

# Drinking Water Operator Certification Training Instructor Guide



## Module 1: General Overview Volume II

Revised April 2013

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)  
Gannett Fleming, Inc.  
Dering Consulting Group  
Penn State Harrisburg Environmental Training Center

# Drinking Water Operator Certification Training



## Module #:2 Groundwater Sources of Supply and Protection Excerpts

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**Slide 53 – Groundwater Sources of Supply and Protection**

We are going to review a few topics from the Groundwater module.

Turn to page i and look at the content descriptions.

**Topical Outline**

**Unit 1 – Introduction to Groundwater**

- I. Definitions
- II. Types of Water
  - A. Atmospheric Water
  - B. Surface Water
  - C. Groundwater
- III. Hydrologic Cycle
  - A. Overview
  - B. Process
  - C. Hydrologic Cycle in Pennsylvania
- IV. Groundwater Usage
  - A. Groundwater in the United States
  - B. Groundwater in Pennsylvania

**Unit 2 – Aquifers**

- I. Types of Aquifers
  - A. Unconfined Aquifer
  - B. Confined Aquifer
  - C. Perched Water Table
- II. Pennsylvania Aquifers
  - A. Sand and Gravel Aquifers
  - B. Sandstone and Shale Aquifers
  - C. Carbonate Rock Aquifers
  - D. Crystalline Rock Aquifers

- III. Groundwater Sources
  - A. Wells
  - B. Springs
  - C. Infiltration Galleries, Radial Collector

Turn to page 1-2 and notice the definitions.

**INSTRUCTOR NOTE:** The module content that is not reviewed during this quick walk through has been deleted in this Instructor Guide. **Instructors should read the additional content that includes questions and the yellow highlighted text.**

# Unit 1 – Introduction to Groundwater

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## Learning Objectives

- Define evaporation, transpiration, evapotranspiration, groundwater, and water table.
- List three types of water and explain each.
- Explain the steps in the Hydrologic Cycle.



**Evaporation** – the change by which any substance is converted from a liquid and carried off as a vapor. It is one of the processes of returning moisture to the atmosphere. Water on any surface (especially ponds, streams, lakes, and oceans) is warmed by the sun until it turns into vapor, or its gaseous form, and rises into the atmosphere.



**Evapotranspiration** – the combined net effect of evaporation and transpiration.



**Groundwater** – underground water located in the zone of saturation below the water table.



**Hydrologic Cycle** – the exchange of water between the earth and the atmosphere through evapotranspiration and precipitation.



**Infiltration** – the entry of water into the soil through cracks, joints, and pores in the soil and rock structure. This is also referred to as percolation.



**Surface Runoff** – the movement of water, usually from precipitation, across the land surface toward stream channels, lakes, depressions, or other low spots.



**Surface Water** – water found on the surface of the land. Usually refers to puddles, ponds, lakes, streams, rivers, and oceans.



**Transpiration** – the direct transfer of water from the leaves of living plants to the atmosphere. Plants take up water through the roots and then lose some through pores in the leaves. As warm air passes over the leaf surface the moisture evaporates into the air.



**Water Table** – the boundary below which all of the spaces and cracks in the soil and rock are filled with water.



**Zone of Saturation** – the area below the groundwater table.

Water is one of earth's basic materials. It can be found around, on, and within the earth.



### Atmospheric Water

Atmospheric water is the water that is found in the air *surrounding* the earth. It can be seen as clouds, fog, and forms of precipitation like rain, snow, and sleet.



### Surface Water

Surface water is water that is *on top* of the earth's surface. This water can be fresh water or salt water and can be seen as oceans, lakes, rivers, or streams.

- ▶ Fresh water – water which is or can be treated to be drinkable.
- ▶ Salt water – water which contains too much dissolved salt and other minerals to be drinkable.

### Groundwater

Groundwater is water that is found *below* the earth's surface. It includes both fresh water and salt water. Groundwater is found in saturated soil, as shown below, or in fractures in the bedrock.

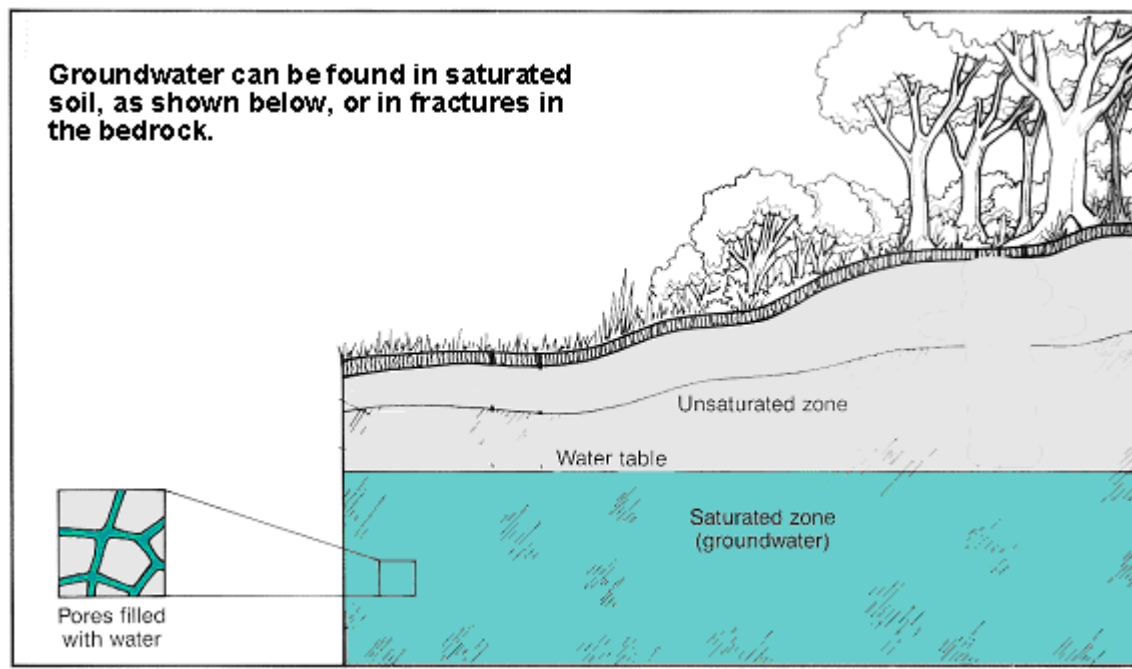


Figure 1.1 - Groundwater



**Slide 54 – Sources of Groundwater for Drinking**

Sources of Groundwater for Drinking Include:

- ▶ Water obtained from dug, drilled, bored, jetted or driven wells.
- ▶ Water obtained from Infiltration Galleries and Radial Collectors.
- ▶ Water obtained from springs.
  - To be classified as a groundwater source, springs must not come into contact with any potential surface water. Therefore, the spring source must be developed within a “springhouse” to protect the source quality.
  - Additionally, the spring source must be evaluated and tested to assure that surface water will not directly contaminate the spring.

Turn to page 1-4 and read the last 2 sentences.



**Slide 55 - GUDI**

Groundwater sources are subject to the direct influence of water that has been classified as a surface water source. If it is determined that the groundwater source has been influenced by surface water, the groundwater source would then require treatment as surface water.

*Q. What's another term we use for groundwater sources that are subject to the direct influence of surface water?*

A. (GUDI)

*Q. What are the consequences of being determined as a GUDI source?*

A. Provide treatment as if it is a surface water system.

*Q. What types of treatment do surface water systems need to provide?*

A. Disinfection and filtration



Turn to page 1-5 and let's look at the hydrologic cycle. These are physical changes that water undergoes continuously.

### Overview



#### Slide 56 – Hydrologic Cycle

The exchange of water between the earth and the atmosphere through evaporation and precipitation is known as the Hydrologic Cycle.

The Hydrologic Cycle is continuous—no starting or ending point.

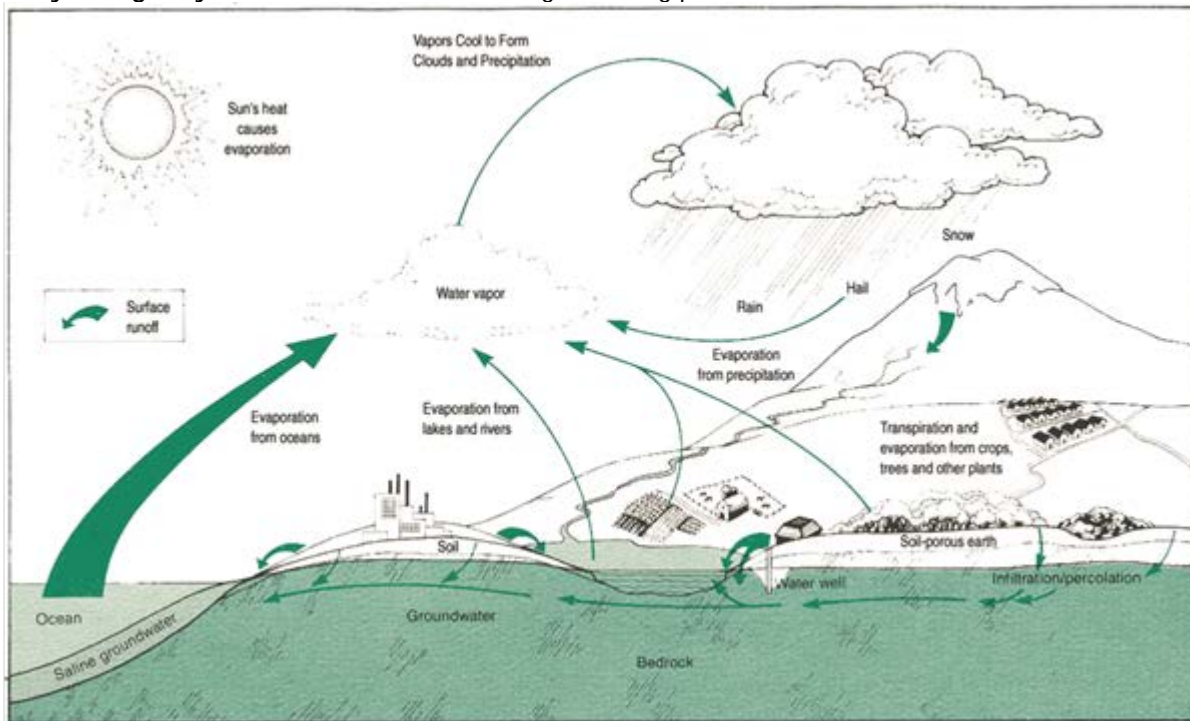


Figure 1.2 - Hydrologic Cycle<sup>1</sup>

### Process

#### Precipitation

Rain or snow falls on the land surface.

- Some of the water flows on the surface to lakes, streams, and wetlands as surface runoff.

#### Evaporation

Most of the precipitation evaporates back into the atmosphere from the ground surface where it condenses and falls again as precipitation.

Pages 1-6 through 1-9 describe the process.

**Infiltration**

The remaining water infiltrates into the ground where one of two things occurs.

- ① Some water is taken up by plant roots and transpired by plants back into the atmosphere where it condenses and falls again as precipitation. This is known as **Transpiration**.

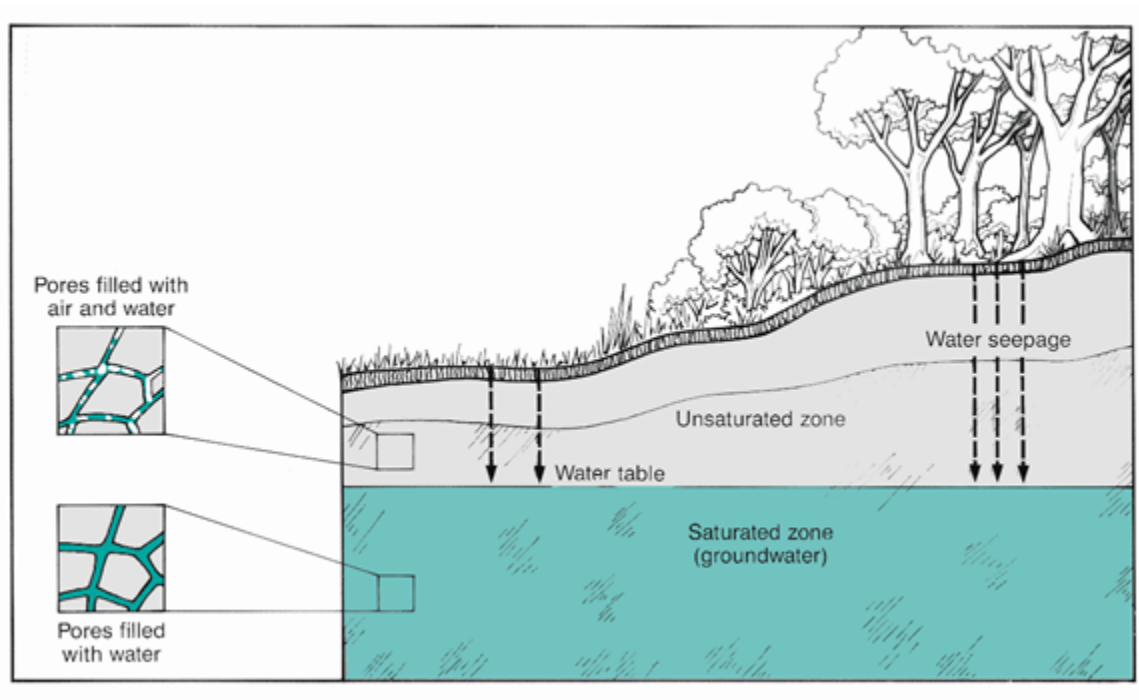


Figure 1.3 - Groundwater Infiltration <sup>2</sup>

- ② The remaining water filters down through an unsaturated zone where the spaces (pores) between the soil particles and rock contain both air and water.

Eventually water reaches the Water Table—the boundary below which all of the spaces and cracks in the soil or rock are filled with water—recharging the groundwater system.

- Zone of Saturation – area where all pore spaces are filled with water
- Water Table – the top of the zone of saturation
- Water below the water table is in Groundwater Storage

## Discharge

The Groundwater moves through the ground, eventually surfacing at an area of discharge—a spring, stream, lake, or wetland.

