



ABC

Exam Review

This study review guide is not a replacement for study materials gained through course work, classes and job experience. This publication is provided as an aide to prepare for the ABC Wastewater Certification exam.

*Study guide courtesy of Morrisville State College

Practice

Problems

Basic Wastewater Treatment Concepts

Practice Worksheet

1. The wastewater that flows to the treatment facility is mostly water. What percentage of the wastewater flow is water and what percentage is actually waste?
2. The characteristics of the wastewater flow is dependant on the source. What would be the expected difference between a domestic wastewater flow and an industrial wastewater flow?
3. What do the letters BOD stand for? What is this test used to measure?
4. What is the difference between settleable solids and suspended solids?
5. Explain the difference between suspended solids and volatile suspended solids.

6. What are the two major objectives of wastewater treatment?

a.

b.

7. What do the letters NPDES stand for?

8. Convert 300 gpm into MGD.

9. Convert $1.5 \text{ ft}^3/\text{sec}$ into gpm.

10. Calculate the flow in a plant influent channel if the velocity of the flow is 2.2 ft/sec and the channel dimensions are 2 ft wide with a water depth of 18 inches. Give the flow in MGD.

11. What would be the flow of a 6 inch pipe flowing full if the velocity is 5 ft/sec ?

12. If a flow of 350 gpm is moving through an 8 inch line, calculate the velocity in the line.

13. If the influent flow to the treatment plant is 10 MGD and the influent BOD is 150 mg/L, calculate the number of dry pounds of solids that are reaching the plant each day.

14. If the same plant (problem 13) has an influent SS level of 210 mg/L what would be the number of pounds of SS reaching the plant each day?

15. What's the difference between the number of pounds of BOD and the number of pounds of SS reaching the plant each day?

Pretreatment of Wastewater

Practice Worksheet

1. What are the major objectives for the pretreatment of wastewater?
2. Where are coarse screens or racks usually found?
3. What are fine mesh screens used for ?
4. What is the difference between comminutors and barminutors in method of operation? How do they work?
5. In a grit removal channel the velocity of flow is slowed to between 0.7 and 1.4 ft/sec. Why?

6. A grit channel at the influent of a small wastewater treatment plant is 3 ft wide. The flow meter shows the current flow through the plant to be 3.8 MGD. In the depth of the flow in the channel is 20 inches, how far down the channel would an average sized particle (0.2 mm dia) travel before it reaches the bottom?

7. How does an aerated grit chamber work?

8. Pre-aeration of the influent wastewater flow is sometimes used to "freshen up" the sewage. In what other ways can pre-aeration of the influent flow help in the overall treatment?

9. Why would chlorine be added to the influent wastewater flow?

10. The influent BOD of the raw wastewater is 195 mg/L. After complete treatment the effluent BOD is measured to be 12 mg/L. Calculate the efficiency of removal for these conditions.

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11. If the influent SS are 232 mg/L and the final effluent SS are 17 mg/L what is the efficiency of removal?

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Primary Treatment

Practice Worksheet

1. What are the two major objectives or purposes of primary treatment?

a.

b.

2. Fill in the blanks for normal percentage of removal in a primary clarifier.

Settleable solids _____

Suspended solids _____

BOD _____

3. What is the purpose of the target baffle or deflector plate in the clarifier?

4. How long does it usually take for the sludge collection mechanism to travel completely around a circular clarifier?

5. A primary clarifier has a diameter of 110 ft and a depth of 10 ft. If the average flow to the tank is 8 MGD calculate the following:

a) Detention time

b) Surface Settling Rate

c) Weir Overflow rate

d) How do your calculated values compare to normal ranges for DT, SSR, and WOR?

6. What would be an average concentration of primary sludge being removed from the tank? How often should it be removed?

7. In what ways could you measure or estimate the amount of primary sludge accumulated over 24 hrs?

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8. Influent flow to the treatment plant is 11.2 MGD. Influent SS = 212 mg/L, BOD = 195 mg/L. Primary effluent SS = 125 mg/L, BOD = 135 mg/L. Calculate the following:

a) Percent removal of SS.

b) Percent removal of BOD

c) Pounds of SS are collected in the primary clarifier each day?

d) If the sludge is removed at a concentration of 4%, how many gallons should be pumped each minute?

e) If the sludge concentration is allowed to increase to 6% before it is removed, how many gallons per minute would be pumped?

