Advanced Water Treatment

Presented by: Stephanie Layfield

Advanced Math

- Please take out Math handout and a calculator

Remember:

- **4 steps to follow with a word problem:**
  1. Write down given numbers with units.
  2. Write down the correct formula.
  3. Fill numbers into formula.
  4. Calculate and convert to correct units.

Using Multiple Formulas

- Sometimes more than one formula will be needed to get to the right answer.
- Be very clear when you list your numbers in step 1.
- It may be beneficial to work backwards.
  - Start with a formula that will give you the right answers and use other formulas to help fill in the needed information.

1. Using Multiple Formulas

How many pounds of pure chlorine are needed to apply a 12.5 mg/l dosage to a tank that is 10 ft tall, 30 ft wide, and 25 ft long?

Step 1

- **Dos = 12.5 mg/l**
- **Height =10 ft**
- **Width = 30 ft**
- **Length = 25 ft**
- **Lbs. = ?**

Step 2

(MG) (mg/l) (8.34) = lbs.

V = Length x Width x Height

Step 3

(MG) (12.5) (8.34) = lbs.

V = 25 ft. x 30 ft. x 10 ft

Step 4

V = 7,500 cu. ft. x 7.48 = 56,100 gallons = 0.0561 MG

Lbs. = 0.0561 x 12.5 x 8.34

= <u>5.8 lbs.</u>

2. Using Multiple Formulas – Your Turn!

Calculate the dosage given to a 750,000-gallon system after adding 20 pounds of 85% calcium hypochlorite?

- Step 1
  - 750,000 gal = 0.75 MG
  - 20 lbs compound

  Dosage = ?

  85% Cl_2 = 0.85 Cl_2
- Step 2
  - Dosage = Lbs. / (MGD x 8.34)
  - Lbs. compound = Lbs. pure / % Cl_2
- Step 3
  - Dosage = Lbs / (0.75 x 8.34)

  20 = Lbs / 0.85
- Step 4
  - 20 = Lbs / 0.85 Lbs = 20 x 0.85 = 17 Lbs
  - Dosage = 17 / (0.75 x 8.34) = 17 / (6.255) = 2.7 mg/l

3. Using Multiple Formulas – Challenge Question!

Calculate the demand of a 4 ft. diameter by 16 ft. tall round tank that was disinfected with 5 pounds of 8% bleach and has a sustained residual of 2.6 mg/l?

- Step 1
  - Demand = ? Diameter = 4 ft Radius =2 ft Height = 16 ft
  - Residual = 2.6 mg/l 5 lbs. = compound 8% = 0.08 Cl_2
- Step 2
  - Dosage = Demand + Residual $V = \pi r^2$ x Height
  - Dosage = Lbs. / (MGD x 8.34) Lbs. Compound = Lbs. pure / % chlorine
- Step 3
  - Dosage = ? + 2.6 mg/l V = 3.14 x 2 x 2 x 16
  - Dosage = Lbs. / (MGD x 8.34) 5 = Lbs. pure / 0.08
- Step 4
  - V= 200.96 c.f.= 1,503 g.= 0.0015 MG 5= Lbs. pure/0.08 ➔ 5 x 0.08= 0.4 lbs.
  - Dosage = 0.4/ (0.0015 x 8.34) = 0.4/0.01251 = 32 mg/l
  - 32 mg/l = Demand + 2.6 mg/l Demand = 32 mg/l – 2.6 mg/l = **29.4 mg/l**

Empty Bed Contact Time

- EBCT is the theoretical detention time calculated by using the volume occupied by the media.
- EBCT = V / F
  - V = Volume of Media
  - F = Flow of Water

1. Empty Bed Contact Time

Determine the amount of carbon media in cu. ft. needed to remove Hydrogen Sulfide if the flow rate is 2.5 GPM. According to the carbon manufacturer, an EBCT of 4.5 minutes is adequate for Hydrogen Sulfide removal.

- Step 1
  - Flow = 2.5 GPM
  - EBCT = 4.5 min.
  - Volume = ?
- Step 2
  - EBCT = V / F
- Step 3
  - 4.5 min. = ? / 2.5 GPM
- Step 4
  - ? = 4.5 min. x 2.5 GPM = 11.25 gal. ➔ ÷ 7.48
  - = <u>1.5 cu. ft. media</u>

2. Empty Bed Contact Time – Your Turn!

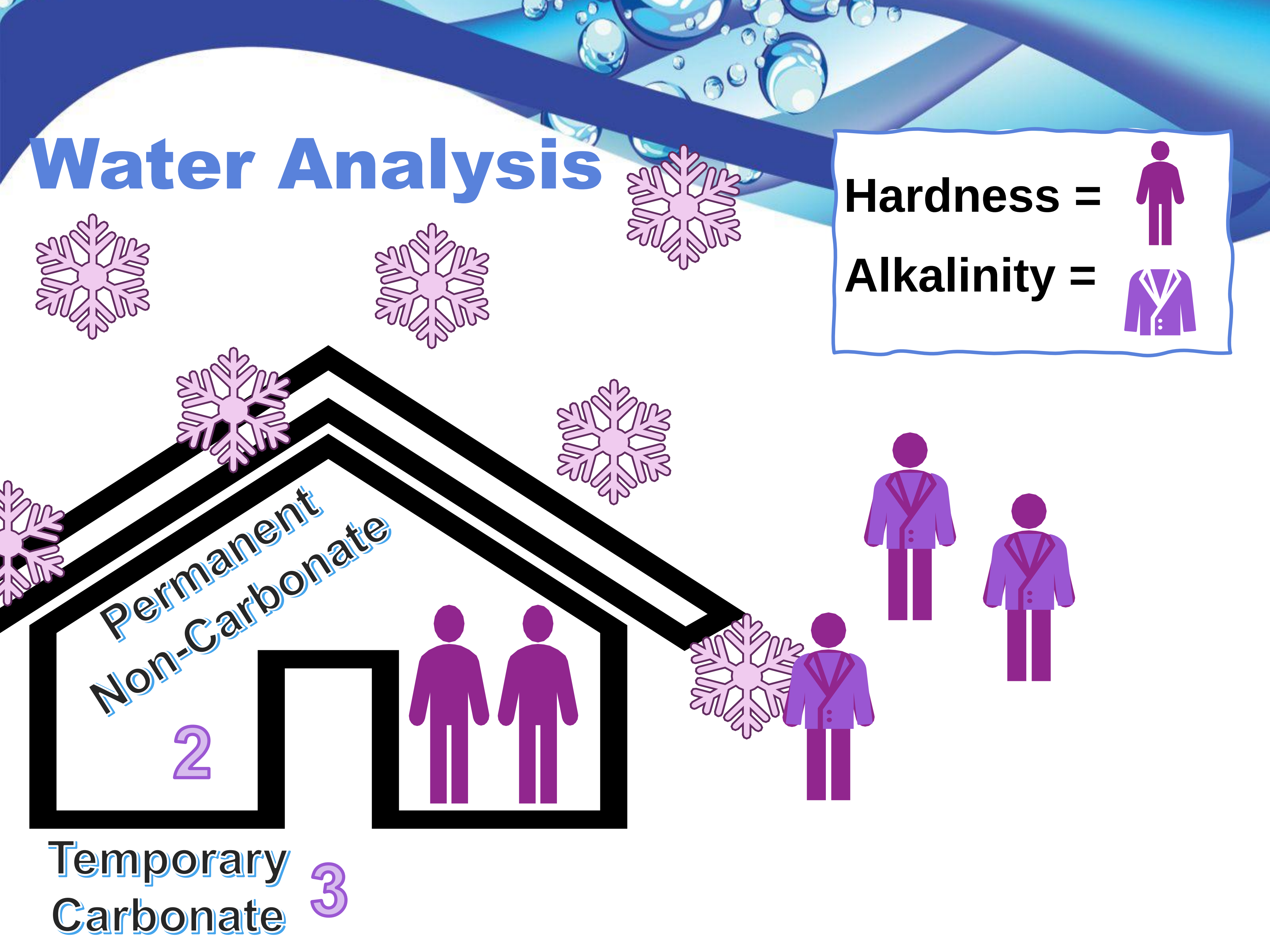
An activated carbon canister is 6 inches in diameter and 18 inches high. The carbon occupies 70% of the canister volume. If the flow rate is 0.11 gallons per minute, what is the EBCT in minutes?

- Step 1
- Diameter = 6 in = 0.5 ft   Radius = 0.25 ft   Height = 18in = 1.5 ft
- V media = 70% x V total   Flow = 0.11 GPM   EBCT = ?
- Step 2
  - V total = π x r^2 x height   EBCT = V media / Flow
- Step 3
  - EBCT = V media / 0.11 GPM
  - V total = 3.14 x 0.25 x 0.25 x 1.5   V media = 0.70 x V total
- Step 4
  - V = 0.29 cu. ft. x 7.48 = 2.2 gal.   V media = 0.70 x 2.2 gal = 1.5 gal
  - **EBCT = 1.5 gal. / 0.11 GPM = 14 minutes**

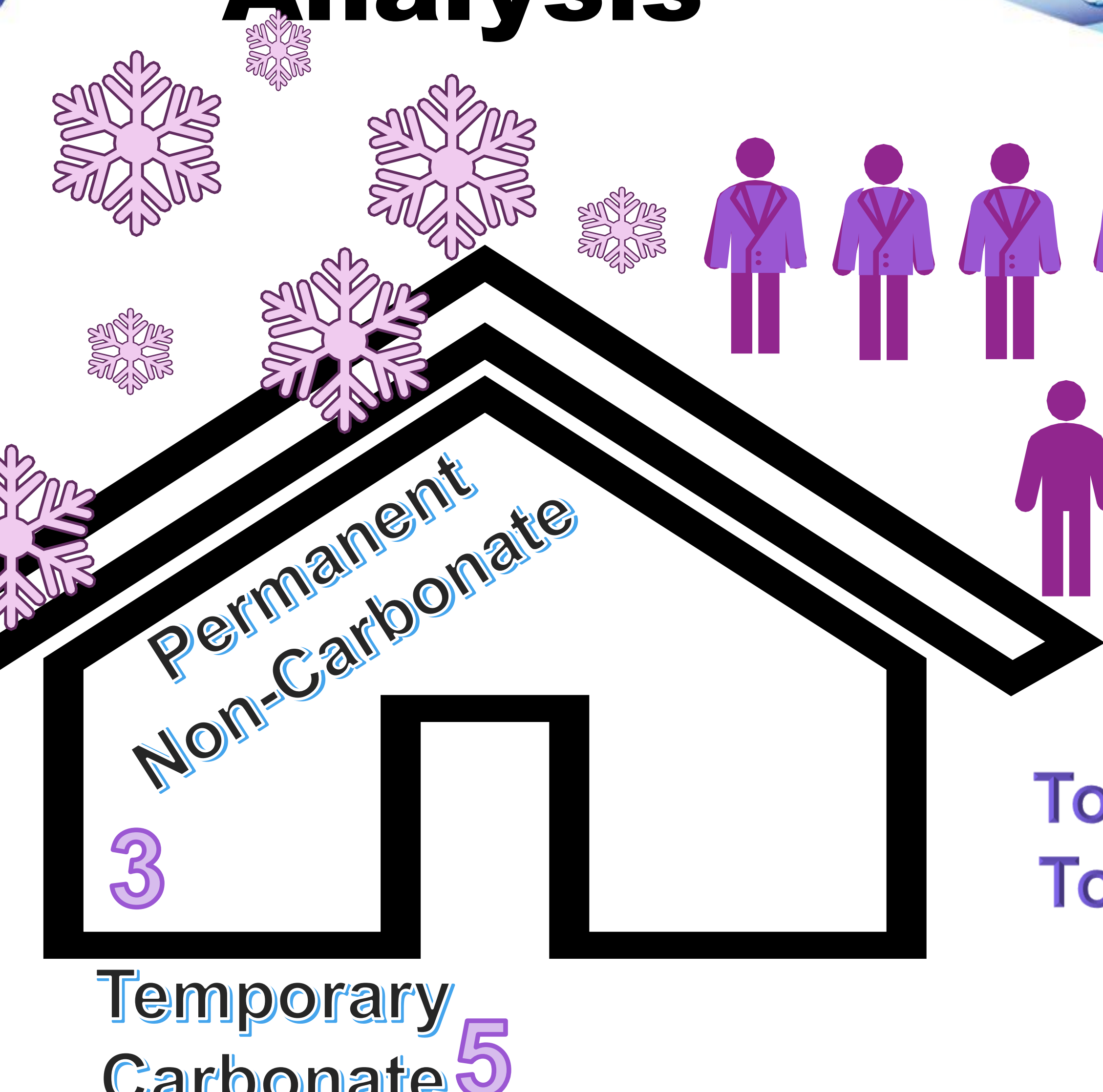
Water Analysis

In a water analysis that gives you total alkalinity and total hardness, you can calculate how much is temporary hardness and how much is permanent hardness

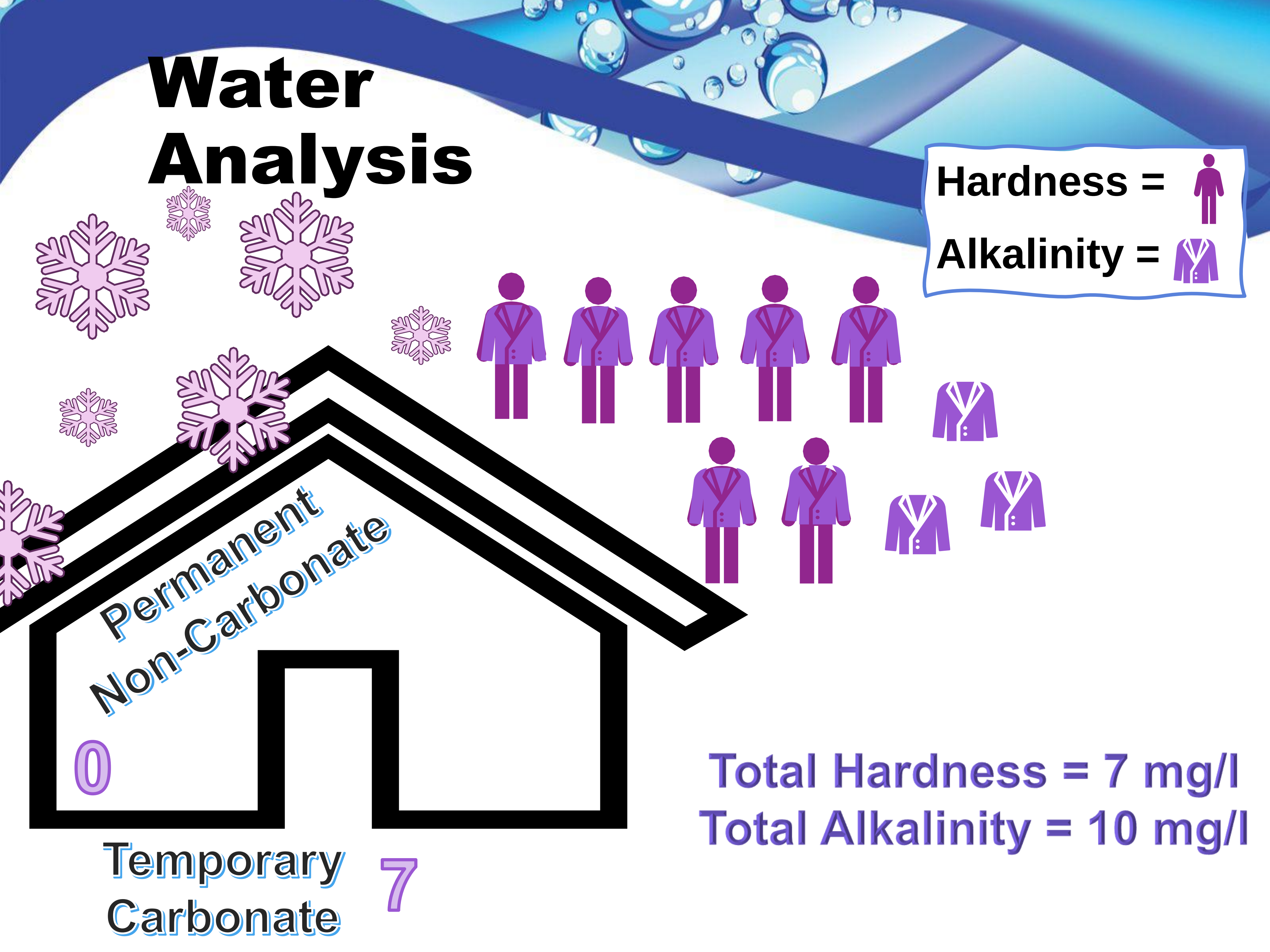
- **Temporary = Carbonate Hardness**
  - Hardness covered by alkalinity
- **Permanent = Non-Carbonate Hardness**
  - Total hardness – Temporary hardness


Water Analysis
Hardness =
Alkalinity =
Permanent
Non-Carbonate
2
Temporary
Carbonate
3

Water Analysis



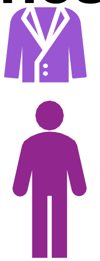
Total Hardness = 8 mg/l
Total Alkalinity = 5 mg/l


Water Analysis
Hardness =
Alkalinity =
Permanent
Non-Carbonate
0
Temporary
Carbonate
7
Total Hardness = 7 mg/l
Total Alkalinity = 10 mg/l

1. Water Analysis

From the following water analysis, determine the type and amount of hardness.

- **Total alkalinity = 300 mg/l**
- **Total Hardness = 200 mg/l**



Temporary (Carbonate) Hardness = 200 mg/l

Permanent (Non-Carbonate) Hardness = 0 mg/l

2. Water Analysis – Your Turn!

From the following water analysis, determine the type and amount of hardness.

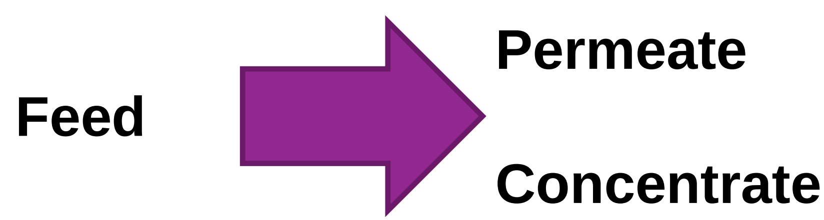
- **Total alkalinity = 150 mg/l**
- **Total Hardness = 350 mg/l**

Temporary (Carbonate) Hardness = 150 mg/l

Permanent (Non-Carbonate) Hardness = 200 mg/l

RO Math

- Feed = Permeate + Concentrate
- Recovery = % product through an RO unit
  - % Recovery = Permeate / Feed x 100
- RO's produce more at higher temperatures
  - 1.5% increase per *F temperature change
- Osmosis Pressure
  - 1 psi = 100 ppm TDS Difference



1. RO Math

Calculate the feed to an RO that is producing 5 gpm permeate and 15 gpm concentrate.

- Step 1
  - Permeate = 5 gpm
  - Concentrate = 15 gpm
  - Feed = ?
- Step 2
  - Feed = Permeate + Concentrate
- Step 3
  - Feed = 5 gpm + 15 gpm
- Step 4
  - Feed = <u>20 gpm</u>

2. RO Math – Your Turn!

Calculate the concentrate to an RO that is producing 10 gpm permeate and with a 40 gpm feed.

- Step 1
  - Permeate = 10 gpm
  - Feed = 40 gpm
  - Concentrate = ?
- Step 2
  - Feed = Permeate + Concentrate
- Step 3
  - 40 gpm = 10 gpm + ? → ? = 40 gpm – 10 gpm
- Step 4
  - Concentrate = 30 gpm

3. RO Math

Calculate the recovery of an RO that has a 80 gpd feed and produces 20 gpd.

- Step 1
  - Feed = 80 gpd
  - Product = 20 gpd
  - Recovery = ?
- Step 2
  - % Recovery = permeate / Feed x 100
- Step 3
  - ? = 20 / 80 x 100
- Step 4
  - % Recovery = <u>25%</u>

4. RO Math – Your Turn!

When 6 gallons of permeate and 24 gallons of concentrate are produced by an RO unit, what is the recovery?

- Step 1
    - Permeate = 6 gallons
    - Concentrate = 24 gallons
    - Recovery = ?
- Step 2
    - % Recovery = permeate / Feed x 100
    - Feed = Permeate + Concentrate
- Step 3
    - ? = 6 / Feed x 100

      Feed = 6 + 24
- Step 4
    - Feed = 30

      % Recovery = 6/30 x 100
    - = 20%

5. RO Math – Your Turn!

Calculate the osmotic back pressure on an RO that has 1600 TDS feed and 100 TDS permeate.