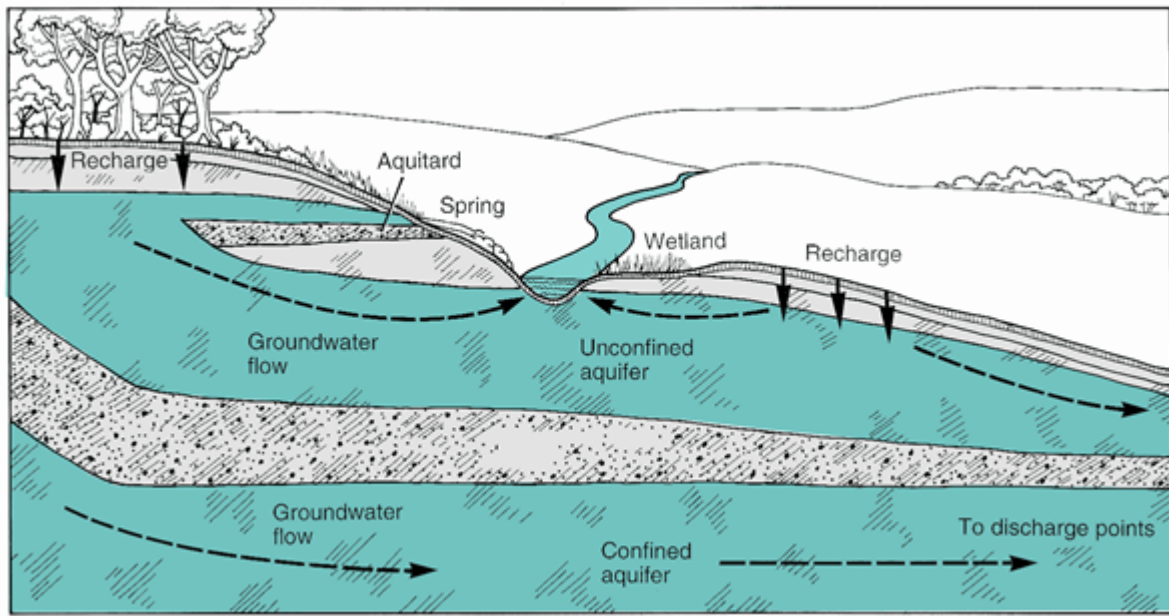
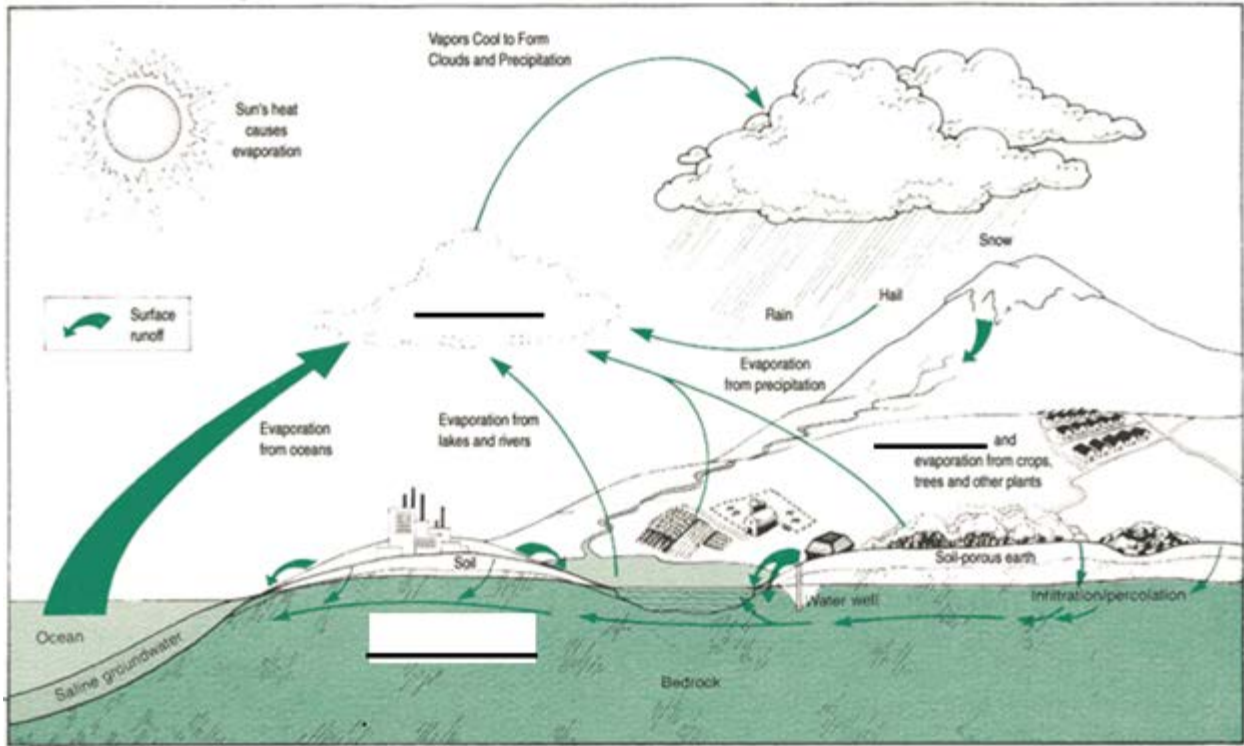


Figure 1.4 - Groundwater Movement <sup>3</sup>

The Water Cycle is complete when **evaporation** from the surface returns this water back to the atmosphere.

Regardless of its origin, water moves between the subsurface, surface, and atmosphere via the Hydrologic Cycle.

Exercise: Fill in the blanks (3 of them) in this Hydrologic cycle:



*Answers: Bottom: groundwater, Center: Water vapor, Right: Evaporation [Ask participants for their answers before you tell them the correct ones.]*

## Hydrologic Cycle in Pennsylvania

### Precipitation

Each year, on average, 41 inches of precipitation falls in Pennsylvania.

- ◆ 6 inches enters streams and lakes directly either as surface runoff or as flow from the unsaturated zone.
- ◆ 20 inches returns to the atmosphere through evaporation and transpiration (evapotranspiration).
- ◆ Remaining 15 inches infiltrates and moves downward to the zone of saturation to recharge groundwater.

## Groundwater Recharge

In Pennsylvania, most groundwater recharge occurs in the spring.

- ◆ Plenty of water from rain and snow melt.
- ◆ Plants not yet actively growing and are not taking water from the soil.
- ◆ Amount of sunlight is less, so evaporation is less.

Following spring recharge, the water table usually lowers steadily during the summer, fall, and winter.

## Recharge Rates

Recharge or infiltration rates vary with type of land cover. Generally,

1. The higher percentage of impervious area in urban areas (sidewalks and roads) results in higher surface runoff and lower infiltration (lower recharge).
2. Forested areas have higher infiltration (higher recharge) due to limited impervious area and therefore less surface runoff.

## Groundwater in the United States

According to United States Geological Survey (USGS), in the United States, Groundwater provides:

- 51% of all drinking water
- 99% of drinking water for the rural population

## Groundwater in Pennsylvania

Pennsylvania groundwater includes both fresh and salt water.

- Salt water can be found beneath fresh water almost everywhere at depths ranging from 200 to over 1000 feet. It contains much more salt than seawater and is called brine or brackish water.
- Pennsylvania has 30 times more groundwater than surface water.
- Groundwater provides two thirds of the water to our surface water streams, lakes, and wetlands.

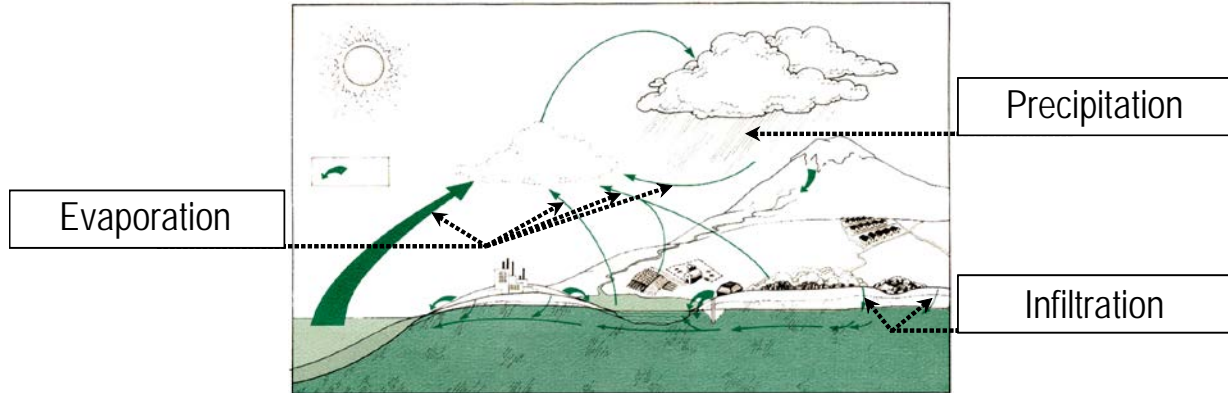
### Pennsylvania Groundwater Statistics

- Ranks 2<sup>nd</sup> (after Michigan) for total number of wells, 2<sup>nd</sup> (after Michigan) for number of household wells, and 3<sup>rd</sup> (after Wisconsin and New York) for number of public water supply wells.
- 33.7% of Pennsylvania's population depends on groundwater for its drinking water supply.
- 978,200 households (2.5 million residents) served by private individual wells.
- 17,500 public supply wells serving 1.5 million residents.
- 243 million gallons per day (MGD) of groundwater supplied by public water systems.



Unit 1 Exercise

1. On the diagram below, label the following parts of the Hydrologic Cycle: Precipitation, Evaporation and Infiltration.



2. In addition to surface water, name two other types of water below and briefly describe each.

A. Groundwater – found beneath earth's surface

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B. Atmospheric water – found in air surrounding the earth – clouds, fog, and precipitation

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3. Match the word with its definition:

| Word Pool          |               |             |
|--------------------|---------------|-------------|
| Evapotranspiration | Transpiration | Groundwater |
| Evaporation        | Water Table   |             |

|                    |  |
|--------------------|--|
| Evaporation        | 1. When water turns into a vapor and returns to the atmosphere   |
| Transpiration      | 2. When water travels through a plant and some evaporates directly from plant to air                           |
| Evapotranspiration | 3. Loss of water by evaporation from the soil and transpiration from plants                                    |
| Groundwater        | 4. Water found beneath earth's surface (can be fresh or salt water). This is our largest source of fresh water |
| Water Table        | 5. The boundary below which all of the spaces and cracks in the soil and rock are filled with water            |

**Slide 57 – Key Points for Unit 1**

Let's turn to page 1-12 to review Unit 1 key points.

*Instructor Note: Read the key points on 1-12.*

**Key points for Unit 1 – Introduction to Groundwater**

- The three types of water are: atmospheric water, surface water, and groundwater.
- Surface water can be classified as fresh water or salt water.
- Groundwater can be either fresh water or salt water.
- The water table is the boundary below which all of spaces and cracks in soil and rock are filled with water.
- Springs can be considered a groundwater source if they are protected from coming into contact with surface water.
- Infiltration of surface water through the water table and into the zone of saturation is also called percolation.
- The hydrologic cycle is continuous and involves the physical changes that water undergoes which are precipitation, evaporation, infiltration, and discharge of water.
- Most groundwater recharge occurs in the spring in Pennsylvania.
- Groundwater in Pennsylvania can contain both fresh water and salt water.

**Let's look at Unit 2 Aquifers**

We aren't going to spend much time in this unit but let's look at page 2-2 to review the definition of aquifer.



## Unit 2 – Aquifers

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### Slide 58 – Unit 2 Objectives

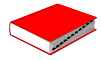
#### Learning Objectives

- List four types of groundwater aquifers found in Pennsylvania
- Identify on a map, the location of Pennsylvania's principal groundwater aquifers.
- Describe the geology of each of the four aquifers.
- List three common types of groundwater sources found in Pennsylvania.

The key to this definition is the term “water-bearing”.



Slide 59 - Aquifer



**Aquifer** - A water-bearing stratum of rock, sand, or gravel.

A stratum is a layer of earth. Therefore, an aquifer could be a layer of limestone, which contains or carries water.

There are three types of Aquifers: Unconfined Aquifer, Confined Aquifer, and, Perched Aquifer or Perched Water Table.

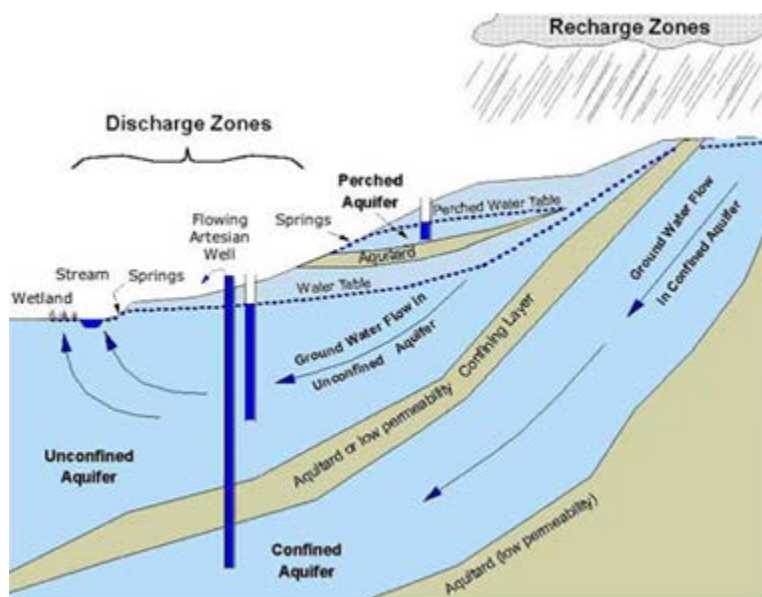


Figure 2.1 - Types of Aquifers

### Unconfined Aquifer or Water Table Aquifer

- Groundwater that is not surrounded by soil or rock on all sides.
- Groundwater is under atmospheric pressure.
- This type of aquifer may feed such surface water sources as springs or streams

### Confined Aquifer

- Groundwater is sandwiched between two impermeable layers or aquitards.
- Confined Aquifers are under pressure greater than atmospheric.

Pages 2-2 through 2-8 describe specific types of aquifers based on their geology.

### Perched Water Table

- Groundwater collects above an impermeable layer above the water table.
- The Perched Water Table usually doesn't hold much water.

 Slide 60 – Types of Aquifers

In Pennsylvania groundwater aquifers are divided into four groups based upon their geology: Sand and Gravel Aquifers, Sandstone and Shale Aquifers, Carbonate Rock Aquifers and Crystalline Rock Aquifers. Each of these has distinct locations, geologies, yields and qualities. The following map and charts help to illustrate these factors.

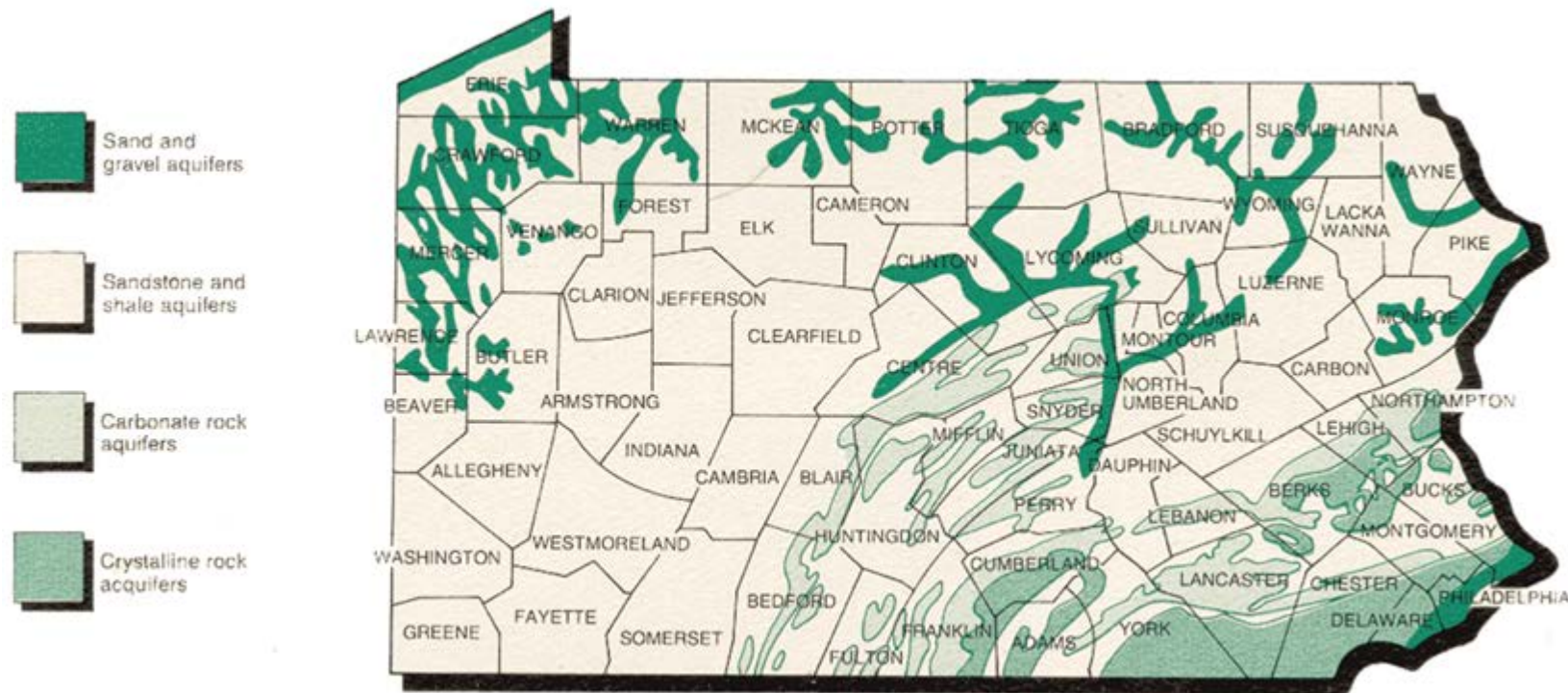


Figure 2.2 - Pennsylvania's Aquifer Distribution

## Sand and Gravel Aquifers

|                 |  |
|-----------------|--|
| <b>Location</b> | <ul style="list-style-type: none"> <li>◆ Southeastern coastal plain, along Delaware River</li> <li>◆ Along Lake Erie shoreline</li> <li>◆ In most major stream valleys</li> </ul>  |
| <b>Geology</b>  | <ul style="list-style-type: none"> <li>◆ Unconsolidated sand and gravel deposits of various geologic formations</li> <li>◆ Vertically separated by clayey or silty confining layers               <ul style="list-style-type: none"> <li>▶ retard vertical flow</li> <li>▶ 60 – 75% of recharge is from upland runoff</li> <li>▶ Contain saline water in places, especially near salt water coastline</li> </ul> </li> </ul>   |
| <b>Yields</b>   | <ul style="list-style-type: none"> <li>◆ Contain large quantities of water</li> <li>◆ Easily withdrawn</li> <li>◆ Well yields of 100 – 800 gallons per minute (gpm)               <ul style="list-style-type: none"> <li>▶ Yield in excess of 1000gpm are common</li> </ul> </li> </ul>  |
| <b>Quality</b>  | <ul style="list-style-type: none"> <li>◆ Quality is variable, but generally good to excellent</li> <li>◆ Typical quality:               <ul style="list-style-type: none"> <li>▶ Dissolved solids – 250 milligrams per liter (mg/l)</li> <li>▶ Hardness – 140 mg/l (hard)</li> <li>▶ pH – 7.2</li> <li>▶ Iron – 0.1 mg/l</li> <li>▶ Nitrate – if found is generally due to surface contamination by fertilizer, animal wastes, or sewage.</li> </ul> </li> <li>◆ Especially susceptible to contamination by human activities.</li> </ul> |

