Wastewater Modules

WW Instructor Guides 1, 4, 5-9 - Answer Key

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Module 1:
Introduction to Wastewater Treatment
Instructor Guide – Answer Key

What are some examples of different interests various audiences may have?

Ans: Officials of regulatory agencies or other operators would want to be provided with detailed information on the operation of the plant. School classes would want to know only very basic information. Public tours or tours of the news media may be interested in water quality, which will help contribute to acceptance and support.

What are some typical safety issues in a plant?

Ans: Some typical safety issues include:

- Chlorine Safety (potentially toxic atmosphere)
- Confined space entry – Most common cause of death from an on-the job accident for collection system operators is through asphyxiation.
- Explosions hazards – anaerobic digester producing methane gas
- Fall hazards
- Electrical Hazards

What are some examples of organic impurities from industrial contributors?

Ans: Examples of organic impurities include:

- Chloroform from leather tanning operations and pharmaceuticals manufacturing
- Trichloroethylene from textile mills and adhesive manufacturing
- Phenols from pesticide manufacturing and from iron and steel manufacturing
- BOD and fats, oils, and greases from food processing industries

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A stream used for trout stocking is one example of a thermal sensitive stream where the stream temperature needs to be regulated. Can anyone think of any other reasons to regulate the temperature of discharges to the receiving stream?

Ans: Additional reasons to regulate the temperature of discharges are:

- To prevent loss of dissolved oxygen (DO)—the amount of DO that can be dissolved into water decreases as the temperature of the water increases, and
- To control undesirable aquatic growth such as algae, which grows faster at higher temperatures.

What are some communicable diseases that could be transmitted via untreated wastewater?

Ans: Typhoid, cholera, dysentery, polio, hepatitis.

Why should the operator be familiar with the wastewater collection and conveyance network?

Ans: The operator should know the origin of wastes reaching the plant, the time it takes, and how the wastes are transported (flow by gravity or by gravity and pumped). Such knowledge will help you spot troubles and take corrective action.

What is typically done with grit once it is removed from wastewater?

Ans: Grit is usually taken to an approved sanitary landfill.

Why is the Parshall Flume widely used for measuring wastewater flow? Why is the Weir not used very frequently to measure influent?

Ans: The parshall flume is widely used for measuring untreated wastewater flow because it creates no obstructions to the flow of wastewater, which minimizes the chance for blockages or accumulations that might affect the depth of flow and subsequently, the measured flow rate.

The weir is not used as frequently because solids may collect behind the weir, which could result in inaccurate flow measurements. This collection of solids could also cause odors.

Why is a secondary clarifier needed after a trickling filter, rotating biological contractor, or aeration tank?

Ans: To allow organisms in treated wastewater to be removed by settling.

Ans:

1. What are the three major components of a Wastewater System?
    1. Collection and Conveyance
    2. Treatment
    3. Disposal

2. Name the three types of collection systems and briefly describe.
    1. Sanitary Sewer- collects commercial and household wastes.
    2. Storm Sewer- Collects runoff from streets, land and roofs.
    3. Combined Sewer- Collects sanitary and storm water.

3. Match the Treatment Processes with the correct description.
    1. C
    2. F
    3. D and/or B
    4. A
    5. B and/or B
    6. G
    7. E

4. Describe two methods of effluent disposal.
    1. Stream Discharge
    2. Land Disposal

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What are examples of conditions that cause violations?

Ans: Conditions that cause violations:

- Overloading conditions that can lead to overflows, by-passes, or process upsets
- Mechanical equipment deficiencies
- Inadequate budget for maintenance or operation of the plant

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What are examples of tasks that would be candidates for a Standard Operating Procedure?

Ans: Examples of tasks would be:

- Field measurement of pH or DO
- Calibrating field montoring instrumentation
- Rotation of duplicate pumping equipment to equalize wear, without changing pumping rates

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Module 4:
Fundamentals of Wastewater Treatment
Instructor Guide – Answer Key

Before we move on to Grit Disposal, who can tell me what purpose grit washing serves within wastewater treatment?

Ans: To remove excess organic materials so that when the grit is removed and disposed of, it less likely to attract vermin or cause odors.

What is the purpose of preliminary treatment as it relates to screening and comminution?

Ans: Screening is the initial removal of floating material and larger suspended solids from the wastewater influent stream. The largest wastes are separated from the wastewater by the water flowing through screens and bar racks which prevent them from moving any further into the plant and interfering with the downstream treatment processes. These items must be removed either manually or mechanically. Comminution is the next step in wastewater treatment. During this process, the now largest wastes are made smaller by cutting them into smaller pieces. Once again a screen is used to

keep out the larger pieces of waste from the flow. It is then cut into smaller pieces that either a) can reenter the flow and continue through the process, or b) must be removed and disposed of.

List at least two differences between screening and comminution.

Ans: 1. Screening REMOVES the LARGEST materials from the influent wastewater stream. Comminution REDUCES the size of materials in the influent stream by cutting or shredding.

Material generally stays in the wastewater (Exception – wood and plastic materials will not pass cutter and must be removed manually).

2. Bar racks and screens are used to protect downstream equipment from damage by large floating objects. Comminutors generally reduce the size of material, preparing this material for further treatment.

What is the detention time at a plant flow of 2.5 MGD in a circular clarifier is 60 feet in diameter, with a water depth of 12 feet? Take a minute to solve this in the space provided.

Clarifier diameter = 60 feet and depth is 12 feet

Volume = Area * h (height/depth)

Area = $\pi * d * d/4$ Note: $\pi/4 = 0.785$

Volume = $0.785 * (d)^2 * h$(height/depth)

Volume = $(0.785) * (60)^2 * 12$

= 33,912 cubic feet

Flow = 2.5 MGD

Therefore,

Detention Time = (33,912 cu ft * 7.48 gal/cu ft * 24 hr/day) / 2.5 MGD

= 6,087,882 gal hr/day / 2,500,000 gal/day

= 2.44 hours

Compute the weir overflow rate for a circular clarifier with a 75 foot diameter overflow weir when 3.5 MGD is the flow rate into the unit.

Ans. Weir Length = 3.1416 * 75 feet = 235.6 feet

Therefore, WOR = 3,500,000 GPD / 235.6 feet

= 14,855 gpd/ft

Problem 2.2: Compute the Surface Loading Rate, when: Flow into a rectangular clarifier 40 feet wide by 110 feet long by 12 feet deep is 5.0 MGD.

Ans: Surface area = 40 feet * 110 feet = 4400 sq ft (Note: that depth is not relevant)

Surface Loading Rate = 5,000,000 GPD / 4400 sq ft

= 1136 GPD/sq ft

Problem 2.3: A circular clarifier with a diameter of 125 ft is operating with a forward flow of 6.0 MGD and a return sludge flow of 2.0 MGD. The MLSS is 4,000 mg/L. Compute the solids loading at which the clarifier is operating.