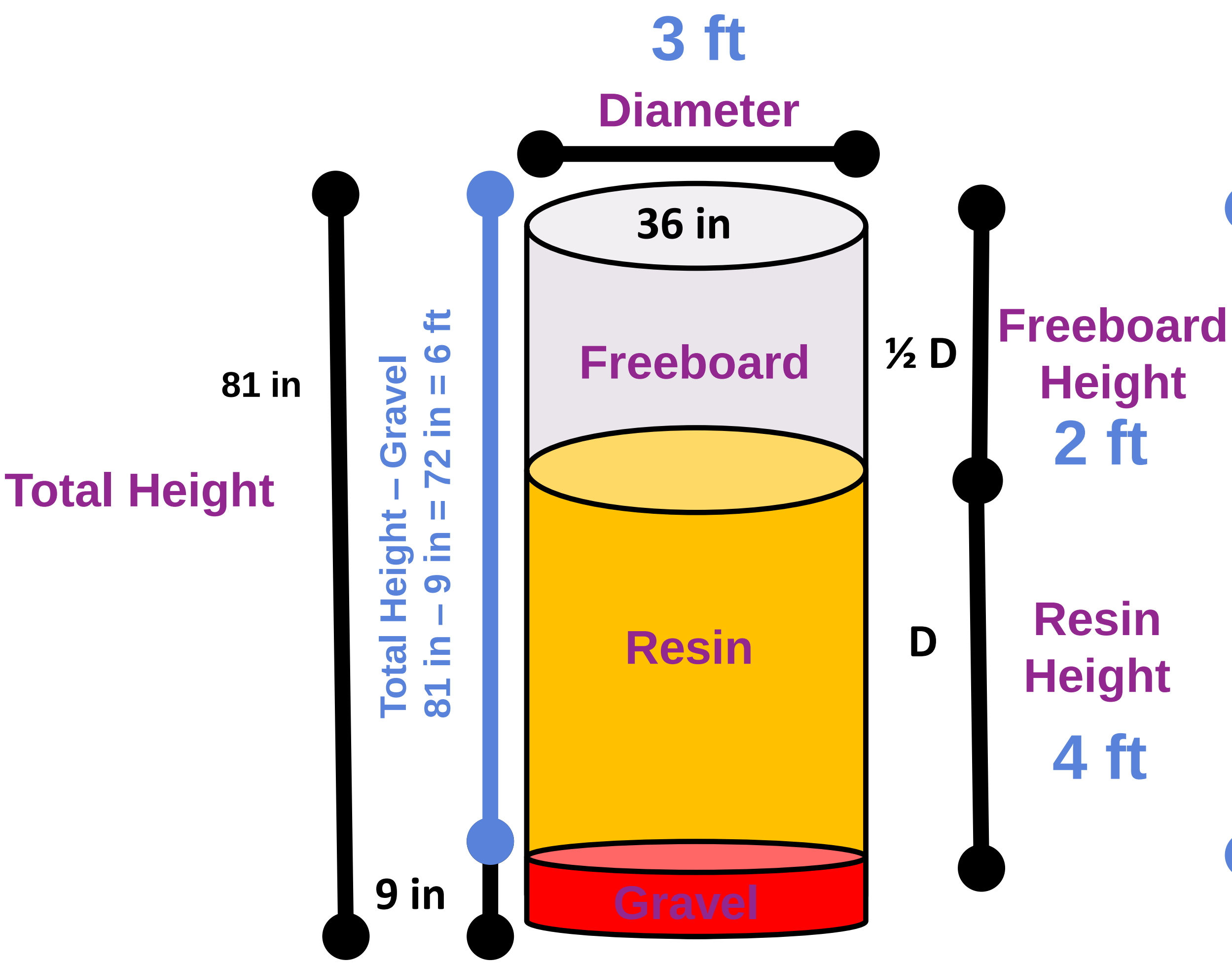
- Step 1
  - Feed = 1600 ppm
  - Permeate = 100 ppm
  - Osmotic pressure = ? psi
- Step 2
  - TDS difference = Feed TDS – Permeate TDS
  - Pressure = TDS diff. / 100
- Step 3
  - TDS diff. = 1600 ppm – 100 ppm
  - Pressure = TDS diff. / 100
- Step 4
  - TDS diff. = 1500
  - Pressure = 1500 / 100
  - = <u>15 psi</u>

6. RO Math – Your Turn!

An RO unit is making 20 gph at 77*f. If the temperature drops to 65*f what will the production rate be?

- Step 1
  - Production = 20 gph
  - Start temp = 77*f		End temp = 65 *f
  - New production = ? gph
- Step 2
  - Change in production = 1.5% x change in temp
  - Change in temp = Start temp – End Temp
- Step 3
  - Change in temp = 77 – 65
  - % change= 1.5% x Change in temp
  - Change in production = % change x Start Production
  - New production = Production – change in production (colder)
- Step 4
  - Change in temp = 12*f		Change in prod. = 1.5% x 12 = 18%
  - 0.18 x 20 = 3.6 gph
  - 20 gph – 3.6 gph = **16.4 gph**

Softener Math



Freeboard + Resin = 6 ft

D + ½ D = 6 ft

[4] + ½ [4] = 6 ft

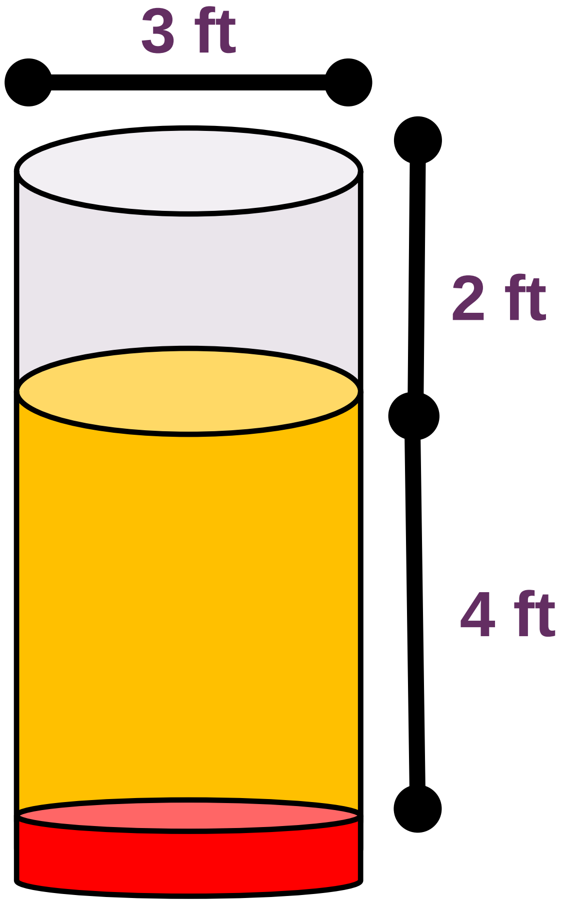
4 ft + 2 ft = 6 ft

Softener Math

How many cubic feet of resin does the unit contain?

How many gallons of water can the freeboard hold?

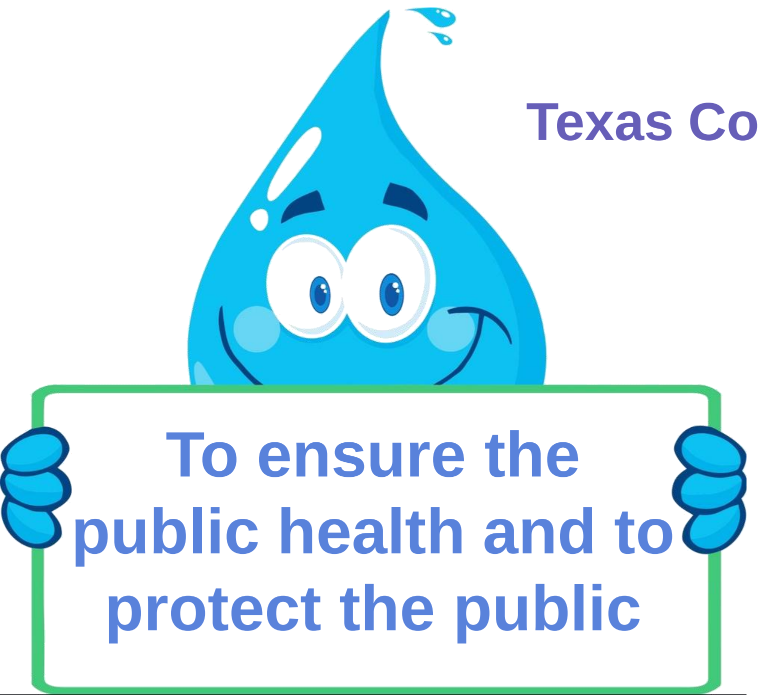
- **Step 1**
  - **Diameter = 3 ft   Radius = 1.5 ft**
  - **Freeboard Height = 2 ft**
  - **Resin Height = 4 ft**
- **Step 2**
- **$V = \pi \times r^2 \times \text{Height}$**
- **Step 3**
- **$V_{resin} = 3.14 \times 1.5 \times 1.5 \times 4$ ft**
- **$V_{F.B.} = 3.14 \times 1.5 \times 1.5 \times 2$ ft.**
- **Step 4**
- **$V_{resin} = 3.14 \times 1.5 \times 1.5 \times 4 =$ <u>28.26 cu. ft.</u>**
- **$V_{F.B.} = 3.14 \times 1.5 \times 1.5 \times 2 = 14.13$ cu ft**
  - **= <u>105.7 gallons</u>**



Chapter 1

Licensing and Regulatory Requirements

Licensing Authority



Texas Commission on Environmental Quality (TCEQ)

Permitting and Registration Support Division (MC-178)

Operator Certification Program

P.O. Box 13087

Austin, TX 78711-3087

512-239-6165

77th Legislature (June 2001) passed legislation transferring the legal authority to Chapter 341 of the Texas Water Code and designating TCEQ as the licensing and regulatory agency for WTS licenses.

Application Procedures for Licenses

For Class 3 license:

1. Complete the Basic and Advanced Water Treatment Specialist Course.
2. Complete the required years of work experience.
3. Fill out the application with the correct fee.
4. Wait for Approval letter.
5. Take and pass the exam.

Exemptions from the WTS License Requirements

- Individuals who are licensed under the Plumbing License Law.
- Employees of industrial facilities who install or service water treatment equipment **at their facilities**.
- Employees of public water systems installing water treatment equipment **at their system** who hold a Class C license or higher.
- Employees of registered operations companies installing water treatment equipment at the facilities for which their operations company has a contract to operate and who hold a Class C license or higher.

Plumbing Acts Permitted Without a Plumbing License

- Plumbing work done by a property owner in a building owned or occupied by him or her as a homestead.
- Plumbing work done outside municipal ordinances.
- …..water treatment installations, exchanges, services or repairs.

All work and service is subject to inspection and approval in accordance with the terms of all local valid city or municipal ordinances.

Prohibited Acts

NO person shall engage in, work at, or conduct the business of plumbing in this state, except as specifically exempted, unless such person is the holder of a valid license as provided by the Plumbing License Law.

Municipal Rules and Regulations

Every city in Texas of more than 5,000 inhabitants shall, and any city or town may, adopt ordinances or laws regulating plumbing activities within their jurisdiction.

They shall provide that no plumbing be done, except in the case or repairing leaks, without a permit being issued.

Adoption of Plumbing Codes

The Texas State Board of Plumbing Examiners had adopted the:

- **Uniform Plumbing Code**
- **International Plumbing Code**.

Cities may adopt either of these plumbing codes or their own plumbing code with minor amendments

Rules for Public Water Systems

- **Minimum Distribution Pressure**
  - Maintain a 35 psi at all points
  - 20 psi under fire fighting conditions
- **Prohibition of Lead-Containing Materials**
  - Pipes, pipe fittings, and fixtures must be considered “Lead Free”
    - Less than 0.25% lead in wet surface areas
  - Solder and flux must contain less than 0.2 % lead

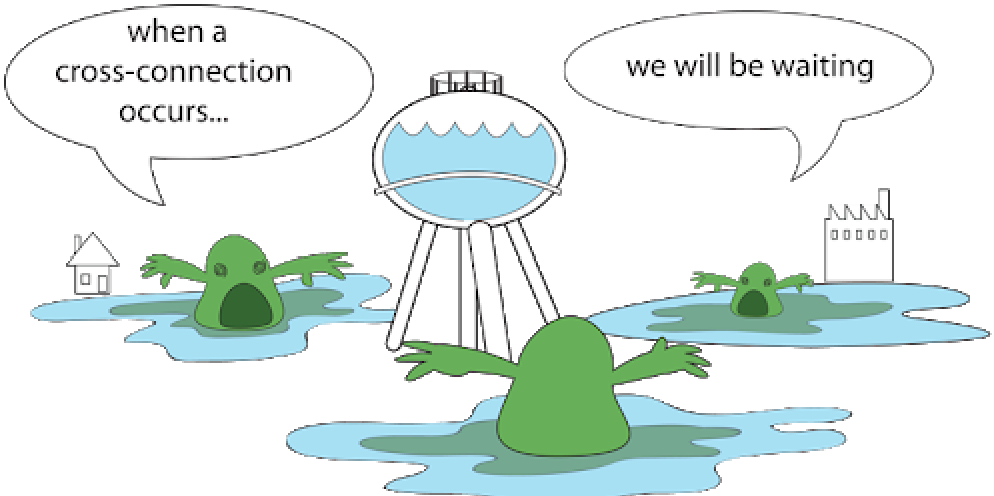
Disinfection and Disinfection Residual Monitoring

- Minimum disinfection residuals required at the farthest tap:
  - Free chlorine residual of **0.2 mg/L**
  - Chloramine residual of **0.5 mg/L**
- Tested using a DPD indicator (diethyl-p-phenylenediamene).
- Maximum levels for disinfectants and disinfection byproducts
  - **4.0 mg/L** Free Chlorine and chloramine
  - 0.8 mg/L Chlorine Dioxide
  - **80 ug/L** THM
  - 60 ug/L Haloacetic Acids

Cross-Connections

- A <u>physical connection </u>between the public water system and:
  - Another supply of unknown or questionable quality
  - Any source which may contain contaminating or polluting substances
  - Any source of water treated to a lesser degree in the treatment process.

No physical connection shall be made between a drinking water supply and a sewer line.

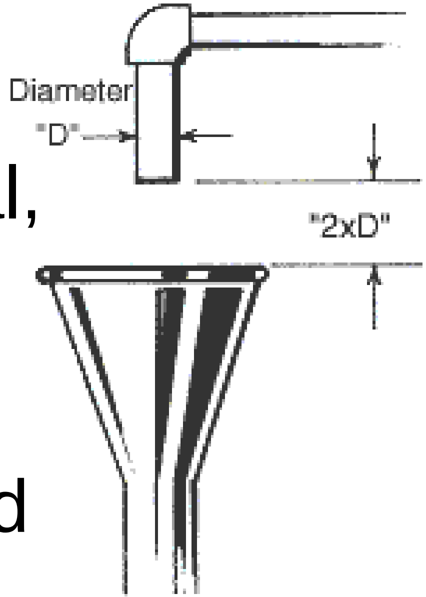


Cross-Connection Control

- Water system representatives must inspect individual water facilities before providing service and periodically thereafter to prevent possible cross-connections.
- Continuous efforts must be made to locate and eliminate cross-connections to prevent possible contamination of the water supplied to the public.

Backflow and Back-Siphonage Prevention

- No water connection from a public drinking water supply is allowed when an actual or potential contamination hazard exists without an air gap separation.
- Where containment air gaps are impractical, mechanical backflow prevention devices may be used.
- Some cities require backflow prevention devices on the supply lines of softeners and other point-of-use equipment
  - Installer’s responsibility to know and follow local plumbing code



Federal and State Water Quality Regulations

- Water is the most regulated material in this country:
  - Surface and ground water quality is regulated through the Clean Water Act.
  - Drinking water quality is regulated through the Safe Drinking Water Act.
  - Bottled water quality and water for pharmaceutical purposes are regulated through the Federal Food and Drug Administration.

Waters of the State

- **Quality of rivers, lakes, bays, oceans, and ground water is regulated through Water Quality Standards (WQS)**
  - Set by States and EPA
- **WQS define water quality goals for water bodies or segments of water bodies.**
- **WQS designate the uses for the water and set criteria to protect these uses.**
  - Criteria are specific limits placed on materials that may be in the water.

Potable Water

- Safe Drinking Water Act establishes 137 primary and secondary standards or treatment techniques for drinking water quality.

Water Quality

- **The quality of water, at is moves through the water cycle, is altered by natural processes and human activities.**
- **Different materials present in water influence what that water can be used for.**
  - Need dissolved O_2 in water for aquatic life
  - High salt water (sea water) not suitable for drinking.

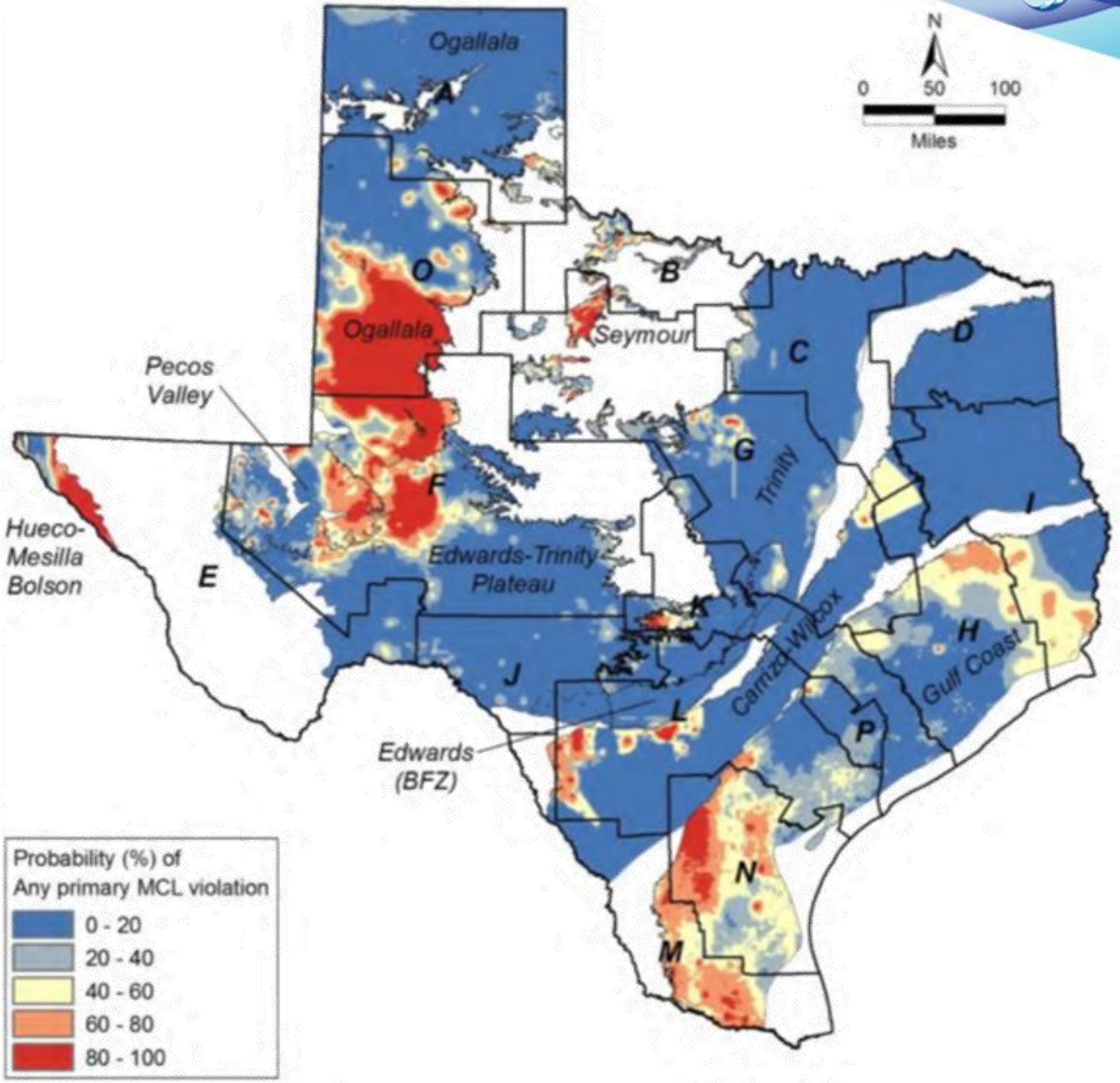
General Water Quality Indicators

- **Minerals**
  - Sodium, Calcium, Chloride, Bicarbonate
- **Disease-Causing Organisms**
  - Typhoid fever, Cholera, Dysentery
- **Heavy Metals**
  - Mercury, Lead
  - Some metals are concentrated by aquatic organisms and buildup in the food chain to toxic levels
- **Synthetic Organic Chemicals (SOCs)**
  - DDT (pesticides), Resist Decomposition
- **Radioactive Materials**
  - Nuclear power, Oil production, Mining, and Health care industries
- **Turbidity and Color**
  - Suspended Solids that reduce sunlight penetration

Standards of Quality for Drinking Water

- EPA generally sets Maximum Contaminant Levels (MCLs) at levels that will limit an individual's risk to between 1 in 10,000 to 1 in 1,000,000 over a lifetime.
- Maximum Contaminant Level is the highest allowable level of a contaminant.

Natural Occurring Groundwater Contamination in Texas



MCLs for Inorganic Chemicals

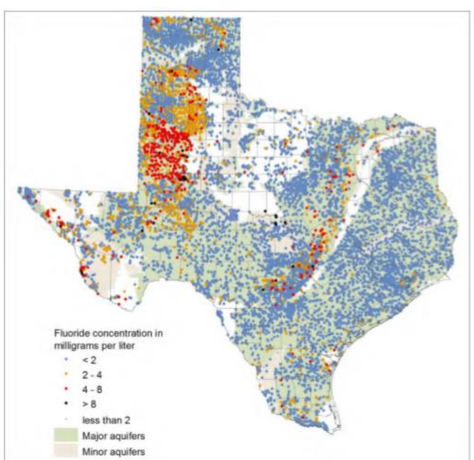
Substance	Problem	Concentration in mg/L
Arsenic	Toxicity	0.010 mg/L
Asbestos	Lung Cancer	7 million fibers per liter
Fluoride	Mottled Teeth	4.0
Nitrate	Blue Babies	10 (as Nitrogen)
Nitrite	Blue Babies	1 (as Nitrogen)
Lead	Nervous System Damage	MCLG- 0.0 Activation level – 0.015

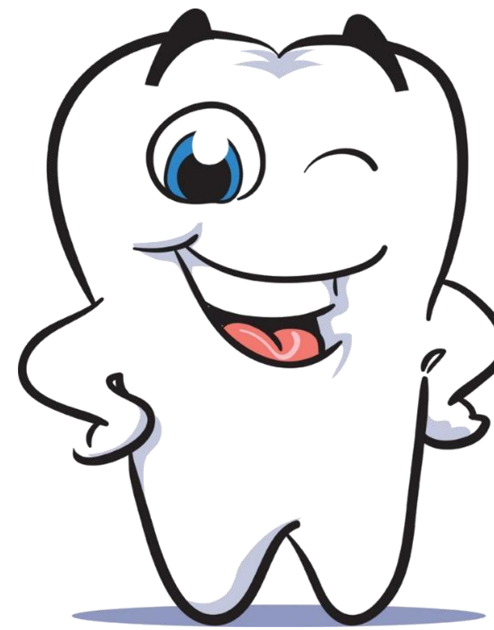
Microbiological Quality

- Drinking water should not contain coliform organisms.
- Any positive coliform sample from a public water system may signal a serious health threat.
- When you get a positive sample; inform residents water may not be safe and take repeat samples.