## Sandstone and Shale Aquifers

|                 |   |
|-----------------|---|
| <b>Location</b> | <ul style="list-style-type: none"> <li>◆ Predominant bedrock aquifer in PA</li> <li>◆ Located in the sandstone, siltstone, and shale areas throughout the state.</li> </ul>   |
| <b>Geology</b>  | <ul style="list-style-type: none"> <li>◆ Consolidated sedimentary rock</li> <li>◆ Almost flay-lying to gently folded</li> <li>◆ Principal coal-bearing formations, consisting of cyclic sequences of sandstone, shale, conglomerate, clay, coal, and minor limestone.</li> <li>◆ Sandstones are the principal water-yielding units</li> <li>◆ Springs common               <ul style="list-style-type: none"> <li>▶ Low permeability rocks, such as shale, siltstone, or ironstone retard vertical water movement.</li> <li>▶ Lateral water movement surfaces at intersections with valley wall.</li> </ul> </li> </ul>   |
| <b>Yields</b>   | <ul style="list-style-type: none"> <li>◆ Interlayered – can be more than one water bearing zone in a vertical thickness</li> <li>◆ Well yields are lower than sand and gravel aquifers               <ul style="list-style-type: none"> <li>▶ Well yields of 20 to 400 gpm</li> </ul> </li> <li>◆ Wells located on fracture intersections can have substantially increased yields</li> </ul>  |
| <b>Quality</b>  | <ul style="list-style-type: none"> <li>◆ Quality of freshwater is somewhat variable but generally satisfactory</li> <li>◆ Typical quality               <ul style="list-style-type: none"> <li>▶ Dissolved solids – 230 milligrams per liter (mg/l)</li> <li>▶ Hardness – 95 mg/l (moderately hard)</li> <li>▶ Water from shale aquifers usually reported to be hard</li> <li>▶ Water from sandstone aquifers usually reported to be soft                   <ul style="list-style-type: none"> <li>▪ pH – 7.3</li> <li>▪ Iron – 0.1 mg/l</li> </ul> </li> </ul> </li> <li>◆ Fresh groundwater circulates only to shallow depths</li> <li>◆ Saline water or brine not far below – separated only by a thin transition zone</li> <li>◆ Improper construction/ plugging of oil and gas wells, and coal mining operations present contamination problems</li> </ul> |

## Carbonate Rock Aquifers

|                 |   |
|-----------------|---|
| <b>Location</b> | <ul style="list-style-type: none"> <li>◆ Limestone and dolomite geologic formations located in the valleys of central and southeastern PA</li> <li>◆ Caves, solution channels, and sinkholes of these regions are caused by water dissolving portions of the carbonate rock</li> </ul>  |
| <b>Geology</b>  | <ul style="list-style-type: none"> <li>◆ Complex geologic structure</li> <li>◆ Sedimentary rock layers are folded and displaced to the northwest</li> <li>◆ Many fractures, faults, and slippage planes</li> </ul>  |
| <b>Yields</b>   | <ul style="list-style-type: none"> <li>◆ Contain large quantities of water</li> <li>◆ Water movement generally along fractures, bedding planes, and solution channels</li> <li>◆ Spring yields of 100 to more than 2000 gpm</li> <li>◆ Well yields of 100 to 1000 gpm, or more, are common               <ul style="list-style-type: none"> <li>▶ Wells located on fracture intersections can have substantially increased yields</li> </ul> </li> </ul>  |
| <b>Quality</b>  | <ul style="list-style-type: none"> <li>◆ Quality is somewhat variable, but generally suitable for water supply</li> <li>◆ Typical quality               <ul style="list-style-type: none"> <li>▶ Dissolved solids – 330 milligrams per liter (mg/l)</li> <li>▶ Hardness – 280 mg/l (very hard)</li> <li>▶ pH – 7.4</li> <li>▶ Iron – 0.1 mg/l</li> </ul> </li> <li>◆ Brackish water at depth</li> <li>◆ Contains relatively large amounts of dissolved solids</li> <li>◆ In some coal-mining area groundwater is mixed with acidic mine water, resulting in large concentrations of iron, manganese, sulfate, and dissolved solids</li> </ul> |

**Crystalline Rock Aquifers**

|                 |  |
|-----------------|--|
| <b>Location</b> | <ul style="list-style-type: none"> <li>◆ Most of southeastern Pennsylvania</li> </ul>  |
| <b>Geology</b>  | <ul style="list-style-type: none"> <li>◆ Dense, almost impermeable bedrock</li> <li>◆ Complex assortment of metamorphic and igneous rocks</li> <li>◆ Water yields primarily from secondary porosity and fractures</li> </ul>   |
| <b>Yields</b>   | <ul style="list-style-type: none"> <li>◆ Rock formations have very small fractures</li> <li>◆ Storage capacity and well yield are relatively low</li> <li>◆ Almost all recharge is from precipitation</li> <li>◆ Variable yields – dependent on factors such as type of rock; number, size and spacing of fractures; degree to which fractures are interconnected; and topographic setting of the well</li> <li>◆ Generally small yields of 5 to 25 gpm</li> </ul> |
| <b>Quality</b>  | <ul style="list-style-type: none"> <li>◆ Quality is generally suitable for drinking and other uses, but iron, manganese, and sulfate occur locally in objectionable concentrations</li> <li>◆ Typical quality               <ul style="list-style-type: none"> <li>➢ Dissolved solids – 230 milligrams per liter (mg/l)</li> <li>➢ Hardness – 160 mg/l (hard)</li> <li>➢ pH – 7.6</li> <li>➢ Iron – 0.1 mg/l</li> </ul> </li> </ul>                                |



**Exercise:** Answer the following questions for your system's aquifer (use the preceding pages).

1. What is the typical yield in gpm?
2. What is the typical pH
3. What is the quality considered?
4. At your system, have you found similar water quality characteristics? If not, how did they differ?
5. Write down one thing you learned about your aquifer (something you didn't know before):

Turn to page 2-10 and let's review the definition of raw water.

 Slide 61 – Types of Groundwater Sources

## Types of Groundwater Sources

Groundwater sources are of three types: wells, springs, and infiltration galleries and radial collectors. These three sources provide raw water to a treatment plant.



Raw water is any untreated water source.

Q. Have you ever had to take a raw water sample? Q. Under what condition?

A. Until groundwater systems install 4-log treatment of viruses, any positive total coliform sample in the distribution system requires a raw source water sample for *E. coli* within 24 hours.

Pages 2-10 and 2-11 describe wells, springs and infiltration galleries.

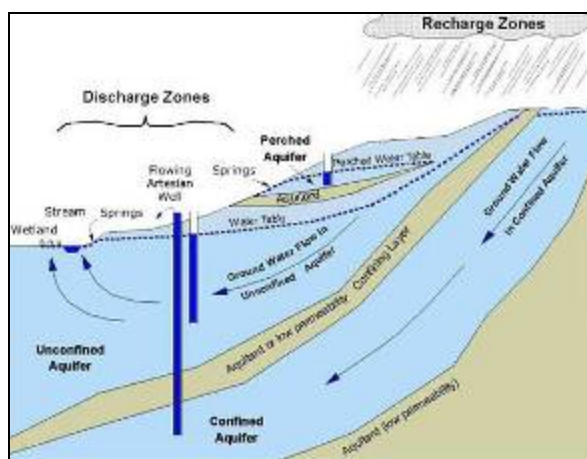


Figure 2.3 - Water Source Placement

## Wells

Wells are dug or drilled holes extending below the water table.

### Types of Wells

- Perched Aquifer Well
  - Dry up during dry season
  - Aren't good places for wells
- Unconfined Aquifer Well
  - Water level in well is at the water table level
- Confined Aquifer Well
  - Artesian wells
  - Water level in well higher than water table level because the water is under pressure

- Water level can be higher than top of well casing – Flowing Artesian Springs

Springs are groundwater that surfaces where the water table intersects the land surface.

- ☑ To be considered as groundwater, it must be collected in a spring house or well box before water is exposed to surface conditions.
- ☑ Springs originate from unconfined or perched aquifers

### Infiltration Galleries, Radial Collectors

Both infiltration galleries and radial collectors collect groundwater and are constructed below the water table.

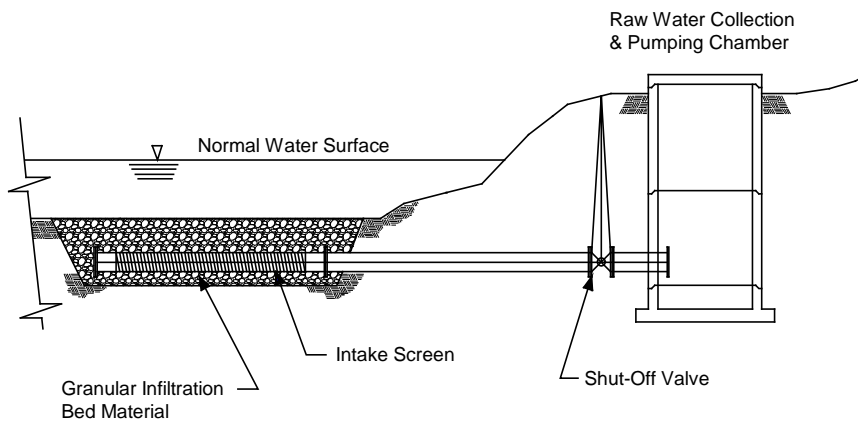


Figure 2.4 – Infiltration Gallery

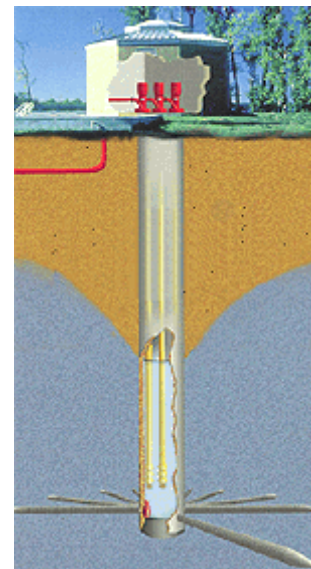


Figure 2.5 – Radial Collector<sup>2</sup>

There are exercises on pages 2-12 and 2-13.



Slide 62 – Unit 2 Wrap



Unit 2 Exercise

- List the three types of groundwater sources.

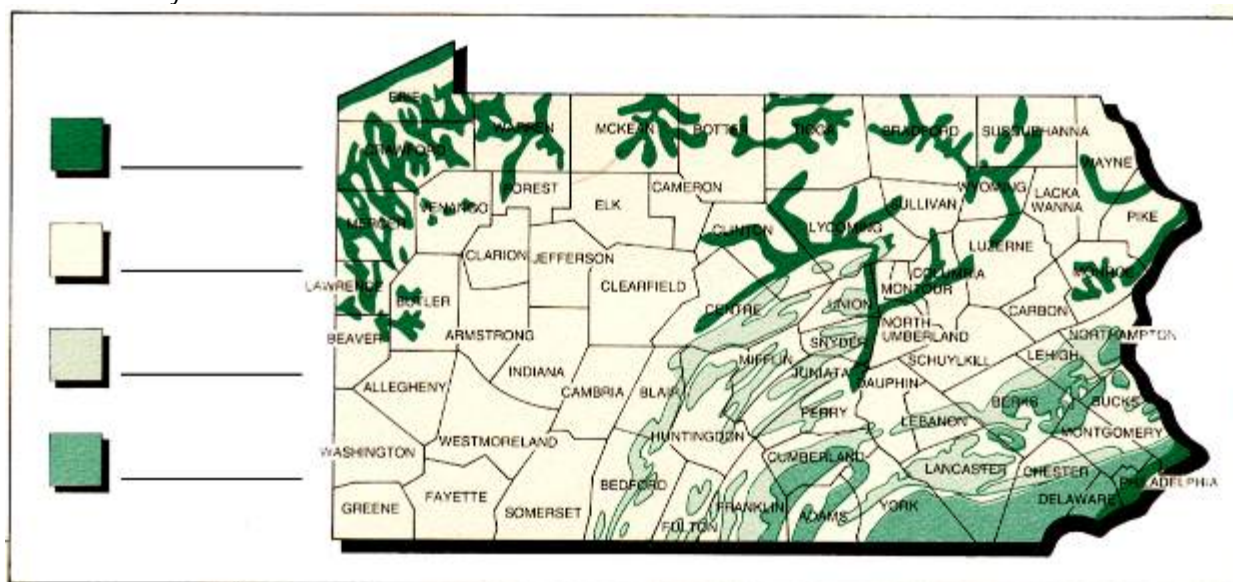
Ans: Wells, springs, infiltration galleries and radial collectors

- True** or False: A stratum is a layer of earth

- Which one of the following best defines the term *aquifer*?

- A low lying area where water pools
- Water-bearing stratum of rock, sand, or gravel**
- Impervious stratum near the ground surface
- Treated water leaving the water system

- On the map below, label the map's key to indicate the geological types of groundwater aquifers found in Pennsylvania.



Ans: Student responses should be as listed in the legend: Sand and Gravel, Sandstone and Shale, Carbonate Rock, and Crystalline Rock Aquifers.

- List the three types of aquifers.

Ans: Unconfined Aquifer, Confined Aquifer, Perched Aquifer or Perched Water Table

6. Based *solely* on **quality** of Water and **yield**, which of the four aquifer formations would provide the largest amount of fresh water? Why?

**Ans:** Sand and Gravel Aquifers

**Yield:** Contain large quantities of water, easily withdrawn, Well yields of 100 – 800 gallons per minute (gpm), Yield in excess of 1000gpm are common.

