GROUNDWATER FILTRATION BASICS

parural water Association

MARCH 2016

PRESENTATION OUTLINE

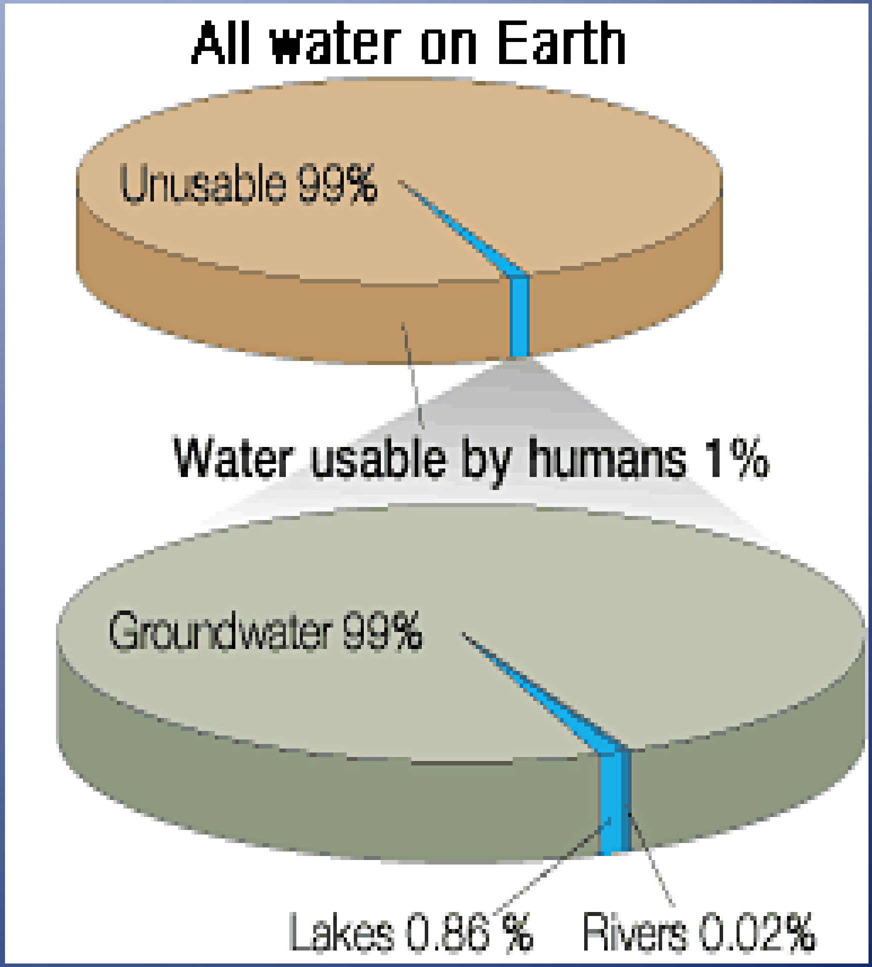
- Groundwater Facts
- Brief Overview of Regulations Governing Groundwater Treatment
  - Groundwater Rule
  - Surface Water Treatment Rule
- Treatment of Groundwater Overview
- Water Treatment – The Basics
  - Treatment Techniques
  - Selecting the Best System Treatment Options
  - Treatment Considerations

PRESENTATION OUTLINE

- Disinfection – The Basics
  - Chemical Disinfection
  - Advantages/Disadvantages
  - Chlorine Basics
- Filtration – The Basics
  - Filtration Overview
  - Filtration Techniques and Typical Contaminant Removal
  - Filtration Methods
    - Pressure Filtration
    - Gravity Filtration
    - Membrane Filtration
    - Ion Exchange
- Comparison of Filtration Systems

WHAT IS GROUNDWATER

- The basics :
  - Over 70% of the earth's surface is covered in water
  - But of that water, just 1% is readily available for human use, and of that 1%, 99% of it is groundwater.
  - Groundwater is important to all of us