Fluoride

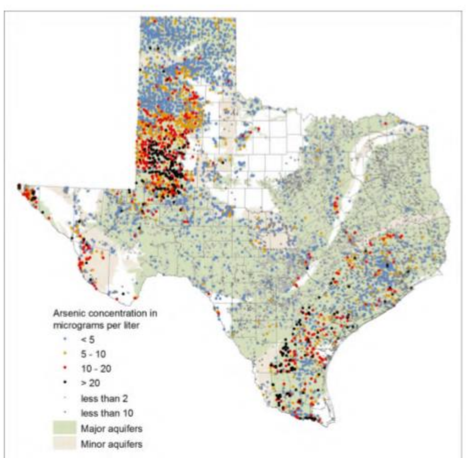
- High levels of fluoride in drinking water may cause **mottled teeth**
  - A brown discoloration that appears in the tooth enamel.
- Secondary standard is 2.0 mg/L
- Primary standard (MCL) is 4.0 mg/L





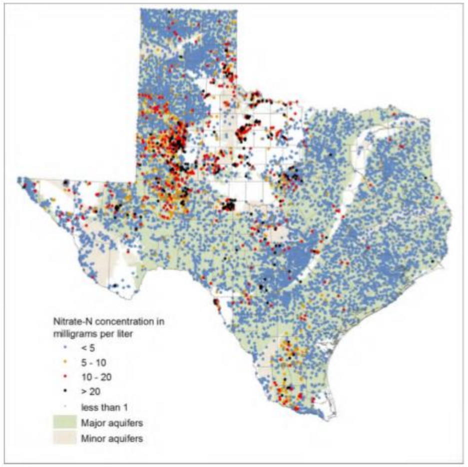
Arsenic

- MCL = 10 ug/L (micrograms per liter)
  - Applies to community, non-community, and non-transient public water supplies.



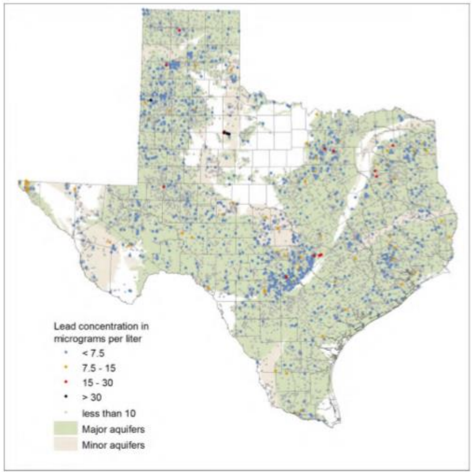
Nitrogen Compounds

- Increase the risk of **blue baby syndrome** and miscarriage.
  - Methemoglobinemia
    - A serious health threat in infants recognized by a blue skin color.



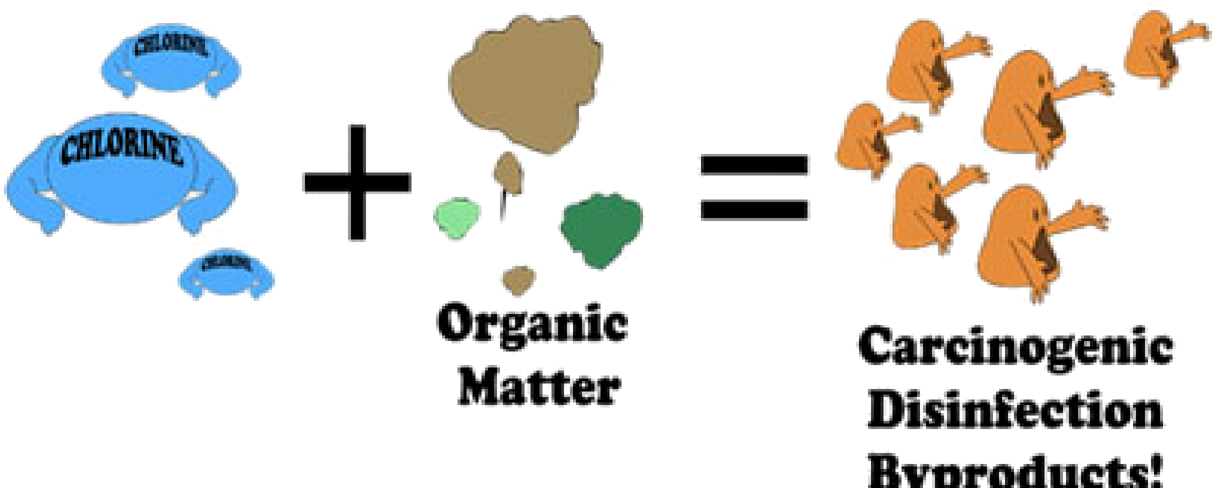
Lead

- Nervous System Toxin
- Primary source is household plumbing fixtures and soldered copper pipe.
- MCL goal is 0.0 Mg/L
- Action level set at 0.015 mg/L



Disinfection Byproduct Rule

- **Locational Running Annual Average (LRAA) MCLs**
  - 80 ug/L Total Trihalomethane (TTHM)
  - 60 ug/L Haloacetic acids (HAA5)
- These contaminants are formed when chlorine is used to disinfect organic materials.

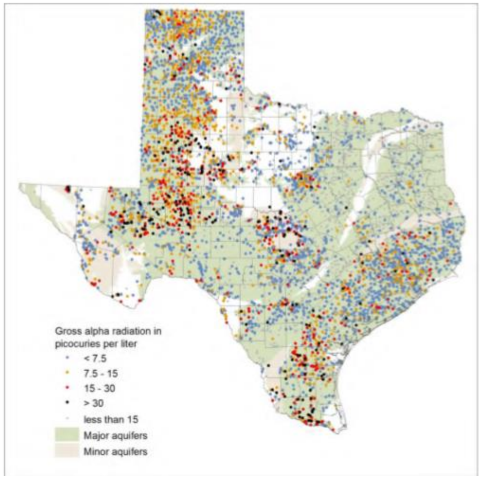


Treatment Techniques

- **Specific required treatment techniques to use if certain contaminants are over their MCLs**
  - **Lead, Copper, *Cryptosporidium, Giardia, Legionella***
- **For Giardia and Crypto. the treatment technique combines effective filtration with disinfection to achieve a 3-log (99.9%) reduction.**
- **Treatment techniques for lead and copper involve water treatment to reduce corrosion.**

Radiological Quality

- **Radon, Uranium, and Radium** spontaneously emit high energy particles that can damage tissue and cause cancers to develop.
- **Curie** (Ci) is the standard measure of radioactivity equal to 1.3 x 10^{10} disintegrations per second.
- **picoCurie** (pCi) is 10^{-12} Curries which is about 2.2 disintegrations per minute.
- A **millirem per year** (mrem/yr) is a dose equivalent that measures energy imparted by radiation and its damaging effect.



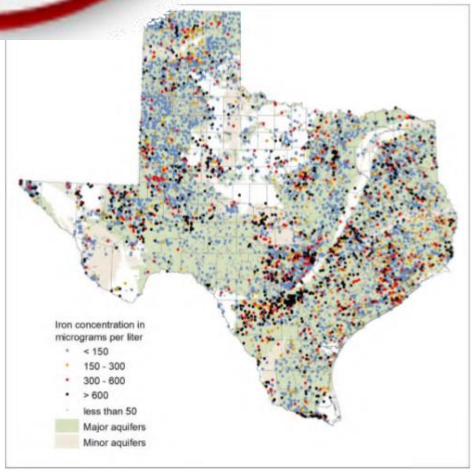
Radiological Quality

Contaminant	MCL	MCLG	Best Available Treatment Technology
Gross Alpha	15 pCi/L	0 pCi/L	Reverse Osmosis
Uranium	30 ug/L	0 pCi/L	Ion exchange, lime softening, RO, Enhanced Coagulation
Combined Radium-226 and 228	5 pCi/L	0 pCi/L	Ion Exchange, Lime Softening, RO
Beta Particles and Photons	4 mrem/yr	0 pCi/L	Ion Exchange, RO

Secondary Drinking Water Standards		
Contaminant	Concentration mg/L	Significance
Aluminum	0.2	Color
*Chloride	300	Salty Taste
Copper	1.0	Taste and Stains
Corrosivity	Non-corrosive	Leaching
Foaming Agents	1.5	Unsightly Foam
*Fluoride	2.0	Mottled Teeth
*Hydrogen Sulfide	0.05	Odor and Taste
*Iron	0.3	Stains and Taste
*Manganese	0.05	Taste and Stains
*pH	>7.0 units	Corrosion
Silver	0.10	Discoloration of skin and eyes
*Sulfate	300	Taste and Laxative Effect
*Total Dissolved Solids	1,000	Taste and Scale
Zinc	5	Taste and Deposits

Forms of Iron in Drinking Water

- **Ferrous Iron**
  - Soluble
  - Clear water iron
- **Ferric Iron**
  - Insoluble
  - Small, red particles
- **Bacterial Iron**
  - Red, slime-like balls and strings
- **Iron above 0.3 mg/L causes color, stains, and turbidity**



Consumer Confidence Reports

- Must be provided by **July 1**
  - Failure to report is a violation of State and Federal Law.
- Purpose is to meet the consumer's right to know about their drinking water quality are required by the Safe Drinking Water Act amendments of 1996.

Quick Review

Please open the Quizizz app to complete review

Chapter 2

Water Characteristics

2.1 Unique Properties of Water

$$2H_2 + O_2 \rightarrow 2H_2O$$

Quality	Metric	English
Density at 3.98˚c	1.0 g/mL	8.34 lbs/Gal 62.4 lbs/Ft^3
Melting/Freezing Point	0˚c	32˚f
Boiling/Condensing Point	100˚c	212˚f
Temperature at maximum density	3.98˚c	39.16˚f
Heat of Fusion	79.71 cal/g	143.5 BTU/Lb
Heat of Vaporization	539.55 cal/g	971.2 BTU/Lb

Unique Properties of Water

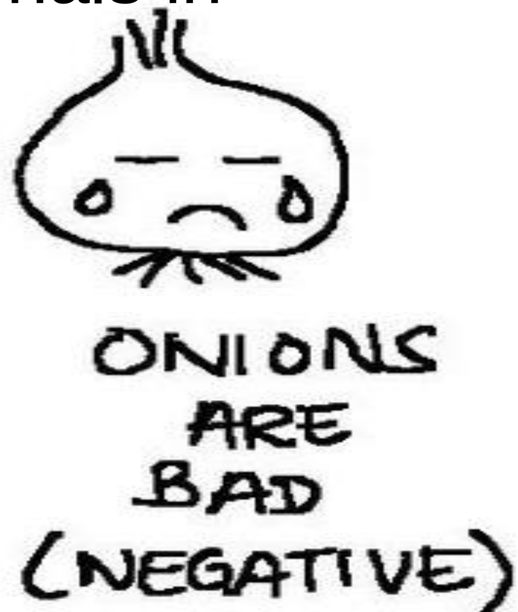
- **High Heat absorbing capacity**
  - Stabilizes temperatures by absorbing large amounts of heat with only small temperature changes.
  - Critical to temperatures on the surface of the earth and within living organisms which are mostly water.

Unique Properties of Water

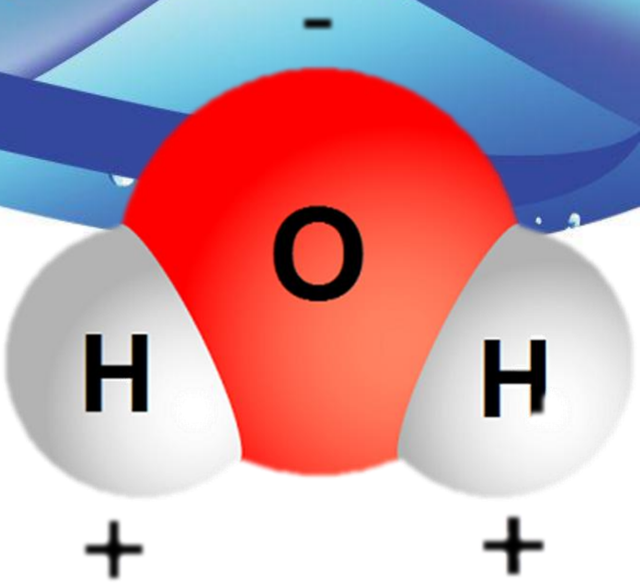
- **Highest Latent heat of fusion**
  - Must loose a lot of energy to become solid (Retards freezing)
- **Highest heat of evaporation of any substance**
  - Important to energy and water transport from earth's surface to atmosphere.

Unique Properties of Water

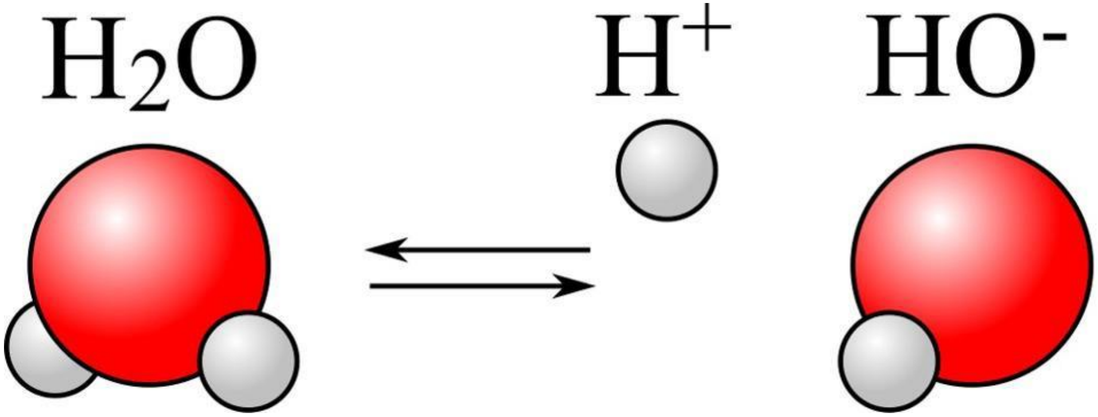
- **Dissolves more substances in greater quantity than other liquid**
  - Makes complex biological systems possible.
  - Important for transportation of materials in solution.



Unique Properties of Water

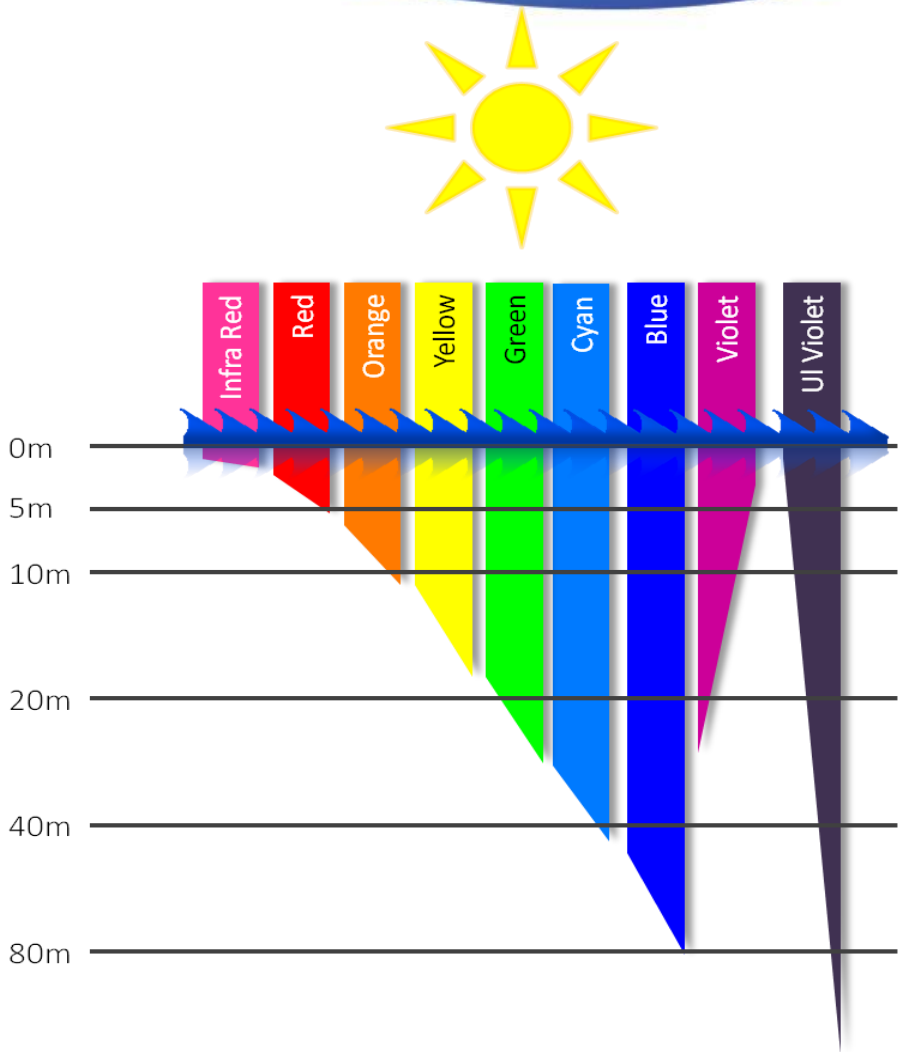


- **Highest Dielectric Constant**
  - Leads to high dissociation of minerals
- **Very Little Electrolytic Dissociation**
  - Stable, yet contains some H+ and OH- ions



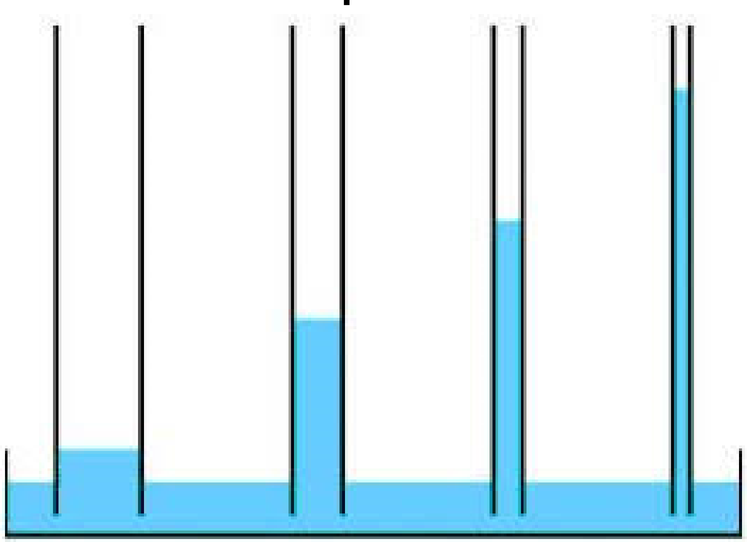
Unique Properties of Water

- **Relatively Transparent**
  - Absorbs much energy in infrared range, but little in visible range, Hence "Colorless"



Liquid Water is Cohesive

- High surface tension
  - Allows insects and heavier objects to walk or float on the surface layer
- Capillary forces enable water to move upward against gravity
  - To the top of tall trees

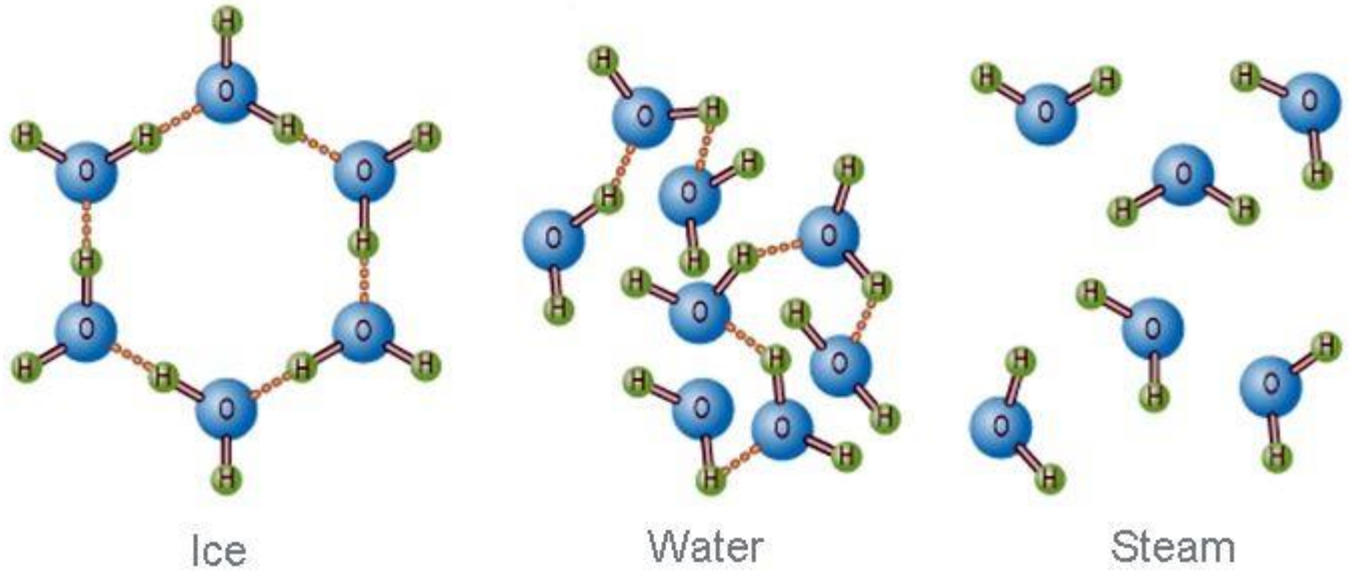


Very Stable

- Does not decompose easily
- Does not readily enter into chemical reactions with MOST other materials
- The water on earth now, is the same water that was here when dinosaurs were on earth.

