time, min}}$$

$$= \frac{9{,}456 \text{ gal}}{60 \text{ min}}$$

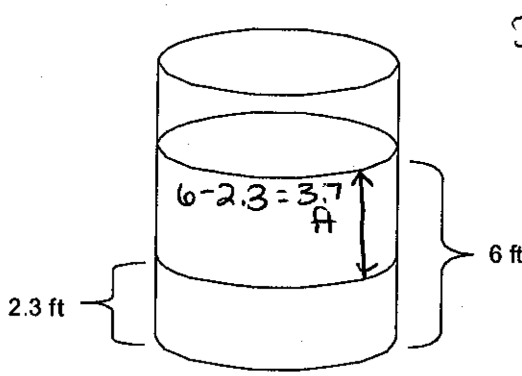
$$= \boxed{157.6 \text{ gpm}}$$

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?

$$\text{Pump Rate, gpm} = \frac{3680 \text{ gal}}{30 \text{ min}}$$

$$= \boxed{122.7 \text{ gpm}}$$

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?



$$\text{Pump Rate, gpm} = \frac{(0.785)(D,\text{ft})(D,\text{ft})(d,\text{ft})(7.48)}{\text{time, min}}$$

$$= \frac{(0.785)(50 \text{ ft})(50 \text{ ft})(3.7 \text{ ft})(7.48)}{120 \text{ min}}$$

$$= \frac{54314.15 \text{ gal}}{120 \text{ min}}$$

$$= \boxed{452.6 \text{ gpm}}$$

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?

fluff

97 min

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

$$= \frac{(12 ft)(12 ft)(10 ft)(7.48)}{97 \text{ min}}$$

$$= \boxed{111 \text{ gpm}}$$

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.

10.5 min

$$\text{Pump Rate, gpm} = \frac{(10 ft)(10 ft)(5 ft)(7.48)}{10.5 \text{ min}}$$

$$= \boxed{356 \text{ gpm}}$$

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?

$$\text{Pump Rate, gpm} = \frac{11{,}321 \text{ gal}}{60 \text{ min}}$$

$$= \boxed{189 \text{ gpm}}$$

ANSWERS

1. 157.6 gpm
2. 122.7 gpm
3. 452.6 gpm
4. 111 gpm
5. 356.2 gpm
6. 188.7 gpm

Applied Math for Wastewater Treatment
Chemical Dosage

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

Chemical Feed Rate (Full Strength), lbs/day

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

lbs/d = (dose, mg/L)(Q, MGD)(8.34 lbs/gal)
= (4.5 mg/L)(8.2 MGD)(8.34)
= 307.7 lbs/day

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

lbs/d = (2.3 mg/L)(4.2368 MGD)(8.34)
= 81.3 lbs/day

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

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

$$\text{lbs/d} = \frac{(\text{dose, mg/L})(\text{Q, MGD})(8.34)}{\text{chem purity, as decimal}}$$

$$= \frac{(6.8\text{ mg/L})(1.3\text{ MGD})(8.34)}{0.65}$$

= 113.4 lbs/d

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

$\frac{(69\text{ gpm})(1440)}{1{,}000{,}000} = 0.09936$ MGD

lbs/d $= \frac{(15\text{ mg/L})(0.09936\text{ MGD})(8.34)}{0.65}$

$=$ **19.1 lbs/d**

Chlorine Dose, Demand and Residual, mg/L

Demand = Dose – Residual *in formula book*
Dose = Demand + Residual
Residual = Dose – Demand

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

demand = dose − residual
3.2 = dose − 0.5
3.2 + 0.5 = dose
3.7 = dose

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

dose = 6 + 1
= 7 mg/L

lbs/d = (7 mg/L)(4.2 MGD)(8.34)
= **245 lbs/d**

Chemical Dosage, mg/L

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

$\frac{(1{,}180)(1440)}{1{,}000{,}000} = 1.6992$ MGD

dose, mg/L $= \frac{\text{lbs/day feed rate}}{(Q\text{, MGD})(8.34)}$

$= \frac{76\text{ lbs/d}}{(1.6992)(8.34)} =$ **5.36 mg/L**

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

$$\text{dose} = \frac{26.5 \text{ lbs/d}}{(1.2 \text{ MGD})(8.34)} = 2.65 \text{ mg/L}$$

$$1.85 = 2.65 - \text{residual}$$

$$\text{resid.} = 2.65 - 1.85 = \boxed{0.8 \text{ mg/L}}$$

Hypochlorination

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

$$\text{HTH, lbs (sol'n mix)} = \frac{(\text{Desired \%})(\text{Desired Vol})(8.34)}{\text{HTH \%}}$$

$$= \frac{(0.05)(25 \text{ gal})(8.34)}{0.65} = \boxed{16 \text{ lbs}}$$

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

$$\text{HTH, lbs} = \frac{(0.05)(10)(8.34)}{0.65}$$

$$= \boxed{6.4 \text{ lbs}}$$

Answers:

1. 308 lbs/day
2. 81.3 lbs/day
3. 113 lbs/day
4. 19.1 lbs/day
5. 3.7 mg/L
6. 245 lbs/day
7. 5.36 mg/L
8. 0.8 mg/L
9. ~~1.9 lbs~~ 16 lbs
10. ~~0.77~~ lbs 6.4 lbs

Applied Math for Wastewater Treatment
Chemical Dosage

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

Chemical Feed Rate (Full Strength), lbs/day pg.5 formula book

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

lbs/d = (dose, mg/L)(flow, MGD)(8.34 lbs/gal)
= (3.2 mg/L)(4.4 MGD)(8.34)
= 117 lbs/d

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

lbs/d = (1.1 mg/L)(1.66 MGD)(8.34)
= 15.2 lbs/d

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

lbs = (dose, mg/L)(Vol., MG)(8.34)
= (2100 mg/L)(0.195 MG)(8.34)
= 3415 lbs

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

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

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

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

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

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

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

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

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

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

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

$$= 234\ lbs/d$$

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

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

$$= 1096\ lbs/d$$

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

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

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

$$= 20.8\ lbs/d$$

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

pg. 9 formula book

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

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

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

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

$$gpd = \frac{(8{,}000\ mg/L)(0.00469744)}{0.40} = \boxed{93.9\ gpd}$$

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

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

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

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

$$8.4 = demand + 0.8$$

$$8.4 - 0.8 = demand$$

$$\boxed{7.6\ mg/L}$$

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

$$Dose = 8 + 1.5 = 9.5$$

$$lbs/d = (9.5\ mg/L)(3.9\ MGD)(8.34) = \boxed{309\ lbs/d}$$

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

Dose = 4.9 + 0.8

= 5.7 mg/L

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

8.8 = demand +

8.8 - 0.9 = demand

7.9 mg/L

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

Dose = 7.9 + 0.6

= 8.5 mg/L

Chemical Dosage, mg/L pg. 5 formula book

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

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

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

2.36 mg/L = 1.85 + Residual

2.36 - 1.85 = 0.51 mg/L

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

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

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

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

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

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

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

Hypochlorination pg. 9 formula book

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

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

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

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

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

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

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

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

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

Use the following information for problems 25 – 28:
At 8:00 a.m. on Monday morning a chlorine cylinder weighs 83 pounds. At 8:00 a.m. on Tuesday morning the same cylinder weighs 69 pounds.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