Ans. Applied solids = (6.0 MGD + 2.0 MGD) * 4,000 mg/L * 8.34 lbs/gal

= 8.0 MGD * 4,000 mg/L * 8.34 lbs/gal

= 266,880 lbs/day

Surface Area = (3.1416 * (125 ft)^2) / 4= 12,272 sq ft

Solids loading = 266,880 lbs/day/12,272 sq ft

= 21.75 lbs/day/sq ft

There are several factors that affect proper clarifier operation. List as many as you can.

Ans: Temperature, detention time, short circuits, weir overflow rate, surface settling rate and, solids loading.

What are some indicators of clarifier problems? List several below.

Ans: Floating Sludge (Bulking); black, odorous septic wastewater entering clarifier; black, odorous septic wastewater leaving clarifier; scum in clarifier effluent; sludge hard to remove from hopper; and low sludge solids.

Miscellaneous problems: Surging flow; Slime growth; and Excessive corrosion.
Mechanical problems: Chain/drive problems; Seal problems; and Bearing problems.

What are the operating principles of the trickling filter process?

Ans: Wastewater is passed over the surface of a fixed media, which, in the presence of aerobic conditions, promotes the growth of a biological slime consisting of bacteria, protozoa, and other organisms on the media. These organisms absorb and use much of the suspended, colloidal, and dissolved organic matter from the wastewater. Part of this organic matter is used by the organisms as food for the production of new cells, while another part is oxidized to carbon dioxide and water. Partially decomposed organic matter, dead organisms (film), and excess organisms are washed off the media and out of the filter with the effluent flow, to be subsequently removed by the secondary clarifiers.

List 5 forms of the activated sludge treatment process.

Ans: extended aeration

contact stabilization

complete mix

sequencing batch reactors

oxidation ditches

What 2 aeration methods are used to provide oxygen to the activated sludge treatment process?

Ans: Mechanical

Diffused

Why might solids be found in the secondary clarifier effluent of an activated sludge treatment plant?

Ans: Return Sludge rate out of balance with process requirements

Sludge not settling (bulking) in clarifier

What are the three types of waste treatment ponds? List them below.

Ans. Aerobic

Anaerobic

Facultative

Module 5:
Disinfection and Chlorination
Instructor Guide – Answer Key

What processes in wastewater treatment serve to remove pathogens?

Ans: See Table at top of page 1-3.

Exercise for Unit 1 – Disinfection and Chlorination Principles

1. Disinfection is the process designed to __kill___ or ___inactivate_____ most microorganisms in wastewater including essentially all pathogenic organisms.

2. Pathogenic organisms consist of ___bacteria__, ___viruses___, or __cysts__ that can cause disease in a host.

3. List three physical processes used in wastewater treatment that are useful in removing some of the microorganisms.
   a. screening
   b. Grit removal
   c. Primary sedimentation

4. The most commonly used disinfection process for wastewater treatment is:
   a. Ultraviolet light
   b. Ozonation
   c. Chlorination
   d. Sterilization

5. Chlorine and its various forms are powerful oxidants that will kill or inactivate most pathogenic organisms that are harmful to human and animal life. Typical forms of chlorine used in wastewater treatment are:
   a. Elemental chlorine
   b. Hypochlorite

c. Chlorine dioxide
d. All of the above

6. Calculate the chlorine dosage required if it is desired to have a chlorine residual of 0.5 mg/l and the chlorine demand is 6.0 mg/l.

Chlorine dosage = Chlorine demand + Chlorine Residual

Chlorine dosage = 6.0 mg/l + 0.5 mg/l = 6.5 mg/l

7. Baffling is used in chlorine contact chambers to aid in mixing and to prevent Short-circuiting.

8. Chlorine is widely used as a disinfectant in wastewater treatment, but it can also be used to:
   a. Control odor
   b. Reduce BOD
   c. Control foaming
   d. Aid in sludge thickening
   e. All of the above

Do you think you might save chemical costs by optimizing the dosage?

Ans: Depends on size of the plant: the smaller the plant, the less likely it is that you would recoup the cost of the compound loop control system.

Exercise for Unit 2 – Chlorination Process Control

1. The most commonly used mode of control in a chlorine feed system is the:
   a. Flow proportional
   b. Step-rate
   c. Time-program
   d. Manual control
   e. Chlorine residual control

2. By using a Chlorination Control Nomograph like the one in this workbook, an operator can determine the setting of a chlorinator in units of
   a. Kg/gallon
   b. Mg/ft
   c. Lbs/day
   d. Lbs/metric tonne

3. Measurement of chlorine residual at a wastewater plant can be determined by the use of which of the following methods:
    a. ORP
    b. Amperometric Titration
    c. DPD Titrimetric
    d. Iodometric
    e. All of the above

4. If the flow thru the wastewater plant is 4.5 mgd and the chlorine dosage is 2.5 mg/l, determine the chlorinator setting in lbs/d. Review of the nomograph scale indicates that it only spans from a flow of 0 to 1.0 mgd. To allow for a flow greater than this multiply both the flow and chlorine feed rate scales by a factor of 10. These two scales now represent a flow of 0 to 10 mgd, and a chlorine feed rate of 0 to 100 lbs/d. Following the same procedures as outlined earlier in this unit, find the chlorine feed rate in lbs/day.

93.8 lbs/day

5. If the chlorine feed rate is 3.5 lbs/d, and the flow through the wastewater plant is 700,000 gallons per day, determine the dosage by using the nomograph.

0.6 mg/l

Exercise for Unit 3 – Chlorine Safety and Handling

1. Chlorine is hazardous and when combined with moisture (including body moisture) it becomes extremely acidic and corrosive.
    a. True
    b. False

2. Any facility that uses chlorine should have a written __safety__ program that is well documented and distributed to all operators.

3. Facilities that store more than 2,500 pounds of chlorine must also have a Risk Management Plan on hand.

4. Chlorine cylinders come in sizes to hold 100 and 150 pounds of chlorine. The cylinders have a shut off valve, a protective cap, and a fusible plug that is designed to fail and leak chlorine to the atmosphere if the temperature rises to a range of __158__ to __165__ degrees Fahrenheit.

5. Ton containers of chlorine should be stored on their sides with the two valves in the __6__ and the ___12_ o'clock position to assure that one valve will release chlorine gas and the other valve will release liquid chlorine.

6. Only trained personnel should respond to a chlorine leak. All others should leave the area until conditions are once again safe.
    a. True
    b. False

7. The largest container that is used to transport chlorine is a railroad tank car.

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Exercise for Unit 4 – Chlorination Equipment and Maintenance

1. The chlorine residual is too high in the plant effluent. The probable causes may include:
    a. The organic strength of the wastewater influent has decreased.
    b. The flow through the treatment plant has changed.
    c. The test equipment used to check chlorine residual needs to be calibrated.
    d. All of the above.

2. Low chlorine gas pressure at the chlorinator is suspected to be due to a depleted chlorine container. The best course of action would be to:
    a. Clean the filter.
    b. Switch to a full chlorine container.
    c. Add baffles to the chamber.
    d. Increase the influent flow.