FACTS ABOUT GROUNDWATER

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Facts About Groundwater

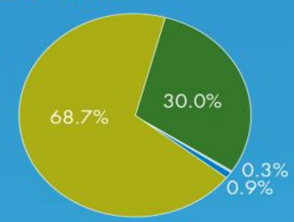
Of all water on Earth only 1% is available for our use

All water on Earth:

0.86% FROM LAKES
0.02% FROM RIVERS

Of all freshwater on Earth:

68.7% is icecaps and glaciers
30.0% is groundwater
0.3% is surface water
0.9% is other



Myths About Groundwater

- Groundwater moves rapidly.
- There is no relationship between groundwater and surface water.
- Groundwater migrates thousands of miles.
- Groundwater removed from the Earth is never returned.
- Groundwater is mysterious and occult.
- Groundwater is not a significant source of water supply.

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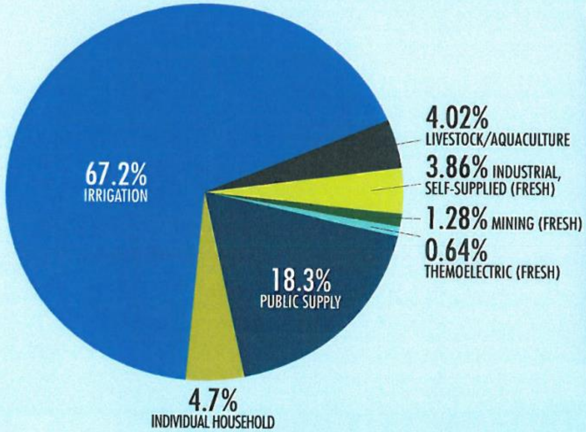
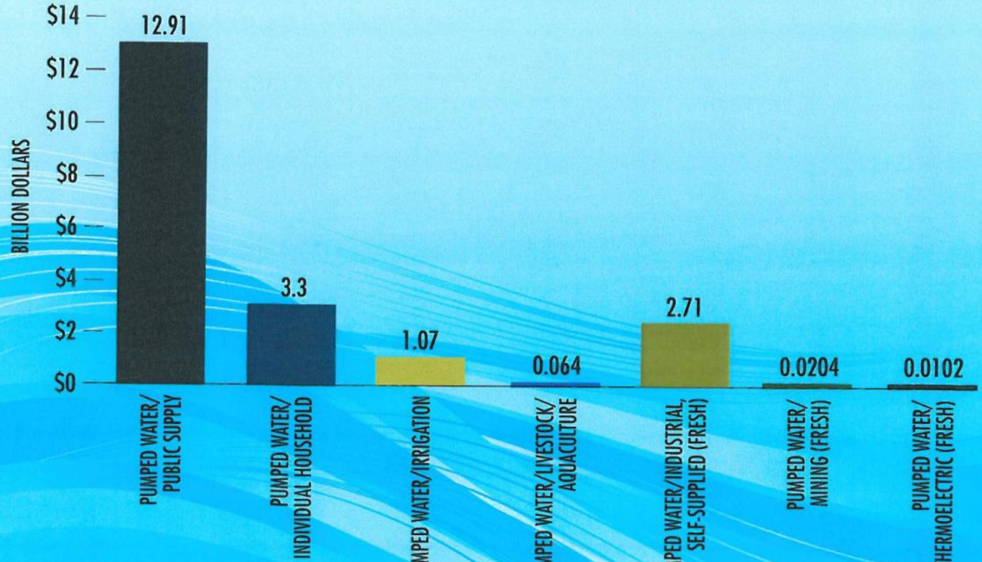
Use of Groundwater in America



Irrigation **53,500** mgd
Public Supply **14,600** mgd
Individual Household **3,740** mgd
Livestock/Aquaculture **3,200** mgd
Industrial, Self-Supplied **3,070** mgd
Mining (Fresh) **1,020** mgd
Thermoelectric (Fresh) **510** mgd
mgd= MILLION GALLONS PER DAY

Groundwater's Role in America's Economic Vitality



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REGULATIONS GOVERNING GROUNDWATER TREATMENT

- Ground water utilization, treatment and distribution is regulated by one of two rules dependent upon the classification of the groundwater in use
  - Ground Water Rule
  - Surface Water Treatment Rule
    - Utilized for those ground water sources classified as groundwater under the direct influence of surface water (GUDI), or where all the groundwater is directly blended with surface water source(s).