298 - 216 = 82 lbs

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

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

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

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

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

Answers:

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

Applied Math for Wastewater Treatment
Sludge Digestion

- Typical Aerobic Digester
  - Detention time greater than 20 days
  - Volatile solids loading = 0.1 – 0.3 lbs VS/day/ft^3
  - DO = 1.0
  - pH = 5.9 – 7.7

- Typical Anaerobic Digester
  - Detention time = 30 – 60 days
  - Heated = 90-95ºF
  - Volatile solids loading = 0.04 – 0.1 lbs VS/day/ft^3
  - pH = 6.8 – 7.2

Volatile Solids to the Digester, lbs/day

1. If a 8,250 lbs/day of solids with a volatile solids content of 68% are sent to the digester, how many lbs/day volatile solids are sent to the digester?

   VS, lbs/d = (sludge, lbs/d)(% Solids)(% VS)

   = (8250 lbs/d)(0.68)

   = 5610 lbs/d

2. A total of 3600 gpd of sludge is pumped to the digester. If the sludge has a 5.7% solids content with 71% volatile solids, how many lbs/day volatile solids are pumped to the digester?

   VS, lbs/d = (3600 gpd)(8.34)(0.057)(0.71)

   = 1215 lbs/d

Digester Loading Rate, lbs VS added/day/ft^3

3. What is the digester loading if a digester, 45 feet in diameter with a liquid level of 20 feet, receives 82,500 lbs/day of sludge with 5.8% solids and 69% volatile solids?

$$\text{Digester Loading, lbs/d/ft}^3 = \frac{(\text{Sludge, lbs/d})(\%\text{ Solids})(\%\text{ VS})}{(0.785)(D, ft)^2(\text{depth, ft})}$$

$$= \frac{(82{,}500\text{ lbs/d})(0.058)(0.69)}{(0.785)(45\text{ ft})^2(20\text{ ft})} = \boxed{0.10\text{ lbs/d/ft}^3}$$

4. A digester, 40-ft in diameter with a liquid level of 18 ft receives 26,400 gpd of sludge with 5.7% solids and 71% volatile solids. What is the digester loading in lbs VS added/day/ft^3?

$$\text{Digester Loading} = \frac{(26400\text{ gpd})(8.34)(0.057)(0.71)}{(0.785)(40\text{ ft})^2(18\text{ ft})}$$

$$= \frac{891.05227}{22608} = \boxed{0.39\text{ lbs/d/ft}^3}$$

Volatile Acids/Alkalinity Ratio

- VA/Alk ratio is an indicator of progress of digestion and the balance between the two stage process of anaerobic digestion
  - First stage – facultative, acid forming organisms convert complex organic matter to volatile (organic) acids
  - Second stage – anaerobic methane-forming organisms convert the acids to odorless end products of methane gas and carbon dioxide
- Normally less than 0.1, acceptable range is 0.1 – 0.2
  - Increase indicates possible excess feeding of raw sludge to the digester or removal of too much digested sludge
  - pH decreases at less than or equal to 0.8

5. The volatile acids concentration of the sludge in an anaerobic digester is 170 mg/L. If the measured alkalinity is 2150 mg/L, what is the VA/Alkalinity ratio?

$$\text{VA/Alk} = \frac{\text{VA, mg/L}}{\text{Alk, mg/L}} = \frac{170\text{ mg/L}}{2150\text{ mg/L}} = \boxed{0.08}$$

Percent Volatile Solids Reduction

- Aerobic digester = 40-50%
- Anaerobic digester = 40-60%

6. The raw sludge to a digester has a volatile solids content of 69% (In). The digested sludge volatile solids content is 53%. What is the percent volatile solids reduction?

$$\% \text{ VS Red.} = \frac{\text{In} - \text{Out}}{\text{In} - (\text{In})(\text{Out})} \times 100$$

$$= \frac{0.69 - 0.53}{0.69 - (0.69)(0.53)} = \frac{0.16}{0.69 - 0.3657} = \frac{0.16}{0.3243} = \boxed{49.3\%}$$

7. The digested sludge volatile solids content is 52%. The raw sludge to the digester has a volatile solids content of 67% (In). What is the percent volatile solids reduction?

$$\% \text{ VS Red.} = \frac{0.67 - 0.52}{0.67 - (0.67)(0.52)}$$

$$= \frac{0.15}{0.67 - 0.3484}$$

$$= \frac{0.15}{0.3216} = \boxed{46.6\%}$$

Volatile Solids Destroyed, lbs VS/day/ft³

- Measure of digester effectiveness

8. A flow of 3750 gpd sludge is pumped to a 35,000-ft³ digester. The solids concentration of the sludge is 6.3% with a volatile solids content of 68%. If the volatile solids reduction during digestion is 54%, how many lbs/day volatile solids are destroyed per ft³ of digester capacity?

$$\text{VS Destroyed, lbs VS/d/ft}^3 = \frac{(\text{sludge, gpd})(8.34)(\%\text{ Solids})(\%\text{ VS})(\%\text{ VS Red.})}{(0.785)(D, ft)^2(d, ft)}$$

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

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

9. A 50-ft diameter digester receives a sludge flow of 2800 gpd with a solids content of 5.8% and a volatile solids concentration of 70%. The volatile solids reduction during digestion if 54%. The digester operates at a level of 20 ft. What is the lbs/day volatile solids reduction per cu ft of digester capacity? Assume the sludge weighs 8.34 lbs/day.

$$\text{VS Red., lbs VS/d/ft}^3 = \frac{(2800\text{ gpd})(8.34)(0.058)(0.70)(0.54)}{(0.785)(50\text{ ft})^2(20\text{ ft})}$$

$$= \frac{511.9692}{39250} = \boxed{0.013\text{ lbs VS/d/ft}^3}$$

Digester Gas Production, ft^3 Gas Produced/lb VS destroyed

- Indicator of the progress of digestion
- Normal range is 12 – 18 ft^3 gas produced / lb VS destroyed
- Sharp increase indicates presence of high organic content of sludge