- f) If the primary sludge pump is rated at 50 gpm, how would you set the timer to remove the sludge at 6% solids?
- g) How much volume would be saved in the digester if the concentration is increased from 4% to 6% ?
- h) What other conditions would you take into account when deciding when to remove sludge from the clarifier?

Secondary Biological Treatment

Practice Worksheet: Part I

1. What is the purpose of secondary biological treatment?
2. What five major groups of microorganisms are found in biological treatment systems?

3. Explain the difference between adsorption and absorption when used to describe the growing process of treatment bacteria.
4. Name three growth "factors" or "pressures" that affect how well the treatment bacteria will grow.

5. The activated sludge process is a suspended growth type treatment process. Either a mechanical or diffused aeration system is used to keep the microorganisms suspended. Which type of aeration system is better?

6. What is the function of the return sludge line (RAS)?

7. What is the function of the waste sludge line (WAS)?

8. Describe the difference between a conventional type activated sludge system and a contact stabilization system.

9. What would be the advantage to a step aeration type of flow pattern in a conventional activated sludge treatment system?

10. What advantages could you see to the use of an ABF treatment process?

11. A trickling filter treatment system is an attached growth system. What does the term "zoogloal slime" describe?

12. What would be the purpose of using a trickling filter as a roughing filter?

13. How could you describe the difference in the characteristics of floc created in an activated sludge process and the floc created in a trickling filter process?

14. What do you think is the advantage to the trickling filter-solids contact treatment process?

15. RBC's are stacks of plastic discs that are rotated through the wastewater flow. The RBC process is usually divided into different sections called _____ . A group or row of rotating drums is called a _____ .

16. Why would the operator of an RBC treatment system change the flow pattern to the drums from parallel to series flow?

17. Why are most waste stabilization ponds called facultative ponds?

18. How does the hydraulic loading and detention time affect the efficiency of operation of a waste stabilization pond?

2. An RBC treatment system has a total surface area of 1,200,000 ft². Flow to the system is 4.1 MGD. Primary effluent BOD is 89 mg/L.

a. Calculate the hydraulic loading:

b. Calculate the organic loading:

c. How do these filter loadings line up in comparison to normal operational loadings?

3. Consider the following plant operational data:

Plant flow	8.0 MGD
Primary effluent BOD	100 mg/L
Aeration basins	
Number of tanks	2
Length (each tank)	165 ft
Width (each tank)	55 ft
Depth (each tank)	13 ft
MLSS	2,500 mg/L
SSV @ 30 min	280
Waste flow (total)	26 gpm
Waste concentration	8,500 mg/L
Effluent SS	10 mg/L

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3. continued:

a. Calculate the F/M ratio:

b. Calculate the MCRT:

c. Calculate the SVI:

d. Calculate the WSF for a target MCRT of 10 days:

e. Can you draw any conclusions about the sludge quality using these numbers?

4. Use the following waste stabilization pond operational data to solve the calculations.

Influent flow	0.45 MGD
Influent BOD	185 mg/L
Pond depth	3.5 ft
Pond width	450 ft
Pond length	810 ft

a. Calculate the pond area in acres:

b. Calculate the pond volume in acre-ft:

c. Calculate the detention time in days:

d. Calculate the hydraulic loading in inches per day:

e. Calculate the organic loading in lbs BOD/day/acre:

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Sludge Digestion

Practice Worksheet

1. What are the major objectives of sludge digestion?
 - a.
 - b.
 - c.
 - d.
 - e.

2. What type of secondary treatment process does aerobic digestion resemble?

3. Aerobic digestion is commonly used on what types of sludges? Why?

4. Name 4 performance factors that effect the aerobic sludge digestion process.
 - a.
 - b.

4. continued:

c.

d.