3. A safety concern with the use of sodium chlorite in a wastewater facility is that it is combustible in the presence of organic compounds.
    a. True ____X____
    b. False _____

4. Day tanks are designed to hold what amount of a chemical compound?
    a. One day.
    b. One week.
    c. One month
    d. Five days.

5. List five major components of a chlorine feed system.

    Answers may vary and may include: cylinders, manual isolation valves, regulating valves, automatic switchover system, drip leg and heater, pressure gauges, chlorinator, expansion tanks, injector, solution tube, piping systems, and evaporators.

6. It is very important to have a detailed maintenance program that is performed on a routine basis. List five items that should be part of a gas feed chlorination maintenance plan.

    Answers may vary. See page 4-7 of the participant workbook for a list of items suggested for a maintenance plan.

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Exercise for Unit 6 - Dechlorination

1. The effluent from a wastewater treatment plant may need to be dechlorinated after disinfection because of harmful affects the chlorine residual may have on fish, wildlife, and even human health.
   a. True
   b. False

2. Common methods of dechlorination include:

   Any four of the following five answers are correct: detention ponds, aeration, sunlight, activated carbon, and the addition of sulfur compounds.

3. One pound of sulfur dioxide will neutralize how many pounds of chlorine?
   a. 4 pounds
   b. 2.5 pounds
   c. 1 pound
   d. Neutralization of chlorine is not possible by using sulfur dioxide.

4. Sulfur dioxide is often used to dechlorinate wastewater effluent, however, like chlorine it is very toxic and must be handled with great care.
   a. True
   b. False

5. A wastewater treatment plant operates with a flow of 2.0 MGD. The Chlorine residual is 3.5 mg/l. How much sulfur dioxide should be used to assure that the chlorine residual has fully reacted in the dechlorination process?

   Assume a SO_2 residual of 0.5 mg/l to assure all of the chlorine is reacted.

   Then, the Feed Rate of SO_2 is (3.5 mg/l) + (0.5 mg/l) = 4.0 mg/l

   Feed Rate in lbs/day = (2,000,000 G/D)x(4.0)/(1,000,000)x(8.34 lbs/G)

   Feed Rate in lbs/day = (2 G/D)x(4.0)x(8.34 lbs/G)

   Feed Rate of SO_2 in lbs/day = 67 lbs/D

Why have an alternative to chlorination?

Ans: Safety – Eliminates issues related to safe handling of chlorine gas.

Health – Eliminates issues related to generation of bi-products having adverse health effects.

Environmental – Eliminates need to dechlorinate the plant effluent.

What is the downside to UV radiation?

Ans: Unlike chlorine where a residual measurement assumes a level of disinfection, routine bacteriological testing of plant effluent must be performed to assure that the system is operating satisfactorily. Also, UV leaves no residual so there is no protection from recontamination.

Cost of equipment and operation are somewhat more expensive than a chlorination system. However, a total system analysis must be performed that includes the cost of safety issues related to chlorine and the reduced size of the contact basin that UV allows for.

What problems could you experience with UV systems?

Ans: UV lamps have a limited life and will experience reduced output as time goes on. This in turn will result in a reduction of pathogen inactivation if the system were not properly sized.

UV sleeves are subject to fouling from materials in the flow stream with accompanying dose (light intensity) reductions.

UV systems are subject to fouling of the quartz sleeve due to crystallization of dissolved solids on the surface of the sleeve and thereby reducing transmission of light into the flow stream and the effectiveness of the system.

UV sleeves are subject to discoloration (known as solarization) resulting in reduced capacity of the lamp to transmit light to the flow stream, reducing its effectiveness. UV sleeves are more prone to solarization when used in medium pressure- high intensity systems.

How can you control UV?

Ans: UV may be controlled by turning on or off selected sections of the UV train and thereby increase or decrease the dosage of UV radiation applied to the flow stream.

UV may be controlled by increasing or decreasing the power to a UV train resulting in increased or decreased levels of radiation emitting from the lamps.

On/Off or variable lamp output can be controlled using signal from plant flow meter – “Flow Pacing.”

On/Off or variable lamp output can be controlled using signals from UV intensity sensor and plant flow meter – “Dose Pacing.”

Dose pacing accounts for: lamp age, condition of quartz sleeve, and the water quality (transmittance). However, with a greater frequency of on/off cycles, the useful life of the lamps will be shorter.

Exercise for Unit 6 – Ultraviolet Radiation

1. UV light used to disinfect or inactivate pathogens has a wavelength of:
   a. 580 kHz
   b. 92.7 MHz
   c. 254 nm
   d. 1760 yd

2. Three typical UV lamp configurations are:
   a. Closed vessel lamp arrangement
   b. Vertical and perpendicular to flow lamp arrangement
   c. Horizontal and parallel to flow lamp arrangement

3. UV light is harmful to the eyes and skin.
   a. True
   b. False

4. Low pressure-low intensity UV lamps are often used in wastewater systems with a flow of
   a. >0.5 MGD
   b. <0.5 MGD
   c. >2.0 MGD
   d. Are rarely used because they get too hot during operation.

5. In a typical UV disinfection system, replacement of the UV lamps should occur more often than replacement of the lamp ballasts.
   a. True
   b. False

6. Flow or dose pacing are means of
   a. UV control
   b. Maintenance planning
   c. Dechlorination
   d. Residual monitoring

Module 6:
Solids Handling and Disposal
Instructor Guide – Answer Key

Can someone tell us why primary sludges are not as well suited for dissolved air flotation thickeners?

Ans: Primary sludges are heavier and tend to settle.

Exercise for Unit 1 – Solids Handling

Matching – Match the gravity thickener parts (A-E) with their proper description (1-5):

C 1. Collects and removes effluent or thickener overflow.

D 2. Slowly rotates to move the settled solids to the middle of the tank.

A 3. Introduces the sludge into the thickener.

B 4. Collects and removes floating debris.

E 5. Provides gentle stirring or flocculation of the settled sludge and releases trapped gas to prevent rising sludge.

A. Inlet and distribution assembly
B. Scum removal equipment
C. Effluent/Overflow weir
D. Sludge rake to move the sludge to a hopper
E. Pickets or vertical steel members

Multiple Choice – Choose the best answer unless otherwise noted:

6. Which of the following are advantages of sludge thickening? (*Choose all that apply*)

a. Cost savings in the construction of new digestion facilities
b. Increased anaerobic digestion heating requirements, since more water has to be heated.
c. Improved digester performance due to a lower volume of sludge

7. The type of sludge that is commonly thickened using a centrifugal thickener is: (*Choose one*)

a. primary sludge
b. secondary sludge
c. tertiary sludge

8. Sludge that is to be thickened using a gravity belt thickener is first preconditioned, typically using what? (*Choose one*)
    a. chlorine
    b. lime
    c. polymer
    d. soda ash
9. The sludge thickener diagrams that were viewed in this unit include which of the following? (*Choose all that apply*)
    a. air floatation thickener
    b. scroll centrifuge thickener
    c. gravity belt thickener
    d. basket centrifuge thickener

So how does digestion reduce the volume of solids in the sludge?