**Quality:** is variable, but generally good to excellent

*Instructor Note:* Read the key points on 2-14



**Advance Slide 62 – Wrap**



### Key points for Unit 2 – Aquifers

- ☐ An aquifer is a water-bearing layer of rock, sand, or gravel.
- ☐ The three general types of aquifers are: unconfined, confined, and perched aquifers.
- ☐ Based on their geological properties, Pennsylvania's aquifers are classified into one of four basic groups.
- ☐ Pennsylvania's four basic aquifer groupings are:
  - Sand and gravel aquifers
  - Sandstone and shale aquifers
  - Carbonate rock aquifers
  - Crystalline rock aquifers
- ☐ Sand and gravel aquifers may contain large amounts of water.
- ☐ Sandstone and shale aquifers are the most commonly occurring aquifer in Pennsylvania.
- ☐ Carbonate rock aquifers may contain large amounts of water. Caves and sinkholes may be common in these areas. Water hardness may be a problem.
- ☐ The three types of groundwater sources are:
  - Wells
  - Springs
  - Infiltration galleries and radial collectors
- ☐ A spring can be considered groundwater only if the spring water is collected in a spring house or well box to prevent the spring water being exposed to surface conditions.

We're switching gears to address water quality characteristics in Module 4.

# Drinking Water Operator Certification Training



## Module: 4 Water Quality and Characteristics Excerpts

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)  
Gannett Fleming, Inc.  
Dering Consulting Group  
Penn State Harrisburg Environmental Training Center

Turn to page 3-3 and look at the Unit 3 topics.

### Topical Outline



#### **Slide 63 – Water Quality and Characteristics**

#### **Unit 3 – Water Quality Classifications**

Introduction: Physical Characteristics

- I. Microorganisms
  - A. Definitions
  - B. Disease Outbreaks
  - C. Current List of Regulated Waterborne Pathogenic Microorganisms and Indicators
  - D. Common Sources of Waterborne Pathogenic Microorganisms
  - E. Three Categories of Microorganism Agents of Waterborne Disease
  - F. Microbial Indicators
  - G. General Groups of Nuisance Microorganisms and Aesthetic Concerns
- II. Inorganic Constituents
  - A. Standards and BATS for Inorganic Constituents That May Occur in Drinking Water Supplies
  - B. Common Sources of Inorganic Constituents
  - C. General Inorganic Chemical and Treatment Terminology
  - D. Acute and Chronic Health Affects
  - E. Aesthetic Concerns
- III. Organic Compounds
  - A. General Categories of Organic Compounds
  - B. Regulations
  - C. Common Sources
- IV. Radionuclides
  - A. Types and Sources of Radionuclides
  - B. Standards and BATS for Radionuclides
  - C. Acute and Chronic Health Affects
- V. Disinfectants and Disinfection Byproducts (D/DBP)
  - A. Disinfectants
  - B. Disinfectant Byproducts



## Unit 3 – Water Quality Classifications

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### Learning Objectives

#### Physical Characteristics

- List the four physical characteristics of water

#### Microorganisms

- List three currently regulated waterborne pathogenic microorganisms (pathogens)
- Name the six common sources of pathogens
- List three indicators of microbiological contamination

#### Inorganic Constituents

- Name three regulated inorganic constituents that occur in drinking water supplies
- Name five common sources of inorganic constituents

#### Organic Compounds

- Name four common sources of SOCs
- Describe one BAT for treatment

#### Radionuclides

- List two regulated radionuclides
- Name two common sources of radionuclides

#### Disinfectants and Disinfection Byproducts (D/DBP)

- List three regulated disinfectants and disinfection byproducts
- Name a common precursor of disinfectant byproducts
- Describe two BATS for treatment

## Physical Characteristics

There are four characteristics of water that are commonly used to define the physical properties. These include:

- **Turbidity** – Measurement of the cloudiness of water due to suspended particles. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms.
- **Taste and Color** – Suspended matter, bacteria, algae, organic waste and chemical pollutants can cause various tastes and colors in water. Organic substances, such as algae and tannins released from vegetation, can cause color. Higher concentrations of some elements, such as iron, calcium, sodium, magnesium, and chloride, can make the water taste bad or bitter.
- **Temperature** – Degree of hotness or coldness of water. The temperature of water can affect such things as dissolved oxygen level, metabolic rate of aquatic organisms, and your treatment process.

Look at the definitions on page 3-6.

*Q. What parameter do we use as an indicator organism based on the definition of indicator?*

**A.** Total coliform organisms are indicator organisms for pathogenic bacteria. We'll spend a few minutes discussing microbial indicators in the following pages.

## Definitions



**Waterborne pathogenic microorganisms** – Microbial agents of human diseases that are present in and conveyed by drinking water supplies.



**Etiologic** – A causal agent of disease.



**Endemic** – Prevalent disease not associated with an outbreak.



**Epidemiology** – The study of the distribution and determinants of disease.



**Heterotrophic** – Microorganisms that use organic carbon for growth and energy (includes almost all waterborne bacterial pathogens with the exception of cyanobacteria).



**Autotrophic** – Microorganisms that use carbon dioxide or bicarbonate ion for growth and energy (includes iron and most sulfur bacteria).



**Indicator** – Surrogate organisms and other water quality parameters used as a sign of a water system's vulnerability to the presence of pathogenic microorganisms.



**Plankton** – Microscopic aquatic life forms (both animal and plant) living free-floating and suspended in natural waters.



**Phytoplankton** – Algae.

## Disease Outbreaks

- It is estimated that only 1 in 25 diseases of waterborne origin is ever recognized. In the majority of outbreaks an infectious agent is never identified.
- Most disease outbreaks involve groundwater systems.
- A significant portion of disease is probably endemic, rather than associated with an outbreak.

Turn to page 3-7 and look at Table 3-1 which lists the regulated waterborne microorganisms.



**Slide 64 – Regulated Waterborne Micros**

**Current List of Regulated Waterborne Pathogenic Microorganisms and Indicators**

Table 3-1  
Current list of Regulated Waterborne Microorganisms

| Microorganism/Indicator         | Regulation                                   | Goal |
|---------------------------------|--|------|
| <i>Cryptosporidium</i>          | TT   | Zero |
| <i>Giardia lamblia</i>          | TT   | Zero |
| <i>E. coli</i>                  | TT   | Zero |
| Fecal coliforms                 | TT   | Zero |
| <i>Legionella</i>               | TT   | Zero |
| Viruses (enteric)               | TT   | Zero |
| Heterotrophic plate count (HPC) | TT   | NA   |
| Total coliforms                 | Max 5% of monthly readings positive          | Zero |
| Turbidity                       | PS: < 0.3 NTU – 95% of readings; 1.0 NTU max | NA   |

TT = Treatment Technique                      NA = Not Applicable

Page 3-8 through 3-12 describe which pathogens are bacteria, protozoa, or viruses.

**Common Sources of Waterborne Pathogenic Microorganisms**

- Naturally occurring
- Municipal wastewater treatment plant discharge
- Industrial wastewater treatment plant discharge
- Non-point sources such as run-off from farm fields and developed areas
- Waterfowl droppings
- Septic fields

Three Categories of Microorganism Agents of Waterborne Disease



Slide 65 – Categories of Micros

**Bacteria**

- Survival in water is usually for a short period of time
- Size ranges from 0.2 µm to 15 µm (microns)
- Reproduction consists of binary fission and can occur in water
- Best Available Technology (BAT) for treatment
  - ✓ Conventional filtration
  - ✓ Disinfection

Bacterial Disease Examples

Table 3-2

| Organism/Group  | Disease                                       | Infectious Dose Estimate |
|---|---|--------------------------|
| Pathogenic <i>Escherichia coli</i> ( <i>E. coli</i> )     | gastroenteritis                               | 10 <sup>7</sup> CFU      |
| <i>Vibrio cholerae</i>                                    | cholera                                       | <10 <sup>6</sup> CFU     |
| <i>Salmonella</i>   | salmonellosis                                 | 10 <sup>5</sup> CFU      |
| <i>Legionella</i>   | legionnaires' disease                         | unknown                  |
| <i>Salmonella typhi</i>                                   | typhoid fever                                 | 10 <sup>7</sup> CFU      |
| <i>Shigella spp.</i>                                      | bacillary dysentary                           | 10 <sup>7</sup> CFU      |
| <i>Campylobacter jejuni</i>                               | gastroenteritis                               | unknown                  |
| Non-tuberculosis <i>mycobacteria</i> (NTM),<br>On EPA CCL | respiratory infections                        | unknown                  |
| <i>Helicobacter pylori</i> ,<br>On EPA CCL                | gastroenteritis, ulcers,<br>stomach carcinoma | unknown                  |

CCL = Contaminant Candidate List (for possible future regulation), CFU = Colony Forming Units per mL



Figure 3-1<sup>1</sup>

*E.coli*



Figure 3-2<sup>2</sup>

*Legionella*

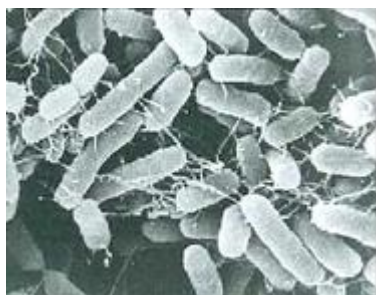


Figure 3-3<sup>3</sup>

*Salmonella*



Figure 3-4<sup>4</sup>

*Vibrio cholerae*



Advance Slide 65 – Categories of Micros

**Protozoa**

- Survival in water up to one year
- Size ranges from 3 µm to 25 µm
- Reproduction is not possible in water
- Best Available Technology (BAT) for treatment
  - ✓ Conventional filtration
  - ✓ Disinfection
- May cause disease even in very low numbers

Table 3-3  
Protozoa Disease examples

| Organism/Group                | Disease           | Size           | Infectious Dose |
|-------------------------------|-------------------|----------------|-----------------|
| <i>Giardia lamblia</i>        | giardiasis        | 5 µm to 15 µm  | 1 to 50 cysts   |
| <i>Cryptosporidium parvum</i> | cryptosporidiosis | 4 µm to 6 µm   | 30 to 130cysts  |
| <i>Entamoeba histolytica</i>  | amoebic dysentery | 10 µm to 15 µm | unknown         |
| <i>Microsporidia</i>          | microsporidiosis  | 1 µm to 5 µm   | unknown         |
| <i>Cyclospora</i>             | cyclosporiasis    | 7 µm to 9 µm   | unknown         |

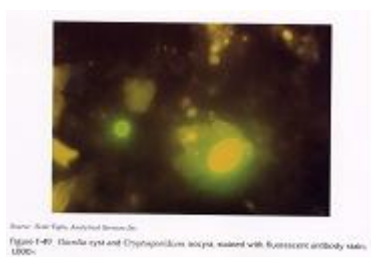


Figure 3-5<sup>5</sup>

*Giardia* cyst and *Cryptosporidium* oocyst



Figure 3-6<sup>6</sup>

*Giardia* detail



Figure 3-7<sup>7</sup>

*Giardia lamblia*

Figure 3-8<sup>8</sup>

*Giardia lamblia*



Figure 3-9<sup>9</sup>

*Cryptosporidium*

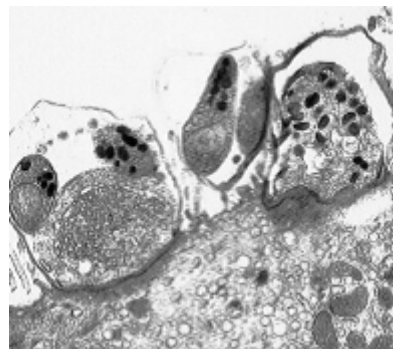


Figure 3-10<sup>10</sup>

*Cryptosporidium parvum*

(stained dark)





Advance Slide 65 – Categories of Micros

**Viruses**

- Survival in water extended up to five months
- Size ranges from 0.02 μm to 0.3 μm
- Reproduction—dependent on a host cell
- Many waterborne species, with over 120 identified to date, are responsible for a variety of diseases. Infectious viruses may be present in waters that meet the total coliforms standard. Coliphages, viruses that infect *E coli* bacterium, may be adopted as viral indicators.
- Best Available Technology (BAT) for treatment
  - ✓ Conventional filtration
  - ✓ Disinfection
- Viruses may cause disease even in very low numbers

Table 3-4  
Virus Disease Examples

| Organism/Group                                      | Disease              | Infectious Dose   |
|---|----------------------|-------------------|
| <i>Rotavirus</i>                                    | gastroenteritis      | 1 to 50 particles |
| <i>Hepatitis A virus</i>                            | infectious hepatitis | 1 to 50 particles |
| <i>Caliciviruses (Norwalk agent),</i><br>On EPA CCL | gastroenteritis      | unknown           |
| <i>Coxsackieviruses A &amp; B,</i><br>On EPA CCL    | aseptic meningitis   | unknown           |

CCL= Contaminant Candidate List (for possible future regulation)

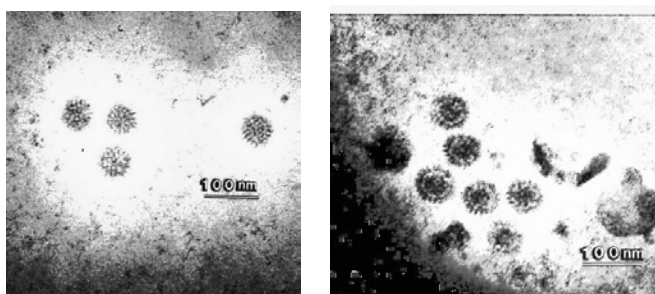


Figure 3-11 <sup>11</sup>

*Rotavirus*

It's not important to know whether the "bug" is classified as bacteria, protozoa or a virus. It's important to recognize that these microscopic organisms make people sick. We treat the water to remove or inactivate these organisms.

Turn to page 3-13 and let's talk about why we use microbial indicators instead of testing for the actual bacteria.



### Slide 66 – Microbial Indicators

## Microbial Indicators

Microbial indicators are often used in place of testing for waterborne pathogenic microorganisms.

Look at the bulleted items that make microbial indicators effective.

Ideal microbial indicators should have the following characteristics to be effective:

- Present in large numbers in fecal matter
- Present when the pathogenic microorganism is present
- High ratio of indicators to pathogens
- Stable and non-pathogenic
- Absent in uncontaminated water
- Should respond similarly to natural conditions and be at least as susceptible to treatment as the pathogenic microorganism
- Easily detected by simple, inexpensive lab tests in the shortest time with accurate results
- Should be suitable for all types of drinking water supplies

Now let's review the information on Table 3-5 found on page 3-14.

We are all familiar with total coliforms because we test for them. Notice that total coliforms are not a health threat; but they do indicate whether other potentially harmful bacteria may be present.

This is why the acute MCL violation for total coliform does not occur until you also have fecal coliform or *E. coli* present.

This is why the Tier 2 MCL for total coliforms does not include any "boil water" language.

Read the last 2 bullets under turbidity:

- Higher turbidity levels are often associated with higher levels of disease-causing microorganisms, particularly those microorganisms that associate with particles.
- Turbidity may provide adsorption/encasement sites for pathogenic organisms, protecting them from disinfection processes.

Those of you operating a surface water treatment plant are familiar with turbidity and this is why we want to keep it as low as possible.