Freezing and Expansion of Water

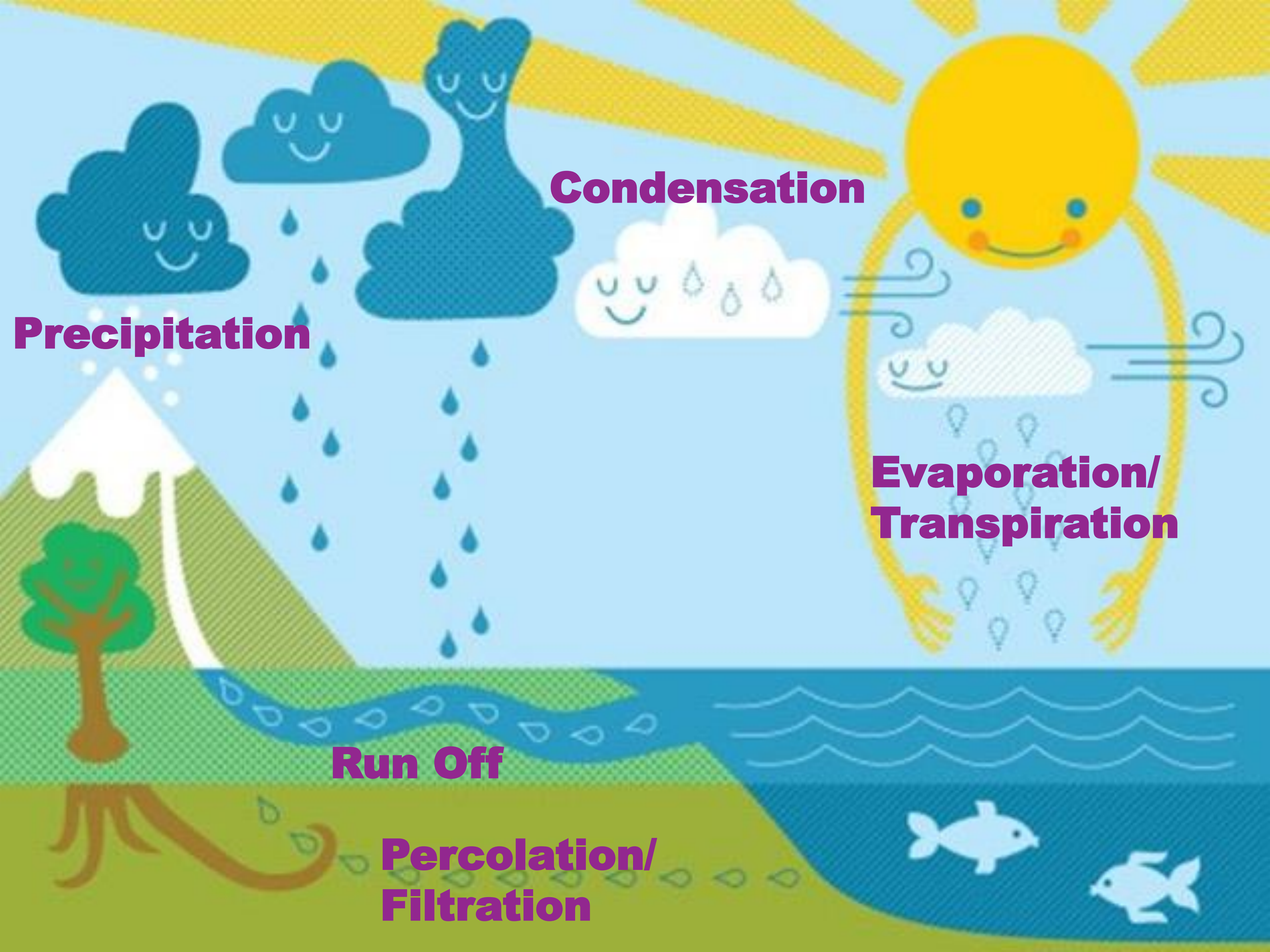
- Phase changes (solid, liquid, gas) are not chemical reactions.
- Maximum density at 3.98*c
- As it gets colder it expands
  - 8% less dense



Uses of Water

- **Uses of Water**
  - Drinking
  - Habitat for Aquatic Organisms and Plants
  - Transport
  - Irrigation
  - Cleaning, flushing, and transporting waste materials
  - Hydroelectric power production
  - Fishing and Aquaculture
  - Cooling, Manufacturing, and Industry
  - Food Processing and Production

- **Good Quality Drinking Water**
  - Has no disease-causing organisms
  - Contains no chemical or radiological impurities in harmful amounts
  - Has lowest possible levels of color, turbidity, or taste and odor
  - Is non-corrosive, non-scaling, and non-staining
- **Different uses for water require different quality standards**



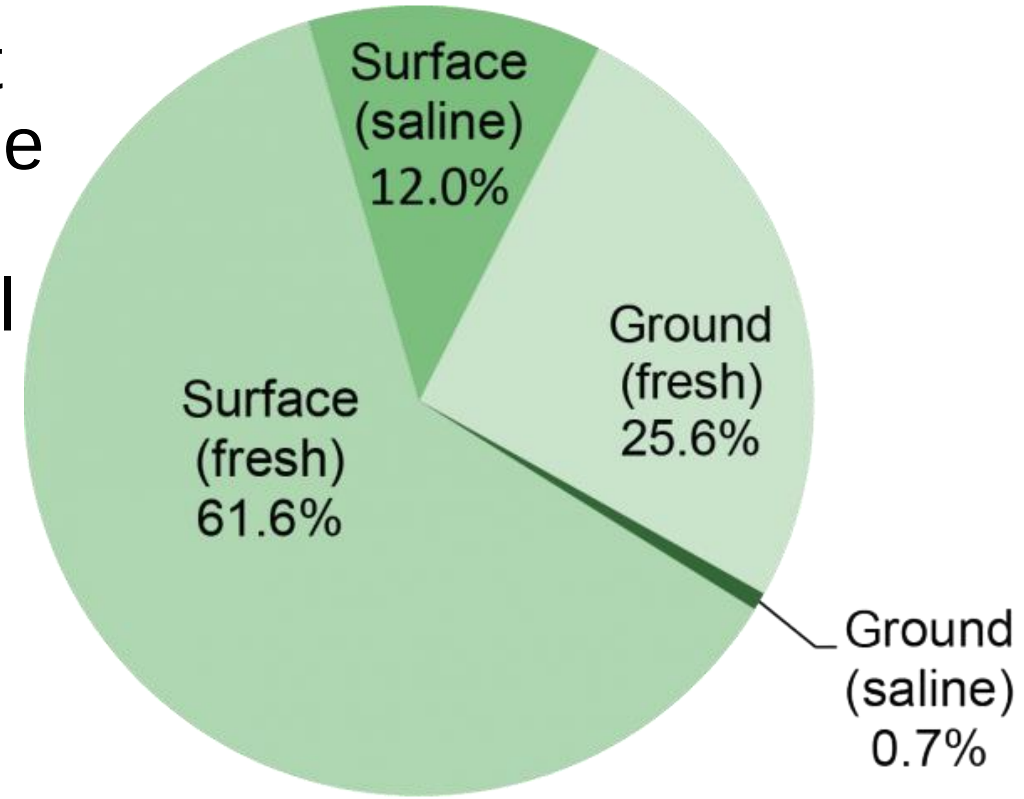
Condensation
Precipitation
Evaporation/
Transpiration
Run Off
Percolation/
Filtration

Sources of Water

- Federal and State regulations require that potable water be from an approved source.
  - Safe and Sanitary
  - Protected from sources of contamination
  - Adequate for its intended uses
- Commonly used sources:
  - Public water supplies
    - Ground water and surface water sources
  - Private water supplies
    - Ground water

Public Water Supplies

- Any water system that provides piped water for human consumption if it serves at least 25 people at least 60 days of the year or has the potential for at least 15 service connections.
- Must be approved by TCEQ

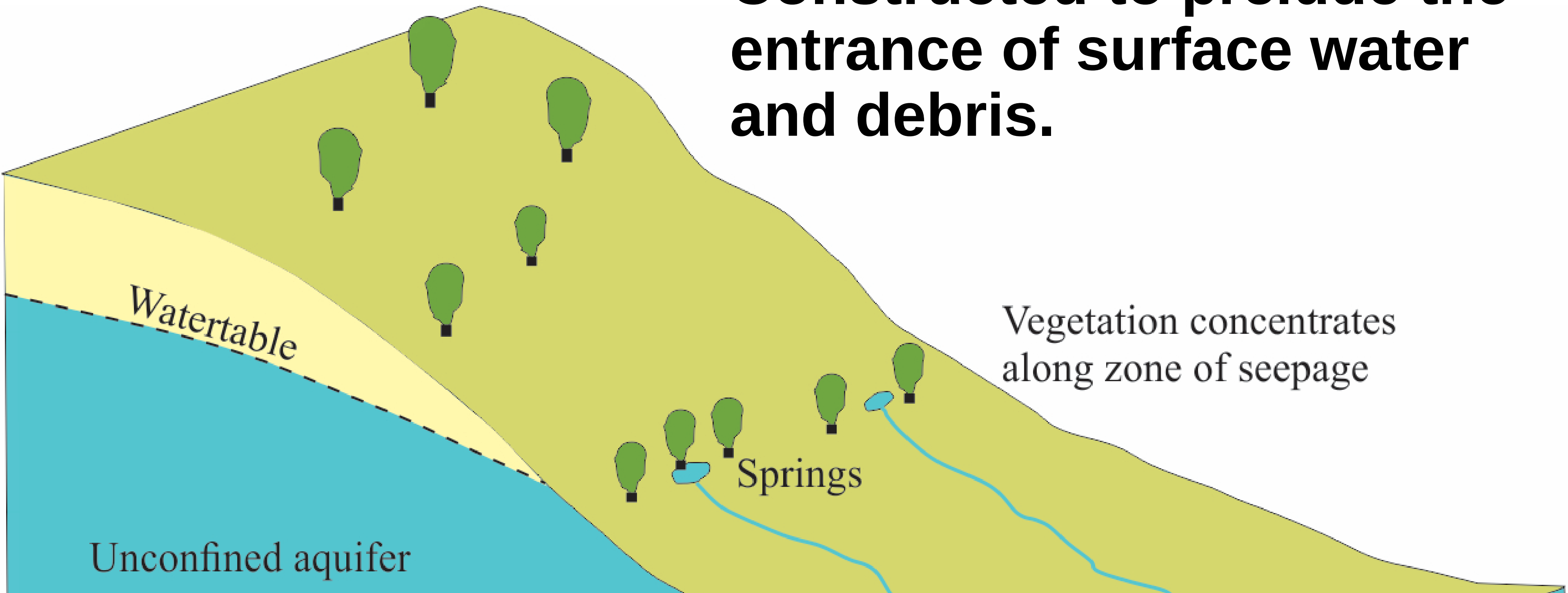


Ground Water Sources

- Located with no danger of pollution.
  - Flooding or insanitary surroundings
    - Privies, Sewage, Sewage treatment plants, Livestock and animal pens, Solid waste disposal sites, Underground fuel storage tanks, or abandoned and improperly sealed wells
- Characteristics:
  - Well filtered with low amounts of suspended solids, turbidity, and color
  - Stable chemical quality and temperature over time
  - Higher mineral content than surface water
  - Lower levels of bacteria, algae, and viruses
  - Higher amounts of dissolved gases, iron and manganese

Spring Water Sources

- Springs required to be located away from danger
- Constructed to prelude the entrance of surface water and debris.



Ground Water under the influence of Surface Water (GUI)

- “Karst” formations inside broken limestone and rapidly recharged from caves, sinkholes, and underground streams.
- Receives little to no filtration
- A number of disease outbreaks reported
- Identified by:
  - Rapid chemical quality changes (pH, alkalinity, Hardness)
  - Seasonal coliform positive samples
  - Turbidity changes
  - Presence of algae, protozoa, or zooplankton
  - Rapid changes of the water table level

Surface Water Sources

- **Must be adequately protected from all sources of contamination**
    - Municipal, agricultural, and industrial wastes
- **Intakes must be located and constructed to minimize contamination and siltation.**
    - Restricted zone of 200 ft from raw water intake.
    - 1,000 ft for boat ramp, marina, dock, floating pier.
- **Characteristics**
    - High amounts of suspended solids, turbidity, and color
    - Rapidly varying chemical quality and temperature over time
    - Lower mineral content than ground water from the same area
    - High levels of bacteria, algae, and viruses
    - Lower amounts of dissolved gases, iron and manganese

Quick Review

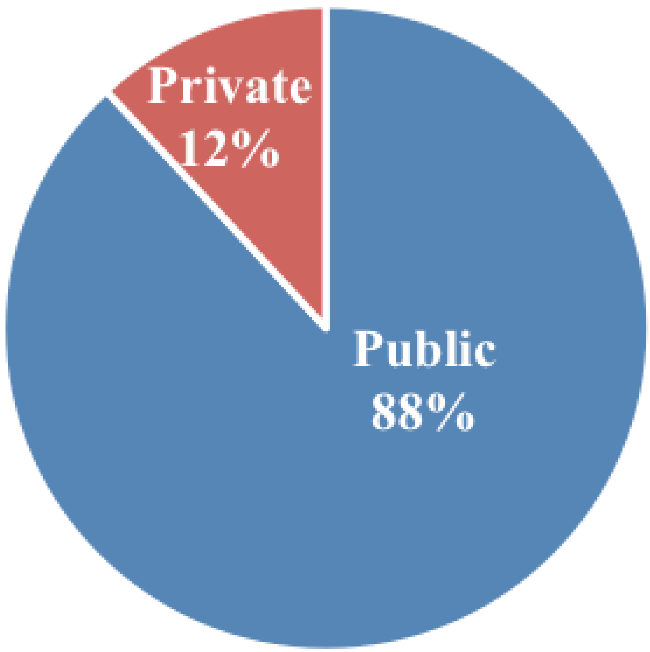
Please open the Quizizz app to complete review

Chapter 4

Home Water Supplies

Types of Home Water Supplies

- Suitable drinking water supplies should be:
  - Safe to drink
  - Pleasant to taste
  - Clear and free of disagreeable odors
  - Adequate for needs
  - Dependable and convenient
- A minimum water supply of 75-100 gallons per person per day is typical in homes with complete plumbing fixtures.



Types of Home Water Supplies

Surface Sources

- Cisterns, Lakes, and Rivers
- Easily contaminated
- Must take special precautions to ensure the protection and maintenance of drinking water supplies
- In arid regions, surface supplies often prove to be inadequate in both quality and quantity

Ground Sources

- Occurs in underground water-bearing formations that are saturated with water
    - Aquifers
- Present nearly everywhere, but it may be so deep or mineralized that it is not usable for home supplies

Components of a Well System

- An aquifer that will yield sufficient quantity and quality of water
- An excavation to the water-bearing formation
- A sealed well for sanitary protection
- A well pump and withdraw pipe

Aquifers

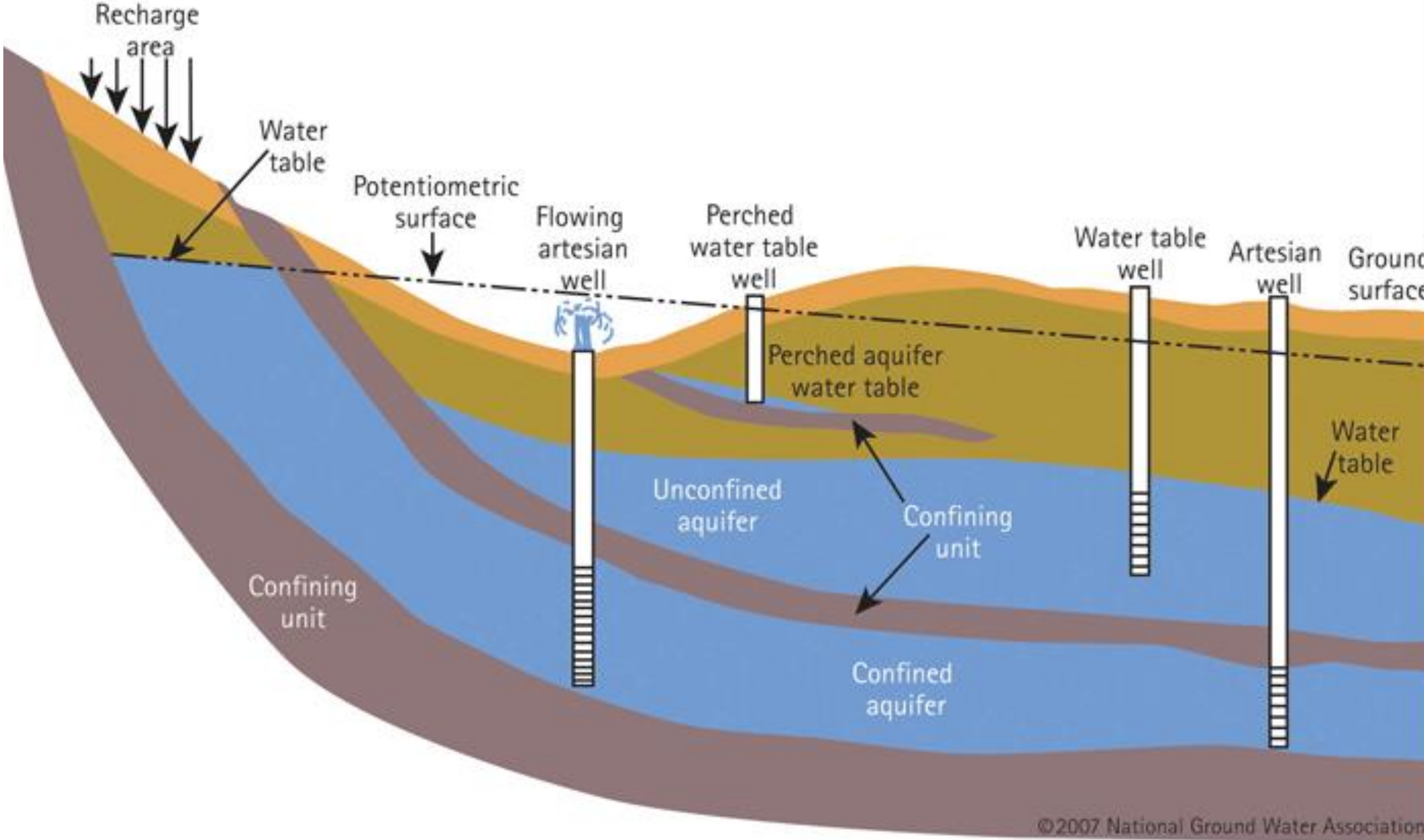
Unconfined Aquifer

- Recharged by local precipitation
- Water table elevation varies seasonally depending upon the amount of precipitation and withdraw

Confined Aquifer

- Has impervious formations both above and below
- Confined and under pressure
- Water table may rise above the aquifer or even above the surface
- Recharged from remote outcrops to the surface
- Better protected from contamination

Confined/Unconfined Aquifers



Excavation to the Water-Bearing Formation

- Wells can be dug, bored, driven or drilled down into the aquifer
  - Shallow wells are usually dug, bored, or driven and provide less protection from contamination than drilled wells
  - Deep wells are usually rotary drilled deep enough to reach more plentiful, reliable, and better protected water sources
- After drilling is completed, the drill stem is withdrawn, and the casing is set
  - The casing is a steel pipe or heavy-wall plastic pipe placed in the drilled well to prevent caving of the soil formations and to protect against contamination

Sanitary Protection Seal

- After the casing is set, the annular space between the bore hole and the casing is filled with watertight cement or clay
    - Process is called pressure grouting
    - Grout and casing protect from contamination
- A concrete sealing block that slopes away from the well is constructed to ensure that surface water and contaminants are excluded
    - Should be at least 4 inches thick, and extend out 2 ft
    - Casing must extend 12 inches above the ground surface

Sanitary Protection Seal

- A well screen is attached to the bottom of the casing and extends down into the water-bearing formation
  - Has holes, slots, or screens to keep sand out and allow water to enter into the casing
- Gravel packing may be necessary for wells that have fine sand and silts in the water bearing formation
  - Most home wells are not gravel-packed

Well Pump

- Needed to raise the water from the casing into the pressure tank which supplies the house
- Most common is a submersible pump
- Other pumps include jet (ejector) pumps, deep shaft turbine pump, airlift pumps, and reciprocating pumps
- Must be able to provide an adequate flow and pressure
- The withdraw pipe is placed in the well below the lowest expected water elevation and ends at the storage tank

Location

Object	Minimum Distance
Property Line	50 ft 5 ft (if pressure grouted)
human or household waste disposal	100 ft
Animal or Poultry Areas	150 ft
Underground Fuel Storage Tanks	150 ft
Sewage Pumping Stations	300 ft
Solid Waste Disposal Areas	500 ft
Animal Feed Lots	500 ft
Land Irrigated by Sewage	500 ft

Protecting a Home Ground Water Supply

- Periodically inspect exposed parts of the well for problems such as:
  - Cracked, corroded, or damage well casing
  - Broken or missing well cap
  - Settling and cracking of surface seals
- Slope the area around the well to drain surface runoff away from the well
- Install a well cap or sanitary seal to prevent unauthorized use of, or entry into, the well
- Have a qualified professional inspect and disinfect the water periodically.

Protecting a Home Ground Water Supply

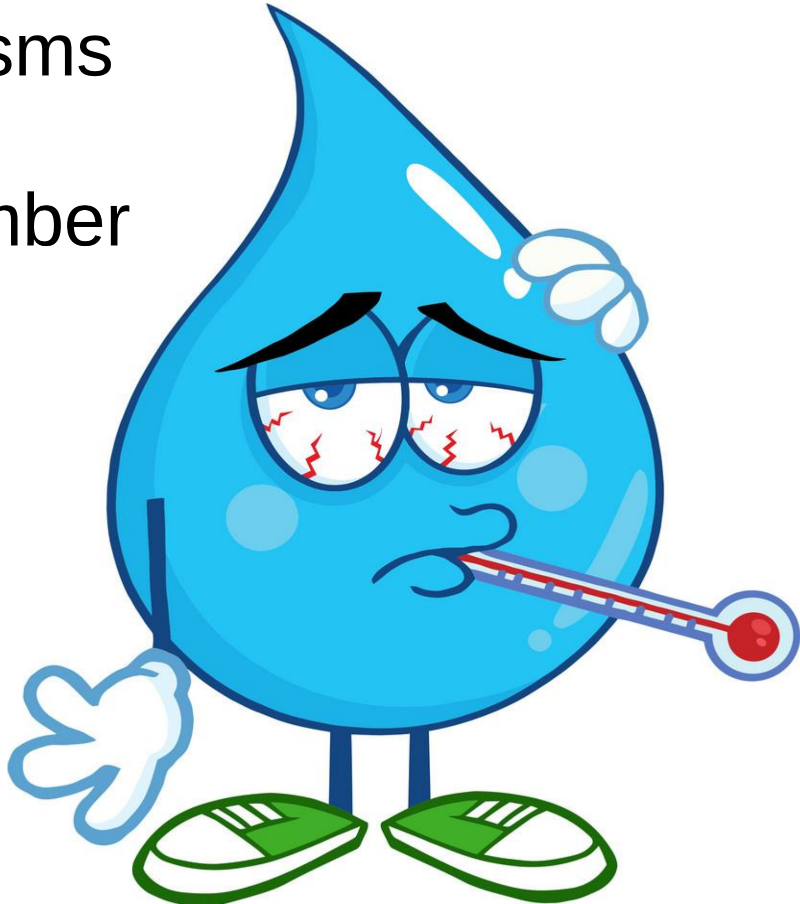
- Have the well tested once a year for coliform bacteria, nitrates, and other contaminants of local concern
  - If there are new additions to the family or visitors who plan to stay several days, have the well tested
- Keep accurate well maintenance records
  - Pump repairs, disinfection, and well treatments
- Employ certified well drillers for new well construction, modifications, and closures.