10. The anaerobic digester at a treatment plant receives a total of 10,500 gpd of raw sludge. This sludge has a solids content of 5.3% of which 64% is volatile. If the digester yields a volatile solids reduction of 61% and the average digester gas production is 22,300 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

$$\text{Digester Gas Prod., ft}^3\text{/lb VS destroyed} = \frac{\text{Gas Produced, ft}^3\text{/day}}{(\text{VS to digester, lbs/d})(\%\text{ VS Red})}$$

$$= \frac{22{,}300\text{ ft}^3\text{/d}}{(10{,}500\text{ gpd})(8.34)(0.053)(0.64)(0.61)}$$

$$= \boxed{12.3\text{ ft}^3\text{/lb VS destroyed}}$$

11. A total of 2060 lbs of volatile solids are pumped to the digester daily. If the percent reduction of volatile solids due to digestion is 57% and the average gas production for the day is 19,150 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

$$\text{Digester Gas Produced} = \frac{19{,}150\text{ ft}^3}{(2060\text{ lbs VS})(0.57)}$$

$$= \boxed{16.3\text{ ft}^3\text{/lb VS destroyed}}$$

Digestion Time, days

- Flow through the digester

12. An aerobic digester 40-ft in diameter has a side water depth of 12 ft. The sludge flow to the digester is 8200 gpd. Calculate the hydraulic detention time in days.

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

$$= \frac{(0.785)(40\ ft)^2(12\ ft)(7.48)}{8200\ gpd} = \boxed{13.7\ days}$$

13. A 50-ft aerobic digester has a side water depth of 10 feet. The sludge flow to the digester is 9500 gpd. Calculate the digestion time in days.

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

$$= \boxed{15.5\ days}$$

Answers:

1. 5610 lbs/day
2. 1215 lbs/day
3. 0.10 lbs/day/ft^3
4. 0.39 lbs/day/ft^3
5. 0.08
6. 49.3%
7. 46.6%
8. 0.021 lbs VS/day/ft^3
9. 0.013 lbs VS/day/ft^3
10. 12.3 ft^3/lb VS destroyed
11. 16.3 ft^3/lb VS destroyed
12. 13.7 days
13. 15.5 days

Applied Math for Wastewater Treatment
Sludge Digestion
Extra Problems

Digester Loading Rate, lbs VS added/day/ft^3

1. A digester 50 ft in diameter with a water depth of 22 ft receives 86,100 lbs of raw sludge per day. If the sludge contains 5% solids and 70% is volatile solids, what is the digester loading in lbs VS added/day/ft^3?

$$\text{Digester Loading} = \frac{(86{,}100\ \text{lbs/d})(0.05)(0.70)}{(0.785)(50\ \text{ft})^2(22\ \text{ft})}$$

$$= \frac{3013.5}{43175} = \boxed{0.07\ \text{lbs VS added/d/ft}^3}$$

2. What is the digester loading in lbs VS added/day/ft^3 if a digester that is 40 ft in diameter with a liquid level of 22 ft receives 28,500 gpd of sludge with 5.6% solids and 72% volatile solids? Assume the sludge weighs 8.34 lbs/gal.

$$\text{Digester Loading} = \frac{(28{,}500\ \text{gpd})(8.34)(0.056)(0.72)}{(0.785)(40\ \text{ft})^2(22\ \text{ft})}$$

$$= \frac{9583.6608}{27632} = \boxed{0.35\ \text{lbs/d/ft}^3}$$

3. A digester that is 50 ft in diameter with a liquid level of 20 ft receives 36,220 gpd of sludge with 5.6% solids and 68% volatile solids. What is the digester loading in lbs VS added/day/ft^3? Assume the sludge weighs 8.34 lbs/gal.

$$\text{Digester Loading} = \frac{(36{,}220\ \text{gpd})(8.34)(0.056)(0.68)}{(0.785)(50\ \text{ft})^2(20\ \text{ft})}$$

$$= \frac{11503.00838}{39250} = \boxed{0.29\ \text{lbs/d/ft}^3}$$

4. A digester that is 50 ft in diameter with a liquid level of 18 ft receives 16,200 gpd of sludge with 5.1% solids and 72% volatile solids. What is the digester loading in lbs VS added/day/ft^3?

$$\text{Digester Loading} = \frac{(16{,}200\ \text{gpd})(8.34)(0.051)(0.72)}{(0.785)(50\ \text{ft})^2(18\ \text{ft})} = \frac{4961.16576}{35325} = \boxed{0.14\ \text{lbs/d/ft}^3}$$

Volatile Acids/Alkalinity Ratio

5. The volatile acids concentration of the sludge in an anaerobic digester is 174 mg/L. If the measured alkalinity is 2220 mg/L, what is the VA/Alkalinity ratio?

$$VA|Alk = \frac{174}{2220} = 0.078$$

6. The volatile acids concentration of the sludge in an anaerobic digester is 160 mg/L. If the measured alkalinity is 2510 mg/L, what is the VA/Alkalinity ratio?

$$VA|Alk = \frac{160}{2510} = 0.064$$

7. The measured alkalinity is 2410 mg/L. If the volatile acids concentration of the sludge in an anaerobic digester is 144 mg/L, what is the VA/Alkalinity ratio?

$$VA|Alk = \frac{144}{2410} = 0.060$$

8. The measured alkalinity is 2620 mg/L. If the volatile acids concentration of the sludge in an anaerobic digester is 178 mg/L, what is the VA/Alkalinity ratio?

$$VA|Alk = \frac{178}{2620} = 0.068$$

Lime Neutralization

9. To neutralize a sour digester, 1 mg/L of lime is added for every mg/L of volatile acids in the digester sludge. If the digester sludge contains 244,000 gallons of sludge with a volatile acid level of 2280 mg/L, how many lbs of lime should be added?

   lbs = (2280 mg/L)(0.244 MG)(8.34)

   = 4639.7 lbs

10. To neutralize a sour digester, 1 mg/L of lime is added for every mg/L of volatile acids in the digester sludge. If the digester sludge contains 200,000 gallons of sludge with a volatile acid level of 2010 mg/L, how many lbs of lime should be added?

    lbs = (2010 mg/L)(0.2 MG)(8.34)

    = 3353 lbs

11. A digester contains 234,000 gallons of sludge with a volatile acid level of 2540 mg/L. To neutralize a sour digester, 1 mg/L of lime is added for every mg/L of volatile acids in the digester sludge. How many lbs of lime should be added?

    lbs = (2540 mg/L)(0.234 MG)(8.34)

    = 4957 lbs

12. A digester sludge is found to have a volatile acids content of 2410 mg/L. If the digester volume is 182,000 gallons, how many lbs of lime will be required for neutralization?

    lbs = (2410 mg/L)(0.182 MG)(8.34)

    = 3658 lbs

Percent Volatile Solids Reduction

13. Sludge entering a digester has a volatile solids content of In 68%. Sludge leaving the digester has a volatile solids content of 52%. What is the percent volatile solids reduction?