REGULATIONS GOVERNING GROUNDWATER TREATMENT

- EPA Ground Water Rule (GWR)
  - Title 40 CFR Part 141
  - Purpose of this rule is to reduce the risk of illness caused by microbial contamination in public ground water systems (GWS)
  - The GWR establishes a risk-targeted approach to identify GWS's susceptible to fecal contamination and requires corrective action to reconcile significant deficiencies and address source water fecal contamination in all public GWS's

EPA GROUND WATER RULE

- Utilities Covered:
  - The GWR applies to all public water systems (PWS) that use ground water including consecutive systems, except that it does not apply to all PWSs that combine all of their ground water with surface water or with groundwater under the direct influence of surface water (GUDI) prior to treatment.

EPA Surface Water Treatment Rule

- EPA Surface Water Treatment Rule
  - Title 40 CFR Part 141

- The purpose of the Surface Water Treatment Rules (SWTRs) is to reduce illnesses caused by pathogens in drinking water. The disease-causing pathogens include *Legionella*, *Giardia lamblia, and Cryptosporidium*.

- Applies to all public water systems (PWSs) using surface water sources or ground water sources under the direct influence of surface water (GWUDI)

- Requires most water systems to filter and disinfect water from surface water sources or GWUDI

- Establishes maximum contaminant level goals (MCLGs) for viruses, bacteria and *Giardia lamblia*

- Includes treatment technique (TT) requirements for filtered and unfiltered systems to protect against adverse health effects of exposure to pathogens

TREATMENT

TREATMENT OF GROUNDWATER

- It is critical to remember groundwater quality is as important as quantity.
- Groundwater contains a variety of chemicals resulting from natural sources as well as from overlying land uses and local management practices, and all of these factors must be considered to develop optimum treatment approaches.
- Water treatment processes are greatly affected by differences in chemical states.
- In summation:
  - **"It is vital to know your source's qualities to select the best approach to groundwater treatment!"**

TREATMENT OF GROUNDWATER

- The minimum treatment requirement for most “true” ground water sources is the requirement of disinfection, and maintenance of a residual disinfectant concentration per the state specified minimum.
- Additional, water quality conditions may require treatment techniques to address secondary drinking water contaminants
- Depending on the bacteriological concentrations, additional treatment techniques may be necessary to ensure compliance with 4-log virus treatment to meet the GWR requirements.

TREATMENT OF GROUNDWATER

- Compliance monitoring ensures that GWS's that provide at least 4-log treatment of viruses using chemical disinfection, membrane filtration or a state-approved alternative treatment technology are consistently and effectively achieving this level of treatment.

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

Commonwealth of Pennsylvania
Department of Environmental Protection
Bureau of Water Standards and Facility Regulation

1/11/2016

Directions:

1) Identify all the segments of your treatment facility between the point of disinfectant application and the entry point (See the "System Example" worksheet). Enter the description for each segment into Column B (e.g., 2-inch pipe from the chlorinator to the storage tank).

2) Enter the minimum temperature of your source water into cell K5. If your finished water storage becomes colder than your source water during winter and you wish to include that stored water in the CT calculation for log inactivation, use the lowest temperature that your stored finished water reaches in winter.

3) Enter the volume (gal) for each segment into Column D if known.

4) If the volume for a segment is unknown, choose the shape of the segment from the drop-down selections in Column C and enter the dimensions in Columns E, F, and G (in feet - use the "Unit Conversions" worksheet to convert to feet if your data is another unit).

Note: For box-shaped segments, enter the length, width, and height into Columns E, F, and G. For cylinders and cones enter only the diameter and the height into Columns F and G. For spheres and half-spheres enter only the diameter into Column F. (ex: for pipes, enter the diameter into Column F and the length into Column G). For horizontal cylindrical tanks, enter the total diameter into Column F, the horizontal lenth into Column E and the minimum water depth into Column G.