Testing a Private Water Supply

- Many laboratories are available to test water quality
- Testing for nitrate and bacteria will usually cost about $30
- Testing for other contaminants will be more expensive and could be several hundred dollars for pesticides and organic chemicals

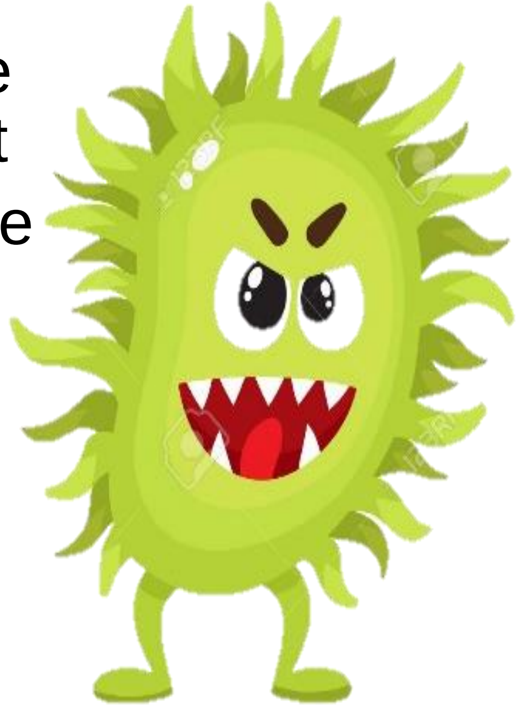
Bacteriological Sampling

- Water used for drinking, cooking, or washing dishes must not be contaminated with microorganisms that cause disease
- Unsafe water can spread a number of diseases that are known as “waterborne” infections
  - Typhoid, Cholera, and Dysentery
- These illnesses are intestinal disorders and are spread when fecal matter from infected individuals gets into the water supply



Bacteriological Sampling

- Coliform Bacteria are a group of bacteria relatively easy to detect in water
  - The coliform group usually does not cause disease, and it is found in the environment
  - Come coliform bacteria are found when the water has been exposed to fecal matter
    - Fecal Coliform and E. Coli
- If coliform are present or may be present, disease causing organisms may also be present



How to take a Water Sample

Do:

- Flame the hose bib or wash with chlorine over time
- Get the sample to the lab within 30 hours of collection
- Control the temperature of sample before/during delivery to lab

Do not:

- Use expired sample bottles or non-lab provided sample bottles
- Over or under-fill the sample bottle

How to take a Water Sample

Sampling equipment:

- Use only sample bottles provided by a certified lab and that have not expired (normally less than 6 months old)
- Gloves, chlorine bleach, spray bottle, lighter, lab forms, sample bottle container from a lab

Sampling time:

- Do not sample on windy (> 20 mph) or rainy days
  - can compromise results

How to take a Water Sample

Sampling location:

- Outdoor faucet or hose bib is preferred, not near tall grass or shrubs
  - Never collect from kitchen sink, bathroom sink, or water fountain
- Faucet or hose bib pointing down at least 18 inches above the ground
- The sample location should be an active connection and one that is used often but not in an area of recent flushing, line extensions, or repairs
- Hose bib / faucet head must be made of material capable of withstanding disinfection (flame, bleach)

How to take a Water Sample

Collecting the sample:

- Wash hands thoroughly
  - wear sterile rubber gloves if possible
- Disinfect the sampling location by applying a concentrated solution of chlorine to completely wet the faucet
- Allow the disinfecting solution to sit on the faucet for 10-15 minutes
  - Alternatively, apply a flame to the outside and inside mouth of the faucet or hose bib using small lighter
- The goal of disinfection is to fully sterilize the faucet so that the sample collected is of the water and not bacteria present on or in the faucet brought by wind, animals, etc. – be very careful with this step
- Open the faucet completely and allow water to run freely for at least 2 minutes before sampling

How to take a Water Sample

Collecting the sample:

- Reduce water flow to diameter of 1/4” (#2 pencil diameter) making sure there is no splash back at the sampling site
- While gloved, remove the lid from the water sample bottle provided by the lab for coliform testing making sure not to touch the mouth of the bottle or inside of the bottle.
- Do not rinse the bottle
- Carefully fill the sample bottle to the fill line at the shoulder of the bottle
- Do not overfill the sample bottle – do not under fill – fill to the line
- Carefully cap the sample bottle making sure the cap is firmly tightened

How to take a Water Sample

Collecting the sample:

- Place the sample bottle in an insulated container with ice after collection and prior to submitting to a certified lab
- Refrigerate (don’t freeze!) samples that are held overnight before delivery to the lab.
- Deliver sample to lab within 30 hours from collection or it will be declared “unsuitable for analysis”
- Fill out the lab sample form
- Make sure the date and time sample was taken are included on your form(s), without this data the lab may declare the sample “unsuitable for analysis”

What the Results Mean

- Positive = Coliform Organisms **Found**
  - **Bad,** coliform organisms were present in the sample and drinking water supply is contaminated.
  - Notify homeowners not to drink water and retest
- Negative = Coliform Organisms **Not Found**
  - **Good,** coliform organisms were not found in the sample and water is considered safe.
- Sample **Unsuitable** for Analysis
  - Over or under filling sample containers
  - Samples not submitted within 30 hours
  - Sample contained obscuring turbidity or non-coliform bacteria
  - Sample leaked during shipment
  - Paperwork not completed correctly

When Coliform Organisms are Found

- Immediately inform customer that the water is not safe.
- Water system should be cleaned, disinfected and repeat samples should be taken as soon as possible
- Contact the TCEQ regional office for guidance
- Public or commercial system violations may lead to public notification
  - A “boil water” notice, or other actions as prescribed by TCEQ

Disinfecting Home Water Supplies

- When to disinfect a home well
  - When first constructed
  - If a well is repaired
  - There was a flood
  - Positive coliform analysis
  - Iron bacteria present
  - Contamination suspected

- Effective and economical method of disinfecting a well is the use of sodium or calcium hypochlorite solutions
- Chlorine sufficient to provide a dosage of approx. 100mg/L should be applied

Disinfecting Home wells

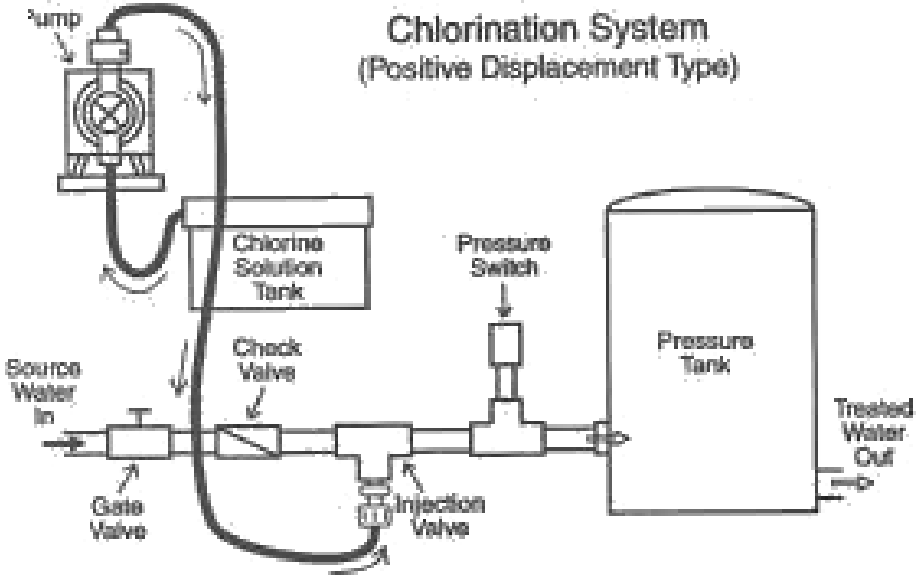
- Chlorine should be distributed throughout the well and home water piping
  - Obtained by using a hose or pipe to run the chlorine solution deeper into the well
  - Well pump may be turned on and the discharge circulated back to the casing
- Open each inside and outside faucet and allow the water to run until the chlorine odor is apparent.
  - Chlorine solution should remain in the water system for up to 24-hours
  - After 24-hours have elapsed, the chlorine must be flushed out of the system
    - Allow water to flush from each faucet until the chlorine odor is no longer noticeable

Disinfecting the Water Supply

- Home water supplies should be continuously disinfected if there are indications that contamination has or may occur.
- Chlorination is widely used for disinfection because it is effective, easy to install and operate, readily available, and relatively low cost.

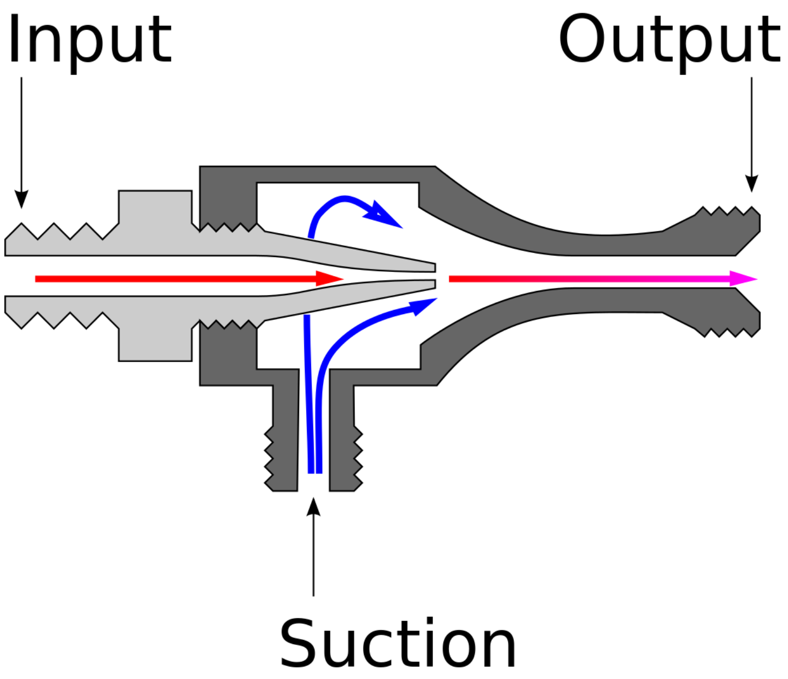
Feeding Chlorine

- A chlorinator is commonly used to disinfect home water supplies
  - Uses a pump to feed chlorine into the well water before it goes into the storage tank
  - The starting and stopping of the chlorine feed works off the electrical supply to the well pump
  - Three main parts:
    - Feed tank
    - Positive-Displacement pump
    - Injector valve



Feeding Chlorine

- Other types of chlorine feeders:
  - Aspirator
    - Draws chlorine solution through a venturi tube and the suction feeder draws the solution into the vacuum created on the suction side of the well pump
  - Tablet Chlorinators
    - Rely on the slow dissolution of chlorine tablets



Feeding Chlorine

- Chlorine becomes more effective with:
  - Increased filtration
  - Higher chlorine residual
  - Longer contact time
  - Lower pH
  - Free chlorine residual
  - Warmer water temperature

Feeding Chlorine

- Contact times of 20-30 minutes are recommended when the chlorine dosage is sufficient to maintain a free chlorine residual of 0.2-0.5 mg/L
  - Chlorine residuals and contact time to provide acceptable disinfection for water at 10*c and 7.0 pH
    - C x T > 120 For unfiltered surface water
    - C x T > 20 For filtered surface water
    - C x T > 6 For well filtered ground water
      - C = free chlorine residual in mg/L
      - T = contact time in minutes
- A free chlorine residual between 0.2 and 1.0 mg/L is usually adequate

Determining the Chlorine Residual

- The level of chlorine disinfectant remaining in the water at any time is called the chlorine residual.
- Measured with an inexpensive test kit and color comparator
  - DPD colorimetric method
    - If chlorine is present, a pink to red color will develop
- Should be checked at least weekly to ensure that the system in operating properly and that the proper chlorine level is maintained in the water supply.

Quick Review

Please open the Quizizz app to complete review

Chapter 3

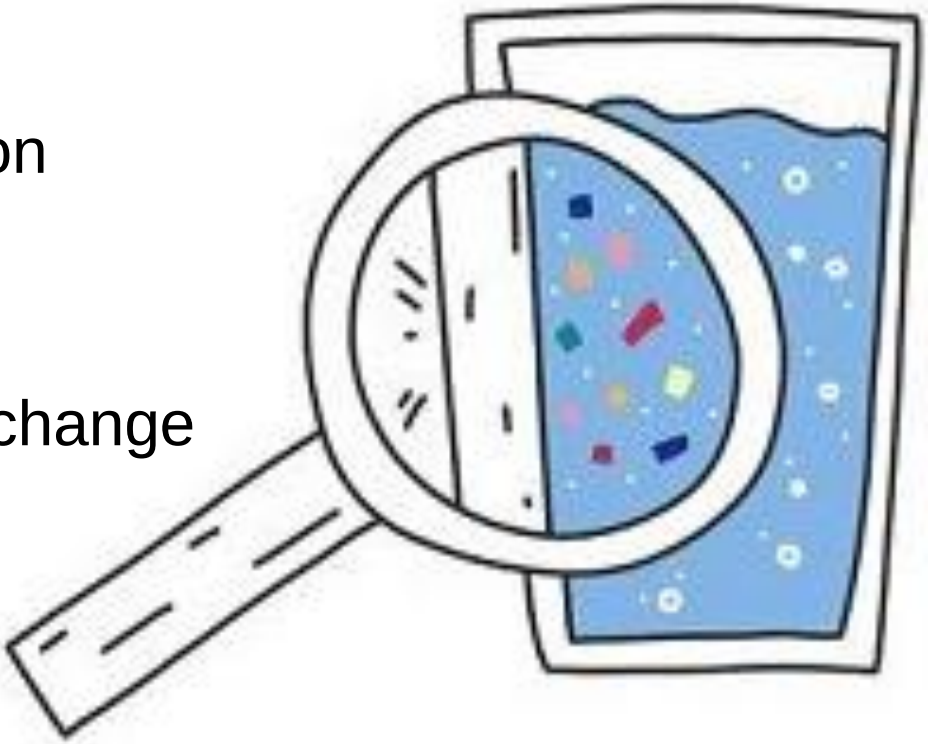
General Water Quality

Water Analyses

- The process of finding out how much of the various impurities are present.
  - Dissolved minerals, organic matter, or metals
  - Dissolved gasses such as Carbon Dioxide and Oxygen
  - Suspended particles of mineral, organic, or metallic nature
  - Turbidity, color, taste, and odor
  - Microorganisms

Measuring Impurities

- Milligrams per Liter mg/L
  - Weight to volume proportion
- Parts per Million ppm
  - Weight to weight proportion
  - In water, 1 mg/L = 1 ppm
- Grains per Gallon gpg
  - Water hardness or ion-exchange
  - 7,000 grains = 1 pound
  - 1 gpg= 17.12 mg/L

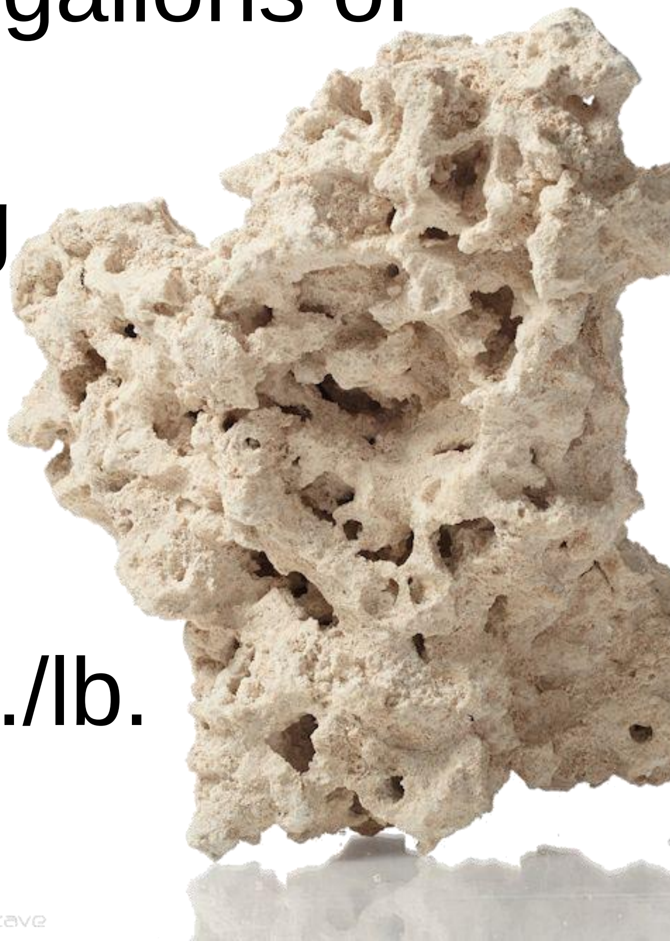


Units of Measurement

Unit of measurement	Equivalent mg/L	Metric Equivalent
1%	10,000	10 g/L
1 ppt	1,000	1 g/L
1 gpg	17.12	17.12 mg/L
1 ppm	1	1 mg/L
1 ppb	0.001	1 ug/L
7,000 grains	1 pound	453.6 g

Hardness Visual

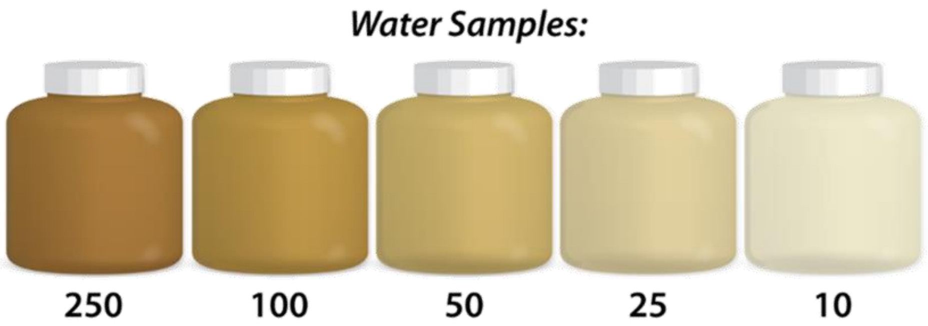
- A small hotel uses 20,000 gallons of water each day.
- The water contains 14 gpg carbonate hardness
- 20,000 gal. x 14 gpg
  - = 280,000 gr./day
- 280,000 gr./day ÷ 7,000 gr./lb.
  - = **<u>40 pounds!</u>**



Physical Descriptions of Water Quality

- Physical quality standards are based on methods that use the physical senses of sight, smell, and feel. The physical quality of water can be evaluated from the results of 5 test procedures.
  - **Turbidity**
  - **Color**
  - **Temperature**
  - **Odor**
  - **Taste**

Turbidity



- Turbidity means cloudiness or haziness.
- SUSPENDED SOLIDS.
  - Anything that prevents sunlight penetration through the water.
- Measured with nephelometric turbidimeter.
  - Standard for treated water is 0.3 NTU.
- Lowering turbidity reduces the possibility of disease organisms hiding in the water.