Table 3-5  
Examples of Microbial Indicators

| Indicator                          | Characteristics   |
|------------------------------------|---|
| Total coliforms                    | <ul style="list-style-type: none"> <li>▪ Indicator of choice for many decades.</li> <li>▪ Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present.</li> <li>▪ Coliforms are naturally present in the environment, as well as in feces.</li> </ul> <p><u>Major Shortcomings:</u></p> <ul style="list-style-type: none"> <li>▪ Only marginally effective for predicting the presence of protozoan and some virus pathogens because of its much greater susceptibility to chlorine disinfection.</li> <li>▪ May proliferate in distribution system biofilms, making determination of distribution system integrity difficult.</li> </ul>   |
| Fecal coliforms/<br><i>E. coli</i> | <ul style="list-style-type: none"> <li>▪ <i>E. coli</i> is the major subset of fecal coliforms.</li> <li>▪ Both fecal coliforms and <i>E. coli</i> are better indicators of recent fecal contamination than total coliforms.</li> </ul> <p><u>Major Shortcomings:</u></p> <ul style="list-style-type: none"> <li>▪ Do not distinguish between human and animal fecal waste.</li> <li>▪ Densities too low to be used for indicators of treatment effectiveness or post treatment contamination.</li> </ul>   |
| Heterotrophic Plate Count (HPC)    | <ul style="list-style-type: none"> <li>▪ An analytic method used to measure the variety of bacteria that are common in water.</li> <li>▪ It is a general indicator of the biological quality of drinking water; the lower the concentration of bacteria in drinking water, the better maintained the water system is.</li> <li>▪ A sudden increase in HPC numbers may suggest a problem with treatment, including disinfection practices.</li> </ul> <p><u>Major Shortcoming:</u></p> <ul style="list-style-type: none"> <li>▪ Does not provide an indication of the presence of pathogens.</li> </ul>  |
| Turbidity                          | <ul style="list-style-type: none"> <li>▪ Turbidity is a nonspecific measurement of the cloudiness of water due to light-scattering particles relative to the amount of light scattered due to a reference suspension.</li> <li>▪ It has been used for decades as an indicator of water quality and filtration effectiveness (e.g., whether the treatment process is susceptible to the passage of disease-causing organisms).</li> <li>▪ Higher turbidity levels are often associated with higher levels of disease-causing microorganisms, particularly those microorganisms that associate with particles.</li> <li>▪ Turbidity may provide adsorption/encasement sites for pathogenic organisms, protecting them from disinfection processes.</li> </ul> <p><u>Major Shortcomings:</u></p> <ul style="list-style-type: none"> <li>▪ Provides no information on the nature of the particles.</li> </ul> |

Turn to page 3-15 and look at the other microbial indicators.

|   |   |
|---|---|
| <p>Particle Counts</p>                        | <ul style="list-style-type: none"> <li>▪ A measurement of number and size of particles in water.</li> <li>▪ It can be used to determine overall log reduction of particles through the entire treatment process.</li> <li>▪ It is a particularly sensitive indicator of filtration effectiveness and for assessing filter operational problems.</li> <li>▪ It generally provides an earlier indication of filter breakthrough than turbidity.</li> <li>▪ Higher particle count levels may be associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria.</li> </ul> <p><u>Major Shortcomings:</u></p> <ul style="list-style-type: none"> <li>▪ Does not distinguish between living and nonliving particles, and between particles from the source water and those due to the addition of chemicals.</li> <li>▪ No standardization between different manufacturers' equipment.</li> </ul> |
| <p>Microscopic Particulate Analysis (MPA)</p> | <ul style="list-style-type: none"> <li>▪ Used as a tool to define whether a groundwater source is under the direct influence of surface water via microscopic sample screening for the presence of plant debris, pollen, rotifers, crustaceans, amoebas, nematodes, insects/larvae, algae, coccidia (<i>Cryptosporidium</i>), and <i>Giardia</i> cysts.</li> <li>▪ Used as a tool to evaluate filter effectiveness of surface water supplies.</li> </ul> <p><u>Major Shortcomings:</u></p> <ul style="list-style-type: none"> <li>▪ Not for routine monitoring due to complexity of procedure and time required to perform analysis.</li> <li>▪ Only identifies larger pathogens such as <i>Giardia</i> and <i>Cryptosporidium</i>.</li> </ul>  |
| <p><i>Clostridium perfringens</i></p>         | <ul style="list-style-type: none"> <li>▪ Bacterium consistently associated with human fecal matter.</li> <li>▪ Not a pathogen, but is excreted in greater numbers than fecal pathogens.</li> <li>▪ Forms spores that are extremely resistant to environmental stresses and disinfection.</li> <li>▪ Analysis is simple and inexpensive.</li> </ul> <p><u>Major Shortcomings:</u></p> <ul style="list-style-type: none"> <li>▪ Insufficient data exists to consistently correlate <i>C. perfringens</i> with pathogenic microorganisms.</li> </ul>   |
| <p>Coliphages</p>                             | <ul style="list-style-type: none"> <li>▪ Viruses that infect <i>E. coli</i>.</li> <li>▪ Field trials currently underway for validation of coliphages as viral indicators.</li> <li>▪ Present in human wastewater.</li> <li>▪ Far easier to analyze than human or animal viruses.</li> <li>▪ Environmentally robust, with long survival times in water.</li> <li>▪ Structurally similar to human enteric viruses.</li> </ul>   |

Table 3-6 on page 3-16 lists nuisance microorganisms.

Q. Has anyone had any problems in their water supply with any of these microorganisms?

### General Groups of Nuisance Microorganisms and Aesthetic Concerns

Table 3-6  
Examples of Nuisance Microorganisms

| Microorganism  | Impact on Water Supply   |
|--|--|
| Algae blooms <ul style="list-style-type: none"> <li>▪ Taste &amp; odor producers</li> <li>▪ Filter cloggers</li> </ul>   | <ul style="list-style-type: none"> <li>▪ Tastes &amp; odors</li> <li>▪ Poor settling</li> <li>▪ Filter clogging</li> <li>▪ Diurnal pH changes</li> <li>▪ Oxidant demand</li> </ul>   |
| Iron bacteria <ul style="list-style-type: none"> <li>▪ Ribbon (stalk) formers - <i>Gallionella</i></li> <li>▪ Tube formers - <i>Crenothrix</i>, <i>Leptothrix</i>, <i>Sphaerotilus</i></li> <li>▪ Consortial heterotrophic incumbents</li> </ul> | <ul style="list-style-type: none"> <li>▪ Forms slimes which create localized anaerobic conditions inside wells and pipelines, leading to:                             <ul style="list-style-type: none"> <li>– Corrosion initiation and tuberculation</li> <li>– Plugging of hydraulic conveyance facilities</li> <li>– “Red water” problems due to bioaccumulation of iron and manganese and subsequent release due to sloughing off of slimes</li> </ul> </li> <li>– Tastes &amp; odors</li> </ul> |
| Sulfur bacteria <ul style="list-style-type: none"> <li>▪ Sulfur reducing bacteria (SRB)</li> </ul>   | <ul style="list-style-type: none"> <li>▪ Severe taste &amp; odor</li> <li>▪ Initiates corrosion</li> <li>▪ Reduces equipment efficiencies, (e.g. partial clogged pump)</li> <li>▪ Reacts with large quantities of sulfates and generates hydrogen sulfide as it grows; hydrogen sulfide reacts with dissolved metals (esp. iron) generating black sulfide particles</li> </ul>   |
| <i>Actinomyces</i> spp.<br>(bacteria that constitute a considerable portion of microorganisms contained in lake and river bottom muds)   | <ul style="list-style-type: none"> <li>▪ Tastes &amp; odors – earthy/musty odors from the metabolites Geosmin and Methyl Isoborneol (MIB)</li> </ul>   |

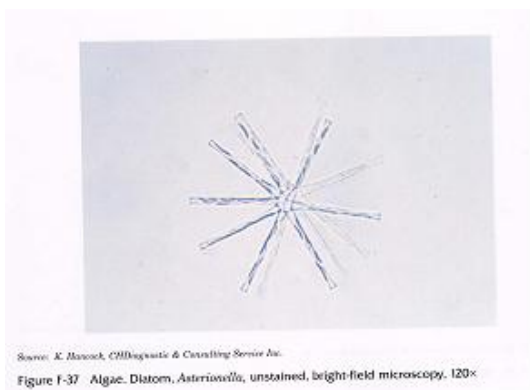


Figure 3-12<sup>12</sup>

*Asterionella*

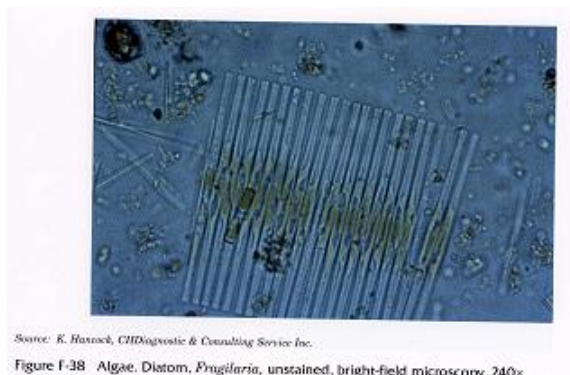


Figure 3-13<sup>13</sup>

*Fragilaria*



Figure 3-14<sup>14</sup>

Iron Bacteria

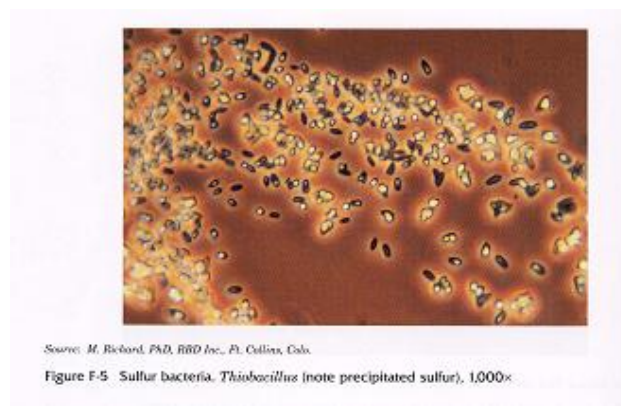


Figure 3-15<sup>15</sup>

Sulfur Bacteria

*Thiobacillus* (stained dark)

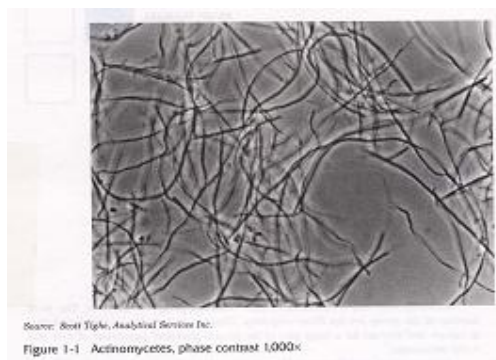


Figure 3-16<sup>16</sup>

*Actinomycetes*

**Exercise - Microorganisms**

[Have the class take five minutes to complete the exercise. They can complete it individually or with a partner. Once completed, take five minutes to review the answers. ]

1. List three examples of regulated waterborne microorganisms.
  - a. Cryptosporidium
  - b. E. coli
  - c. Fecal Coliforms
  
2. Waterfowl droppings, septic fields, and run-off from farm fields are some of the common sources of waterborne pathogenic microorganisms.
  - a. True
  - b. False
  
3. Protozoa can survive in water for up to
  - a. One hour
  - b. One day
  - c. One month
  - d. One year
  
4. Best Available Technologies for treating water with bacteria include conventional filtration and disinfection.
  - a. True
  - b. False
  
5. List three examples of microbial Indicators and give one shortcoming for each.
  - a. Total coliforms - May proliferate in distribution system biofilms, making determination of distribution system integrity difficult
  - b. *Clostridium perfringens* - Insufficient data exists to consistently correlate *C. perfringens* with pathogenic microorganisms.
  - c. *E. coli* - Do not distinguish between human and animal fecal waste.



Turn to page 3-19 and read the definition of inorganic constituents. They are metals and salts.

**INORGANIC CONSTITUENTS:** Inorganics are chemicals that do not contain carbon chains (matter that is not of plant or animal origin). These include such things as metals and salts. Many inorganic chemicals are naturally occurring at low levels. However, higher level can cause human health and environmental problems.

### Standards and BATS for Inorganic Constituents That May Occur in Drinking Water Supplies

Table 3-7  
Regulated Waterborne Inorganic Constituent Standards

| Parameter                            | MCL                      | SMCL      | PMCLG  |
|--------------------------------------|--------------------------|-----------|--------|
| Antimony - mg/L                      | 0.006                    | NA        | 0.006  |
| Arsenic - mg/L                       | 0.01                     | NA        | Zero   |
| Asbestos - fibers/L >10 µm           | 7x10 <sup>6</sup> fibers | NA        | NA     |
| Barium - mg/L                        | 2.0                      | NA        | 2      |
| Beryllium - mg/L                     | 0.004                    | NA        | 0.004  |
| Cadmium - mg/L                       | 0.005                    | NA        | 0.005  |
| Chromium (total) - mg/L              | 0.1                      | NA        | 0.1    |
| Lead - mg/L                          | 0.015 (Action Level)     | NA        | Zero   |
| Copper - mg/L                        | 1.3 (Action Level)       | 1.0       | 1.3    |
| Mercury, Total (inorganic) - mg/L    | 0.002                    | NA        | 0.002  |
| Nickel - mg/L                        | 0.1                      | NA        | 0.1    |
| Selenium - mg/L                      | 0.05                     | NA        | 0.05   |
| Thallium - mg/L                      | 0.002                    | NA        | 0.0005 |
| Zinc - mg/L                          | NA                       | 5.0       | NA     |
| Iron - mg/L                          | NA                       | 0.3       | NA     |
| Manganese - mg/L                     | NA                       | 0.05      | NA     |
| Aluminum - mg/L                      | NA                       | 0.05-0.20 | NA     |
| Silver - mg/L                        | NA                       | 0.1       | NA     |
| Chloride - mg/L                      | NA                       | 250       | NA     |
| Sulfate - mg/L                       | NA                       | 250       | 500    |
| Sodium - mg/L                        | NA                       | NA        | 20     |
| TDS - mg/L                           | NA                       | 500       | NA     |
| Nitrate (as N) - mg/L                | 10                       | NA        | 10     |
| Nitrite (as N) - mg/L                | 1                        | NA        | 1      |
| Nitrate + Nitrite (both as N) - mg/L | 10                       | NA        | 10     |
| Fluoride - mg/L                      | 2                        | 2.0       | 4      |

MCL = Primary Maximum Contaminant Level  
 SMCL = Secondary Maximum Contaminant Level  
 PMCLG = Primary Maximum Contaminant Level Goal  
 NA = Not Applicable

Look at Table 3-8 on page 3-20. Please read the footnote under lead (last sentence on this page).

Table 3-8  
BATS for Inorganic Constituents

| Parameter  | GAC | Oxidation | Coagulation/Filtration | Ion Exchange | Membranes                   | Lime Softening | Activated Alumina | Corrosion Control |
|--|-----|-----------|------------------------|--------------|-----------------------------|----------------|-------------------|-------------------|
| <b>Metals</b>                                      |     |           |                        |              |                             |                |                   |                   |
| Antimony   |     |           | X                      |              | X (RO)                      |                |                   |                   |
| Barium   |     |           |                        | X (Cation)   | X (RO,ED)                   | X              |                   |                   |
| Beryllium  |     |           | X                      | X            | X (RO)                      | X              |                   |                   |
| Cadmium  |     |           | X                      | X (Cation)   | X (RO)                      | X              |                   |                   |
| Chromium (+3)                                      |     |           | X                      | X (Cation)   | X (RO)                      | X              |                   |                   |
| Chromium (+6)                                      |     |           | x                      | X (Anion)    | X (RO)                      | X              |                   |                   |
| Lead*  |     |           |                        |              |                             |                |                   | X                 |
| Manganese  |     | X         | X (w/preoxidation)     | X (Cation)   |                             | X              |                   |                   |
| Mercury  | X   |           | X                      |              | X (RO)                      | X              |                   |                   |
| Molybdenum   |     |           |                        | X (Anion)    | X (RO, NF)                  |                |                   |                   |
| Nickel   |     |           |                        | X (Cation)   | X (RO)                      | X              |                   |                   |
| Thallium   |     |           |                        | X (Anion)    |                             |                | X                 |                   |
| <b>Miscellaneous Inorganics and Inorganic Ions</b> |     |           |                        |              |                             |                |                   |                   |
| Arsenic (+3)                                       |     |           | X (w/preoxidation)     |              | X (RO,, ED)<br>(RO, NF, ED) |                |                   |                   |
| Arsenic (+5)                                       |     |           | X (w/preoxidation)     |              | X (RO, ED)<br>(RO, NF, ED)  |                |                   |                   |
| Boron  |     |           |                        | X            | X (RO, NF)                  | X              |                   |                   |
| Nitrate  |     |           |                        | X (Anion)    | X (RO, ED)                  |                |                   |                   |
| Nitrite  |     |           |                        | X (Anion)    | X (RO)                      |                |                   |                   |
| Nitrate and Nitrite                                |     |           |                        | X (Anion)    | X (RO)                      |                |                   |                   |
| Sulfate  |     |           |                        | X            | X (RO,NF, ED)               |                |                   |                   |
| Selenium (+4)                                      |     |           | X                      | X (Anion)    | X (RO, ED)                  | X              | X                 |                   |
| Selenium (+6)                                      |     |           |                        | X (Anion)    | X (RO, ED)                  | X              | X                 |                   |
| Fluoride   |     |           |                        |              | X (RO)                      |                | X                 |                   |

ED = Electrodialysis/Electrodialysis Reversal (membrane process used both to demineralize brackish water and seawater, and soften hard water; limited to removing ionic contaminants, not effective for removing pathogens and organics).