5) Select the baffling condition for each segment (see "Baffling Factors" worksheet for descriptions). If a segment is assigned a baffling factor of zero (0), **do not include** the segment on the spreadsheet.

6) Enter the peak flow rate (gal/min) of your facility into cell E5.

7) The minimum chlorine residual at the entry point is defaulted to 0.40 mg/L. You can change this in cell I5 to experiment with different values.

Total Effective Contact Time (min)	Total CT's (mg/L*min)	Log Inactivation of Viruses (pH 6-9)
22.28	8.91	4.46

PWS Name:

PWS ID:

Entry Point ID:

Peak Flow Rate (gal/min) = 85

Minimum Chlorine Residual at EP (mg/L) = 0.40

Minimum Temp (C) = 5.0

A	B	C	D	E	F	G	H	I	J	K
Segment #	Description of Segment	Shape	Volume (gal) (if known)	Tank Length (feet)	Width or Diameter (feet)	Min Water depth or Pipe-Length (feet)	Volume (cubic feet)	Volume (gal)	Choose a Baffling Condition for each segment	Effective Contact Time (min)
1	6-inch pipe from the chlorinator to the storage tank	Cylinder / Half-sphere			0.5	100	19.64	146.88	Near-Plug Flow / Plug flow	1.73
2	cylindrical upper portion of the storage tank	Cylinder / Half-sphere			15	3	530.15	3965.76	Unbaffled / Poor	4.67
3	hemi-spherical bottom of storage tank	Half-sphere / Cone			15		883.58	6609.60	Unbaffled / Poor	7.78
4	6-inch pipe from the storage tank	Cylinder / Half-sphere			0.5	25	4.91	36.72	Near-Plug Flow / Plug flow	0.43
5	6-inch undergound pipe	Cylinder / Half-sphere			0.5	400	78.54	587.52	Near-Plug Flow / Plug flow	6.91
6	2-inch pipe to the distribution system	Cylinder / Half-sphere			0.1667	400	8.73	65.31	Near-Plug Flow / Plug flow	0.77
		Select a shape / Sphere						0.00	Select a baffling condition / Unbaffled	
		Select a shape / Sphere						0.00	Select a baffling condition / Unbaffled	
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		Select a shape / Sphere						0.00	Select a baffling condition / Unbaffled	

Signature of Certified Operator or Professional Engineer ______________________ Date __________

Official Use Only: ☐ 4-Log treatment of viruses confirmed ☐ Denied

WATER TREATMENT – THE BASICS

TREATMENT TECHNIQUES

- Each system is unique and has specific needs.
  - "One-size does not fit all"

- Thus, it is necessary to review the basic and key topics of discussion relative to "why is water treatment needed and "what are the needs and level of treatment to be implemented"

TOPICS OF DISCUSSIONS TO BE HAD WHEN CONSIDERING TREATMENT TECHNIQUES

- Disinfection
- Organics Removal
- Iron and Manganese Removal
- Corrosion Control Treatment
- Treatment Systems in Combination
- General Water Treatment Guidelines
- ANSI/NSF Standards

SELECTING THE BEST SYSTEM TREATMENT OPTIONS

- When looking to select the best system options the team should at a minimum conduct the following:
  - Perform a complete water analysis evaluation of the source
  - Talk to other systems with similar issues
  - Consult guidance materials available from EPA, DEP, etc.
  - Consult with your engineer, your system operators and DEP
  - Consult with organizations
    - Pennsylvania Rural Water Association
    - American Water Works Association
    - Etc.