Color

- Two types of color:
  - True color
    - Caused by dissolved substances (tannins)
    - Cannot be removed by filtration
  - Apparent color
    - Caused by suspended particles in the water
      - Clay particles, oxidized iron, algae
    - Can be removed by filtration
- Color can be read with instruments and compared against color standards.
- Standard for drinking water is 15 color units
  - When below 10, the water looks clear and clean

Tannins

Temperature

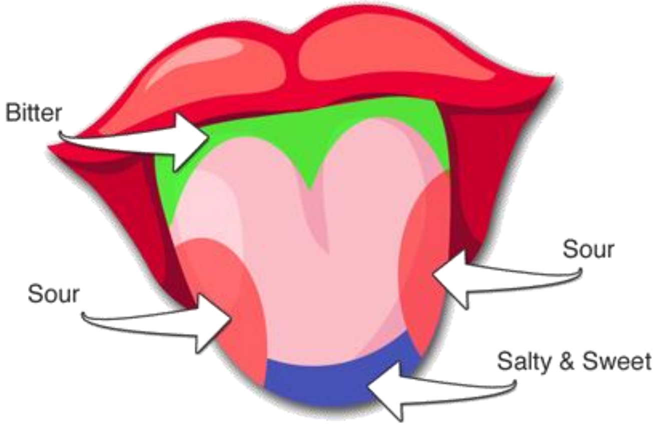
- Measured with thermometers
- No quality standards set (DUH!)
- Boiling can ensure the microbiological safety of water.
- Temperature has a significant impact on density.
  - Maximum density at 3.98*c
  - Ice is 8% less dense than liquid water
- Also has a significant impact on R.O. production
  - 1.5% increase in flux for every 1˚f increase

Odor

- Test called the threshold odor
  - Produces TON (threshold odor number)
- Quality standard for drinking water is 3 TON

Taste

- No quality standard has been established
  - Can be tested using “Flavor Profile Method” by a panel of taste judges.
- Sense of taste is much less sensitive than smell

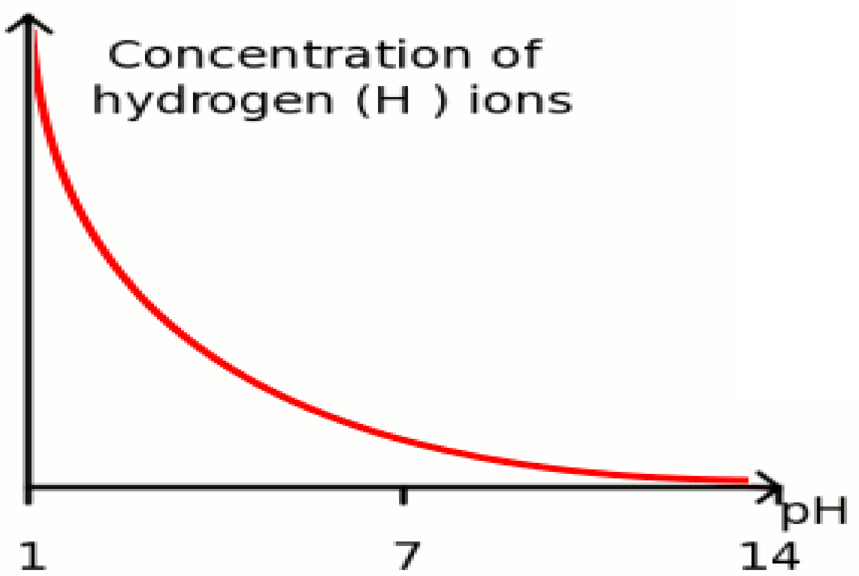


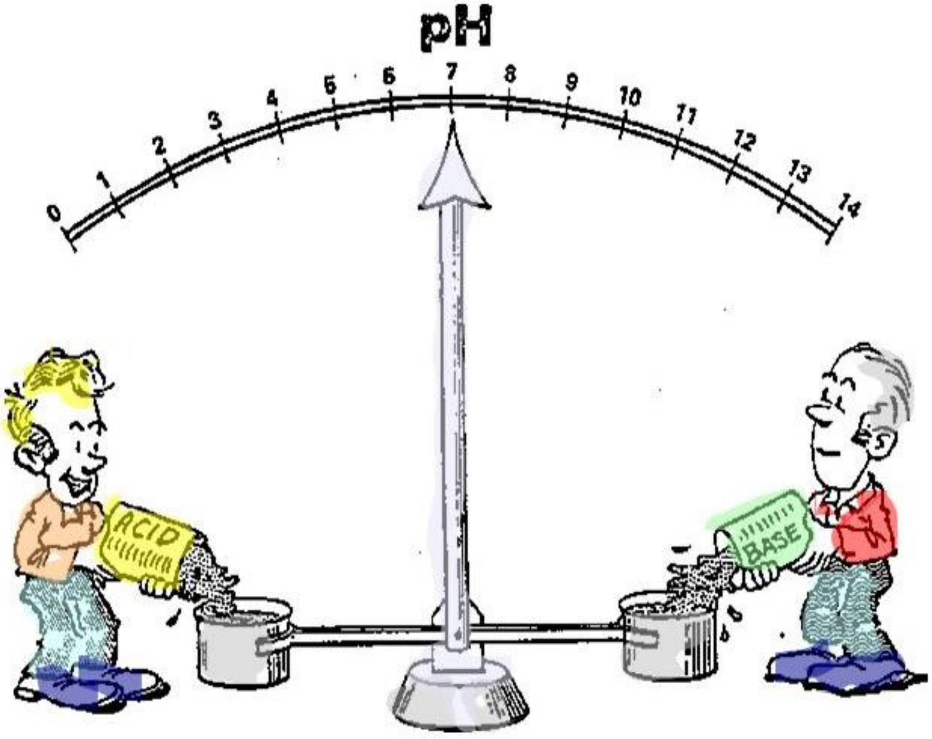
Chemical Quality

- Five general chemical characteristics help define water quality.
  - pH
  - Alkalinity
  - Hardness
  - Total Dissolved Solids
  - Conductivity

The Meaning of pH

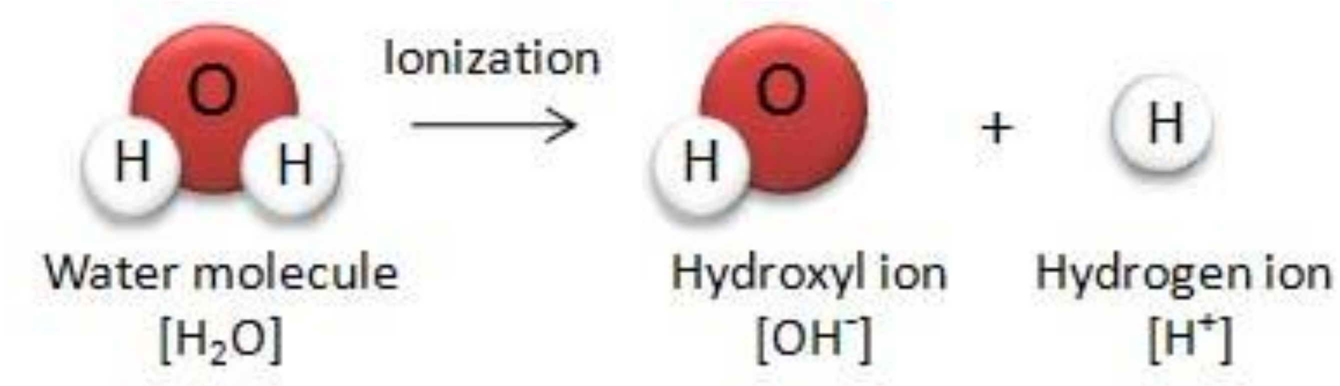
- The pH scale indicates the acidity or basicity of the water.
- Is a measure of intensity along a logarithmic scale





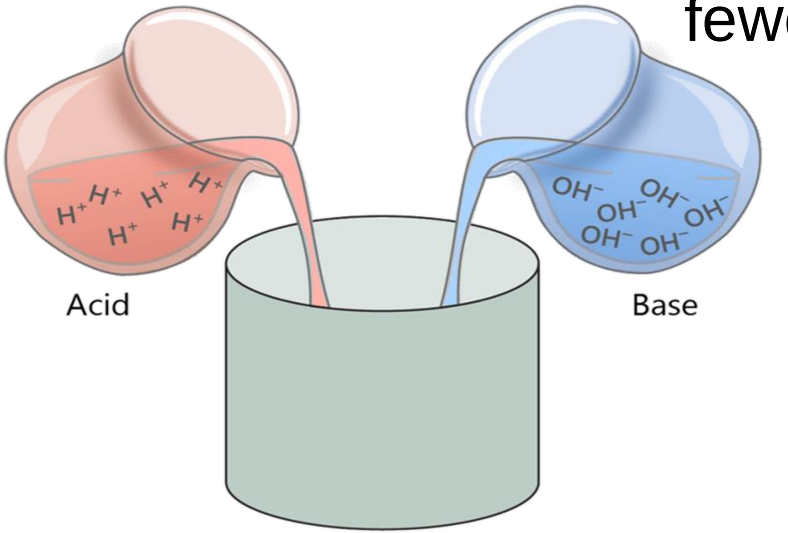
The Meaning of pH

- Even pure water will separate into Hydrogen (H+) and Hydroxide (OH-) ions.
  - Only tiny amounts are typically present in water
- Acidity and basicity of the water depends on the relative amounts of these ions



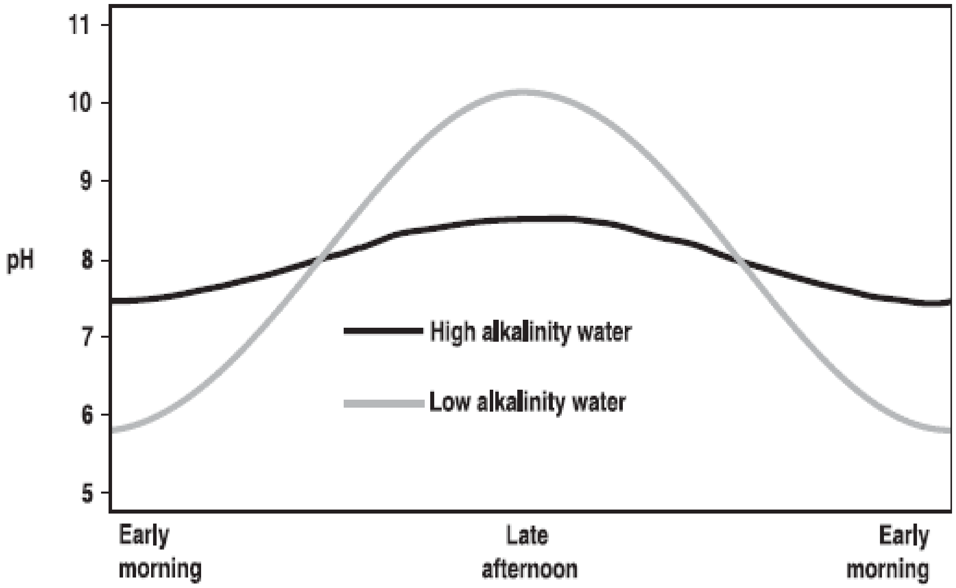
The Meaning of pH

- When an acid (HCL) is added to water:
  - Hydrogen ions are released, and the water contains more hydrogen ions and fewer hydroxide ions
- When a base (NaOH) is added to water
  - Hydroxide ions are released, and the water contains more hydroxide ions and fewer hydrogen ions

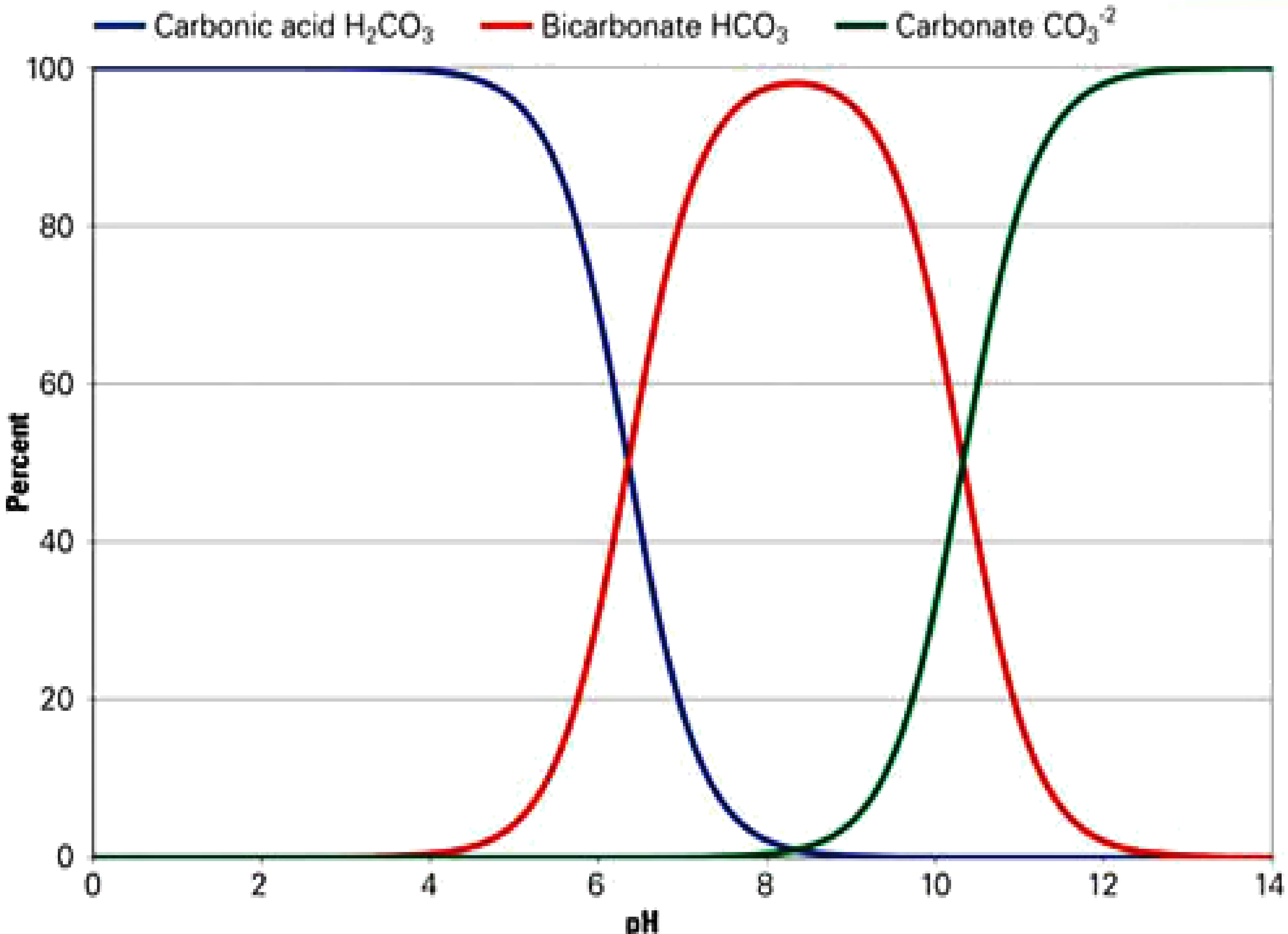


Alkalinity

- Measures the amount of acid that can be neutralized by the water.
- Test performed by adding acid to the water being tested until the pH drops to a specific level.
- Mostly Carbonate and Bicarbonate ions.
- Important to water stability, coagulation, and precipitation softening.



Alkalinity Interpretation



Hardness

- Hardness materials in water react with soap to turn the soap into useless soap curds.
- Hardness reacts with alkalinity to form deposits and scale.
- Made mostly of Calcium (Ca^{+}) and Magnesium (Mg^{++})

Temporary (**Carbonate** Hardness)

- Bicarbonate and Carbonate (anions)

Permanent (**Non-Carbonate** Hardness)

- Chloride and Sulfate (anions)

Total Dissolved Solids (TDS)

- Determined by filtering the water sample and evaporating the water away from the filtrate.
  - The solid residue is the TDS of the water
  - Mostly the mineral content of the water
- Quality standard for public water supply is 1,000 mg/L for TDS.
- Tap water TDS is approximately ½ the conductivity in uS

Conductivity

- Measure of the water's ability to conduct an electric current
- The higher the mineral content of the water, the more ions in the water, and the more readily the water will conduct an electric current
- Usually measured in micro siemens (uS)
  - Pure water is theoretically 0.05482 uS
- Another way to describe purity is by resistance
  - Measured in megohms
  - Pure water is theoretically 18.24 megohms

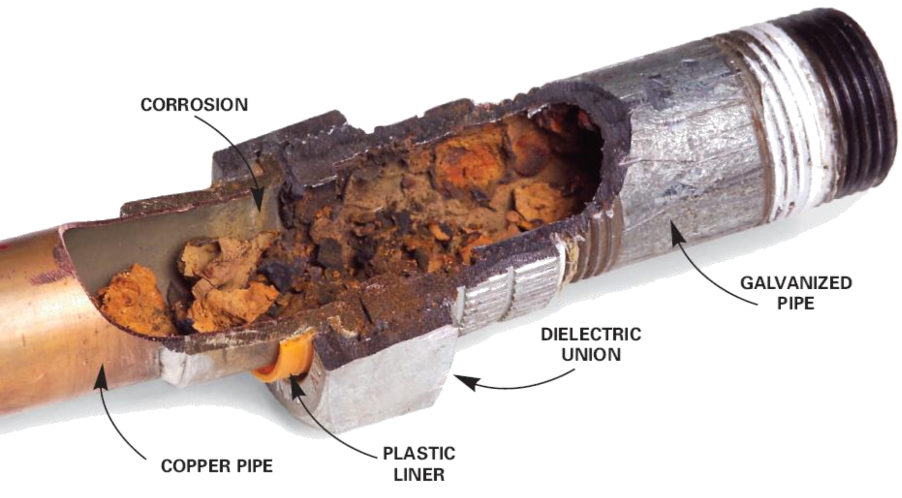
Corrosivity

- Water becomes more corrosive, with a tendency to dissolve steel pipe when;
  - Low pH
  - Low Alkalinity
  - Low TDS
    - Sometimes low hardness
  - High Temperature
  - High Dissolved Gasses
    - carbon dioxide, oxygen

- Corrosive water can lead to Lead and Copper problems.

Galvanic Corrosion

- When two dissimilar metals are physically connected
  - Iron and copper



- Electrons are lost by the iron, and the iron undergoes rapid corrosion
- Results in loss of pipe strength and leaks

Scaling

- Water tends to deposit scale (calcium carbonate) when there is;
  - High Hardness
  - High Alkalinity
  - High pH

Mineral Content

Cations			Anions		
Name	Symbol	Effect	Name	Symbol	Effect
Sodium	Na+	Metallic Taste	Bicarbonate	HCO_3-	Alkalinity
Calcium	Ca+	Hardness	Chloride	Cl-	Brackish taste
Magnesium	Mg++	Hardness	Sulfate	SO_4-	Laxative Effect

Typically comprise more that 95% of the materials that are found in water.

Quick Review

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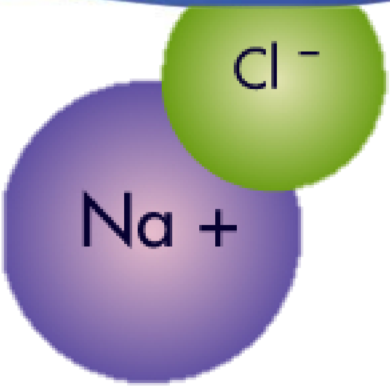
Chapter 5

Ion Exchange

Ion Exchange

- A process that removes dissolved materials from water by exchanging one type of ion for another
  - Ions in the water exchange with ions of the same charge on the resin surface
  - Softeners and demineralizers are the two most common
    - Softeners remove hardness only
    - Demineralizers remove all ions
- Accomplished on natural or synthetic resins
  - Synthetic resins have a much higher exchange capacity compared to natural Zeolite

Common Ions



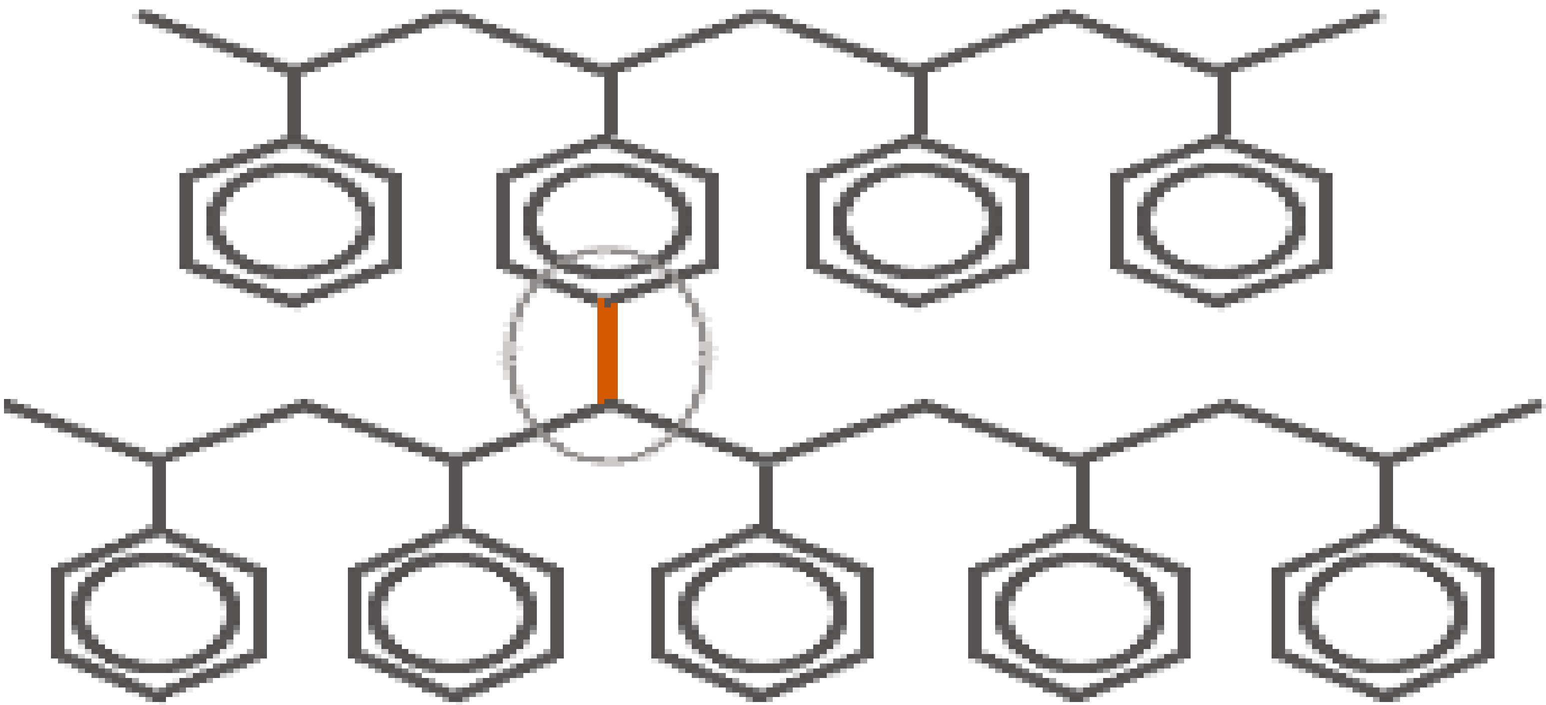
- When minerals dissolve in water they are converted into an ionic form
  - Ordinary table salt is Sodium Chloride, but when dissolved in water it is sodium ion (Na+) and Chloride ion (Cl-)

Common Ions in Water and Their Effects

Cations			Anions		
Name	Symbol	Effect	Name	Symbol	Effect
Hydronium	H+	Acidity	Hydroxide	OH-	Basic
Sodium	Na+	Metallic Taste	Bicarbonate	HCO3-	Alkalinity
Potassium	K+	Nutrient	Carbonate	CO3--	Alkalinity
Calcium	Ca++	Hardness	Chloride	Cl-	Brackish Taste
Magnesium	Mg++	Hardness	Sulfate	SO4--	Laxative effect
Manganese	Mn++	Taste and brownish stains	Nitrate	NO3-	Blue babies
Ferrous Iron	Fe++	Red Water	Fluoride	F-	Mottled Teeth
Cupric	Cu++	Blue Stains	Sulfide	HS-	Black Stains
Stannous	Zn++	Metalic Taste	Iodide	I-	Allergen
Ammonium	NH4+	Pollutant	Phosphate	PO4---	Pollutant
Selenium	Se++	Toxicity	Silicate	SiO2-	Sealing