$$\% \text{ VS Red.} = \frac{0.68-0.52}{0.68-(0.68)(0.52)}$$

$$= \frac{0.16}{0.68-0.3536} = \frac{0.16}{0.3264} = \boxed{49\%}$$

14. Sludge leaving a digester has a volatile solids content of 54%. Sludge entering the digester has a volatile solids content of 70%. What is the percent volatile solids reduction?

$$\% \text{ VS Red.} = \frac{0.70-0.54}{0.70-(0.70)(0.54)}$$

$$= \frac{0.16}{0.70-0.3780} = \frac{0.16}{0.322} = \boxed{49.7\%}$$

15. The raw sludge to a digester has a volatile solids content of 70%. The digested sludge volatile solids content is 55%. What is the percent volatile solids reduction?

$$\% \text{ VS Red.} = \frac{0.70-0.55}{0.70-(0.70)(0.55)}$$

$$= \frac{0.15}{0.70-0.385} = \frac{0.15}{0.315} = \boxed{47.6\%}$$

16. The volatile solids content of a digested sludge is 54%. The raw sludge to a digester has a volatile solids content of 69%. What is the percent volatile solids reduction?

$$\% \text{ VS Red.} = \frac{0.69-0.54}{0.69-(0.69)(0.54)}$$

$$= \frac{0.15}{0.69-0.3726} = \frac{0.15}{0.3174} = \boxed{47.3\%}$$

Volatile Solids Destroyed, lbs VS/day/ft^3

17. A flow of 3800 gpd sludge is pumped to a 36,500 ft^3 digester. The solids concentration of the sludge is 6.3% with a volatile solids content of 73%. If the volatile solids reduction during digestion is 57%, how many lbs/day volatile solids are destroyed/ft^3 of digester capacity? Assume the sludge weighs 8.34 lbs/gal.

$$\text{VS Destroyed, lbs/d/ft}^3 = \frac{(3800\text{ gpd})(8.34)(0.063)(0.73)(0.57)}{36{,}500\text{ ft}^3}$$

$$= \boxed{0.023\text{ lbs VS/d/ft}^3}$$

18. A flow of 4520 gpd sludge is pumped to a 34,000 ft^3 digester. The solids concentration of the sludge is 7% with a volatile solids content of 69%. If the volatile solids reduction during digestion is 54%, how many lbs/day volatile solids are destroyed/ft^3 of digester capacity? Assume the sludge weighs 8.34 lbs/gal.

$$\text{VS Destroyed lbs/d/ft}^3 = \frac{(4520\text{ gpd})(8.34)(0.07)(0.69)(0.54)}{34{,}000\text{ ft}^3}$$

$$= \boxed{0.029\text{ lbs VS/d/ft}^3}$$

19. A 50-ft diameter digester receives a sludge flow of 2600 gpd with a solids content of 5.6% and a volatile solids concentration of 72%. The volatile solids reduction during digestion is 52%. The digester operates at a level of 18 ft. What is the lbs/day volatile solids reduction/ft^3 of digester capacity? Assume the sludge weighs 8.34 lbs/gal.

$$\text{VS Destroyed lbs/d/ft}^3 = \frac{(2600\text{ gpd})(8.34)(0.056)(0.72)(0.52)}{(0.785)(50\text{ ft})^2(18\text{ ft})}$$

$$= \frac{454.6354176}{35325}$$

$$= \boxed{0.013\text{ lbs VS/d/ft}^3}$$

20. The sludge flow to a 40-ft diameter digester is 2800 gpd with a solids concentration of 6.1% and a volatile solids concentration of 65%. The digester is operated at a depth of 17 ft. If the volatile solids reduction during digestion is 56%, what is the lbs/day volatile solids reduction per 1000 ft^3 of digester capacity? Assume the sludge weighs 8.34 lbs/gal.

$$\text{VS Destroyed, lbs/d/1000ft}^3 = \frac{(2800\text{ gpd})(8.34)(0.061)(0.65)(0.56)}{\left[\frac{(0.785)(40\text{ft})^2(17\text{ft})}{1000}\right]}$$

$$= \frac{518.507808}{21.352} = \boxed{24.3 \text{ lbs VS/d/1000ft}^3}$$

Digester Gas Production, ft^3 Gas Produced/lb VS destroyed

21. A digester gas meter reading indicates that, on average, 6600 ft^3 of gas are produced per day. If 500 lbs/day volatile solids are destroyed, what is the digester gas production in ft^3/lb VS destroyed?

$$\text{Gas Prod., ft}^3\text{/lb VS dest.} = \frac{6600\text{ ft}^3\text{/d}}{500\text{ lbs/d}}$$

$$= \boxed{13.2 \text{ ft}^3\text{/lb VS destroyed}}$$

22. A total of 2110 lbs of volatile solids are pumped to the digester daily. If the percent reduction of volatile solids due to digestion is 59% and the average gas production for the day is 19,330 ft^3, what is the daily gas production in ft^3/lb VS destroyed daily?

$$\text{Gas Prod.} = \frac{19{,}330\text{ ft}^3}{(2110\text{ lbs})(0.59)}$$

$$= \boxed{15.5 \text{ ft}^3\text{/lb VS destroyed}}$$

23. A total of 582 lbs/day of volatiles solids are destroyed. If a digester gas meter reading indicates that 8710 ft^3 of gas are produced per day, on average, what is the digester gas production in ft^3/lb VS destroyed daily?

$$\text{Gas Prod.} = \frac{8710\text{ ft}^3}{582\text{ lbs}} = \boxed{15.0 \text{ ft}^3\text{/lb VS destroyed}}$$

24. The percent reduction of volatile solids due to digestion is 54% and the average gas production for the day is 26,100 ft^3. If 3320 lbs of volatile solids are pumped to the digester daily, what is the gas production in ft^3/lb VS destroyed daily?

$$\text{Gas Prod.} = \frac{26{,}100\ ft^3}{(3320)(0.54)}$$

$$= 14.6\ ft^3/lb\ \text{VS destroyed}$$

Digestion Time, days

25. An aerobic digester 40-ft in diameter has a side water depth of 10 ft. The sludge flow to the digester is 8250 gpd. Calculate the hydraulic detention time in days.

$$\text{Digestion Time, d} = \frac{(0.785)(40\ ft)^2(10\ ft)(7.48)}{8250\ gpd}$$

$$= 11.4\ days$$

26. A 40-ft aerobic digester has a side water depth of 12 feet. The sludge flow to the digester is 9100 gpd. Calculate the digestion time in days.