5. A small activated sludge package plant has a rectangular aerobic digester. The digester is 35 ft long, 15 ft wide, and 10 ft deep. 14,430 gallons of 1% sludge are pumped from the secondary clarifier to the digester. If the volatile content of the sludge is 54% calculate the volatile solids loading at this plant. How much volume of the tank will this sludge occupy?

6. The anaerobic digestion process is described as being a two stage process. What happens in the first stage?

7. What happens during the second stage of the anaerobic digestion process?

8. It is important that the temperature in an anaerobic digester not change more than one degree per day. What is the normal operating temperature of an anaerobic digester?

9. On the average, between 12 and 18 ft³ of gas are produced during the anaerobic digestion process for each pound of volatile solids reduced. What makes up this digester gas (give percentages)?
10. How can the VA/Alk ratio be used to help control the anaerobic digestion process? Why not just use pH?

Consider the following operational data from a primary and secondary treatment facility with an anaerobic digester.

Primary Sludge Characteristics:

concentration	6.0%
volatility	85%
volume	7,800 gpd

Secondary Sludge Characteristics:

concentration	0.8%
volatility	54%
volume	16,486 gpd

Feed sludge volatility	78%
Digested sludge volatility	56%
Digester volume	20,000 ft ³

Calculate the following:

11. Total volume of sludge pumped to the digester each day (gallons).

12. Hydraulic detention time in the digester (days).

13. Pounds of total solids pumped from the primary clarifier (lbs).

14. Pounds of volatile solids pumped from the primary (lbs).

15. Pounds of total solids pumped from the secondary (lbs).

16. Pounds of volatile solids pumped from the secondary (lbs).

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17. Total number of volatile solids fed to the digester each day (lbs).

18. Volatile solids loading (lbs VS/day/ft³).

19. Volatile solids reduction (percent).

20. Name two dewatering processes that require chemical pre-conditioning of sludge before processing.

21. What is the most commonly used type of centrifuge? At what concentration is the sludge cake coming from this type of centrifuge?

Effluent Chlorination and Disinfection

Practice Worksheet

1. The major objective of disinfection is the reduction in the numbers of pathogenic organisms. An activated sludge treatment process will reduce pathogenic organism numbers by what percentage?
2. When chlorine is mixed with water two components are created. List below those two components.

3. Define the following terms:

Free chlorine residual:

Combined chlorine residual:

Breakpoint chlorination:

4. How does the pH of the wastewater affect the chlorination process?

5. How does the amount of mixing time affect the chlorination process?

6. The chlorine demand of the wastewater effluent is the amount of chlorine that is burned up by material in the flow. How is the chlorine demand calculated?

7. 2.5 MGD of treated effluent leaves the plant through a contact chamber that allows for 20 minutes of contact time. If the measured residual at the end of the contact chamber is 0.8 mg/L calculate the chlorine dosage and the chlorine demand. The chlorine feed rate is 115 lbs/day.

8. List below two of the three basic methods used for measuring residual chlorine.

9. The amount of chlorine residual that is maintained is determined by the desired microorganism population. The allowed level of microorganisms is set by the NPDES permit. The microorganism population is estimated by measuring the coliform group of bacteria. What are coliform bacteria?

10. What methods are used to measure coliform bacteria?

11. Chlorine is sometimes used as a treatment in other areas of the wastewater treatment plant. Give two possible places (other than the disinfection process) where chlorine might be used.

12. Why is sulfur dioxide sometimes added before the treated effluent reaches the receiving stream?

13. If the chlorine residual at the end of the contact basin is 2.5 mg/L, what dosage of SO_2 would be required for dechlorination?

14. What are the two compounds that result from the reaction of SO_2 , H_2O , and the chlorine residual (HOCl) ?

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Pumps and Maintenance

Practice Worksheet

1. Describe the function of the following centrifugal pump components?

Impeller:

Volute case:

2. Describe how energy is transferred or changed in form by a centrifugal pump.

3. What is the difference between pressure head and elevation head?

4. Fill in the blanks below:

Pressure = height of the fluid X the _____ of the fluid.