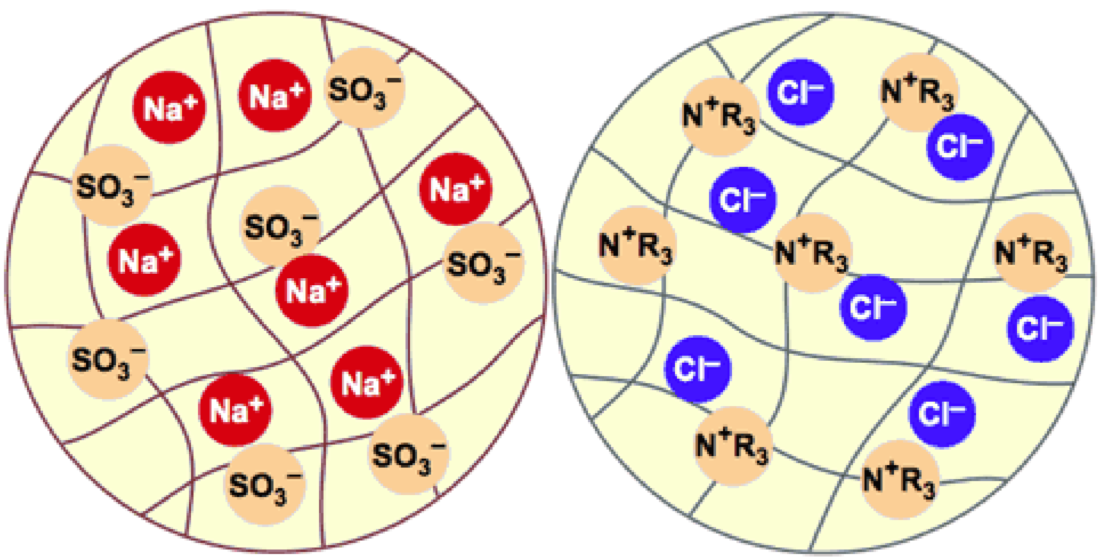
Ione Exchange Resins

- Polystyrene linked with Divinyl Benzene
  - Small plastic bead-like material that can be regenerated almost indefinitely



5.2.1 Resins

- Two major groups
  - Cation Resin exchanges positive ions
    - Negative functional (Hands)
  - Anion Resin exchanges negating ions
    - Positive functional (Hands)



Equilibrium Nature of Resins

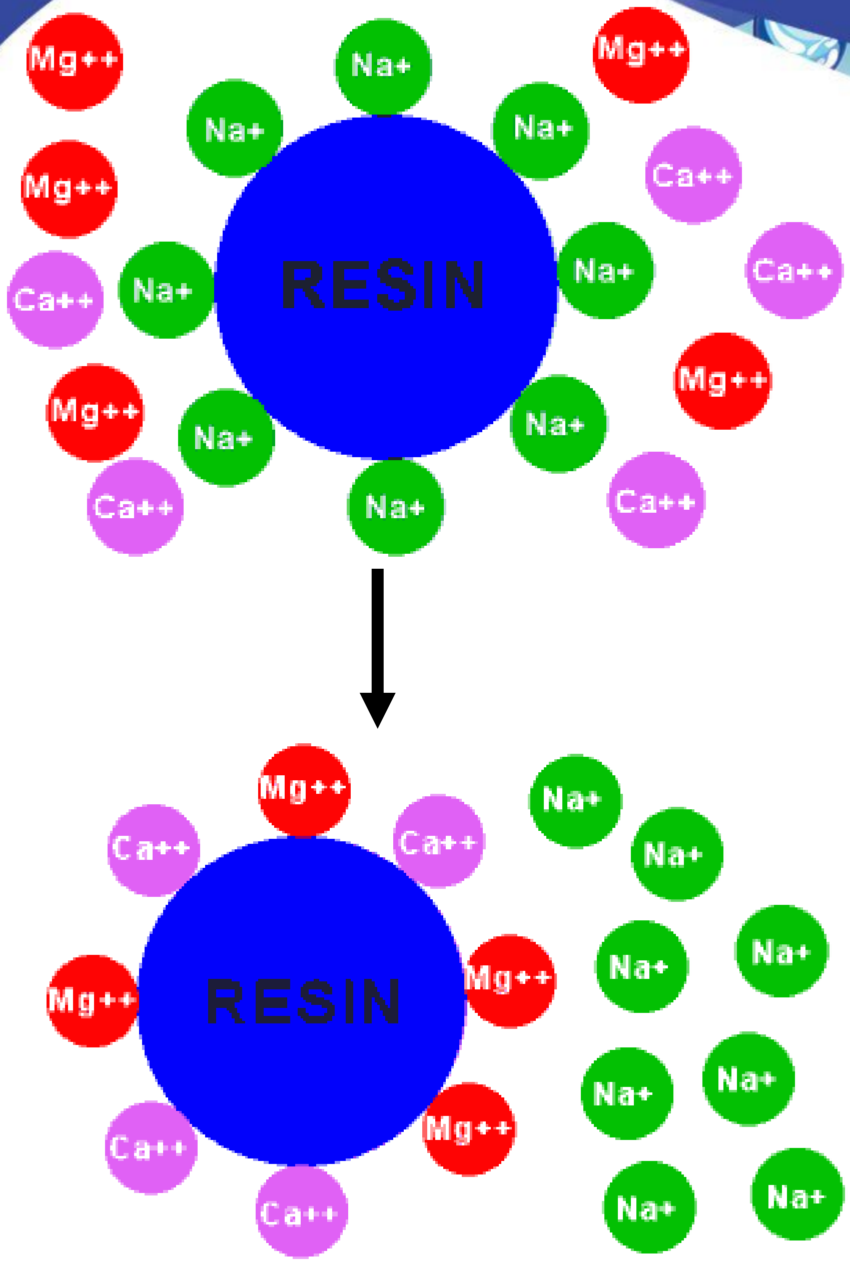
- Resin material has a different affinity for each type of ion
  - Called selectivity
- Cation resin selectivity
  - $Fe^{3+} > Al^{3+} > Ba^{2+} > Fe^{2+} > Mn^{2+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+} > H^{+}$
- Anion resin selectivity
  - $SO_4^{2-} > CO_2^{2-} > NO3^{-} > HSO_4^{-} > Cl^{-} > HS^{-} > HCO_3^{-} > F^{-} > SiO_2^{-} > OH^{-}$

Operating Cycle

- Service/Exhaustion
  - Removes and replaces the contaminating ions with a more acceptable ion
- Regeneration:
  - Backwash
    - Expands, cleans, and regrades the bed
  - Brine
    - Returns the resin to active condition by treatment with a high concentration of the regenerating chemical
  - Rinse
    - Completes regeneration by displacing excess regenerate and prepares the bed for service

Softening

- Removes essentially all hardness from the water
- Contains only Cation Resin
- Regenerated with brine
  - A concentrated solution of sodium chloride and water
- During service, calcium and Magnesium hardness ions attach to the resin at the active exchange sites as sodium ions are released into the water
  - May also remove iron, manganese, and aluminum
    - These materials may foul the resin over time depending on the amount present
- Hardness is removed but the water’s sodium content increases in proportion to the amount of hardness removed



Mg++
Na+
Mg++
Na+
Na+
Ca++
Mg++
Ca++
Na+
RESIN
Na+
Ca++
Mg++
Mg++
Na+
Na+
Ca++
Na+
Ca++
Mg++
Na+
Ca++
Ca++
Na+
Na+
Na+
RESIN
Mg++
Mg++
Na+
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Mg++
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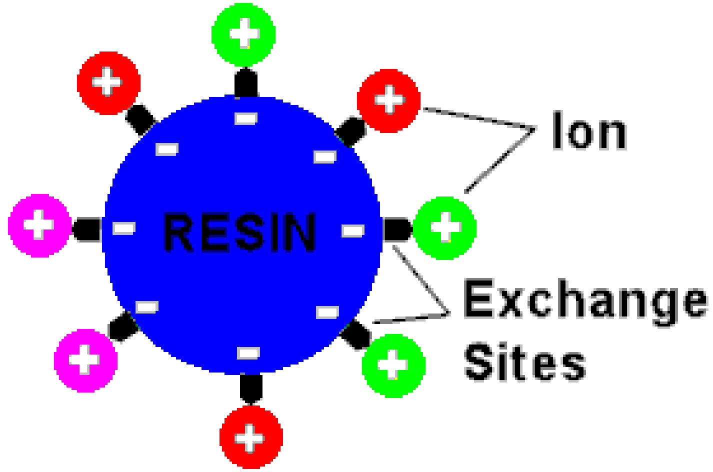
Ca++
Ca++
Na+
Na+



Ion
RESIN
Exchange
Sites

Steps in Softener Operation

- Service
  - Removes hardness from the water
- Regeneration
  - Backwash
  - Brine
    - Strong salt solution
  - Rinse
- Return to service
- Some units use a different regeneration sequence
- Since softening increases the sodium content of water, softened water for drinking is often treated by reverse osmosis to remove sodium and other ions from the water

Demineralization

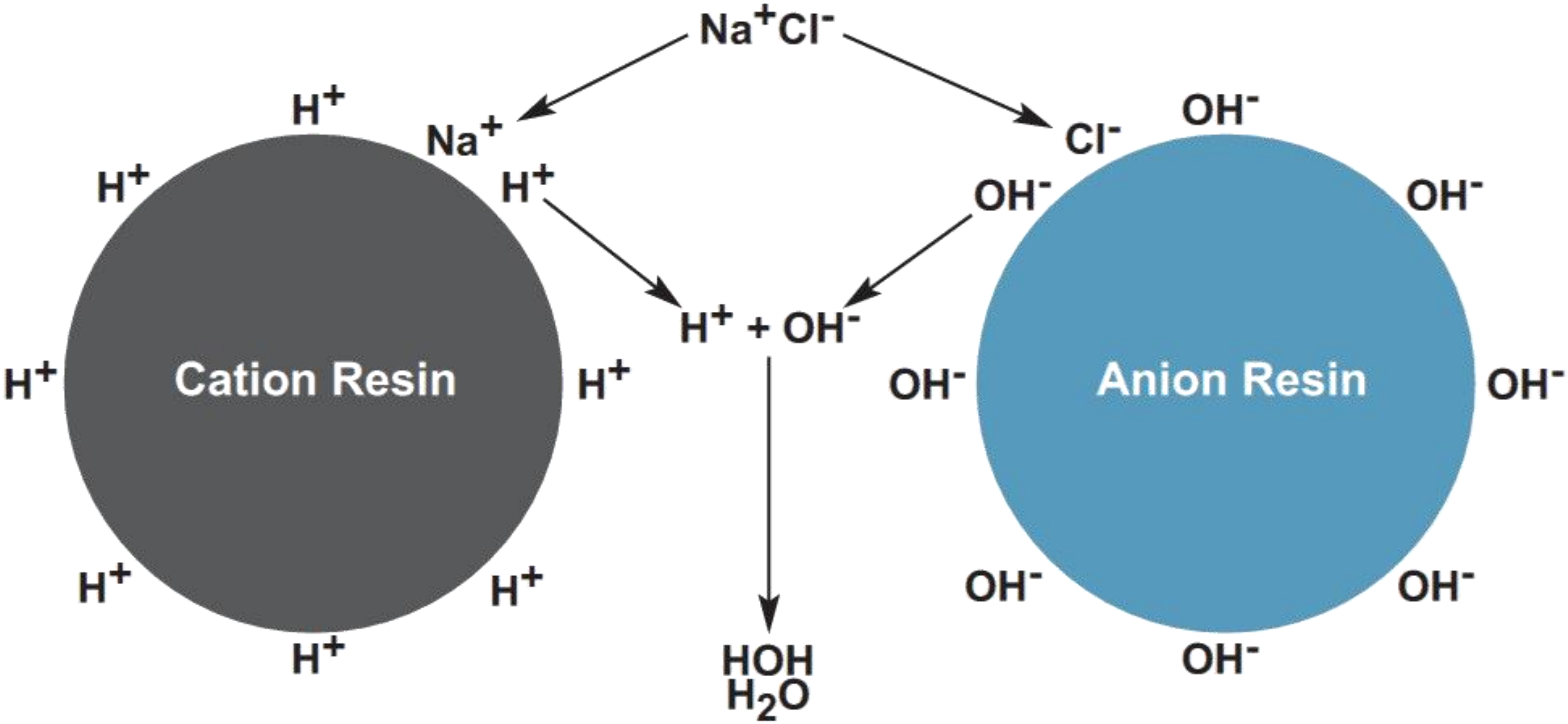
- Ion exchange process that removes ALL ions from the water.
- Contains 2 types of resin
  - Cation resin
    - Removes all cations
    - Replaces cations with H+
    - Regenerated with a strong acid
  - Anion resin
    - Removes all anions
    - Replaces anions with OH-
    - Regenerated with a strong base

DI Cation Resin

- Regenerated with a strong acid
  - Sulfuric or Hydrochloric
- Regeneration places hydrogen ions on the active sites
- During service, all cations are exchanged with hydrogen
  - Including sodium, potassium, calcium, magnesium, iron, manganese, and aluminum
- Hydrogen ions released by the cation resin can react with hydroxide ions released by the anion resin to form water

DI Anion Resin

- Either Strongly Basic or Weakly Basic
  - Strongly Basic Anion
    - Regenerated with Sodium Hydroxide (NaOH)
      - Caustic, or caustic soda
- During service, anion resin collects chloride, sulfate, bicarbonate, and nitrate
  - Releases Hydroxide (OH-)
- After leaving the resin, hydroxide ions combine with the hydrogen ions from cation resin to form water



Na+Cl-
H+
Na+
Cl-
OH-
H+
H+
OH-
OH-
H+ + OH-
H+
Cation Resin
H+
OH-
Anion Resin
OH-
H+
H+
OH-
OH-
H+
OH-
HOH
H2O

Common Problems

- Amine taste
- Short cycle time
- Scaling
- Organic fouling
- Silica leakage

Amine Taste

- Strong base anion resins may impart a particularly strong amine taste to the water
- Using mixed-bed systems or following the anion resin bed with a mixed-bed unit will reduce the amine taste
- Periodic salt regeneration followed by a caustic regeneration may also help reduce amine taste and odor

Short Cycle Time

- Caused by insufficient regeneration
- Weak chemicals or poor-quality chemicals may be the culprit
- Fouling of resin beds by precipitated or organic matter may also reduce run times
- Gradual disintegration of the resin due to oxidants or mechanical problems can result in short cycles

Scaling

- Permanent hardness such as calcium sulfate may deposit scale on the resin and reduce its effectiveness
  - Risk of using sulfuric acid to regenerate
- When hard water is used during regeneration, backwash, and rinsing, these precipitates are more likely to form
- Hydrochloric acid may be used to remove sulfate scale from either the cation or anion resin beds

Organic Fouling

- Organic materials may foul an anion resin bed
    - Because of the negative surface charge that these materials have
- It is best to remove organic matter by activated carbon adsorption to protect resin beds

Silica Leakage

- Silica is nearly non-ionic and may not be effectively removed by a weakly basic resin
- Efficient regeneration of strongly basic anion resin is required to remove silica and prevent the accumulation of silica on the resin

Quick Review

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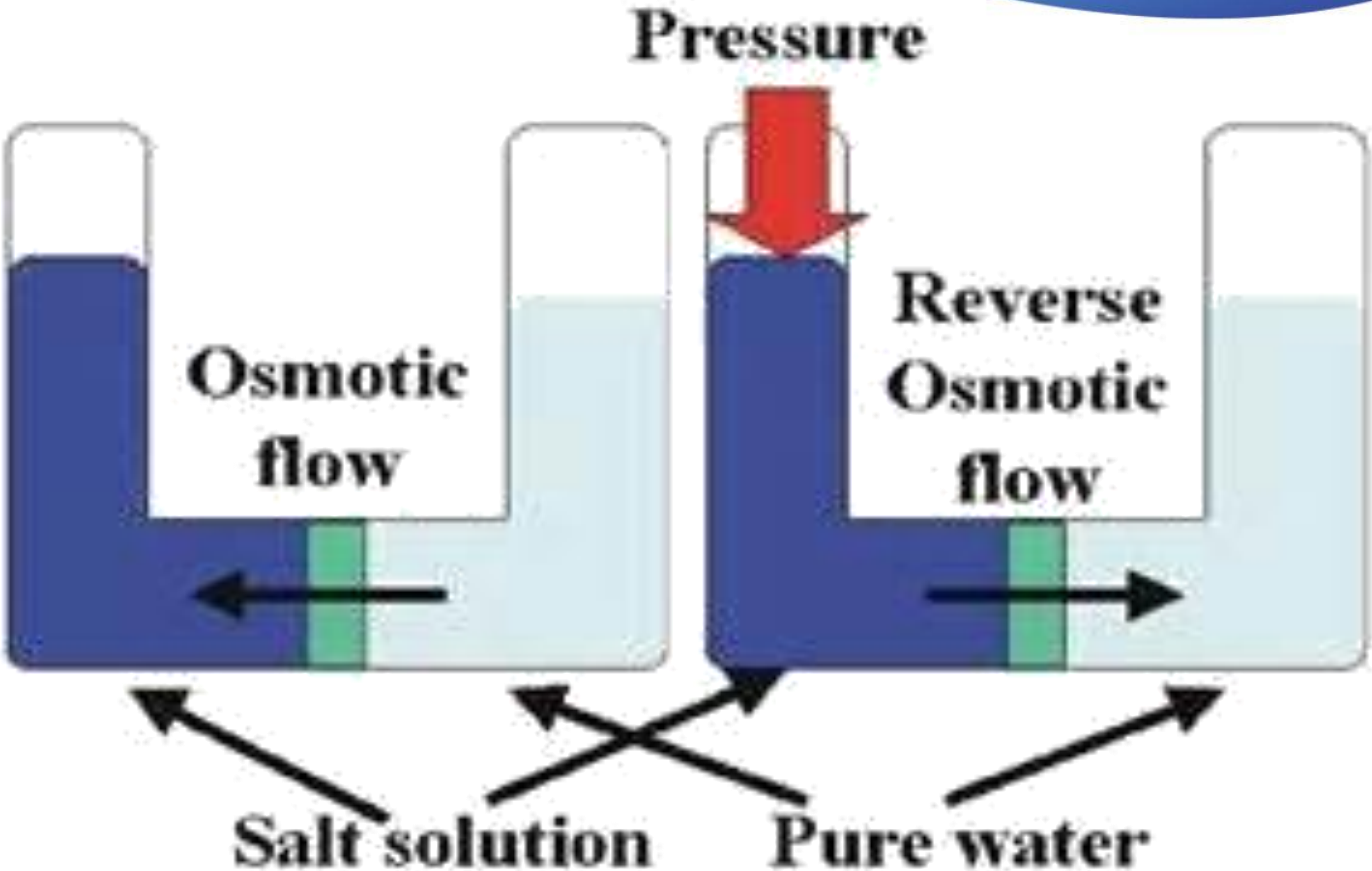
Chapter 6

Reverse Osmosis

Membrane Separation Processes

- Water that is relatively pure is at a higher energy level than water that contains dissolved minerals
  - Always requires more “work” to clean up dirty water and make purer water
- Higher energy level cannot be seen or felt but it can cause a considerable pressure differential to develop across a membrane
  - Water passes naturally through a semi-permeable membrane from the clean water side of the membrane to the dirty water side
    - Called Osmosis



Pressure
Osmotic
flow
Reverse
Osmotic
flow
Salt solution
Pure water

Membrane Separation Processes

- During osmosis, clean water will move across the membrane until the water pressure (or level) on the dirty water side offsets the osmotic pressure
- Osmotic pressure difference
    - 1 psi for each 100 ppm TDS difference
        - Ordinary tap water is typically between 5 and 15 psi

Membrane Separation Process

- Reverse Osmosis (RO) is a membrane separation process which uses pressure to force water through a semipermeable membrane
- Thin polymer membranes along with pressure are used to selectively pass water while limiting the passage of inorganic chemicals, organic molecules, and micro-organisms
- Ideal semipermeable membrane
  - Allows water molecules to pass easily while stopping other materials
  - Strong, unaffected by chlorine or other disinfectants, and have a high recovery

Types of Membranes

- Types of Membrane Polymers
  - Cellulose acetate
    - Can be attached and degraded by bacteria
  - Cellulose triacetate
    - Can be attached and degraded by bacteria
  - Polyamide and Polysulfone
    - Commonly bonded together to form a membrane called thin-film composite (TFC)
    - Affected strongly by oxidants
      - Chlorine and ozone

Types of Membranes

- Commonly arranged in elements:
  - Hollow fibers, tubular, plate and frame, or as spiral wound units
- Membranes can also be arranged in various series or arrays to obtain higher recoveries and production rates.
- Membrane arrangement should provide the high surface area needed to obtain sufficient product water from each element.