Ans: The answer is on the next page of the workbook.

How many have a gas system?
[(Note: everyone with an anaerobic digester should have a gas system.)

How many use the gas for heat?
[(Note: everyone with an anaerobic digester should use the gas for heat.)

What kinds of problems do you have with your gas systems?

Ans: [Expect moisture problems, clogs, low methane content, leaks, corrosion, etc.

What type of meters do people in the class use?

Ans: *[These responses could be brands (Trident, Neptune, Ford, WT, Watts) or working types (displacement, turbine, propeller).]*

Which types of meters have worked the best?

Ans: *[It is common for the ones that have worked the best to be the ones that were installed with the proper upstream protections. Expect responses of blockage and corrosion to be the items that downgraded the performance of the meters.]*

How do you check your waste gas burners?

Ans: Visual observation from the ground is probably the most common method of checking the burner. A better way is close visual observation of the burner. Once you are close you can also see if fasteners are loose, material is being eaten away, the auxiliary flame source is still lit, or obstructions are developing in the airways.

Does anyone have any tips for checking waste gas burners?

Ans: Access is a big concern. Therefore, methods of getting to the burner, ladders, platforms, mirrors, closed circuit TV, are important.

Considering all the waste streams arriving at the digester, which one gives your plant the most problems in transport and why?

Ans: Scum is probably on the top of the list because the grease and oils foul the pipes. It is also the most difficult to pump. Hopefully, most of the grit and stringy material has been removed from the flow stream. The sludges may have gas entrained in them that hinders efficient pumping, but the gas is less of a problem than plugged piping.

What types of tests should be conducted before entering a digester that has been taken off-line?

Ans: Since this may be a confined space, the required tests for confined space entry should be completed: oxygen, explosive gases, hydrogen sulfide, carbon monoxide.

Exercise for Unit 2 – Anaerobic Digestion

Multiple Choice – Choose the best answer unless otherwise noted:

1. Anaerobic digestion reduces pathogens by what percentage?
    a. 50-65%
    b. 70-84%
    c. 85-99%

2. Psychrophilic bacteria would be used in which kind of digester?
    a. Cold digester
    b. Warm digester
    c. Hot digester

3. A sour digester occurs when:
    a. The gas produced by the acid formers gets caught in surfactant

b. Acid formers grow faster than methane formers
c. Soap and detergent reduce the surface tension of liquids

4. Which V.A./ALK (volatile acids/alkalinity) ratios are within problem levels? *(Choose all that apply):*
   a. 0.08
   b. 0.1
   c. 0.8
   d. 1.0

5. An acidic (low pH) digester can be cured by adding alkalinity to the digester. Which one of the following compounds is the most cost effective in curing an acidic digester?
   a. Sodium Bicarbonate
   b. Anhydrous Ammonia
   c. Lime ($Ca(OH)_2$)
   d. Sulphuric Acid

Fill in the blank with a correct response:

6. A material is considered _dewaterable_ if water will readily drain from it.

7. An anaerobic digester will produce twelve to eighteen cubic feet of gas for every _pound_ of volatile matter destroyed.

8. Normally a digester should be fed often. This can be anywhere from two to _twenty_ times per day.

9. Anaerobic digesters produce methane gas and carbon dioxide gas. If the amount of CO_2 reaches 45 % or more, the gas mixture will not be burnable.

10. When a digester's working volume reaches _60_ % or less of its design volume, it is time to shut down and clean the digester.

Exercise for Unit 3 – Aerobic Digestion

1. The target level of dissolved oxygen in an aerobic digestion tank is:

   a. 6 mg/L

   b. 1 mg/L

   c. 0 mg/L

2. Sludge is usually kept in the aerobic digestion tank for:

a. 1 day

b. 5 days

c. 10 days

d. 20 days

3. Aerobic digestion creates a waste that is better for disposal or beneficial use (reduced volume through dewatering, reduced pathogens and a more stabilized product through the reduction of volatile solids).

   a. True b. False

4. Scum is typically the biggest problem when using aerobic digesters.

   a. True b. False

5. Odors are not generally a problem with aerobic digesters. If odors occur, what are two remedies that may correct the odor problem?

   a. Ensure that proper mixing is occurring in the tank.

   b. Ensure that proper dissolved oxygen levels are being maintained.

Do you think there is a fire risk when anaerobic digested sludge is applied on a drying bed?

Ans: Yes (see next question).

Why is anaerobic more dangerous then aerobic sludge?

Ans: Anaerobic sludge contains methane gas. Aerobic sludge should not contain methane gas.

For those drying beds not equipped with vehicle treads, what can be used to facilitate the use of wheelbarrows on the drying bed?

Ans: Planks, grating, plywood.

Exercise for Unit 4 – Solids Management Planning

1. In a drying bed the typical sludge thickness is _ten_ to _twelve_ inches.

2. A drying bed requires about 14 to 20 days of drying time.

3. Reed beds can last up to 10 years.

4. Most sewage sludges are classified as:
   a. hazardous waste
   b. non-hazardous waste
   c. radioactive waste
   d. none of the above

5. Sludge dewatering methods include drying beds, reed beds, lagoons and mechanical dewatering systems.
   a. True b. False

Module 7:
Basics of Chemical Feed Systems
Instructor Guide – Answer Key

☑ Chemical Usage Table Exercise

[Refer to the Chemical Usage Table to answer the following questions.]

1. List the chemicals you might add to wastewater to control odor. Include the chemical name and best feeding form for each.
   Ans:
   [($KMnO_4$) Potassium Permanganate. Best feeding form: dry to form solution.
   (H_2O_2) Hydrogen Peroxide. Best feeding form: liquid.
   ($FeSO_4 \cdot 7\ H_2O$) Ferrous Sulfate (Odophos). Best feeding form: dry granular to form solution.]

2. List several chemicals that might be added to wastewater to promote phosphorus removal. Include examples of both dry and liquid chemicals and identify the normal batch strength of the food solution.
   Ans:
   ($Al_2(SO_4)_3 \cdot 14\ H_2O$) Aluminum Sulfate (Alum). Batch strength: 0.5 lb/gal
   ($Al_2(SO_4)_3 \cdot X\ H_2O$)Aluminum Sulfate (Liquid Alum). Batch strength: Neat
   (FeCl3) Ferric Chloride. Batch strength: Neat
   ($Fe_2(SO_4)_3 \cdot X\ H_2O$) Ferric Sulfate. Batch strength: 5.5 lb/gal max.
   ($FeSO_4 \cdot 7\ H_2O$) Ferrous Sulfate (Odophos). Batch strength: 0.5 lb/gal

3. Synthetic organic polymers can be used to enhance the flocculation process in wastewater treatment plants.

a. ___X__ True b. ____ False

4. In a lime stabilization process, if the pH is allowed to fall below 9.0, _biological_ activity could resume and create the potential for offensive odors.