1 psi = _____ ft of head

1 ft of head = _____ psi

5. Water is stored in a tank with the water level 210 ft above a small town. What would the pressure read on a gage (psi) at the bottom of the 210 ft column?

6. A sewage pump station has a wet well that is 12 ft by 12 ft. The centrifugal pump in this station is flow tested to measure actual operating capacity. A drop in the water level in the wet well is measured and timed after the pump is turned on. It is found that the level dropped 18 inches in 1 minute. Calculate the flow of this pump in gpm.

7. What is the difference between a suction head and a suction lift condition for a centrifugal pump application? While the pump is running, what would the pressure gage read if you were operating under a suction lift condition?

8. During the operation of a pump system the pressures are recorded on both the inlet side and the discharge side of a centrifugal pump. The inlet pressure reads 25 psi and the discharge pressure reads 180 psi. Calculate the TDH.

9. If water horsepower is the energy imparted into the water by the pump what is brake horsepower?
10. A centrifugal pump in a lift station is pumping 550 gpm against a head of 36 ft. What horsepower (water horsepower) will be required to do the work?
11. What is meant by the term wire-to-water efficiency? How would you calculate the wire-to-water efficiency?
12. A plant water transfer pump is producing 350 gpm. The inlet pressure on the pump reads 12 psi and the discharge pressure reads 56 psi. If the pump to be used is 85% efficient and the motor is 95% efficient, what motor horsepower will be required? If this pump is operated for 1 hour, how many kilowatt-hours (kWh) will it take to operate this pump?

13. A pump curve is a graph showing the operating characteristics of a particular pump. Most pump curves are put together based on what two components or characteristics of the pump?

a. _____

b. _____

14. Based on the operational characteristics of the pump, the pump curve can give you other operational characteristics or requirements. What other characteristics (besides those given in question #13) can be found on a pump curve?

a. _____

b. _____

c. _____

d. _____

Wastewater Operations: Certification Review

Answers to Practice Worksheets

Section I: Basic Wastewater Treatment Concepts

1. 99.9% water 0.1% waste
2. Domestic: organic and inorganic, balanced
Industrial: concentrated organic or inorganic, toxics
3. Biochemical Oxygen Demand: The amount of organic material used to determine strength of the sewage
4. **Settleable solids** - those solids that are large and heavy enough to settle without treatment. Imhoff cone test, 30 min settling.
Suspended solids - composed of both settleable and nonsettleable solids. Defined by the test run, material caught on the filter paper.
5. **Volatile solids** - organic material burned off as a "fuel" in an oven at high temp (600°C).
6. a. remove organic material
b. eliminate disease producing agents
7. National Pollutant Discharge Elimination System
8. 0.432 MGD
9. 673.2 gpm
10. area = 3 ft²; flow = 6.6 ft³/sec or 4.265 MGD
11. area = 0.1963 ft²; flow = 0.98 ft³/sec or 440.6 gpm
12. area = 0.349 ft²; flow = 0.7799 ft³/sec so V = 2.23 ft/sec
13. 12,510 lbs
14. 17,514 lbs
15. 5,004 lbs not used by bacteria

Section II: Pretreatment of Wastewater

1. protection of equipment and downstream processes
2. very front end of the plant, influent pump station, by-pass channels
3. in place of primary treatment, storm bypass
4. comminutors- rotating or oscillating drums
barminutors - U-shaped bars, moving scroll
5. collection system velocity is > 2 ft/sec. Slowing down the flow to let the heavier material settle out but not the light organic material.
6. $Q = 5.88$ ft³/sec; area = 5 ft²; $V = 1.18$ or 1.2 ft/sec
Particle takes 22.2 secs to settle; travels 26.7 ft
7. reduce specific gravity, spiral flow brings grit to the bottom and moves grit along the bottom. Freshens and washes grit.
8. help in grit removal, flush out gases, float grease
9. oxidize anaerobic by-products, H₂S
10. 93.85%
11. 92.67%

Section III: Primary Treatment

1. a. remove settleable material
b. remove floatable material
2.