$$\text{Digestion Time, d} = \frac{(0.785)(40\ ft)^2(12\ ft)(7.48)}{9100\ gpd}$$

$$= 12.4\ days$$

27. An aerobic digester is 80 ft long by 25 ft wide and has a side water depth of 12 ft. The sludge flow to the digester is 7800 gpd, what is the hydraulic digestion time, in days?

$$\text{Digestion Time, d} = \frac{(80\ ft)(25\ ft)(12\ ft)(7.48)}{7800\ gpd}$$

$$= 23\ days$$

28. An aerobic digester is 90 ft long by 20 ft wide and has a side water depth of 10 ft. The sludge flow to the digester is 7600 gpd, what is the hydraulic digestion time, in days?

$$\text{Digestion Time, d} = \frac{(90\,ft)(20\,ft)(10\,ft)(7.48)}{7600\,gpd}$$

$$= 17.7 \text{ days}$$

Answers:

1. 0.07 lbs VS added/day/ft^3
2. 0.35 lbs VS added/day/ft^3
3. 0.29 lbs VS added/day/ft^3
4. 0.14 lbs VS added/day/ft^3
5. 0.078
6. 0.064
7. 0.060
8. 0.068
9. 4640 lbs
10. 3353 lbs
11. 4957 lbs
12. 3658 lbs
13. 49.0%
14. 49.7%
15. 47.6%
16. 47.3%
17. 0.023 lbs VS/day/ft^3
18. 0.029 lbs VS/day/ft^3
19. 0.013 lbs VS/day/ft^3
20. 24.3 lbs VS/day/1000 ft^3
21. 13.2 ft^3/ lb VS destroyed
22. 15.5 ft^3/ lb VS destroyed
23. 15.0 ft^3/ lb VS destroyed
24. 14.6 ft^3/ lb VS destroyed
25. 11.4 days
26. 12.4 days
27. 23 days
28. 17.7 days

Applied Math for Wastewater Treatment Laboratory

Bacteriological, fecal coliform and *E. coli*

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

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

$$\sqrt[12]{5.7024 \times 10^{15}} = 20.6 = \boxed{21}$$

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

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

$$\sqrt[10]{1.171875 \times 10^{14}} = 25.5 = \boxed{26}$$

Solutions

3. How many mL of 0.7 N NaOH is needed to get 750 mL of 0.05 N NaOH? (N_1 = 0.7, V_2 = 750, N_2 = 0.05)

$$N_1V_1 = N_2V_2$$

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

$$V_1 = \frac{(0.05)(750)}{0.7} = \frac{37.5}{0.7} = \boxed{53.6\text{ mL}}$$

4. How many mL of 0.5 N NaOH react with 800 mL of 0.1 N HCl? (N_1 = 0.5, V_2 = 800, N_2 = 0.1)

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

$$V_1 = \frac{(0.1)(800\text{ mL})}{0.5} = \frac{80}{0.5} = \boxed{160\text{ mL}}$$

Settleable Solids (Imhoff Cone)

5. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 16.5 mL/L and the settleable solids of the effluent are 0.6 mL/L.

$$\% = \frac{\text{In} - \text{Out}}{\text{In}} \times 100$$

$$= \frac{16.5 - 0.6}{16.5} = \frac{15.9}{16.5} = \boxed{96.4\%}$$

6. The settleable solids of the raw wastewater is 18 mL/L. If the settleable solids of the clarifier is 0.9 mL/L, what is the settleable solids removal efficiency of the clarifier?

$$\% = \frac{18-0.9}{18} = \frac{17.1}{18} = \boxed{95\%}$$

7. The settleable solids of the raw wastewater is 20 mL/L. If the settleable solids of the clarifier is 0.8 mL/L, what is the settleable solids removal efficiency of the clarifier?

$$\% = \frac{20-0.8}{20} = \frac{19.2}{20} = \boxed{96\%}$$

Settleability

8. The settleability test is conducted on a sample of MLSS. What is the percent settleable solids if 410 mL settle in the 2000-mL graduate?

$$\%\text{ Settleable Solids} = \frac{\text{mL settled solids}}{2000\text{ mL sample}} \times 100$$

$$= \frac{410}{2000} \times 100 = \boxed{20.5\%}$$

9. A 2000-mL sample of activated sludge is poured into the 2000-mL graduate. If the settled sludge is measured as 315 mL, what is the percent settleable solids?

$$\%\text{ Sett. Solids} = \frac{315}{2000} \times 100 = \boxed{15.75\%}$$

10. The settleability test is conducted on a sample of MLSS. What is the percent settleable solids if 390 mL settle in the 2000-mL graduate?

$$\%\text{ Sett Solids} = \frac{390\text{ mL}}{2000} \times 100 = \boxed{19.5\%}$$

Suspended Solids and Volatile Suspended Solids

11. Given the following information regarding a primary effluent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 50 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	25.6715 g	25.6701 g
Weight of Dish (Tare Wt.)	25.6670 g	25.6670 g

$$TSS = \frac{(25.6715 - 25.6670)(1{,}000{,}000)}{50} = 90 \text{ mg/L}$$

$$VSS = \frac{(25.6715 - 25.6701)(1{,}000{,}000)}{50} = 28 \text{ mg/L} / 90 \text{ mg/L} = \boxed{31.1\%}$$

12. Given the following information regarding a primary effluent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 25 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	36.1544 g	36.1500 g
Weight of Dish (Tare Wt.)	36.1477 g	36.1477 g

$$TSS = \frac{(36.1544 - 36.1477)(1{,}000{,}000)}{25} = 268 \text{ mg/L}$$

$$VSS = \frac{(36.1544 - 36.1500)(1{,}000{,}000)}{25} = 176 \text{ mg/L} / 268 \text{ mg/L} = \boxed{65.7\%}$$

SVI and SDI

- Values normally fall in the range of 50-150
- A rise indicates young bulky sludge
- A decrease below the range of 50-150 indicates old sludge
- A good settling quality of activated sludge is a low SVI around 50-80

13. The settleability test indicates that after 30 minutes, there are 215 mL of suspended solids in the 1-liter graduate cylinder. If the MLSS concentration in the aeration tank is 2180 mg/L, what is the sludge volume index?

$$SVI = \frac{(\text{Settled Sludge Vol, mL/L})(1{,}000)}{\text{MLSS, mg/L}} = \frac{(215 \text{ mL/L})(1000)}{2180}$$

$$= \boxed{98.6}$$

14. The activated sludge settleability test indicates 380 mL settling in the 2-liter graduate cylinder. If the MLSS concentration in the aeration tank is 2260 mg/L, what is the sludge volume index?

need mL/L

$380/2 = 190\ mL/L$

$$SVI = \frac{(190)(1000)}{2260} = 84.1$$

15. The MLSS concentration in the aeration tank is 2050 mg/L. If the activated sludge settleability test indicates 219 mL settled in the one-liter graduated cylinder, what is the sludge density index?