Terminology

- **Osmotic pressure**
  - Pressure difference between two solutions on either side of a semipermeable membrane because of the difference in water purity
  - 100 ppm TDS = 1 psi
- **Net Pressure**
  - Feed pressure – osmotic pressure – back pressure
  - Minimum for home RO unit is about 30 psi
- **Element**
  - A usable physical arrangement into which the membrane material is formed
- **Module**
  - A combination of membrane elements and the housing or pressure vessel into which the elements are inserted for use in a RO system

Terminology

- **Feed Water**
  - Pretreated water under pressure that enters into the membrane system
- **Permeate**
  - Portion of the feed stream which passes through the membrane and becomes product water
  - Aka Product
- **Concentrate**
  - Concentrate, reject, or brine which contains the contaminants or impurities rejected by the membrane and carried away by the waste stream
- **Recovery**
  - The percentage of feed water that passes through the membrane as permeate

Terminology

- **Water Horsepower**
  - Useful output of a centrifugal pump
- **Static Discharge Head**
  - Difference in elevation between a pump and the level that it is pumping into
- **Total Dynamic Head**
  - Total pressure that a pump operates against including static head, friction head, and velocity

Terminology

- **Rejection**
  - Removal of a material by the membrane is measured in percent.
  - Rejection for most materials is between 90 – 97%
- **Flux**
  - Flow rate of permeate (rate of production) through a membrane or membrane element reported as the amount of water produced per hour per square foot of membrane area
  - Directly proportional to net pressure
    - If the net pressure increases by 50%, the flux should increase by 50%
  - Also increases with increasing temperature
    - 1.5% for each *F temperature change

Reverse Osmosis Systems

- A membrane is one part of the RO system
- System must protect the membrane from fouling and damage while delivering the necessary quantity of treated water
- Components include:
  - A pump for pressure and capacity maintenance
  - Pretreatment to remove fouling or damaging materials
  - A product water storage tank
  - Reject water disposal

Pressure Source

- Since flux of a RO membrane increases when the net pressure increases, more water and higher purity water can be produced by operating at higher pressures
  - Usually accomplished by using centrifugal pumps to pump raw or pretreated water through the RO system
- Net driving pressures range from 30 psi to 1,000 psi
  - 1,000 psi = practical limit for RO systems
  - When raw water is highly mineralized (sea water) pressures of several hundred psi may be required
- With higher recoveries, the salt concentration and osmotic pressure increases

Pretreatment

- RO membranes are easily fouled or damaged and pretreatment is required.
- Types of fouling:
  - Scaling
  - Colloidal Fouling
  - Biofouling
- Oxidants, such as chlorine, damage TFC membranes
- Bacteria harm cellulosic membranes
  - Sensitive to hydrolysis above pH 8.0

Pretreatment

- **Scaling**
  - Calcium from hard water
  - Formed when the mineral content of the water exceeds the solubility of the compound
  - Calcium carbonate and Calcium Sulphate most common
    - Form from the back end of the membrane forward
  - Pretreatment involved softening

Pretreatment

- **Colloidal Fouling**
  - Caused by microorganisms, clay particles, silt, oil, sulfur and sulfides, iron and manganese, an natural organic matter (humic acid and tannins)
  - Pre-filters and activated carbon adsorption are used to remove these colloidal materials

Pretreatment

- **Biofouling**
  - Occurs when microorganisms (usually bacteria) reach the membrane surface and begin to colonize
  - Nutrients and an optimal pH and temperature will increase the bacterial growth rate
  - Results in a gradual increase in feed pressure with reduced permeate flow
  - Pretreatment with activated carbon and periodic membrane cleaning

Unit Sizing, Water Storage and Waste Flow

- RO is used for:
  - Drinking, food and beverage preparation, watering plants, and making ice
- Typical home use is 0.5-1 gallon per person per day
- Units should be sized to meet the expected home demand with storage for approximately one-day
  - An under-the-sink pressure storage tank from 2-5 gallons capacity is usually adequate
- Waste flow for home units with a 25% recovery is 3 gallons for every gallon of product water
  - Waste flow usually has little impact on the wastewater treatment system

Testing and Maintenance

1. Test conductivity of feed and permeate
   - If conductivity is significantly lower in permeate, move to step 2
   - If conductivity is not significantly lower, move to step 3
2. Test percent recovery of membrane
   - If recovery is near what is expected, membrane is good
   - If recovery is low, there is either scale, colloidal, or biofouling preventing water from moving through the membrane
3. Test chlorine residual before and after the membrane
   - If there is a chlorine residual after the membrane, then the chlorine removal failed, and the membrane has been oxidized
   - If there is no chlorine residual, then there is a mechanical problem allowing water to bypass the membrane

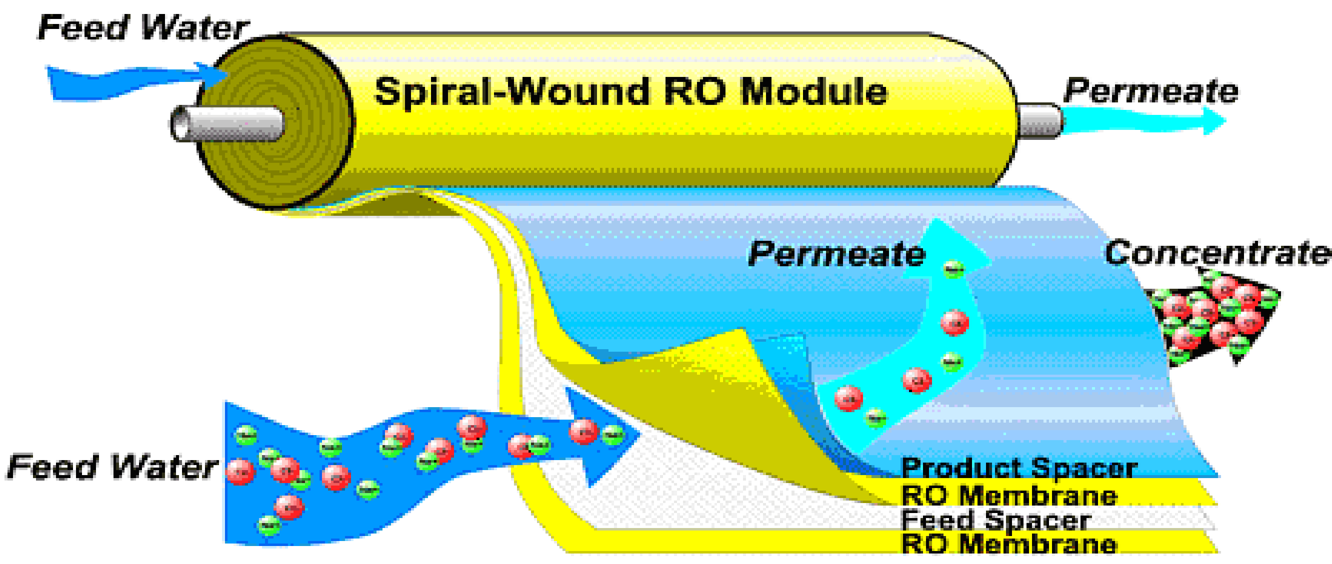
- Prefilters should be maintained regularly to protect the integrity of the membrane.

Membrane Elements

- To be useable, membranes must be packed into a membrane element or module that provides a high surface area and strength
- It is economically desirable to pack as much membrane as possible into a small area
- Membrane fouling can increase if the membrane is spaced too closely

Membrane Elements

- **Spiral Wound**
  - A bag of membrane layers is wound around a permeate tube
  - Water is passed by the outside of the bag from the inlet to outlet and the purified water passes through the membrane into the permeate tube
  - Packing density is high and the resistance to fouling is relatively low



Quick Review

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Chapter 7

Water Treatment Technologies

Water Treatment Technologies

- The selection of water treatment processes for removing impurities from water is based on specific requirements.
- The factors considered when evaluating the various treatment options are:
  - Quality of the water source, its type, and degree of prior treatment
  - Type and amount of impurities to be removed and quantity to be treated
  - Desired product water quality and treatment requirements
  - Waste disposal requirements
  - Costs

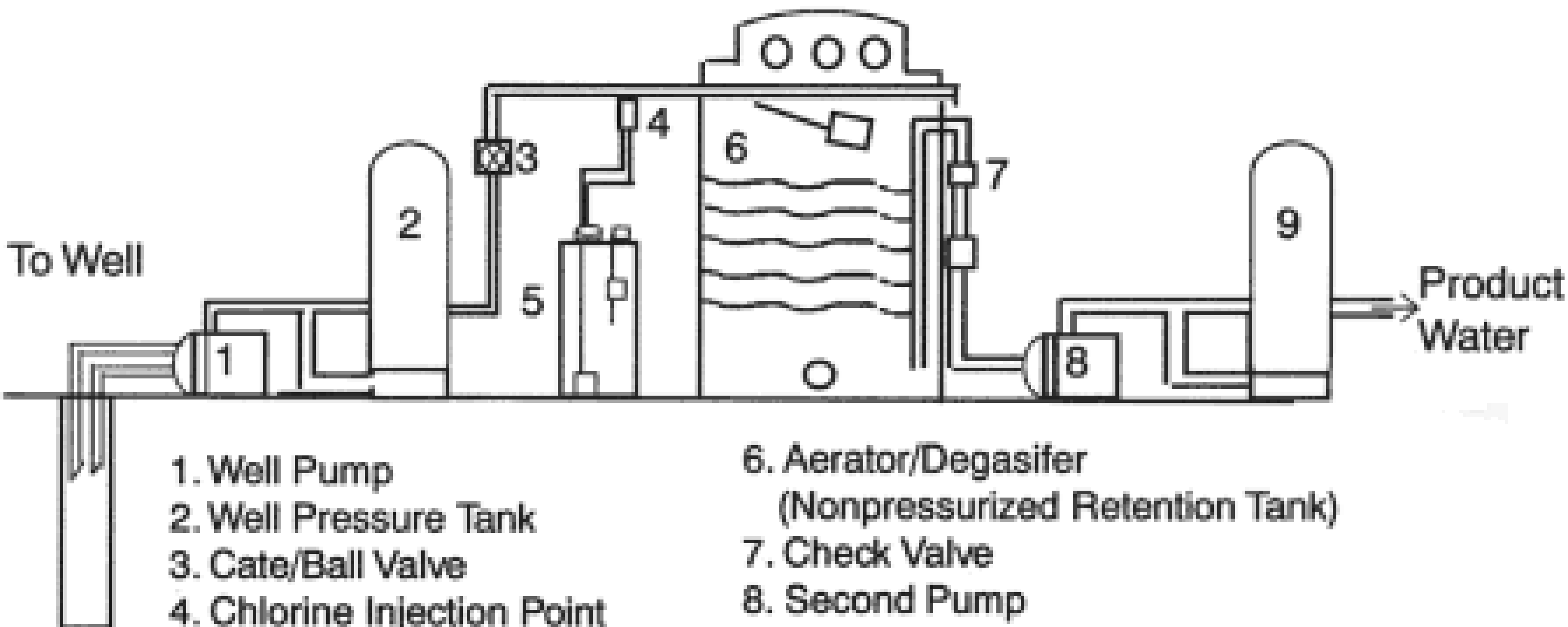
Water Treatment Technologies

- Treatment technologies are used to control a wide variety of impurities including;
  - Organics, turbidity, fluoride, heavy metals, iron and manganese, hardness, nitrate, microorganisms, color, taste and odor, chlorine, and radioactive materials
- It is unlikely that any single process can produce the desired product quality.
- Treatment is usually provided as a series of unit processes or steps.

Aeration

- Releases:
  - Carbon Dioxide, Hydrogen Sulfide, Methane
  - Radon, heat, VOCs, and SOCs
- Creates a system to bring air and water into contact with each other so that **dissolved gasses** can be released.
- Often used in conjunction with Oxidation/Filtration

Typical Domestic Open-Gravity Aerator System



1. Well Pump
2. Well Pressure Tank
3. Cate/Ball Valve
4. Chlorine Injection Point
5. Chemical Feed Pump on
   16-gal. Solution Tank
6. Aerator/Degasifer
   (Nonpressurized Retention Tank)
7. Check Valve
8. Second Pump
9. Second Tank

Source: Water Quality Assoc.

Filtration

- Filters are used to remove particulate matter from water
  - Clay, Silt, and Microorganism
  - Decreases turbidity to increase disinfection efficiency
  - Protects membrane units from fouling
  - Will not remove dissolved solids

Depth Filters

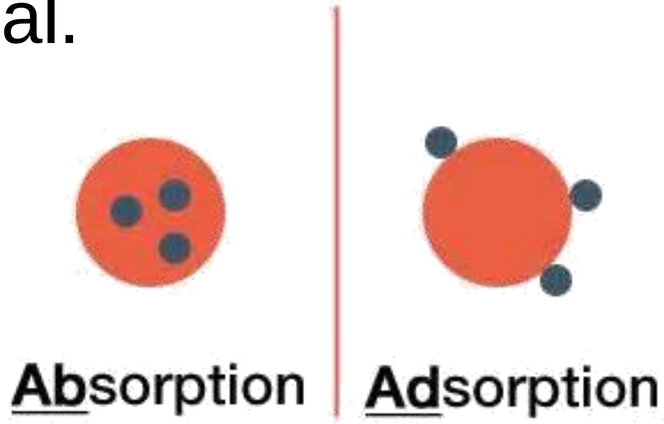
- As the water flows through progressively smaller openings in the filter media bed, progressively smaller particles are removed.
  - Trap particulate matter throughout the depth of the filter
- Treatment of the water with coagulants and filter aids greatly increases the effectiveness of depth filters.
- Variations:
  - Slow sand filters; single, dual, and mixed media filters, and pressure filters

Surface filters

- Typically point-of-use filters.
- Filtration occurs on the surface layer.
  - Using sieves, screens, or fabric with small holes
- Size of the holes in the filter media determines the size of particles that are removed.
- Rated as either Absolute or Nominal.
  - **Absolute** means 99.9% of particles larger that micron rating will be trapped.
  - **Nominal** indicates the approximate size particle which will not pass through
    - 85% or more

Adsorption

- Activated carbon removes;
  - Some inorganic chemicals, chlorine, and chlorine by-products, VOCs, SOCs.
- Used extensively for organic taste and odor.
- Activation acts by adsorbing contaminants
  - The attraction and retention of one material to the surface of a second material.



Activated Carbon

- High Surface area and pore structure.
- 1 pound = more than 100 acres of surface area.
- Think of it as a sponge, with the ability to trap and hold large amounts of organic matter.
- Raw materials:
  - Bituminous coal, lignite, petroleum coke, wood, and nut shells (coconut)
- Provides a medium for the growth and accumulation of bacteria.
  - Microbial control following treatment

Lime-Soda Ash Softening

- Used by municipalities to partially soften public water supplies
  - Reduces carbonate hardness to about 40 mg/L
  - When more than 60 mg/L of non-carbonate hardness is present, the total hardness is reduced to about 100 mg/L
- Not commonly used in private treatment systems, but can have significant effects on public water chemistry
- Lime and Soda Ash precipitate out hardness from solution
- Results in low hardness, but high pH

Chemical Oxidation

- Used in a variety of ways:
  - Iron and Manganese oxidized to insoluble ferric and manganese hydroxides to be filtered.
  - Hydrogen Sulfide can be oxidized to elemental sulfur or sulfate.
  - Inorganic Taste and odor control

Chemical Oxidant	Strength
Ozone (O_3)	Very Strong
Hydrogen Peroxide (H_2O_2)	Very Strong
Potassium Permanganate ($KMNO_4$)	Strong
Chlorine Dioxide (ClO_2)	Strong
Free Chlorine (HOCl)	Strong

Iron and Manganese

- Iron is present in many groundwater supplies, but manganese is much less common and usually appears along with iron
- Presence of more then 0.3 mg/L iron or more than 0.05 mg/L manganese is considered to be objectionable
  - Stain or grey fabrics and fixtures
  - Iron may stimulate the growth of iron bacteria
    - Create stringy, gelatinous growths in water piping

Iron Removal Methods

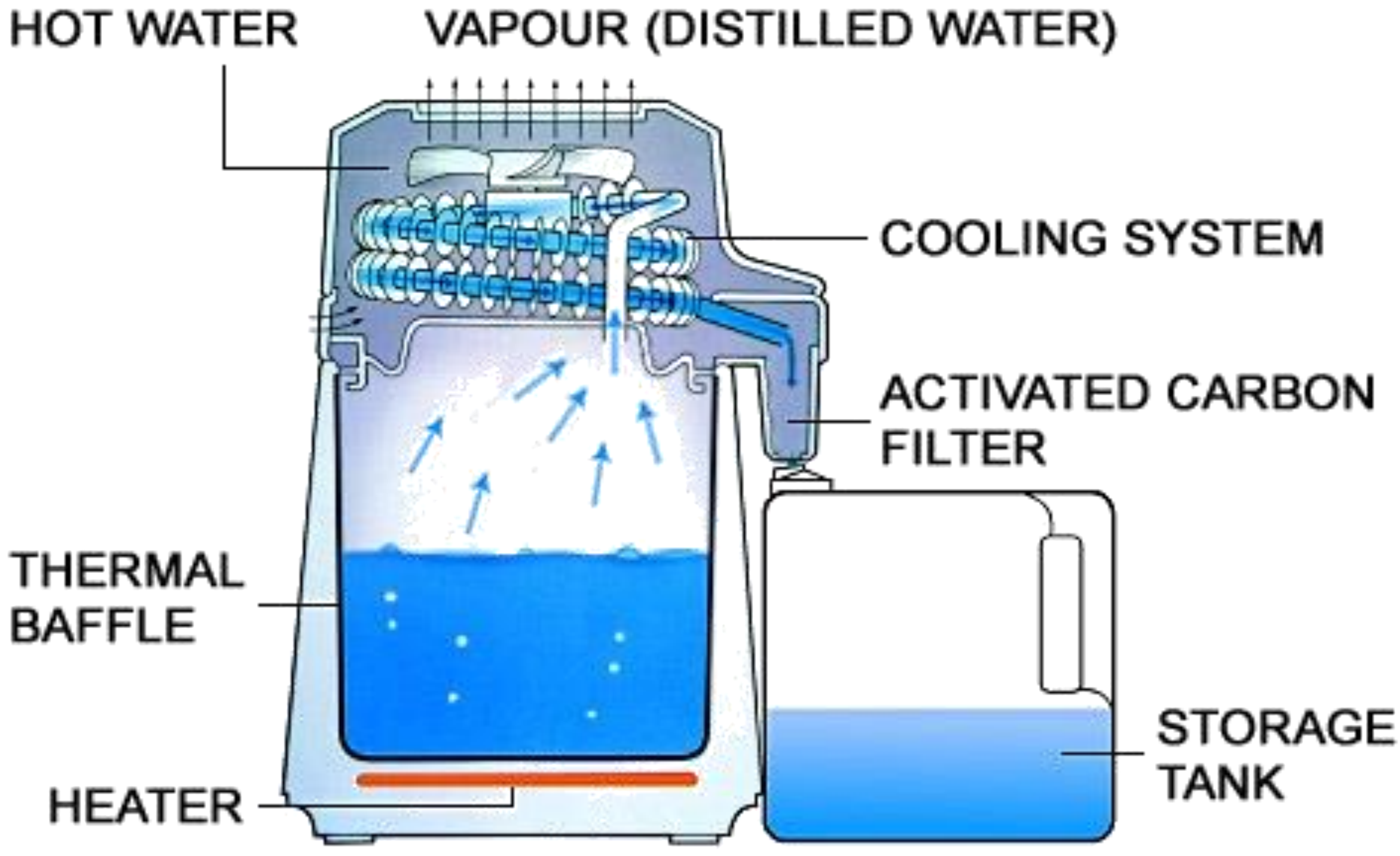
- When carbonates are present in the water
  - Lime addition can completely precipitate iron and manganese carbonates if the pH is between 8.0-8.5
- When carbonates are low
  - Oxidation with air, chorine, or potassium permanganate followed by filtration
    - Water's pH is critical and must be higher (>7) when air oxidation is used
- Manganese green sand resin beds can be used to adsorb iron and manganese and oxidize the adsorbed ions
  - Backwashing removes the oxidized materials and potassium permanganate may be added periodically to coat exchange material
- Ferrous and Manganous ions can also be removed by ion exchange softening
  - Air should not be present because fouling oxides can form
  - Hardness should be at least eight times greater than the iron content to avoid resin fouling

Iron Sequestering

- With low levels of iron and Manganese
  - 1 mg/L or less
- Polyphosphates are added to the water to "tie up" soluble iron and manganese
  - Not removed
  - Prevents oxidation
  - Must be added before oxygen or oxidizing agents (chlorine) are introduced
    - Not effective for higher levels of iron and manganese and may be affected by heating

Distillation

- Process of separating water from organic and inorganic contaminants through **evaporation and condensation.**
- Process:
  - Water heated till steam
  - Particulates are left behind as steam separates
  - Steam cooled and condensed to form pure water
- Effectively removes
  - Metals, hardness, salt, nitrate, and particulates.
  - High temp. used kills bacteria, cysts, and viruses.



HOT WATER
VAPOUR (DISTILLED WATER)
COOLING SYSTEM
ACTIVATED CARBON
FILTER
THERMAL
BAFFLE
HEATER
STORAGE
TANK

Disinfection with Chlorine, Ozone and UV Light

- To reduce the numbers of disease-causing organisms to safe levels and to destroy pathogenic organisms without impairing the quality of the water
- The most important step in the production of drinking water
    - Prevents water-born diseases
        - These diseases have been around for centuries and are ready to cause large numbers of illnesses and death when they become epidemic
- Cholera, Typhoid and paratyphoid, Bacillary Dysentery, Amoebic Dysentery, Giardiasis, Cryptosporidiosis, Hepatitis, Viral Gastroenteritis

Disinfectants

- Rated by their ability to reduce pathogens to safe levels
  - To be effective, a disinfectant must contact the microorganisms for a period of time
    - CT value (Concentration x Time)
    - Higher the CT value to kill the microorganism, the weaker the disinfectant

Disinfectant	CT value for 99.99% Virus Inactivation	CV value for 99.9% Giardia Cyst Inactivation
Ozone	1.0	1.43
Chlorine Dioxide	25.1	23
Free Chlorine	6	137
Chloramine	1,491	1,850

Disinfection with Chlorine

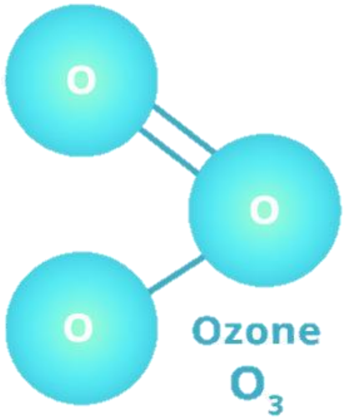
- Most commonly used disinfectant for community and non-community public water supply systems
  - Readily available, effective, low cost, and provides a measurable residual that can be tested periodically
- Commercially available in three forms
  - Liquid solutions of sodium hypochlorite (bleach)
  - Solid calcium hypochlorite
  - Pure chlorine as a compressed gas
- For disinfection to be effective, it must be applied continuously and at high enough concentrations over the required contact time

Chlorination Terms

- **Dosage**
  - Amount of chlorine added to the water and reported as mg/L
- **Demand**
  - Amount of chlorine that is used up by reactions with impurities in the water
- **Residual**
  - Amount of chlorine remaining after the contact period
  - Can be measured by chlorine test methods such as DPD colorimetric method, FAS titration method, or amperometric titration
    - DPD method is commonly used
    - Indicator dye turns pink to red depending on the concentration of chlorine in the sample

Disinfection with Ozone

- Ozone is a very quick and effective disinfectant
  - Nearly 100 times more effective than free chlorine for Giardia cyst inactivation
- Because it is unstable, must be generated on site and used quickly
- Produced by an ozone generator
  - Uses high-voltage electrical corona to convert the oxygen in clean, dry air into ozone
- Can also be produced by ultraviolet light when operated at a specific short wavelength
- Only small residual concentrations are required for disinfection
  - 0.1-0.2 mg/L



Disinfection with Ultraviolet Light (UV)

- Wavelength for disinfection is 253.7 nanometers
  - Close to the optimum germicidal wavelength
- In a UV light system;
  - Water enters the disinfection unit and passes through the space between the quartz lamp sleeve and the outside chamber wall
  - Light must penetrate through the water for maximum effectiveness
    - Color, turbidity, low temperature, low voltage, and organic matter may interfere with the effectiveness

Quick Review

Please open the Quizizz app to complete review

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