Settleable solids	<u>90% to 99%</u>
Suspended solids	<u>40% to 60%</u>
BOD	<u>20% to 50%</u>
3. even distribution of flow, adsorb energy of flow
4. 30 min
5. a) Detention time = 2.13 hrs
b) Surface Settling Rate = 841.8 gpd/ft²
c) Weir Overflow rate = 23,149.8 gpd/ft
d) DT = 1 to 2 hrs; SSR= 300 - 1200 gpd/ft²; WOR=10,000 - 20,000gpd/ft

6. 4% to 8%, as continuous as possible
7. SS removal through tank
Imhoff cone
8. a) Percent removal of SS = 41%
b) Percent removal of BOD = 31%
c) 8,126.5 lbs
d) 24,360 gpd; 16.9 gpm
e) 16,240 gpd; 11.3 gpm
f) 676.67 gal/hr; 13.53 min/hr; 6.8 min/30 min
g) 8,120 gal; 1,085.6 ft³
h) age of sludge, septic sewage

Section IV: Secondary Biological Treatment

Part 1:

1. reduce SS and DS that will not settle, further reduce BOD load
2. bacteria
 protozoa
 viruses
 algae
 fungi
3. adsorption - sticking on the outside
absorption - taking inside the cell
4. food. hydraulic loading
 oxygen. temp
 pH. toxics
5. fine bubble diffused aeration usually more efficient for larger system
mechanical for smaller systems
6. bring back resting organisms to be "reactivated"
7. remove excess sludge from the system
8. contact stabilization has second aeration tank
used for higher loadings

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9. to avoid overloading the front end of the tank
10. takes advantage of the low power usage and shock adsorbing ability of attached growth and good settling qualities of suspended growth
11. multi-layers of organisms attached to the media
12. reduce the BOD load ahead of a second treatment process
13. AS floc is usually lighter and more feathery
TF floc is more concentrated, heavy, and granular
14. use the aerated channel to pre-flocculate the TF solids
Change TF floc form and remove more fine SS
15. stages, trains
16. put more treatment time on sludge, promote nitrification
17. most of the bacteria that do the work are facultative bacteria; aerobic bacteria near the surface, facultative bacteria throughout the volume, and anaerobic bacteria at the bottom
18. the greater the hydraulic loading means a shorter detention time; a shorter detention time reduces the efficiency of the pond

Part II:

1. a. Hydraulic loading: Area = 50,893.8 ft²; HL = 110 gpd/ft²
b. Organic loading: Volume = 330,809.7 ft³; 330.81 -1000 ft³ units; lbs of BOD = 4,250.06 lbs; OL = 12.85 lbs BOD/day/1,000 ft³
c. standard rate filter
d. 81%
2. a. Hydraulic loading: 3.42 gpd/ft²
b. Organic loading: lbs BOD = 3,043.27 lbs; 2.54 lbs BOD/day/1,000 ft²
c. conventional loadings
3. Aeration basin volume = 235,950 ft³ (total); 1.765 MG
Clarifier area = 11,349 ft² (total); Blt = 21,563.11 ft³; 0.161 MG
Waste flow (total) 26 gpm; 37,440 gpd; 0.037 MGD
a. $F/M = \frac{6672 \text{ lbs}}{36800.25 \text{ lbs}} = 0.18$
b. $MCRT = \frac{36800.25 \text{ lbs}}{2622.93 \text{ lbs} + 667.2 \text{ lbs}} = 11.2 \text{ days}$
c. $SVI = \frac{280 \times 1000}{2500} = 112$

$$d. \text{ Lbs to be wasted} = \frac{36800.25 \text{ lbs}}{10 \text{ days}} - 667.2 \text{ lbs} = 3,012.83 \text{ lbs/day}$$

$$\text{WSF gal/day} = \frac{3012.83 \text{ lbs/day} \times 1000000 \text{ gal/MG}}{8500 \text{ mg/L} \times 8.34 \text{ lbs/gal}} = 42,500 \text{ gal/day}$$