$$SVI = \frac{(219)(1000)}{2050} = 106.8$$

$$SDI = \frac{100}{SVI}$$

$$= \frac{100}{106.8} = 0.936$$

Biochemical Oxygen Demand, BOD

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

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

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

$$P = \frac{5}{300} = 0.01667$$

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

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

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

$$P = \frac{10}{300} = 0.0333$$

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

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

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

$$\frac{190+198+205+202+210+201+197}{7} = \frac{1403}{7} = \boxed{200.4 \text{ mg/L}}$$

Alkalinity

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

$$\text{Alk.} = \frac{(B)(N)(50{,}000)}{\text{mL of sample}} = \frac{(24)(0.02)(50{,}000)}{100} = \boxed{240 \text{ mg/L}}$$

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

$$\text{Alk} = \frac{(10.1)(0.02)(50{,}000)}{100} = \boxed{101 \text{ mg/L}}$$

Oxygen Uptake Rate

21. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake rate, mg/L/hr.

Use 2 + 5 minute data

Elapsed Time, min	DO, mg/L
0	7.9
1	6.8
* 2	6.1 * Start
3	5.3
4	4.6
* 5	3.9 * End

$$\text{OUR} = \frac{\text{Start DO} - \text{End DO}}{\text{min}} \times 60 \text{ min} = \frac{6.1-3.9}{3} \times 60 = \boxed{44 \text{ mg/L/hr}}$$

Temperature

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

$$°C = 5/9(°F - 32)$$
$$= 0.5556(72-32)$$
$$= 0.5556(40) = \boxed{22.2°C}$$

23. Convert 56° F to degrees Celsius.

$$°C = 0.5556(56-32)$$
$$= 0.5556(24) = \boxed{13.3°C}$$

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

$$°F = 9/5(°C) + 32$$
$$= 1.8(22) + 32$$
$$= 39.6 + 32$$
$$= \boxed{71.6°F}$$

Answers:

1. 21
2. 26
3. 53.6 mL
4. 160 mL
5. 96.4%
6. 95%
7. 96%
8. 20.5%
9. 15.8%
10. 19.5%
11. 90 mg/L SS; 68.9% VSS
12. 268 mg/L SS; 34.3% VSS
13. 98.6
14. 168.1
15. 0.936
16. 150 mg/L
17. 123 mg/L
18. 200 mg/L
19. 240 mg/L
20. 101 mg/L
21. 44mg/L/hr
22. 22.2°C
23. 13.3°C
24. 71.6°F

Applied Math for Wastewater Treatment
Laboratory
Extra Problems

Bacteriological, fecal coliform and *E. coli*

1. Determine the geometric mean for the following samples:

   Sample #1 = 20.0 mg/L
   Sample #2 = 20.0 mg/L
   Sample #3 = 210.0 mg/L
   Sample #4 = 3,500.0 mg/L

   $\sqrt[4]{(20)(20)(210)(3500)}$

   $\sqrt[4]{294{,}000{,}000}$

   $= 130.9 = 131$ mg/L

2. Determine the geometric mean for the following samples:

   Sample #1 = 45.0 mg/L
   Sample #2 = 61.0 mg/L
   Sample #3 = 98.0 mg/L
   Sample #4 = 150.0 mg/L

   $\sqrt[4]{(45)(61)(98)(150)}$

   $\sqrt[4]{40351500}$

   $= \boxed{79.7 \text{ mg/L}}$

3. Determine the bacteria colonies/100 mL for a 25 mL sample that had 50 colonies grow on the membrane filter for fecal coliforms.

   $\text{Bacteria Colonies}/100\text{ mL} = \frac{(50)(100)}{25\text{ mL}} = \boxed{200 \text{ cfu}}$

4. A membrane filtration test was performed for *E. coli*, after 24-hours of incubation, 57 colonies were counted. The sample volume used was 75 mL.

   $\frac{(57)(100)}{75} = \boxed{76 \text{ cfu}}$

Solutions

5. How many mL of 0.2N NaOH will react with 500 mL of 0.01N HCl?

$$(V_1)(0.2) = (500\,mL)(0.01)$$
$$V_1 = \frac{(500)(0.01)}{0.2} = 25\,mL$$

6. A 2-liter volume of 0.05N HCl solution is to be prepared. How many mL of 9N HCl must be diluted with water to prepare the desired volume?

needs to be in mL
2L=2000mL

$$(V_1)(9) = (2000)(0.05)$$
$$V_1 = \frac{(2000)(0.05)}{9} = 11.1\,mL$$

7. It takes 8.2 mL of a solution of HCl to neutralize 10 mL of 4N NaOH. What is the concentration of the HCl solution?

$$(8.2)(N_1) = (10)(4)$$
$$N_1 = \frac{(10)(4)}{8.2} = 4.9N$$

Settleable Solids (Imhoff Cone)

8. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 16.5 mL/L and the settleable solids of the effluent are 0.6 mL/L.

In / Out

$$\% = \frac{16.5-0.6}{16.5} = \frac{15.9}{16.5} \times 100 = 96.4\%$$

9. The settleable solids of the raw wastewater is 18 mg/L. If the settleable solids of the clarifier is 0.9 mL/L, what is the settleable solids removal efficiency of the clarifier?

In / Out

$$\% = \frac{18-0.9}{18} = \frac{17.1}{18} \times 100 = 95.0\%$$

10. The settleable solids of the raw wastewater is 20mg/L. If the settleable solids of the clarifier is 0.8 mL/L, what is the settleable solids removal efficiency of the clarifier?

In / Out

$$\% = \frac{20-0.8}{20} = \frac{19.2}{20} \times 100 = \boxed{96.0\%}$$

Settleability

11. A settleability test is conducted on a sample of MLSS. What is the percent settleable solids if 440 mL settle in a 2000-mL graduated cylinder?

$$\% = \frac{440}{2000} \times 100 = \boxed{22.0\%}$$

12. A 2000-mL sample of activated sludge is taken. If the settled sludge is measured as 320 mL, what is the percent settleable solids?

$$\% = \frac{320}{2000} \times 100 = \boxed{16.0\%}$$

13. A settleability test is conducted on a sample of MLSS. What is the percent settleable solids if 410 mL settle in a 2000-mL graduated cylinder?

$$\% = \frac{410}{2000} \times 100 = \boxed{20.5\%}$$

From Stand. Methods

% TS = $\frac{(A-B) \times 100}{C-B}$

% VS = $\frac{(A-D) \times 100}{A-B}$

A = wt. of dried residue + dish, mg
B = weight of dish, mg
C = wt. of wet sample + dish, mg
D = wt. of residue + dish after ignition, mg

Total Solids and Volatile Solids

14. Given the following information regarding a primary effluent sample, calculate (a) the percent total solids and (b) the percent volatile suspended solids of the sample.