TREATMENT CONSIDERATIONS

- Water Chemistry
  - pH, anions, cations, sulfate, nitrate/nitrite, hardness, metals, total dissolved solids (TDS)
- Life Cycle Costs
  - Operating expenses: Chemicals, power, maintenance
  - Capital Costs
- Waste Considerations
  - Solids
  - Liquids
  - Disposal requirements of backwash waste
- Operator Skill and availability
- Space Considerations (if retrofitting)

DISINFECTION – THE BASICS

DISINFECTION

- While disinfection usually exists as the final treatment process before distribution, some groundwater sources may only require disinfection practices, and hence are going to be discussed early on as they are an integral part of groundwater treatment.

CHEMICAL DISINFECTION

- Chlorination is used to inactivate bacteria and viruses that may be introduced into the water system
  - Serves as a disinfectant
  - Serves as an oxidant
- Regulations require a PWS to maintain a minimum chlorine residual after contact time at the entry point
  - GWR establishes a minimum of 0.4 mg/L
  - SWTR establishes a minimum of 0.2 mg/L
- Daily Chlorine residual readings are required
  - Consult your permit conditions for the frequency

CHLORINATION SYSTEMS ADVANTAGES / DISADVANTAGES

- Advantages:
  - Effectively destroys bacteria, viruses, and other pathogenic microorganisms
  - Provides a barrier of protection throughout the system when adequate CL_2 residuals are maintained
  - A disinfectant residual can be easily monitored
  - Can also serve as a multi purpose chemical agent, such as an oxidant to suspend metals in solution for better filtration treatment performance
  - Oxidizes hydrogen sulfide to reduce nuisance odor

ADVANTAGES / DISADVANTAGES CONTINUED

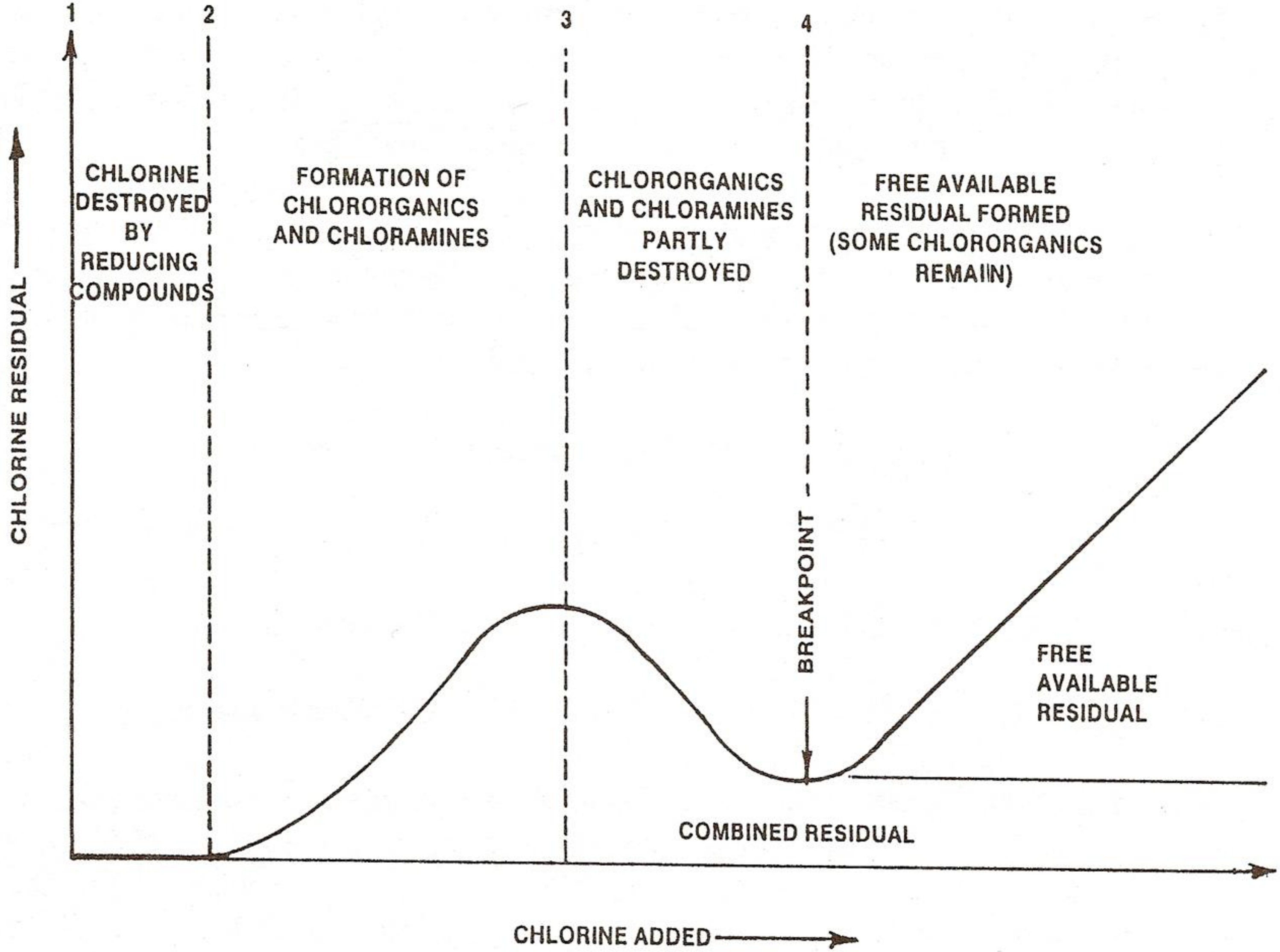
- Disadvantages:
  - Is a chemical additive and has the potential for disinfection by-products
  - Requires a skilled certified operator
  - Requires sufficient chlorine contract time (tankage, piping, etc.) for effective disinfection.
  - Requires a disinfectant residual that MUST be maintained and MONITORED on a DAILY basis.
  - Water quality conditions, such as those with mineral content and associated oxidation, may necessitate the need to install filtration treatment (commonly iron and/or manganese).