42,500 gal/day = 29.5 gpm; this represents a increase in sludge wasting from 26 gpm to 29.5 gpm to decrease the MCRT from 11.2 days to 10 days

4. a. pond area: $450 \text{ ft} \times 810 \text{ ft} = 364,500 \text{ ft}^2$

$$\text{area in acres} = \frac{364500 \text{ ft}^2}{43560 \text{ ft}^2/\text{acre}} = 8.37 \text{ acres}$$

b. pond volume: $8.37 \text{ acres} \times 3.5 \text{ ft} = 29.29 \text{ acre-ft}$

c. detention time: volume in gal = $1,275,750 \text{ ft}^3 \times 7.48 = 9,542,610 \text{ gal}$

$$\text{detention time} = \frac{9542610 \text{ gal}}{450000 \text{ gal/day}} = 21.2 \text{ days}$$

d. hydraulic loading: inches/day (depth = $3.5 \text{ ft} \times 12 \text{ in/ft} = 42 \text{ in}$)

$$\text{hydraulic loading} = \frac{42 \text{ in}}{21.2 \text{ days}} = 1.99 \text{ or } 2 \text{ in/day}$$

e. organic loading: lbs BOD/day/acre

$$\text{lbs BOD/day} = 0.45 \text{ MGD} \times 185 \text{ mg/L} \times 8.34 \text{ lbs.gal} = 694.3 \text{ lbs/day}$$

$$\text{organic loading} = \frac{694.3 \text{ lbs/day}}{8.37 \text{ acres}} = 82.95 \text{ lbs BOD/day/acre}$$

Section V: Sludge Digestion

1. a. Stabilization

b. Reduce mass and volume

c. Destroy pathogenic organisms

d. Condition sludge for further handling (dewatering)

e. Produce usefule byproducts (gas and sludge)

2. activated sludge, maybe extended aeration

3. secondary sludges, just an extension of the process

4. a. sludge type, air supply and DO residual

b. Digestion time, percent VS reduction

c. Digestion temp

d. Volatile solids loading

5. lbs VS = 1,200.96; tank volume = $5,250 \text{ ft}^3$

$$\text{VS loading} = 0.23 \text{ lbs VS/day/ft}^3$$

$$14,430 \text{ gal} = 1,929.14 \text{ ft}^3; \text{ represents } 3.67 \text{ ft of depth of the tank}$$

6. Volatile acid forming bacteria convert volatile organics into volatile acids, CO_2 , H_2O , and energy

7. Methane forming bacteria convert volatile acids into CH_4 , CO_2 , energy

8. 90 - 98°F
9. 56 - 70 & methane 30 - 35% carbon dioxide
10. shows condition of inside of tank. Changes much faster than pH.
11. Total volume of sludge pumped to the digester each day (gallons).
7,800 + 16,486 = 24,286 gal
12. Hydraulic detention time in the digester (days).
$$\frac{149600 \text{ gal vol}}{24286 \text{ gal/day}} = 6.16 \text{ days}$$
13. Pounds of total solids pumped from the primary clarifier (lbs).
3,903 lbs
14. Pounds of volatile solids pumped from the primary (lbs).
3,317.65 lbs
15. Pounds of total solids pumped from the secondary (lbs).
1,099.95 lbs
16. Pounds of volatile solids pumped from the secondary (lbs).
593.97 lbs
17. Total number of volatile solids fed to the digester each day (lbs).
3,911.62 lbs VS (total solids = 5,002.95 lbs TS)
18. Volatile solids loading (lbs VS/day/ft³).
0.196 lbs VS/day/ft³
19. Volatile solids reduction (percent).
64.1% reduction (why? high level of feed sludge volatility)
20. centrifugation, belt press, vacuum filtration
plate press, float thickening
21. solid bowl, 20-25%