5. Which of the following chemicals are commonly used to supplement alkalinity in wastewater treatment processes? (Check all that apply.)

   a. ___X__ Lime

   b. ___X__ Sodium Hydroxide

   c. ____ Sulphuric Acid

   d. ___X__ Magnesium Hydroxide

   e. ____ None of the above.

Exercise for UNIT 2 – SAFETY AND HANDLING: 5 minutes

[Use the MSDS on pages 2-3 through 2-6 to complete the following.]

1. MSDS stands for

Ans: *[Material Safety Data Sheet]*

2. This MSDS is for what chemical?

Ans: *[Aluminum Sulfate, Liquid]*

3. What protective clothing precautions should you take when working with this chemical?

Ans: *[At least: Chemically protective gloves, boots, aprons, and gauntlets, protective chemical safety goggles, per OSHA eye-and face protection regulations. (Section 8)*

Preferred – All of the above and – Seek professional advice prior to respirator selection and use. Respiratory protection following OSHA regulations, and if necessary wear a MSHA/NIOSH-approved respirator.]

4. List the five components of chemical handling equipment.

Ans: *[Selection of equipment*
Labels and warning signs
Breathing Protection
Protective Clothing
Protective Equipment]

Exercise for UNIT 3 – CHEMICAL DOSAGE CALCULATION: 10 minutes

1. A 1.0 MGD treatment facility uses 12.5 % sodium hypochlorite solution for disinfection. Laboratory testing has determined that the active chemical strength of the hypochlorite is 1.04 pounds of chlorine per gallon. The desired chemical feed rate is 2.5 mg/l.

   Determine the required chemical feed pump setting assuming that the feed pump calibration curve is identical to the alum feed pump in the class problem.

   [Participants work on problem for 5 minutes. Then, provide the solution on the flip chart as follows:]

[Solution:

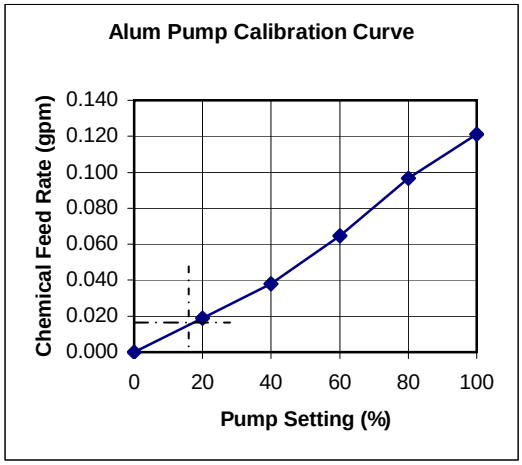
Step 1 – Compute the required chemical feed rate (#/day).

Feed Rate (R) (#/day) = 1.0 (mgd) x 2.5 (mg/l) x (8.34 #/gal)
= 20.85 #/day

Step 2 – Compute the required solution feed rate in gal/day.

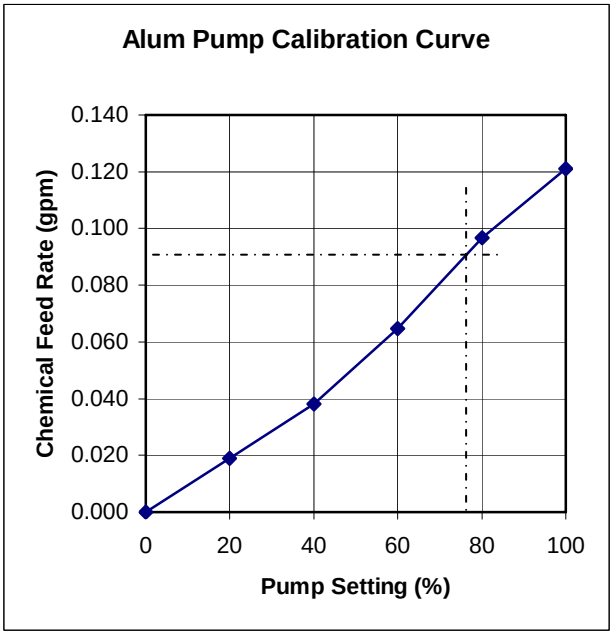
Solution feed (gal/day) = 20.85 #/day ÷ 1.04 #/gal
= 20.05 gal/day
Solution feed (gal/min) = 20.05 gal/day ÷ 1440 min/day
= 0.014 gal/min

Step 3 – Determine feed pump setting using the calibration curve from the class problem.]



Ans: *[Chemical feed rate = 0.014 gal/min ➔ Feed Pump Setting = 14%]*

2. Use the graph in Figure 3.7 to answer this question. From the graph, determine the pump setting if you need a feed rate of 0.090 gpm.



Pump Setting = 75%

3. Match the common liquid feeders below with the range of feed rates needed.

Feeding Pump	Feed Rate
A. c Positive Displacement	a. 0.1 to 10 gph
B. a Solenoid Metering	b. less than 0.1 gph
C. b Peristaltic Pump	c. 0.1 to 600 gph

D. _d_ Jet Pump d. Not defined in our workbook

4. A multi-station Jar Test Stirrer lab equipment station usually has 4 to 6 beakers for simultaneous testing of various strengths of coagulant chemicals.

   a. _X_ True b. ____ False

The two common types of gas feed equipment are _direct_ feed and _solution_ feed.

*****

Exercise for UNIT 4 – CHEMICAL FEED SYSTEMS: 5 minutes

A. Identify each of the following statements with a T for true or F for false.

_____ 1. Chemical storage should be in the vicinity of feeders to avoid necessary handling.

Ans: True

_____ 2. All chemicals should be stored in spill containment areas.

Ans: False (only liquids)

_____ 3. Gaseous chemical storage is usually in an adjacent room or outside building at a location close to the feed room.

Ans: True

_____ 4. The minimum chemical amount of chemical storage is 30 days supply at average use.

Ans: False (10 days supply)

B. What type of Chemical Feed System is represented by the following schematic? Write your answer in the space provided.

Ans: Typical Bulk Liquid Chemical Feed System

C. List the two Feed Systems that require leak detection equipment.

Ans: Liquid and Gaseous

Optional Activity (page 3-13) – Class Problem: 5 minutes

[Divide the class into pairs or small groups and have them solve the problem. After 3 minutes, review the solution on the Flip Chart as with previous examples.]