GAC = Granular activated carbon

NF = Nanofiltration (membranes containing slightly larger diameter pores than RO; used for softening hard waters and removing disinfectant byproduct precursors (organics)).

OX = Oxidation

RO = Reverse osmosis (desaltation)

\* Consumers with high lead levels can reduce lead in their drinking water from their kitchen sink taps by running the tap water for 30 seconds.

**Q. How many of you were familiar with running the water for 30 seconds to reduce the lead results?**

**Q. Have any of you exceeded the lead action level and done lead public education?**

**A. Running the water before consuming is one of the consumer actions that is included in the lead public education materials.**

Pages 3-21 and 3-22 list the inorganic constituents and their sources

*Q. Does this look like the information you need to include in the Consumer Confidence Report?*

**Common Sources of Inorganic Constituents**

Table 3-9

List and Sources of Inorganic Constituents

| Parameter                                      | Naturally Occurring         | Industrial Discharges  | Stormwater Runoff                      | Distribution System Pipe Corrosion  | Water Treatment Product                          |
|--|-----------------------------|--|--|---|--|
| <b>Metals</b>                                  |                             |  |  |   |  |
| Antimony                                       |                             | Petroleum refineries; fire retardants; ceramics; electronics; solder                       |  |   |  |
| Asbestos                                       | Erosion of natural deposits | Mining discharge   |  | Decay of asbestos cement pipe   |  |
| Barium   | Erosion of natural deposits | Drilling wastes; metal refineries; brick and ceramic manufacturers                         |  |   |  |
| Beryllium                                      |                             | Metal refineries and coal-burning factories; electrical, aerospace, and defense industries |  |   |  |
| Cadmium  | Erosion of natural deposits | Metal refineries; waste from electroplating  | Runoff from waste batteries and paints | Galvanized pipe corrosion   |  |
| Chromium<br>(total of valence states III & VI) | Erosion of natural deposits | Steel and pulp mills; waste from electroplating, garbage and fossil fuel combustion        |  |   |  |
| Lead   | Erosion of natural deposits |  |  | Corrosion of distribution system lead pipe and household plumbing systems |  |
| Copper   | Erosion of natural deposits |  |  | Corrosion of household plumbing systems                                   | Copper salts used for algae control in reservoir |

|                                  |                                   |  |   |                                      |  |
|----------------------------------|-----------------------------------|--|---|--------------------------------------|--|
| Mercury,<br>Total<br>(inorganic) | Erosion of<br>natural<br>deposits | Refineries and<br>factories  | Runoff from<br>landfills and<br>croplands |                                      |  |
| Nickel                           | Erosion of<br>natural<br>deposits |  |   |                                      |  |
| Thallium                         |                                   | Leaching from ore-<br>processing sites;<br>electronics, glass,<br>and drug factories |   |                                      |  |
| Iron                             | Erosion of<br>natural<br>deposits |  |   | Corrosion of<br>distribution<br>pipe | Overdose of iron<br>salt coagulant                   |
| Manganese                        | Erosion of<br>natural<br>deposits | Discarded batteries;<br>steel alloys;<br>agricultural products                       |   |                                      | coagulant  |
| Aluminum                         | Erosion of<br>natural<br>deposits |  |   |                                      | Overdose of alum<br>coagulant                        |
| Silver                           |                                   |  |   |                                      | Some domestic<br>treatment<br>systems                |
| Sodium                           | Erosion of<br>natural<br>deposits |  |   |                                      | Sodium<br>hypochlorite,<br>caustic soda, soda<br>ash |
| Zinc                             | Erosion of<br>natural<br>deposits |  |   | Corrosion of<br>galvanized<br>pipe   | Some phosphate-<br>based corrosion<br>inhibitors     |

Beginning on page 3-23, you will see definitions.



### Slide 67 – Inorganic

## General Inorganic Chemical and Treatment Terminology



**Alkali** – Certain soluble salts, such as sodium, potassium, magnesium, and calcium that have the property of combining with acids to form neutral salts. The most commonly used alkali in water treatment contains either sodium (caustic soda, soda ash) or calcium (lime).



**Alkalinity, Total** – The capacity of water to neutralize acids due to the water's content of carbonate, bicarbonate, hydroxide, and possibly minor amounts of other radicals, expressed in terms of calcium carbonate equivalent. It is a measure of how much acid must be added to a liquid to lower the pH to 4.5, using a titration procedure.



**Alkalinity, Bicarbonate ( $\text{HCO}_3^-$ )** – A form of all alkalinity when pH is less than 8.3, commonly referred to as natural alkalinity.



**Alkalinity, Phenolphthalein** – A measurement of that portion of total alkalinity, contributing to pH greater than 8.3, which can include bicarbonate ( $\text{HCO}_3^-$ ), carbonate ( $\text{CO}_3^{2-}$ ), and hydroxide ( $\text{OH}^-$ ).



**Amperometric Titration** – A method used to measure concentrations of strong oxidizers, among other substances, based on the electric current that flows during a chemical reaction.



**Anion** – An elemental atom or compound with a negative charge.



**Buffer** – Water whose chemical makeup neutralizes acids or bases without a great change in pH.



**Buffer Capacity** – A measure of the capacity of water for offering a resistance to changes in pH.



**Calcium Carbonate Equivalent ( $\text{CaCO}_3$ )** – An expression of water quality constituents in terms of their equivalent value to calcium carbonate.



**Cation** – An elemental atom or compound with a positive charge.



**Catalyst** – A substance that can “speed up” a chemical reaction without being permanently changed.



**Colloidal** – The dispersion of extremely small particles ( $< 1.0 \mu\text{m}$  in size) in water that cannot settle naturally, primarily due to electrostatic repulsive forces of particle surface charges.



**Coagulation** – The addition of a chemical compound (typically a metal salt) to water in order to destabilize colloidal and suspended particles by neutralizing particle electrostatic charges (which are primarily negative). The result is that these particles aggregating into larger particles (flocs) that can be more readily removed by clarification and/or filtration processes.



**Colorimetric Measurement** – A method of determining the concentrations for a range of water quality parameters by measuring a sample's color adsorption following the addition of analyte-specific reagent(s).



**Conductivity** – A surrogate for ionic strength; a measure of the ability of a water to carry an electric current, which depends on the presence of ions, their total concentration, mobility, valence and the temperature of the water during the measurement. Expressed in mhos (or more commonly micromhos), the reciprocal of electrical resistance units of measure, ohms. A ratio between conductivity and TDS is site-specific; however, typically it is in the range of 55% to 70% TDS: conductivity. Measurement of conductivity may help determine the amount of ionic reagent needed to affect precipitation or neutralize reactions in water treatment.



**DPD** – A commonly used method for measuring chlorine residual in water, using either burette titration or a color comparison to a standard. DPD is an abbreviation for N, N-diethyl-*p*-phenylenediamine.



**Gram Equivalent Weight** – The gram molecular weight of a compound (or atomic weight, for elements) divided by the valence state of an element or compound.



**Gram Molecular Weight** – The molecular weight of a compound (or atomic weight, for elements) in grams.

Look at page 3-24.

*Q. Does anyone have hard water? What is it made of?*

**A. (calcium and magnesium). Remember that fact!**



**Hardness, Total** – The presence of divalent metallic cations in water due to dissolution of minerals (primarily salts of calcium and magnesium) in geologic formations by natural waters; supersaturated concentrations of these dissolved minerals may result in scaling of distribution systems, hot water heaters, boilers, etc. Highest hardness usually occurs in wells (groundwater sources) as opposed to rivers or lakes.



**Hardness, Calcium** – That portion of total hardness that is due to calcium ions.



**Hardness, Carbonate** – That portion of total hardness equivalent to the total alkalinity.



**Hardness, Magnesium** – That portion of total hardness that is due to magnesium ions.



**Hardness, Noncarbonate** – That portion of total hardness that is in excess of alkalinity.



**Insoluble** – A solid element or compound that is incapable of being dissolved.



**Kinetics** – The speed or velocity of chemical reactions, which depend on factors such as temperature, pH, presence of catalysts, etc.



**Mole** – Refers to the molecular weight in grams of an element or compound (same as gram molecular weight).



**Normality** – The number of gram equivalent weights of a solute per liter of solution.



**Organic complex** – An element or compound associated with Dissolved Organic Carbon (DOC).



**Oxidation** – A metal or metal-like element loses electrons to a nonmetal, thereby gaining stability as it transforms from a soluble phase to a solid phase.



**Oxidation-Reduction Potential (ORP)** – The electrical potential required to transfer electrons from one compound or element (the oxidant, or oxidizer) to another compound or element (the redundant, or reducer). The measurement is used as a qualitative indicator of the state of oxidation in water treatment.



**Percent Saturation** – The amount of a substance that is dissolved in a solution compared with the amount that could be dissolved in the solution, expressed as a percent.



**pH** – The measurement of hydrogen ion activity which affects many chemical reactions.



**Precipitation** – The physical and chemical reactions due to supersaturation of specific dissolved chemical ions that result in conversion of some or all of those ions into solid particles so that equilibrium is restored to a solution (the separation from a solution of an insoluble substance).



**Reagent** – A pure chemical substance that is used in chemical tests to measure, detect, or examine other substances.



**Soluble** – A dissolved phase of an element or compound.



**Solute** – The dissolved component of a solution.



**Standard Solution** – A solution in which the exact concentration of a chemical or compound is known.



**Stoichiometry** – The methodology by which the quantities of reactants and products in chemical reactions are determined.



**Titration** – The analytical method whereby a chemical solution of known strength is added drop by drop until a specific end point is reached, identified by a color change, precipitate or pH change. This method is commonly used for determining levels of alkalinity and hardness.



**Total Dissolved Solids** – A surrogate for ionic strength in water, consists mainly of dissolved inorganic salts. Site specific, but typically in the range of 55% to 70% of conductivity reading.

Turn to page 3-26 and look at Table 3-10. Notice that the subheading above this table is “Acute and Chronic Health Effects”

The health effects listed on page 3-26 are primarily chronic (meaning it happens as a result of long-term exposure)





Slide 68 – Acute Vs. Chronic

Acute and Chronic Health Affects

Table 3-10  
Health Effects of Waterborne Inorganic Constituents

| Parameter   | Potential Health Affects  |
|---|---|
| Antimony  | Increase in blood cholesterol; decrease in blood sugar  |
| Arsenic   | Can cause Blackfoot disease or problems with circulatory systems. May increase the risk of contracting skin cancer.   |
| Asbestos  | Increased risk of developing benign intestinal polyps; suggestions of elevated risk for developing kidney and pancreatic cancer   |
| Barium  | Chronic exposure may lead to increase in blood pressure   |
| Beryllium   | Intestinal lesions  |
| Cadmium   | Chronic exposure may cause liver and kidney damage  |
| Chromium  | Allergic dermatitis; Chromium VI is toxic   |
| Lead  | Infants and children: delays in physical or mental development; children could show slight deficits in attention span and learning abilities. Adults: kidney problems; high blood pressure.   |
| Copper  | High short term exposure: gastrointestinal distress; anemia. Long term exposure: liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level.             |
| Mercury (inorganic)   | Auto-immune kidney damage   |
| Nickel  | Possible mutagenic, chromosomal aberration  |
| Selenium  | Hair or fingernail loss; numbness in fingers or toes; circulatory problems  |
| Thallium  | Hair loss; changes in blood; kidney, intestine, or liver problems   |
| Zinc  | Excessive zinc interferes with iron & copper adsorption   |
| Silver  | Skin discoloration, a cosmetic effect related to silver ingestion; does not impair body function  |
| Sulfate   | Laxative effect above 1000 mg/L, above 600 mg/L for infants   |
| Sodium  | Contributes to hypertension   |
| Nitrate (as N)<br>Nitrite (as N)<br>Nitrate + Nitrite (both as N) | Infants below the age of six months who drink water containing nitrate and/or nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.                          |
| Fluoride  | Chronic high levels: bone fluorosis (pain and tenderness of the bones); acute overdosing due to excess fluoride feed (20 mg/L to 200 mg/L) can result in nausea, diarrhea, abdominal pain. Safe and effective dose is considered to be 0.7 to 1.2 mg/L. |



Slide 69

Turn to page 3-27 and note the health effects for nitrate that we mentioned earlier. This one is acute in both ways – acute health effects to infants under 6 months of age (i.e., seriously ill) and acute exposure (meaning that it happens as a result of short-term exposure).

Table 3-11 provides a list of aesthetic concerns.

**Aesthetic Concerns**

Table 3-11  
List of Aesthetic Concerns

| Standards Related to:                          | Possible Water Quality Contributor(s)   | Possible Indication of:   |
|--|---|---|
| Metallic or salty taste                        | Copper, Iron, Manganese, Zinc, pH, Total Dissolved Solids(TDS), Sulfate, Chloride | Improper treatment, resulting in corrosion of pipe materials  |
| Color  | Aluminum, Copper, Iron, Manganese, Total Dissolved Solids (TDS)                   | Improper and/or inadequate source water treatment; corrosion of pipe materials  |
| Cosmetic effects                               | Silver  | Possible evidence of Argyria, a skin discoloration, due to leaching from home water treatment devices containing silver for disinfection  |
| Tooth discoloration and/or pitting in children | Fluoride  | High levels of fluoride in water supply; excessive fluoride feed  |
| Corrosion and staining                         | Copper, Iron, Manganese, Zinc, pH, Total Dissolved Solids(TDS), Chloride          | Improper and/or inadequate treatment, contributing to passage of raw water contaminants and/or corrosion of pipe materials leading to staining (blue-green, brown, black) of plumbing fixtures, laundry, etc.   |
| Scale and sediments                            | Iron, pH, Total Dissolved Solids (TDS), Aluminum.                                 | High levels of hardness, excessive alkali feed and/or deficient treatment may result in scale formation and sediments, mineral deposits which build up on the insides of water mains, hot water pipes, boilers, and heat exchangers, restricting or even blocking water flow. |

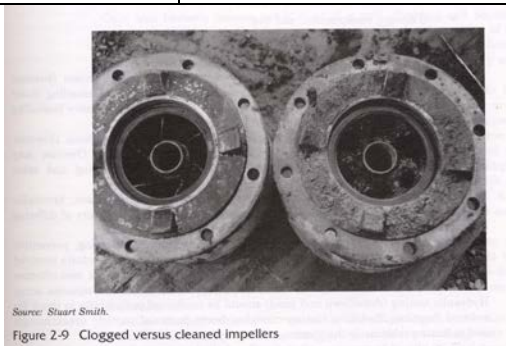


Figure 3-17<sup>17</sup>

Clogged vs. cleaned pump impellers

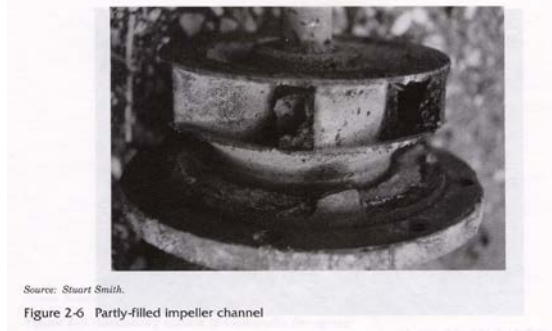


Figure 3-18<sup>18</sup>

Partly filled pump impeller channel

**Slide 70 Exercise - Inorganics****Exercise - Inorganic Constituents**

*[Have the class take five minutes to complete the exercise. They can complete it individually or with a partner. Once completed, take five minutes to review the answers. ]*

1. Give the Maximum Contaminant Level (MCL) for the following inorganic constituents.
  - a. Arsenic = 0.01 mg/L
  - b. Fluoride = 2 mg/L
  - c. Cadmium = 0.005 mg/L
  - d. Mercury = 0.002 mg/L
  
2. List the Best Available Technologies (BATs) for treating water with the following inorganic constituents.
  - a. Mercury GAC
  - b. Cadmium Coagulation/Filtration
  - c. Arsenic Coagulation/Filtration
  
3. List three common inorganic constituents and their sources. There are many answers.
  - a. Asbestos - Erosion of natural deposits
  - b. Cadmium - Erosion of natural deposits
  - c. Iron - Erosion of natural deposits
  
4. What could cause a metallic or salty taste in drinking water?  
**A:** Copper, iron, manganese, zinc, pH, total dissolved solids, sulfate or chloride
  
5. High levels of fluoride in drinking water could cause tooth discoloration.
  
6. Which of the following produce water with the highest hardness?
  - a. Lake
  - b. Well
  - c. River
  - d. Stream
  
7. True or False: Hard water is caused by iron in the water

Pages 3-30 through 3-32 provide information about organic compounds and the best available technologies to treat water contaminated with these organic compounds.