CHLORINE BASICS

- Factors Influencing Disinfection
  - pH
  - Temperature
  - Turbidity
  - Organic Matter
  - Inorganic Matter
  - Reducing agents (Iron, Manganese)
  - Microorganisms
  - Point of Application (need adequate contact time)

CHOLRINE BASICS CONTINUED

- Chlorine Residual
  - Minimum free chlorine residual at distant points in the distribution system is required (0.2 – 0.5 mg/L)
  - In order to achieve effective disinfection and maintain adequate residual at end points in the system, chlorine residual at the system entry points is paramount (1.0 – 2.0 mg/L)
  - Total Chlorine residual is the sum of the free and combined chlorine residuals.



Breakpoint chlorination

CHLORINE BASICS CONTINUED

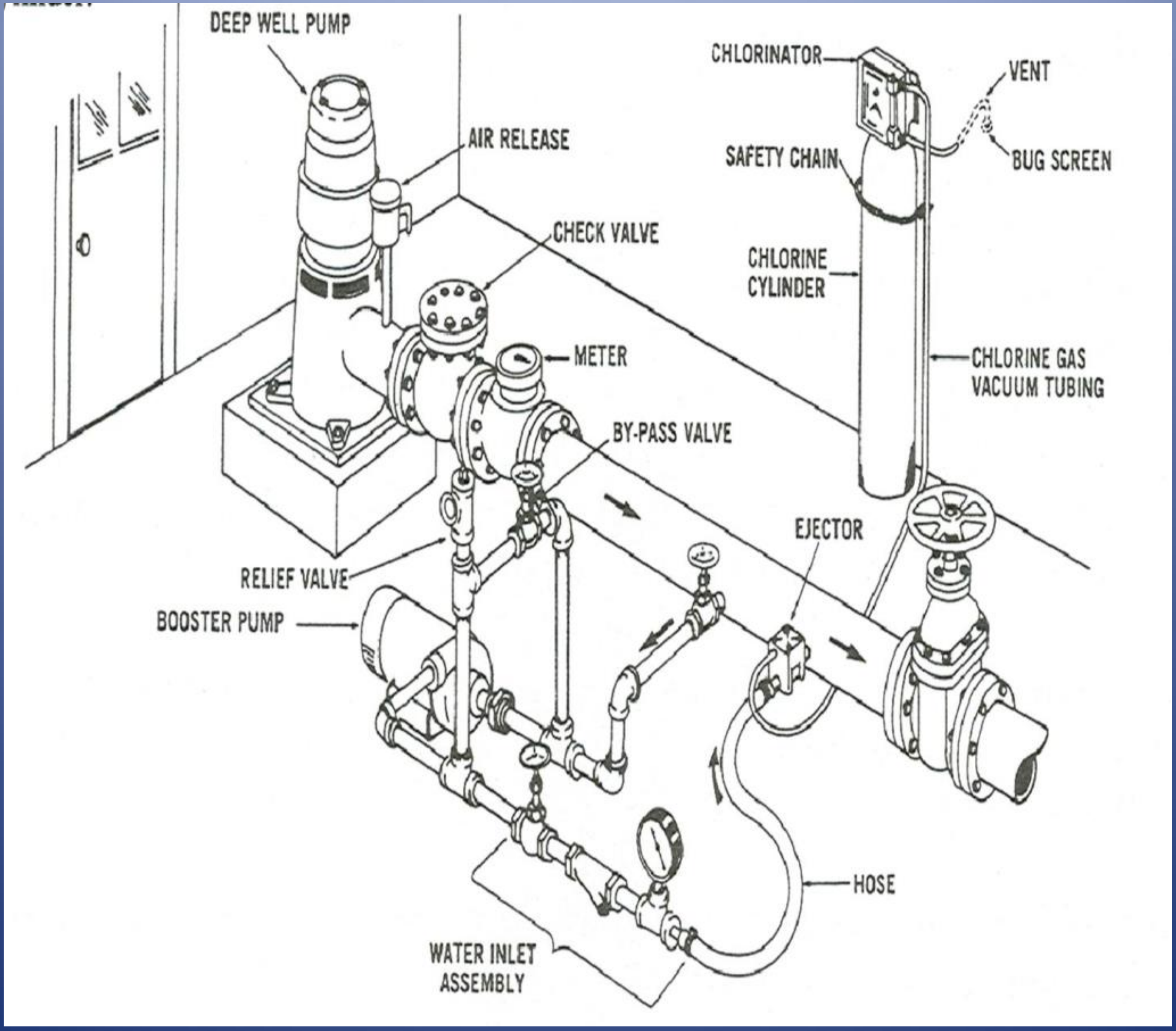
- Chlorination can be in provided in various forms
  - Liquid
    - Liquid or chlorine solutions (liquid bleach) contain chlorine in the chemical form of hypochlorite (Sodium Hypochlorite; Calcium Hypochlorite) and are usually prepared from chlorine and caustic soda, thus giving sodium hypochlorite.
    - These solutions are highly alkaline, with the alkalinity helping to preserve them, however makes them very corrosive.
    - Fresh solutions can have sodium hypochlorite content typically up to 15% by weight but these solutions can be highly unstable, losing up to 50% of their strength within a few months in a sealed container.
    - Commercial bleach (Clorox) is 5.25% sodium hypochlorite.
    - Care should be taken in handling because of the risk of contact with skin and eyes.
    - Calcium hypochlorite is a superior form of solid hypochlorite also known as "High Test Hypochlorite, HTH". It is produced as a free-flowing granular material. The available chlorine content is between 65-70%. Under normal conditions, a loss of strength of only 3-5% occurs, giving a much more satisfactory shelf life than other chlorine products.

CHLORINE BASICS CONTINUED

– Gaseous

- Chlorine gas is considered a dangerous chemical and is supplied in steel cylinders. In this form it can only be added to water with special equipment and knowledge, and requires special design considerations for storage, ventilation and application.
- Chlorine gas is typically a greenish-yellow in color
- Chlorine gas is 2 ½ times heavier than air
- Chlorine gas is corrosive, especially to metal.
- Typically 150 lbs. cylinders; however can be provided in other quantities, such as tone cylinders, etc.
- In this form, chlorine gas in not a practical form for the “field disinfection” of water/environment.