[Solution: Step 1 – Compute the chemical feed rate in #/day

Phosphorous Loading = 1.0 MGD x 10 mg/l x 8.34 #/gal = 8.34 #/day

Required Aluminum Sulfate = 10 parts/part PO_4 = 10 X 8.34 #/day

= 83.4 #/day

Step 2 – Compute the required solution feed rate in gal/day

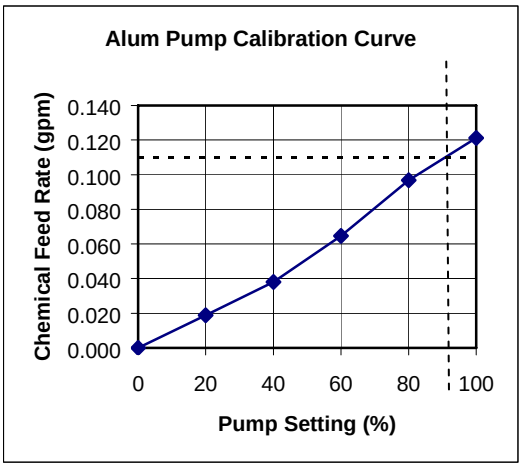
= Solution feed = 83.4 #/day ÷ 0.5 #/gal

= 166.8 gal/day

= 166.8 gal/day ÷ 1440 min/day = 0.11 gal/min (Conversion from gallons per day to gallons per minute (24 hr/day x 60 min/hr = 1440 min/day)]

Display Slide 15—Alum Feed Pump Calibration Curve.

[Step 3 – Establish Feed Pump Setting]



[= Feed Pump Setting = 91 %]

[Step 4 – Compute batching requirements

= Batch strength = 0.5 #/gal

= Batch Quantity = 400 gal

= Chemical Requirement = 0.5 #/gal x 400 gal

= 200 #

Step 5 – Compute batch life

= *Batch volume = 400 gal*
= *Feed rate = 166.8 gal/day*
= *Batch life = 400 gal ÷ 166.8 gal/day*
= 2.4 days]

Module 8:
Overview of Advanced Wastewater Treatment Processes
Instructor Guide – Answer Key

Exercise for Unit 1 – Odor Control

1. Describe some of the maintenance schedules used at your treatment plant:

Ans: *For headworks: is there a chemical addition schedule; is aeration employed routinely?*

For primary clarifiers: are chemicals or air added routinely; are sludge levels checked routinely; are tanks covered?

For anaerobic digesters: is the cover seal checked routinely; is the tank checked for leaks; is the gas burner status automatically checked?

For disinfection systems: is the operation of the chlorinator checked routinely; is the dosage matched to the plant effluent flow rate; is the system checked routinely for leaks; is sludge removed routinely from the contact chamber?]

Exercise

1. What is the importance of mixing in the coagulation process?

Ans: *[Vigorous mixing during coagulation is important to ensure that the coagulants are thoroughly mixed into the waste stream and that the solids particles make physical contact with each other.]*

2. What is flocculation?

Ans: *[Flocculation is the actual gathering together of smaller suspended particles into flocs, thus forming a readily settleable mass.]*

3. Briefly describe the jar test procedure.

Ans: [*Various types of chemicals or different doses of a single chemical are added to sample portions of wastewater in a jar test unit and all portions of the samples are rapidly mixed. After rapid mixing, the samples are slowly mixed to approximate the conditions in the plant. Mixing is stopped and the floc formed is allowed to settle. The appearance of the floc, the time required to form a floc, and the settling conditions are recorded. The supernatant is analyzed for turbidity, suspended solids, and pH. With this information the operator selects the best chemistry or best dosage to feed on the basis of clarity of effluent and minimum cost of chemicals.]*

Exercise

1. When should a gravity filer be cleaned?

Ans: *[A gravity filter should be cleaned when the solids capacity of the media has nearly been reached but before solids break through into the effluent.]*

2. How is head loss through the filter media determined?

Ans: [*The head loss through the filter media is determined by measuring the water pressure above and below the filter media. When water flows through the media, the pressure below the media will be less than the pressure above the media (when the pressure levels are measured or read at the same elevation). The difference between the two readings is the head loss.]*

3. What can happen if the filter media is not thoroughly cleaned during each backwashing?

Ans: *[If the filter media is not thoroughly cleaned during each backwashing, a buildup of solids will occur. The end result of incomplete cleaning is the formation of mudballs within the bed].*

Exercise

1. List the major components of a pressure filter system.

Ans: *[The major components of a pressure filter system include: a holding tank or wet well; filter feed pumps; chemical coagulant feed pump system; filters; filter backwash wet well; filter backwash pumps; and decant tank.]*

2. What is the purpose of the holding tank located just ahead of a pressure filter?

Ans: *[The purpose of the holding tank is to store water and to allow additional settling of the suspended solids before the water is applied to the filter.]*

3. What could cause high operating filter differential pressures?

Ans: *[High operating differential pressures could occur if either (1) the media is filled with suspended material; and/or (2) excessive chemical feed is blinding the media].*

Exercise

1. What happens if the air lift is allowed to operate without wastewater flowing to the filter?

Ans: *[Dirty sand will be carried to the top of the filter and deposited at the top of the sand bed. This dirty sand will slough off solids into the filter effluent when the filter is restarted for normal operation.]*

2. What are the advantages of continuous backwash, upflow, deep-bed silica sand media filters over other types of granular media filters?

Ans: *[They do not need to be shut down to clean the filter media, consequently they can be run continuously. Therefore, they can provide the same filtration capacity using fewer or smaller filter systems. Also, they provide excellent quality effluent with very low turbidity because of the deep-bed media design.]*

3. How is silica sand media cleaned in a continuous backwash, upflow, deep-bed silica sand media filter?

Ans: *[Dirty sand is carried to the top of the filter by an air lift pump. Sand and dirty water are separated there and the dirty sand falls through a baffled launder where it is contacted with upflowing filtered water. This water helps to clean the sand as it passes through the launder and it carries the sloughed solids to the reject compartment where they are discharged over a weir. The clean sand falls out of the launder onto the top of the sand bed, replenishing the sand bed with clean sand.]*

Exercise

1. How do cross flow filtration processes differ from conventional filtration?

Ans: *[In cross flow filtration, wastewater flows across the surface of a membrane rather than through a bed of granular media. The membrane permits water to pass through but blocks the passage of particles. Other differences include the length of the filter run and the ease of cleaning the membranes.]*

2. The amount of flux across a membrane is dependent on what factors?

Ans: *[The amount of flux across a membrane is dependent upon transmembrane pressure (driving force), flow rate across the membrane surface (turbulence on the membrane), concentration of waste material, temperature, viscosity and cleanliness of the membrane surface.]*

3. List the steps for cleaning (washing) a membrane.

Ans: *[The steps are as follows:*

1. *Displacement of waste from the system with water.*
2. *Washing the membranes with a caustic and surfactant to remove oils and grease.*
3. *Flushing the surfactant from the membrane with warm water.*
4. *Washing the membrane with an acid cleaner to remove salt buildup.*
5. *Flushing the acid from the membrane with warm water.*
6. *Recording clean water flux as a check on cleaning effectiveness.]*

REVIEW QUESTIONS:

1. What is the luxury uptake of phosphorus?

Ans: *[It is a microbiological process in which the wastewater environment is manipulated to encourage the microorganisms to absorb more phosphorus into their cell mass then they would normally absorb.]*

2. The phosphorus stripping process using luxury uptake is similar to an activated sludge plant with the exception of what tanks?