Section VI: Effluent Chlorination and Disinfection

1. 90-98%, some still remain
2. HOCl - hypochlorous acid
OCl⁻ - hypochlorite ion

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3. Free chlorine residual: only HOCl or OCl⁻ present, no combined forms
 Combined chlorine residual: mono-, di-, or trichloramines
 combined with ammonia
 Breakpoint chlorination: chlorine added until all the interfering
 materials and combined residual is burned up
4. the lower the pH the better the disinfection because of the greater
 concentration of HOCl
5. longer contact time the better the disinfection
6. Chlorine Demand = Dosage - Residual
7. Feed rate of 115 lbs/day; Dosage = 5.52 mg/L; Demand = 4.72 mg/L
8. Iodometric Method
DPD Titrimetric Method: Amperometric Titration
9. non-pathogenic bacteria that reside in the intestine of warm-blooded
 animals, an indication of pathogenic organisms
10. MPN method, Membrane filter
11. Collection system, grease control, BOD reduction
AS bulking control, Digester - supernatant and foaming control
12. to protect wildlife by removing toxic chlorine
13. dosage is 1:1; 2.5 mg/L SO₂
14. small amounts of acid: HCl and H₂SO₄

Section VII: Pump Basics and Operation

1. impeller: imparts velocity (velocity head) to the water being pumped
 volute case: shape causes change from energy as velocity to pressure
2. electrical energy to changed to mechanical energy by the motor, to velocity
 head by the impeller, and to pressure head by the volute case
3. elevation head is a form of stored energy due to the elevation of the water
 level; pressure head is the energy of the water under pressure in a
 pipeline that can be represented as a head elevation
4. Pressure = height of the fluid X the weight of the fluid.

1 psi = 2.31 ft of head

1 ft of head = 0.433 psi

5. $210 \text{ ft} \times 0.433 \text{ psi/ft} = 90.9 \text{ psi}$

6. Area = 144 ft²; volume = 216 ft³ or 1,615.7 gallons; flow = 1,615.7 gpm

7. **Suction head:** water level on the inlet side of the pump that is above the pump centerline.

Suction lift: water level on the inlet side of the pump that is below the pump centerline.

Under a suction lift condition the pump inlet pressure gage would read a pressure less than atmospheric pressure either as a negative psi or in inches of mercury vacuum.

8. Inlet: $25 \text{ psi} \times 2.31 \text{ ft/psi} = 57.75 \text{ ft}$
Discharge: $180 \text{ psi} \times 2.31 \text{ ft/psi} = 415.8 \text{ ft}$
TDH: $415.8 \text{ ft} - 57.75 \text{ ft} = 358.05 \text{ ft}$

9. Brake horsepower is the energy transferred from the motor to the pump through the pump shaft.

10. $\text{WHP} = \frac{(550 \text{ gpm})(36 \text{ ft})(8.34)}{(33,000)} = 5 \text{ WHP}$

11. Wire-to-water efficiency is the combined efficiency of the motor and the pump. Calculated by multiplying the motor efficiency as a decimal times the pump efficiency as a decimal.

12. TDH: $(56 \text{ psi} - 12 \text{ psi}) \times 2.31 \text{ ft/psi} = 101.64 \text{ ft}$
 $\text{WHP} = \frac{(350 \text{ gpm})(101.64 \text{ ft})(8.34)}{(33,000)} = 8.99 \text{ or } 9.0 \text{ WHP}$

$$\text{BHP} = \frac{9 \text{ whp}}{0.85} = 10.6 \text{ BHP}$$

$$\text{MHP} = \frac{10.6 \text{ bhp}}{0.95} = 11.16 \text{ MHP}$$

Or with wire-to-water efficiency: $0.85 \times 0.95 = 0.81 \text{ or } 81\%$

$$\text{MHP} = \frac{9.0 \text{ whp}}{0.81} = 11.16 \text{ MHP}$$

Convert to kWh: $11.16 \text{ hp} \times 0.746 \text{ kWh/hp} = 8.32 \text{ kWh}$

13. a. head
b. capacity

14. a. motor horsepower or brake horsepower
b. efficiency
c. speed (rpm), d. NPSH, impeller diameter