## General Categories of Organic Compounds



### Slide 71 Organic Compounds

- Synthetic (man-made) Organic Chemicals (SOC)
- Natural Organic Matter (NOM)

## Regulations

- Synthetic Organic Chemicals (SOC) are generally classified as either Volatile Organic Compounds (VOC) or non-volatile organic compounds.
- NOM is regulated in the Disinfection/Disinfectant Byproduct Rule which is discussed later in this Unit.

### Standards and BATS for Volatile Organic Compounds (VOC)

Table 3-12  
Standards and BATS for VOCs

| Volatile Organics                       | MCL [parts per million (ppm)] | BAT      |
|---|-------------------------------|----------|
| Benzene                                 | 0.005                         | GAC, PTA |
| Carbon Tetrachloride                    | 0.005                         | GAC, PTA |
| (Mono) Chlorobenzene                    | 0.1                           | GAC, PTA |
| o-Dichlorobenzene                       | 0.6                           | GAC, PTA |
| p-Dichlorobenzene                       | 0.075                         | GAC, PTA |
| 1,2 Dichloroethane                      | 0.005                         | GAC, PTA |
| 1, 1 Dichloroethylene                   | 0.007                         | GAC, PTA |
| cis - 1,2 Dichloroethylene              | 0.07                          | GAC, PTA |
| trans-1,2 Dichloroethylene              | 0.1                           | GAC, PTA |
| 1,2 Dichloropropane                     | 0.005                         | GAC, PTA |
| Ethylbenzene                            | 0.7                           | GAC, PTA |
| Methylene Chloride<br>(Dichloromethane) | 0.005                         | PTA      |
| Styrene                                 | 0.1                           | GAC, PTA |
| Tetrachloroethylene (PCE)               | 0.005                         | GAC, PTA |

| <b>Volatile Organics</b> | <b>MCL [parts per million (ppm)]</b> | <b>BAT</b> |
|--------------------------|--------------------------------------|------------|
| Toluene                  | 1.0                                  | GAC, PTA   |
| 1,2,4 Trichlorobenzene   | 0.07                                 | GAC, PTA   |
| 1,1,1 Trichloroethane    | 0.2                                  | GAC, PTA   |
| 1,1,2 Trichloroethane    | 0.003                                | GAC, PTA   |
| Trichloroethylene (TCE)  | Zero                                 | GAC, PTA   |
| Vinyl Chloride           | Zero                                 | PTA        |
| Xylenes                  | 10.0                                 | GAC, PTA   |

PTA = Packed Tower Aeration, GAC = Granular Activated Carbon  
 TT = Treatment Technique, PAP = Polymer Addition Practices

**Standards and BATS for Non-Volatile Organic Compounds**

Table 3-13

Standards and BATS for Non-Volatile Organic Compounds

| <b>Non-Volatile Organics</b>  | <b>MCL (ppm)</b> | <b>BAT</b> |
|-------------------------------|------------------|------------|
| Acrylamide                    | TT               | PAP        |
| Alachlor                      | 0.002            | GAC        |
| Aldicarb (proposed)           | (0.003)          | GAC        |
| Aldicarb sulfone (proposed)   | (0.002)          | GAC        |
| Aldicarb sulfoxide (proposed) | (0.004)          | GAC        |
| Atrazine                      | 0.003            | GAC        |
| Benzo(a)pyrene                | 0.0002           | GAC        |
| Carbofuran                    | 0.04             | GAC        |
| Chlordane                     | 0.002            | GAC        |
| 2,4 D                         | 0.07             | GAC        |
| Dalapon                       | 0.2              | GAC        |
| Dibromochloropropane (DBCP)   | 0.0002           | GAC, PTA   |
| Di(2-ethylhexyl)adipate       | 0.4              | GAC, PTA   |
| Di(2-ethylhexyl)phthalate     | 0.006            | GAC        |
| Dinoseb                       | 0.007            | GAC        |

| <b>Non Volatile-Organics</b>    | <b>MCL (ppm)</b>   | <b>BAT</b> |
|---------------------------------|--------------------|------------|
| Diquat                          | 0.02               | GAC        |
| Endothall                       | 0.1                | GAC        |
| Endrin                          | 0.002              | GAC        |
| Epichlorohydrin                 | TT                 | PAP        |
| Ethylene Dibromide (EDB)        | 0.00005            | GAC, PTA   |
| Glyphosate                      | 0.7                | OX         |
| Heptachlor                      | 0.0004             | GAC        |
| Heptachlor epoxide              | 0.0002             | GAC        |
| Hexachlorobenzene               | 0.001              | GAC        |
| Hexachlorocyclopentadiene       | 0.05               | GAC, PTA   |
| Lindane - ( $\delta$ BHC)       | 0.0002             | GAC        |
| Methoxychlor                    | 0.04               | GAC        |
| Oxamyl (Vydate)                 | 0.2                | GAC        |
| Pentachlorophenol               | 0.001              | GAC        |
| Pichloram                       | 0.5                | GAC        |
| Polychlorinated Biphenals (PCB) | 0.0005             | GAC        |
| Simazine                        | 0.004              | GAC        |
| 2,3,7,8 TCDD (Dioxin)           | $3 \times 10^{-8}$ | GAC        |
| Toxaphene                       | 0.003              | GAC        |
| 2,4,5 TP (Silvex)               | 0.05               | GAC        |



Can you think of some common sources of Natural Organic Compounds (NOMs)?

**Ans:** Many answers including: breakdown of plant debris including algae, aquatic plants, leaves, humic matter from wetlands in the watershed.

"Humic matter" can be defined as a substance derived from humus, a black or brown organic substance consisting of partially or wholly decayed vegetable matter.



Can you think of some common sources of Synthetic Organic Chemicals (SOCs)?

**Ans:** Many answers including: chemical industrial discharges, metal degreasing chemicals, wasted dry cleaning chemicals, leakage from old electrical transformers (PCB), agricultural runoff containing pesticides, drinking water chemicals, storm water runoff from developed areas.

**Advance Display Slide 71****Exercise - Organic Compounds**

1. SOC is an acronym for Synthetic Organic Chemicals
2. Synthetic Organic Chemicals can be further classified as Volatile Organic Compounds or Non-volatile Organic Compounds.
3. List the Maximum Contaminant Level (MCL) for the following volatile organic compounds.
  - a. Benzene = 0.005 ppm
  - b. Ethylbenzene = 0.7 ppm
  - c. Vinyl Chloride = 0.002 ppm
4. List three non-volatile organic compounds.  
*[Instructor: See page 3-27 for possible answers.]*
  1. Atrazine \_\_\_\_\_
  2. Diquat \_\_\_\_\_
  3. Lindane \_\_\_\_\_
5. List the best available technologies (BATS) for removing Benzene from drinking water.

**GAC and PTA**



Pages 3-35 and 3-36 address the radionuclides in the same manner.



**Display Slide 72**

## Types and Sources of Radionuclides

Table 3-14  
Types and Sources of Radionuclides

| Parameter            | Source   |
|----------------------|--|
| Gross alpha emitters | Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation |
| Radium 226+228       | Erosion of natural deposits  |
| Uranium              | Erosion of natural deposits  |

## Standards and BATS for Radionuclides

Table 3-15  
Standards and BATS for Radionuclides

| Parameter                                   | MCL | BAT        |
|---|-----|------------|
| Radium 226 + 228 - pCi/L                    | 5   | LS, IX, RO |
| Beta-particle and Photon Emitters - Mrem/yr | 4   | CF, IX, RO |
| Uranium - µg/L                              | 30  | CF, LS, AX |
| Gross Alpha Emitters - pCi/L                | 15  | CF, RO     |

MM = Multimedia                      IX = Ion Exchange  
 AR = Aeration                         RO = Reverse Osmosis  
 AX = Advanced Oxidation         LS = Lime Softening  
 CF = Coagulation/Filtration

MCL = Maximum Contaminant Level,      MCLG = Maximum Contaminant Level Goal

## Acute and Chronic Health Affects

Table 3-16  
Health Affect of Radionuclides

| <b>Parameter</b>                | <b>Potential Health Affects</b>           |
|---------------------------------|---|
| Beta particle & photon emitters | Increased risk of cancer                  |
| Alpha emitters                  | Increased risk of cancer                  |
| Radium 226+ 228                 | Increased risk of cancer                  |
| Uranium                         | Increased risk of cancer, kidney toxicity |

Turn to page 3-37 and look at Table 3-17. This table contains the MRDL for chlorine, chloramines and chlorine dioxide.



Advance Display Slide 72

## Disinfectants

### Standards and BATS for Disinfectants

Table 3-17  
List of Regulated Disinfectants and BATS

| Parameter                                   | MRDL | MRDLG | BAT |
|---|------|-------|-----|
| Chlorine – mg/L as Cl <sub>2</sub>          | 4    | 4.0   | DC  |
| Chloramines – mg/L as Cl <sub>2</sub>       | 4    | 4.0   | DC  |
| Chlorine dioxide – mg/L as ClO <sub>2</sub> | 0.8  | 0.8   | DC  |

DC = Disinfection Control System  
MRDL = Maximum Residual Disinfectant Level  
MRDLG = Maximum Residual Disinfectant Level Goal

### Parameters for Monitoring

- Chlorine is measured to:
  - ✓ Determine the concentration of Free Available Chlorine (FAC) residual in the distribution system.
  - ✓ Optimize reactions with soluble iron and manganese, hydrogen sulfide, ammonia, and taste & odor compounds.
  - ✓ Control levels of Disinfectant Byproduct (DBP) formation by minimizing chlorine dose.
- Chloramine is measured to:
  - ✓ Determine the concentration of Total Available Chlorine (TAC) residual in the distribution system.
  - ✓ Optimize reactions of chlorine with ammonia, which generate chloramines.
- Chlorine dioxide is measured to:
  - ✓ Optimize reactions with taste & odor compounds, soluble iron and manganese.
  - ✓ Control levels of DBP formation by minimizing chlorine dioxide dose.
- Ozone is measured to:
  - ✓ Optimize reactions with taste & odor compounds, soluble iron and manganese.
  - ✓ Control levels of DBP formation by minimizing ozone dose.

## Disinfectant Byproducts

### Standards and BATS for DBPs

Table 3-18  
Disinfectant Byproducts, Standards, and BATS

| Parameter                     | MCLG | MCL   | BAT               |
|-------------------------------|------|-------|-------------------|
| Total Trihalomethanes         | NA   | 0.080 | AD, PR, DC/EC+GAC |
| Chloroform (THM)              | NA   | NA    | EC                |
| Bromodichloromethane (THM)    | Zero | NA    | EC                |
| Dibromochloromethane (THM)    | 0.06 | NA    | EC                |
| Bromoform (THM)               | Zero | NA    | EC                |
| Total Haloacetic Acids (HAA5) | NA   | 0.06  | EC/GAC            |
| Trichloroacetic Acid          | 0.3  | NA    | EC                |
| Dichloroacetic Acid           | Zero | NA    | EC                |
| Bromate                       | Zero | 0.010 | DC                |
| Chlorite                      | 0.8  | 1.0   | DC                |

NA = Not applicable

AD = Alternative Disinfectants

DC = Disinfection System Control

EC = Enhanced Coagulation

GAC = Granular Activated Carbon

PR = Precursor Removal

MCL = Maximum Contaminant Level

MCLG = Maximum Contaminant Level Goal



### Exercise - Radionuclides and DBP

- Besides alpha emitters, radium-226 and radium-228, what radionuclide must be monitored?

ANS: uranium

- True or False: The source of most radionuclides is the erosion of natural deposits

ANS: True

3. Which of the following are reasons a water system measures chloramine?
- Use the chloramine result to determine how well reactions of chlorine with ammonia are working
  - Determine if chlorine will react with hydrogen sulfide
  - Determine the concentration of Total Available Chlorine (TAC) residual in the distribution system
  - Determine the acidity of the water

**ANS:** a. Use the chloramine result to determine how well reactions of chlorine with ammonia are working and c. Determine the concentration of Total Available Chlorine (TAC) residual in the distribution system

4. List the Maximum Disinfectant Residual Levels (MDRLs) for the following disinfectants:
- Chlorine 4.0 mg/L
  - Chloramines 4.0 mg/L
  - Chlorine dioxide 0.8 mg/L

Turn to page 3-40 and we'll complete our Volume II exercise.

**Instructor Note:** Review answers and give page numbers if participants gave wrong answers and wanted to find the correct answer.

### Volume II Exercise

Using the workbook, answer the following questions:



#### **Slide 73 – Answers Volume II Exercise**

1. The boundary below which all of the spaces and cracks in the soil and rock are filled with water is known as the **water table**. (pages 1-2 and 1-6)
2. How are sinkholes formed in carbonate rock aquifers? **By water dissolving portions of the carbonate rock** (page 2-7)
3. List one example of a regulated waterborne microorganism.
  - a. ***E. coli*, *Cryptosporidium*, *Giardia lamblia*, Fecal coliforms, Legionella, Viruses, Heterotrophic plate count, total coliforms, turbidity** (page 3-7)
4. Waterfowl droppings, septic fields, and run-off from farm fields are some of the common sources of waterborne pathogenic microorganisms.
  - a. **True** (page 3-7)
  - b. False
5. List one characteristic of an effective microbial indicator. (page 3-13)  
**Present in large numbers in fecal matter**

**Present when the pathogenic microorganism is present**

**High ratio of indicators to pathogens**

**Stable and non-pathogenic**

**Absent in uncontaminated water**

**Should respond similarly to natural conditions and be at least as susceptible to treatment as the pathogenic microorganism**

**Easily detected by simple, inexpensive lab tests in the shortest time with accurate results**

**Should be suitable for all types of drinking water supplies**







6. A sudden increase in Heterotrophic Plate Count (HPC) may suggest a problem with treatment, including disinfection practices.
  - a. True (page 3-14)
  - b. False
7. Waterfowl droppings, septic fields, and run-off from farm fields are some of the common sources of waterborne pathogenic microorganisms.
  - a. True (page 3-7)
  - b. False
8. List the Maximum Disinfectant Residual Level (MDRL) for chlorine: **4 mg/L as Cl<sub>2</sub> (page 3-37)**
9. Give the Primary Maximum Contaminant Level (PMCL) for cadmium **0.005 mg/L (page 3-19)**
10. Hard water is caused by iron in the water:
  - a. True
  - b. False (primarily calcium and magnesium salts, page 3-24)

**Slide 74 – Key points on 3-41**

Turn to page 3-41 to review the Unit 3 key points.

**Instructor Note:** Read the key points on 3-41.

**Key points for Unit 3 – Water Quality Classifications**

-  Waterborne pathogenic microorganisms present in drinking water can cause disease in humans.
-  Drinking water disease outbreaks most often involve groundwater systems.
-  Waterfowl droppings, septic fields, and farm run-off are common sources of waterborne pathogenic microorganisms.
-  The three categories of microorganism agents of waterborne disease are bacteria, protozoa, and viruses.
-  Microbial indicators are often used in place of testing for waterborne pathogenic microorganisms.
-  A colloidal suspension of extremely small particles in water will not settle naturally and requires chemical additives or special techniques to remove the particles.