Ans: *[Anaerobic selector tank]*

3. Why is it important to closely control the detention time in the anaerobic phosphorus stripping tank?

Ans: *[Because if the microorganisms are kept in the tank too long, they will die. If they are not kept in there long enough, they will not be forced to release phosphorus from their cell mass.]*

REVIEW QUESTIONS:

1. What is a typical pH range for operation of a lime precipitation system for phosphorus removal?

Ans: *[pH of 10 to 11]*

2. Why would you perform a jar test when removing phosphorus by the lime precipitation process?

Ans: *[Jar tests can be used to determine what pH levels and polymer dosages form the largest floc possible and allow the fastest settling of the floc formed.]*

3. When removing phosphorus by the lime precipitation process, the phosphorus concentration normally does not control the lime dosage required, what does?

Ans: *[The amount of alkalinity present controls the lime dosage.]*

Exercise for Unit 3 – Phosphorous Removal

1. How would you determine the optimum alum dosage for phosphorus removal?

Ans: *[Conduct a jar test to find the dosage that produces the best clarification with the least amount of alum. Confirm the removal by testing the supernatant for phosphorus.]*

2. What would you do first if you observed a cloudy appearance in the effluent from a filtration unit in a phosphorus removal system that uses alum?

Ans: *[Check to make sure that the alum feed system is not overdosing because the cloudy condition of the effluent is indicative of an alum overdose.]*

3. What safety hazard might operators encounter in areas where aluminum sulfate is mixed with water?

Ans: *[Slippery surfaces, especially slippery floors.]*

4. Two chemical processes are commonly used to remove phosphorus from wastewater are __lime__ precipitation and __alum__ flocculation and precipitation.

5. A polymer is often used as a flocculation aid with alum, because the aluminum phosphate precipitate is not dense enough to provide adequate removal.
   a. __X__ True b. ____ False

6. Luxury uptake is a term used to describe a reaction of microorganisms after they have been depleted of _phosphorous_.

7. Aerobic is a condition in which atmospheric or dissolved molecular _oxygen_ is present in the aquatic environment.

8. A strict anaerobic environment is necessary in the anaerobic selector to force the microorganisms to utilize the polyphosphates in their cell mass for energy to survive their stay in the anaerobic selector.

   a. _X_ True b. ____ False

9. Typically, the pH of the wastewater will be raised to the range of _10_ to _11_ with the addition of lime to properly precipitate the phosphorus present.

10. When alum is mixed with wastewater, it acts as an acid, reducing the pH of the wastewater (by reducing alkalinity). Optimum phosphorus removal is generally achieved at a pH range of approximately _6.0_ to _7.0_.

11. _pH_ testing is recommended to optimize the alum dosage and to avoid overdosing.

Exercise

1. Nitrification can be accomplished by the use of what two types of biological growth reactors?

Ans: ***[****Nitrification can be accomplished by using suspended growth reactors or attached growth reactors.]*

2. What can an operator do to maintain sufficient alkalinity in a nitrification process?

Ans: *[Sufficient alkalinity can be maintained in a nitrification process by adding calcium oxide (lime) or soda ash.]*

3. What tests must be conducted to monitor nitrogen levels in the reactors during the nitrification process?

Ans: *[Nitrogen tests that must be performed at various key points along the reactors during the nitrification process include ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). A predominance of ammonia indicates inadequate nitrification. A predominance of nitrite indicates incomplete nitrification. A predominance of nitrate, with essentially no ammonia, indicates successful nitrification.]*

Exercise

1. Explain how the breakpoint chlorination process works.

Ans: *[By adding sufficient quantities of chlorine to wastewater containing ammonia nitrogen, the complete oxidation of the ammonia nitrogen takes place at a level of chlorine addition normally referred to as the "breakpoint".]*

2. What is the appropriate application for breakpoint chlorination?

Ans: *[Secondary or filtered effluent is the appropriate application for breakpoint chlorination. Breakpoint chlorination also is frequently used as final cleanup following other nitrogen removal processes.]*

Module 9:
Basics of Pumps and Hydraulics
Instructor Guide – Answer Key

Activity 1.1: Convert 45 psi to feet of head.

***[Ans**: 45 psi x $\frac{1 \text{ ft.}}{0.433 \text{ psi}}$ = 103.8 ft]*

Activity 1.2: Determine pressure (in psi) on the wall of a sedimentation basin 2 ft., 5 ft., and 10 feet below the water surface.

[Ans**: 2 ft. x 0.433 psi/ft. of head = 0.866 **psi

*5 ft. x 0.433 psi/ft. of head = 2.165 **psi***

*10 ft. x 0.433 psi/ft. of head = 4.33 **psi]***

Activity 1.3: What is upward force on an empty tank caused by a groundwater depth of 8 feet above the tank bottom? The tank is 20 feet by 40 feet.

***[Ans:** Head pushing up on bottom is 8 ft.*

Pressure pushing up on bottom is 8 ft. x 0.433 psi/ft. = 3.464 psi (pounds per square inch)

Next, convert to pounds per square feet. Since there are 144 sq. in. in 1 sq. ft., pressure is 3.464 psi x 144 sq. in./sq. ft. = 499 lbs/sq. ft.

Total force is pressure x area

Area of basin bottom is 20 ft. x 40 ft. = 800 sq. ft.

*Total force = 499 lbs./sq. ft. x 800 sq. ft. = 399,200 **lbs.]***

Example 1.2: Determine factor to convert cfs to gpm.

***[Ans:** There are 7.48 gallons in one cu. ft.*
There are 60 seconds in one minute.
Therefore

$$\frac{1 \text{ cu. ft.}}{\text{sec.}} \times \frac{7.48 \text{ gal.}}{\text{cu. ft.}} \times \frac{60 \text{ sec.}}{\text{min.}} = \frac{449 \text{ gal.}}{\text{min.}} \text{ (gpm)]}$$

Activity 1.4: Determine factor to convert MGD to gpm.

***[Ans:** There are 60 min./hr. x 24 hr./day = 1,440 min./day*
Therefore,

$$\frac{1{,}000{,}000 \text{ gal.}}{\text{day}} \times \frac{1 \text{ day}}{1{,}440 \text{ min.}} = \frac{694 \text{ gal.}}{\text{min.}} \text{ (gpm)]}$$

Activity 1.5: Determine factor to convert MGD to cfs.

[Ans: *There are 60 sec./min. x 60 min./hr. x 24 hr. day = 86,400 sec./day*
As previously stated, there are 7.48 gallons in 1 cu. ft.
Therefore,

$$\frac{1{,}000{,}000 \text{ gal.}}{\text{day}} \times \frac{1 \text{ day}}{86{,}400 \text{ sec.}} \times \frac{1 \text{ cu. ft.}}{7.48 \text{ gal.}} = \frac{1.547 \text{ cu. ft.}}{\text{sec.}} \text{ (cfs)]}$$

Activity 1.6: A rectangular channel 3 ft. wide contains water 2 ft. deep flowing at a velocity of 1.5 fps. What is the flow rate in cfs?