	Sludge (Total Sample)	After Drying (Before Burning)	After Burning (Ash)	Diff.
Weight of Sample & Dish	C = 85.78 g	A = 26.27 g	D = 24.31 g	= 1.96 g
Weight of Dish (Tare Wt.)	B = 21.50 g	B = 21.50 g	B = 21.50 g	
Diff.	64.28 g	4.77 g	2.81 g	

(get us to mg)

% TS = $\frac{(4.77 g)(1000)(100)}{(64.28)(1000)}$ = **7.42% TS**

% VS = $\frac{(1.96 g)(1000)(100)}{(4.77)(1000)}$ = **41.1%**

15. Given the following information regarding a primary effluent sample, calculate (a) the percent total solids and (b) the percent volatile suspended solids of the sample.

	Sludge (Total Sample)	After Drying (Before Burning)	After Burning (Ash)	Diff
Weight of Sample & Dish	C = 75.48 g	A = 22.67 g	D = 21.45 g	= 1.22 g
Weight of Dish (Tare Wt.)	B = 20.80 g	B = 20.80 g	B = 20.80 g	
Diff =	54.68 g	1.87 g	0.65 g	

% TS = $\frac{(1.87)(1000)(100)}{(54.68)(1000)}$ = **3.42% TS**

% VS = $\frac{(1.22)(1000)(100)}{(1.87)(1000)}$ = **65.2% VS**

Suspended Solids and Volatile Suspended Solids

16. Given the following information regarding a primary effluent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 50 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	25.6818 g	25.6802 g
Weight of Dish (Tare Wt.)	25.6715 g	25.6715 g

TSS = $\frac{(25.6818 - 25.6715)(1,000,000)}{50 \text{ mL}}$ = **206 mg/L**

VSS = $\frac{(25.6818 - 25.6802)(1,000,000)}{50 \text{ mL}}$ = 32 mg/L / 206 mg/L = **15.5% VSS**

17. Given the following information regarding a treatment plant influent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 25 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	36.1588 g	36.1543 g
Weight of Dish (Tare Wt.)	36.1496 g	36.1496 g

$$TSS = \frac{(36.1588 - 36.1496)(1{,}000{,}000)}{25} = 368 \text{ mg/L}$$

$$VSS = \frac{(36.1588 - 36.1543)(1{,}000{,}000)}{25} = 180 \text{ mg/L} / 368 \text{ mg/L} = \boxed{48.9\%}$$

18. Given the following information regarding a treatment plant influent sample, calculate (a) the mg/L suspended solids and (b) the percent volatile suspended solids of the sample.

Sample Volume = 25 mL	After Drying (Before Burning)	After Burning (Ash)
Weight of Sample & Dish	28.3196 g	28.3082 g
Weight of Dish (Tare Wt.)	28.2981 g	28.2981 g

$$TSS = \frac{(28.3196 - 28.2981)(1{,}000{,}000)}{25} = 860 \text{ mg/L}$$

$$VSS = \frac{(28.3196 - 28.3082)(1{,}000{,}000)}{25} = 456 \text{ mg/L} / 860 \text{ mg/L} = \boxed{53.0\%}$$

SVI and SDI

19. After 30 minutes, a settleability test resulted in 220 mL of settleable solids in a 1-liter graduated cylinder. If the MLSS concentration in the aeration tank is 2210mg/L, what is the sludge volume index?

$$SVI, \text{mL/g} = \frac{(220 \text{ mL/L})(1{,}000)}{2210 \text{ mg/L}} = \boxed{99.5 \text{ mL/g}}$$

20. An activated sludge settleability test resulted in 410 mL settling in a 2-liter graduated cylinder. If the MLSS concentration in the aeration tank is 2310 mg/L, what is the sludge volume index?

$$\frac{410 \text{ mL}}{2 \text{ L}} = 205 \text{ mL/L}$$

$$SVI, \text{mL/g} = \frac{(205 \text{ mL/L})(1{,}000)}{2310 \text{ mg/L}}$$

$$= \boxed{88.7 \text{ mL/g}}$$

21. The MLSS concentration in an aeration tank is 2110 mg/L. If the activated sludge settleability test indicates that 222 mL settled in a 1-liter graduated cylinder, what is the sludge density index?

$$SVI = \frac{(222\ mL/L)(1000)}{2110\ mg/L} = 105.2\ mL/g$$

$$SDI = \frac{100}{105.2} = \boxed{0.95}$$

22. Activated sludge in an aeration tank is found to have a concentration of MLSS of 2140 mg/L. If the settleability test results in 186 mL settleable solids in a 1-liter graduated cylinder after 30 minutes, what is the sludge density index?

$$SVI = \frac{(186\ mL/L)(1000)}{2140\ mg/L} = 86.9\ mL/g$$

$$SDI = \frac{100}{86.9} = \boxed{1.15}$$

23. After 30 minutes, a settleability test resulted in 215 mL of settleable solids in a 1-liter graduated cylinder. If the MLSS concentration in the aeration tank is 2510 mg/L, what is the sludge volume index?

$$SVI = \frac{(215\ mL/L)(1000)}{2510\ mg/L} = \boxed{85.7\ mL/g}$$

Biochemical Oxygen Demand, BOD

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

Sample Volume = 7 mL
BOD Bottle Volume = 300 mL
Initial DO of Diluted Sample = 8 mg/L D_1
Final DO of Diluted Sample = 3.7 mg/L D_2

$$P = \frac{7}{300} = 0.0233 \qquad BOD = \frac{8-3.7}{0.0233} = \boxed{184.3\ mg/L}$$

25. Results from a BOD test are provided. Calculate the BOD of the sample after 5 days:

Sample Volume = 12 mL
BOD Bottle Volume = 300 mL
Initial DO of Diluted Sample = 8.7 mg/L
Final DO of Diluted Sample = 4.4 mg/L

$$P = \frac{12}{300} = 0.04 \qquad BOD = \frac{8.7-4.4}{0.04} = \boxed{107.5\ mg/L}$$

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

March 23 – 190 mg/L
March 24 – 198 mg/L
March 25 – 205 mg/L
March 26 – 202 mg/L
March 27 – 210 mg/L
March 28 – 201 mg/L
March 29 – 197 mg/L

$$\text{Avg.} = \frac{(190+198+205+202+210+201+197)}{7}$$

$$= \frac{1403}{7} = \boxed{200.4 \text{ mg/L}}$$

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

April 10 – 220 mg/L
April 11 – 315 mg/L
April 12 – 265 mg/L
April 13 – 198 mg/L
April 14 – 112 mg/L
April 15 – 255 mg/L
April 16 – 279 mg/L

$$\text{Avg.} = \frac{(220+315+265+198+112+255+279)}{7}$$

$$= \frac{1644}{7} = \boxed{234.9 \text{ mg/L}}$$

Alkalinity

28. Alkalinity titration on a 100-mL sample resulted in 5.1 (B) mL of 0.02N (N) H_2SO_4 to drop the pH from 7.8 to 4.5.

$$\text{Alk} = \frac{(5.1)(0.02)(50{,}000)}{100 \text{ mL}}$$

$$= \boxed{51 \text{ mg/L}}$$

29. To drop the pH from 7.7 to 4.5 on a 100-mL sample 12.3 (B) mL of 0.02N (N) H_2SO_4 was used to determine the alkalinity.

$$\text{Alk} = \frac{(12.3)(0.02)(50{,}000)}{100}$$

$$= \boxed{123 \text{ mg/L}}$$

Oxygen Uptake Rate

30. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake rate, mg/L/hr.