- ☐ The process of coagulation involves adding a chemical compound (like alum) to water to destabilize colloidal and suspended particles to form a floc that can be removed by settling and/or filtration.
- ☐ Colorimetric testing methods are used to measure a water sample's color adsorption after adding specific reagents to the water.
- ☐ A measurement of pH indicates the hydrogen ion activity which affects many chemical reactions.
- ☐ Organic compounds are classified as Synthetic Organic Chemicals (SOC) or Natural Organic Matter (NOM).
- ☐ Common chemical disinfectants are Chlorine, Chloramines, Chlorine Dioxide, and Ozone.

The final general topic we want to review in Volume II involves a few basic concepts about matter.



# Drinking Water & Wastewater Operator Certification Training



## Module 29: General Chemistry Excerpts

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)  
Gannett Fleming, Inc.  
Dering Consulting Group  
Penn State Harrisburg Environmental Training Center

Topical Outline

**Unit 1 – Fundamentals of Chemistry**

The Structure of Matter

Classification of Matter

Physical Properties of Matter

## Unit 1 – Fundamentals of Chemistry

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### Slide 75 – Mod 29, Chemistry Concepts

- List three states of matter and explain the difference among them.
- List and define four physical properties of matter.
- Explain the difference between elements, compounds and mixtures.
- Explain the differences between elements, compounds and mixtures.
- List the primary difference between a physical and chemical change of matter.



Slide 76 – Classification of Matter

Turn to page 4-2 and look at Figure 1.4 (Classification of Matter)

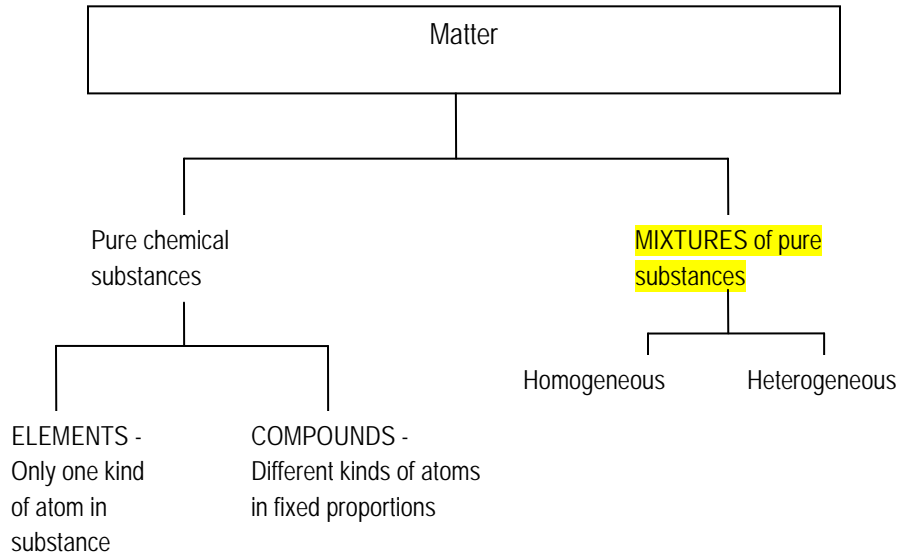


Figure 1.4 Classification of Matter

States of Matter

Matter exists in three states.

- ◆ A solid state in which the matter has a fixed shape and a fixed volume. Solid matter is characterized by rigidity. Examples of matter that exist in a solid state include things such as a desk, the floor or even a piece of paper in this workbook.
- ◆ A liquid state in which the matter has no fixed shape but has a fixed volume. Liquid matter is a relatively incompressible fluid. Examples of matter in the liquid state include things such as milk, water and gasoline.
- ◆ A gas state in which the matter has no fixed shape and no fixed volume. Matter in the gaseous state is easily compressible. Examples of matter in the gaseous state include hydrogen sulfide, methane, natural gas or the air that we breathe.

Under certain conditions, a material substance can exist in all three states. For example, at room temperature, water is a liquid, but below 32° F, it becomes a solid - ice. If water is heated, it will eventually boil and become a vapor or gas.

When we perform dosage math calculations, we need to determine if we are using pure chemical substances or a mixture of substances.



### Slide 77 – General Chemistry Definitions

Turn to pages 4-3 and look at the definitions.

## Physical Properties of Matter

A physical property is an observable characteristic which does not involve a change in the chemical identity of the material.

### Mass



**Mass** is the amount of matter present in a given object. It is expressed in units such as pounds (lbs) or grams (g).

- ◆ Since mass is the amount of material in an object, it stays the same no matter what force is acting on it. This is what differentiates “mass” and “weight.”
- ◆ All matter, including chemicals and substances, are commonly described on the basis of “mass.”

*Instructor Note: Read **highlighted** text below.*

### Weight



**Weight** is the mass of an object being acted upon by gravity. The weight of an object is proportional to its mass.

- ◆ There is less gravitational force on the moon than on Earth; therefore, an object on the moon will weigh less than the same object on Earth. The mass of the object remains the same but the weight is different.

### Density



**Density** is the mass of a substance per unit of volume of the substance. All matter has mass and volume; therefore, all matter has a density.

- ◆ Density is important because it can be used to relate how a solution compares to water.
- ◆ Density is expressed as a mass per volume, such as mg/L or lbs/ft<sup>2</sup> and is calculated as follows:

$$\text{Density (d)} = \frac{\text{Mass (m)}}{\text{Volume (v)}}$$

**Density of Water**

- ◆ By definition, 1 Liter of water = 1 kilogram of mass, therefore:

$$\begin{aligned} \text{Density of water} &= 1,000 \text{ grams per } 1,000 \text{ milliliters} \\ &= 1,000 \text{ grams} / 1,000 \text{ ml} \\ &= 1 \text{ g/ml or } 1 \text{ g/cm}^3 \end{aligned}$$

- ◆ Water has a density of 1 g/ml, 1 g/cm<sup>3</sup> or 8.34 lbs/gallon. If you weigh a gallon of water, it will weigh 8.34 lbs. Likewise, if you weigh a milliliter of water it will weigh 1 gram.
- ◆ Substances with a greater density will displace those with less density. If a solution has a higher density than water, it will sink in the water; however, if a solution has a lower density than water, it will float on the water. For example, lead will sink in water but oil will float on the water.

**Specific Gravity**



Specific gravity is the density of a substance compared to the weight of the same volume of water.

- ◆ Specific Gravity =  $\frac{\text{Weight}}{\text{Density}}$
- ◆ Specific gravity is used to check chemical purity. It is also used to calculate volume for a given weight of chemical or to calculate weight for a given volume of chemical.

**Calculating Specific Gravity**

- ◆ Specific gravity is calculated by comparing the weight of a given volume of a substance to the weight of the same volume of water.
- ◆ Water has a density of 1 gram/milliliter (g/ml) so its specific gravity is equal to its density.

*Example*

Calculate the specific gravity of 1 ml of a substance that weighs 2 grams.

$$\text{Specific Gravity} = \frac{\text{Weight}}{\text{Density}}$$

$$\text{Specific Gravity} = \frac{2 \text{ gm/ml}}{1 \text{ gm/ml}} \quad 2$$

In this example, the substance is twice as dense as water.

***Calculating the Weight of a Gallon of Chemical***

- ◆ To calculate the weight of a gallon of a chemical, multiply the specific gravity of the chemical by the weight of a gallon of water.



**Slide 78 – Example 1**

*Example 1:* Calculate the weight of a gallon of 50% NaOH (sodium hydroxide or caustic soda), given that a 50% solution of caustic soda has a specific gravity of 1.53.

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

Weight, lbs/gal = (1.53) x (8.34 lbs/gal)

Weight = A gallon of 50% solution of NaOH weighs 12.8 lbs



**Slide 79 – Example 2**

***Calculating the Weight of a Chemical Solution in a Drum or Tank of Chemical***

*Example 2:* What would be the weight of a 55 gallon drum of the coagulant Sternpac if the specific gravity of the product is 1.27?

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

**Step 1:** Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight, lbs/gal = (1.27) x (8.34 lbs/gal)

Weight, lbs/gal = ONE gallon of Sternpac weighs 10.6 lbs

**Step 2:** Multiply 1 gallon weight in lbs/gal X volume of drum or tank in gallons

? lbs = [insert Step 1 answer in lbs/1 gallon] X 55 gallons = 583 lbs

Step 2 Unit Cancellation:

? lbs =  $\frac{10.6(\text{lbs})}{1 \text{ gallon}}$  X 55 ~~gallons~~ = 583 pounds [weight of 55 gallon drum of Sternpac]

*Calculating the Number of Gallons of a Chemical Solution in a Drum or Tank*



**Slide 80 – Example 3**

*Example 3*

Calculate the number of gallons of 2,000 pounds of 12% NaOCl (sodium hypochlorite), given its specific gravity of 1.12.

Weight, lbs/gal = (specific gravity of substance) x (weight of a gallon of water)

**Step 1:** Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight, lbs/gal = (1.12) x (8.34 lbs/gal)

Weight = A gallon of 12% solution of NaOCl weighs 9.3 lbs

**Step 2:** Calculate the numbers of gallons of 2,000 lbs. of 12% NaOCl

(total weight of chemical in lbs) ÷ (Step 1 weight lbs/gallon) = gallons of 12% NaOCl

(2,000 lbs) ÷ (9.3 lbs/gal) = 215 gallons of 12% NaOCl

Step 2 Unit cancellation steps to solve for unknown # of gallons using total weight of 2000 lbs and 9.3 lbs/gal weight of solution.

$$? \text{ gal} = \frac{1 \text{ gal}}{9.3 \text{ lbs}} \times \frac{2000 \text{ lbs}}{1} = \frac{2000}{9.3} = 215 \text{ gallons}$$

**Class Exercise - Instructor Note: Give the class time to complete the following problems, then go over together.**

Class Exercise



**Slide 81 – Class Exercise – answers come with each click**

1. The specific gravity of Aqua Mag is 1.4. How much (lbs) does a one gallon weigh?

$$? \text{ lbs/gal} = (\text{S.G.}) \times (8.34 \text{ lbs/gal}) = 12. \text{ lbs/gal}$$



2. How much does a 30 gallon drum of 60% fluorosilic acid weigh (lbs) if it has a specific gravity of 1.46?

**Step 1:** Solve weight equation (lbs/gal) for 1 gallon of chemical

$$\text{Weight, lbs/gal} = (\text{S.G.}) \times (8.34 \text{ lbs/gal})$$

$$\text{Weight, lbs/gal} = \text{ONE gallon of 60\% fluorosilic acid weighs} = (1.46) \times 8.34 = 12.17 \text{ lbs/gal}$$

**Step 2:** Multiply 1 gallon weight in lbs/gal X volume of drum or tank in gallons

$$? \text{ lbs} = [\text{insert Step 1 answer in lbs/1 gallon}] \times 30 \text{ gallons} = \underline{365 \text{ lbs}}$$

$$\text{Unit Cancellation: } ? \text{ lbs} = \frac{12.17 \text{ lbs}}{1 \text{ gallon}} \times 30 \text{ gallons} = 365 \text{ pounds}$$

3. Your plant has a 10,000 gallon tank of Aluminum Chloride. The specific gravity of Aluminum Chloride is 1.2. How much (in pounds) does the tank of Aluminum Chloride weigh when the tank is full?

**Step 1:** Solve weight equation (lbs/gal) for 1 gallon of chemical

$$\text{Weight, lbs/gal} = (\text{S.G.}) \times (8.34 \text{ lbs/gal})$$

$$\text{Weight, lbs/gal} = \text{ONE gallon of aluminum weighs} = 1.2 \times (8.34 \text{ lbs/gal}) = 10 \text{ lbs/gal}$$

**Step 2:** Multiply 1 gallon weight in lbs/gal X volume of drum or tank in gallons

$$? \text{ lbs} = [\text{insert Step 1 answer in lbs/1 gallon}] \times 10,000 \text{ gallons} = \underline{100,000 \text{ pounds}}$$

$$\text{Unit Cancellation: } ? \text{ lbs} = \frac{10 \text{ lbs}}{1 \text{ gallon}} \times 10,000 \text{ gallons} = 100,000 \text{ pounds}$$

### *Converting temperatures between the Fahrenheit and Celsius scales*



#### **Slide 82 – Formulas for converting between Fahrenheit and Celsius**

$$0.555 (°F - 32) = °C$$
$$(1.8 \times °C) + 32 = °F$$

(NOTE: 0.555 = 5/9 which is on the formula/conversion sheet)

Problem:

Convert 10 °C = ? °F



#### **Slide 83 – Convert 10°C = ? °F**

#### **Problem Set Up and Calculation:**

Step 1: Select correct conversion formula which is:  $(1.8 \times °C) + 32 = °F$

Step 2: Insert known value into formula:  $(1.8 \times 10) + 32$

Step 3: Complete the math within the parentheses  $(1.8 \times 10) = 18$

Step 4: Do the addition for final answer =  $50 °F$

- Water is most dense at 4 °C (39 °F).
- The density of water is a consideration in various aspects of water treatment. For example, the settling rate of a particle becomes much slower as the temperature drops. The colder the water temperature becomes, the longer particles take to settle out. This means that longer periods of time or lower flow rates are required for colder water temperatures.

### **Changes of Matter**

Matter can undergo both physical and chemical changes.

- ◆ A physical change in matter is a change in the form of matter but not in its chemical identity. Examples include dissolving and distillation.
- ◆ A chemical change in matter is a change in which one or more kinds of matter are transformed into a new kind of matter. Examples include burning or rusting.

**☑ Physical and Chemical Changes**

*[Review the following statements and mark whether the change is physical or chemical.]*

|   | PHYSICAL | CHEMICAL |
|---|----------|----------|
| 1. Drinking water from ocean water by means of evaporation and condensation | ✓        |          |
| 2. Sodium from sodium chloride  |          | ✓        |
| 3. Pulverizing rock salt  | ✓        |          |
| 4. Burning wood   |          | ✓        |
| 5. Dissolving sugar into water  | ✓        |          |
| 6. Rusting of Iron  |          | ✓        |
| 7. The evaporation of alcohol   | ✓        |          |

**Slide 84 Module 29 Wrap Up****Review Exercise**

1. Define the term matter and list the three states of matter.

**Ans:** Matter occupies space and has mass. The air that surrounds us, the pencil that we write with and the water that we drink are all examples of matter. The three states of matter are solid, liquid and gas.

2. Differentiate between mass, weight, density and specific gravity.

**Ans:** Mass is the amount of matter present in a given object.

Weight is the mass of an object being acted upon by gravity.

Density is the mass of a substance per unit of volume of the substance.

Specific gravity is the density of a substance compared to the weight of the same volume of water.

3. Explain the difference between a physical and a chemical change in matter.

**Ans:** A physical change in matter is a change in the form of matter but not in its chemical identity. A chemical change in matter is a change in which one or more kinds of matter transform into a new kind of matter.

4. List and define three classes of matter.

**Ans:** Element – a substance that cannot be decomposed into simpler substances by any chemical reaction.

Compound – a substance that is composed of two or more elements that are chemically combined in fixed proportions.

Mixture – a material that can be separated by physical means into two or more substances.

Turn to page 4-10 to review the Unit 1 Key points.



### Slide 71 – Key Points for Unit 1 Fundamentals of Chemistry

**Instructor Note:** Read the key points on page 4-10.

#### Key Points for Unit 1 – Fundamentals of Chemistry

- Matter exists in three states: solid, liquid and gas.
- Density is the mass of a substance per unit of volume of the substance. Density can be used to relate how a solution compares to water.
- Water has a density of 8.34 lbs/gallon.
- Specific gravity is the density of a substance compared to the weight of the same volume of water.
- Specific gravity is used to calculate volume for a given weight of chemical or to calculate weight for a given volume of chemical.
- Weight, lbs/gal = (Specific gravity of substance) X (weight of a gallon of water).
- Temperature conversions from °C to °F and vice versa are as follows:
  - $(1.8 \times ^\circ\text{C}) + 32 = ^\circ\text{F}$
  - $0.555 (^\circ\text{F} - 32) = ^\circ\text{C}$
- Water is most dense at 4 °C (39 °F).