[Ans: *First determine the Area (A).*
Cross sectional area is 3 ft. x 2 ft. = 6 sq. ft.

Using the Continuity Equation (Q = V x A)
Q = 1.5 fps x 6 sq. ft. = 9.0 cfs]

Activity 1.7: Flow in an 8-inch pipe is 500 gpm. What is the average velocity?

[Ans: *First determine the Area (A)*

$$\text{Area of an 8-inch pipe} = \frac{\pi \times 8^2}{4} \text{ sq. in.} \times \frac{1 \text{ sq. ft.}}{144 \text{ sq. in.}} = 0.349 \text{ sq. ft.}$$

$$\text{Flow rate(Q) in cfs} = 500 \text{ gpm} \times \frac{1 \text{ cfs}}{449 \text{ gpm}} = 1.11 \text{ cfs}$$

Re-arrange Continuity Equation to solve for velocity

$$Q = V \times A \;\gg\; V = Q/A$$

Therefore, V = 1.11 cfs ÷ 0.349 sq. ft. = 3.18 fps]

Optional Activity 2.1: What is the flow rate in the channel described in Figures 2.2 and 2.3? Use the Manning Equation to determine V (flow velocity) and the Continuity Equation to determine flow rate.

[Ans*:*

1. *Using Manning Equation:*

$V = \frac{1.49}{0.014} \times 0.857^{(2/3)} \times 0.006^{(1/2)} = 7.44$ fps

2. *Using Continuity Equation:*

Q = V x A = 7.44 fps x 6 sq. ft. = 44.6 cfs]

Activity 2.2: What is the flow (gpm) in a sedimentation basin effluent trough, 20 feet long, with 90-degree V-notch weirs along both sides, if the V-notches are spaced 6-inches apart and the head over the weirs is 1.5 inches?

[Ans: *Calculate the number of V-notches in the trough:*
n = (20 ft. ÷ 0.5 feet per notch) x 2 sides = 80 notches

Convert head over weir from inches to feet:
1.5 inches ÷ 12 inches/ft. = 0.125 feet

Calculate the flow using the V-notch weir equation:
$Q = 2.5 \times (0.125)^{(5/2)} \times 80$ notches = 1.105 cfs

Convert from cfs to gpm:
1.105 cfs x 449 gpm/cfs = 496 gpm]

Exercise for Unit 2 – Open Channel Gravity Flow

1. The two devices used most often to measure open channel flow rate are flumes and weirs .

2. In a steady state open channel flow situation which of the following factors stay the same from the upstream end of the channel to the downstream end of the channel:

   a. _____ shape of the channel
   b. _____ depth of flow
   c. _____ flow velocity
   d. _x_ all of the above

3. The Manning formula is used to estimate friction losses in open channel steady state flows.

4. For most commonly used pipe materials the roughness coefficient (n) can be estimated to be:

   a. _____ zero
   b. _____ 0.010
   c. __x__ 0.014
   d. _____ 0.35

5. Slope is the difference in elevation between upstream and downstream ends of a channel divided by the horizontal length of the channel. Slope is expressed in units of __ft / ft__.

6. Each occurrence of minor losses will contribute approximately __0.2__ to __0.3__ feet of head losses in open channel flow.

7. Weirs should not be used with:

   a. _____ treated wastewater
   b. _____ clean spring water
   c. __x__ untreated waste water
   d. _____ all of the above

Activity 3.1: What would the head and pressure at Point D be?

***[Ans**: Head would be 3.0 feet. Pressure would be 3.0 x 0.433 = 1.3 psi]*

Exercise for Unit 3 – Pressure Flow in Force Mains

1. Explain the difference between pressure flow in force mains and flow in an open channel.

   Answers may vary somewhat, but in an open channel the top of the channel may be open to the atmosphere or it could be a partially filled pipe with the air above the water level is open to the atmosphere. In pressure flow in force mains, the pipes are completely filled with water and the water is not open to the atmosphere.

2. HGL is the abbreviation for Hydraulic Grade Line.

3. A friction loss in water flow is caused by turbulence along the walls of the pipes.
4. List three examples of things that will cause minor losses:
    a. See Figure 3.4
    b. See Figure 3.4
    c. See Figure 3.4

5. Which of the following devices would normally be expected to have the greatest minor loss?
    a. _____ Butterfly Valve 15 inch
    b. _____ 90 degree bend 12 inch
    c. __X__ Swing Check Valve
    d. _____ Gate Valve

6. The difference in elevation of the HGLs at the ends of a flow system is called Static Head.
7. Explain why a magnetic flow meter is less susceptible to clogging than a venturi meter. The magnetic flow meter has an open unobstructed design that will not trap debris or solids.

Activity 4.1: If a pump is operating at 2,200 gpm and 60 feet of head, what is the water horsepower? If the pump efficiency is 71%, what is the brake horsepower?

[Ans: *Water Horsepower = $\frac{2{,}200 \times 60}{3{,}960}$ = 33.3 HP*

Brake Horsepower = $\frac{33.3}{0.71}$ = 46.9 HP]

Activity 4.2: If operating at 60 ft of head, what are flow, efficiency, and brake horsepower?

Ans: *[Find 60 feet on the y-axis. Move right until you intersect the Head/Flow curve. From this point move straight down until you intersect the x-axis. Read the flow from the x-axis (520 gpm).*

From 520 gpm on the x-axis, move straight up until you intersect the efficiency curve. From this point move to the left until you intersect the y-axis. Read the efficiency from the y-axis (73%).

From 520 gpm on the x-axis, move straight up until you intersect the Brake Horsepower curve. From this point move to the right until you intersect the vertical axis. Read the brake horsepower from the right vertical axis (10.8 HP).

Check the numbers read from the graph using the formula on page 4-3 of the participant workbook.

Brake Horsepower = $\frac{520 \times 60}{3{,}960 \times 0.73}$ *= 10.8 HP - Check]*

Exercise for Unit 4 – Pump Types and Applications

1. A pump has an efficiency rating of 65%. How much horsepower is actually applied to the water if 100 HP is applied to the shaft of the pump?

   a. _____ 35 HP b. __X__ 65 HP c. _____ 165 HP d. _____ 15.38 HP

2. The impeller in a centrifugal pump can be either open or closed.

   a. __X__ True b. _____ False

3. The system head in a system will decrease as the system flow increases.

   a. _____ True b. __X__ False

4. __Positive__ displacement pumps are usually used to pump water with a very high solids concentration, such as waste sludge.

5. Suction pumps may create small cavities in the flow of water due to pockets of water vapor. The collapse of these cavities is called __cavitation__.