Elapsed Time, min	DO, mg/L	
0	8.2	
1	7.3	
2	6.7	Start
3	6.5	
4	6.3	
5	6.2	End

$$OUR = \frac{(6.7-6.2)}{3} \times 60$$

$$= \frac{0.5}{3} \times 60$$

$$= (0.1667)(60)$$

$$= \boxed{10 \text{ mg/L/hr}}$$

31. Dissolved air concentrations are taken on an air-saturated sample of digested aerobic sludge at one-minute intervals. Given the following results, calculate the oxygen uptake rate, mg/L/hr.

Elapsed Time, min	DO, mg/L	
0	8.5	
1	7.8	
2	7.3	Start
3	6.7	
4	6.1	
5	5.3	End

$$OUR = \frac{(7.3-5.3)}{3} \times 60$$

$$= \frac{2}{3} \times 60$$

$$= (0.6667)(60)$$

$$= \boxed{40 \text{ mg/L/hr}}$$

Temperature

32. The influent to a treatment plant has a temperature of 70°F. What is this temperature expressed in degrees Celsius?

$$°C = 5/9(70-32)$$

$$= 0.5556(38)$$

$$= \boxed{21.1°C}$$

33. Convert 60°F to degrees Celsius.

$$°C = 0.556(60-32)$$
$$= 0.556(28)$$
$$= 15.6°C$$

34. The effluent of a treatment plant is 24°C. What is this temperature expressed in degrees Fahrenheit?

$$°F = 1.8(24) + 32$$
$$= 43.2 + 32$$
$$= 75.2°F$$

35. What is 16°C expressed in terms of degrees Fahrenheit?

$$°F = (1.8)(16) + 32$$
$$= 28.8 + 32$$
$$= 60.8°F$$

Answers:

1. 131 mg/L
2. 79.7 mg/L
3. 200 cfu
4. 76 cfu
5. 25 mL
6. 11.1 mL
7. 4.9N
8. 96.4%
9. 95.0%
10. 96.0%
11. 22.0%
12. 16.0%
13. 20.5%
14. 7.4% TS; 41.1% VS
15. 3.4% TS; 65.2% VS
16. 206 mg/L SS; 15.5% VSS
17. 368 mg/L SS; 48.9% VSS
18. 860 mg/L SS; 53.0% VSS
19. 99.5 mL/g
20. 88.7 mL/g
21. 0.95
22. 1.15
23. 85.7 mL/g
24. 184.3 mg/L
25. 107.5 mg/L
26. 200 mg/L
27. 235 mg/L
28. 51 mg/L
29. 123 mg/L
30. 10 mg/L/hr
31. 40 mg/L/hr
32. 21.1°C
33. 15.6°C
34. 75.2°F
35. 60.8°F

Basic Lab for Water and Wastewater
Metric Conversions

1. 1 m = __________ cm 1.00 = 100
2. 1 g = __________ mg 1.000 = 1000
3. 1 kg = __________ g 1.000 = 1000
4. 1 cm = __________ mm 1.0 = 10
5. 10 cm = __________ mm 10.0 = 100
6. 50 cm = __________ mm 50.0 = 500
7. 8 km = __________ m 8.000 = 8000
8. 19 km = __________ m 19.000 = 19,000
9. 29 L = __________ mL 29.000 = 29,000
10. 83 m = __________ mm 83.000 = 83,000
11. 1.8 cm = __________ mm 1.8 = 18
12. 2.5 mg = __________ g 2.5 = 0.0025
13. 2.6 km = __________ m 2.600 = 2,600
14. 8.5 km = __________ m 8.500 = 8,500
15. 80 mL = __________ L 80. = 0.08
16. 150 mm = __________ cm 150.0 = 15
17. 5000 m = __________ km 5000.0 = 5
18. 1300 g = __________ kg 1300. = 1.3
19. 17 mm = __________ cm 17. = 1.7
20. 125 mm = __________ cm 125.0 = 12.5
21. 170 L = __________ mL 170.000 = 170,000
22. 155 m = __________ km 155.0 = 0.155

23. A particular pipe is delivered in sections 5 meters long. How many sections are required to span a distance of 1 kilometer?

$$1.000 = \frac{1000 \text{ meters}}{5 \text{ meter/sec}} = \boxed{200 \text{ sections}}$$

24. You need to measure 34.6 milligrams of a chemical to make a solution. If the display on the scale only shows grams, what will the reading be?

$$34.6 = \boxed{0.0346 g}$$

25. During your last visit to the doctor, the nurse told you that you weighed 98 kilograms. Assuming that a nickel weighs approximately 5 grams, how many nickels would it take to equal your weight? If that were true, then how much is your weight worth in nickels?

$$98.000 = \frac{98,000 \text{ grams}}{5 \text{ grams/nickel}} = \boxed{19,600 \text{ nickels}}$$

$$(19,600)(\$0.05) = \boxed{\$980}$$

26. Your favorite coffee mug at work holds about ½ a liter. If you average about 8 milliliters each time you take a sip, how many sips does it take to get to the bottom of your mug?

$\frac{1}{2}$ L = 0.5L   0.500 = 500 mL

$\frac{500 \text{ mL}}{8 \text{ mL/sip}}$ = **62.5 sips**

Answers:

1. 100 cm
2. 1000 mg
3. 1000 g
4. 10 mm
5. 100 mm
6. 500 mm
7. 8000 m
8. 19,000 m
9. 29,000 mL
10. 83,000 mm
11. 18 mm
12. 0.0025 g
13. 2600 m
14. 8500 m
15. 0.08 L
16. 15 cm
17. 5 km
18. 1.3 kg
19. 1.7 cm
20. 12.5 cm
21. 170,000 mL
22. 0.155 km
23. 200 sections
24. 0.0346 g
25. 19,600 nickels, $980
26. 62.5 sips