CHLORINE GAS FEED SYSTEM



CHLORINE BASICS
HYPOCHLORITE

- Sodium Hypochlorite
  - Liquid Form
  - 5-15% available chlorine
  - Possesses the same residuals as with gas chlorine
- Calcium Hypochlorite
  - Dry or tablet form
  - 65-70 % available chlorine
  - Possesses the same residuals as gas chlorine

BREAK

FILTRATION – THE BASICS

FILTRATION

- Filtration is the process of removing suspended solids from water by passing the water through a permeable fabric or porous bed of materials.
- Groundwater is naturally filtered as it flows through porous layers of soil. However, groundwater and groundwater under the direct influence of surface water is subject to contamination from many sources.
- Some of these contaminants pose a threat to human health, and filtration is one of the oldest and simplest methods of removing them.
- Filtration methods can be permitted in many forms, dependent upon the water quality, using various treatment techniques such as slow and rapid sand filtration, diatomaceous earth filtration, direct filtration, packaged filtration, membrane filtration and cartridge filtration.

FILTRATION

- While some water sources are such that only disinfection is necessary, many groundwater sources require additional levels of treatment to remove contaminants of concern, be it a primary or secondary contaminant.

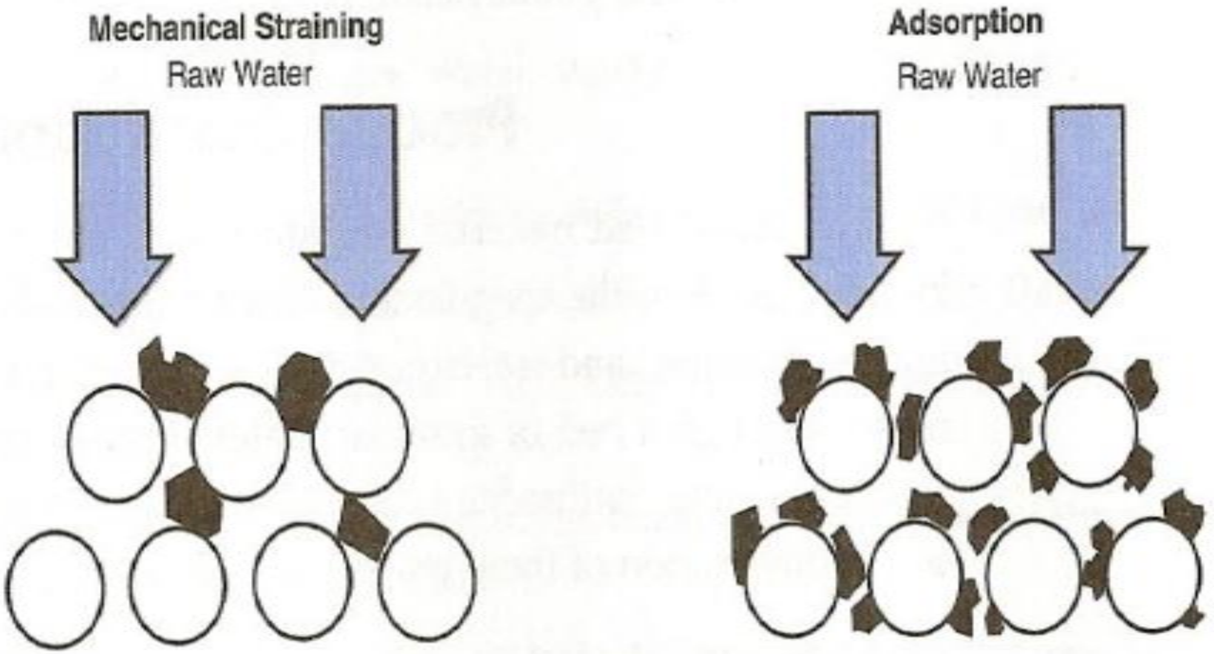
- Thus, we will devote the following discussion to filtration techniques and applications.

FILTRATION

- The removal of impurities from water by means of a fine physical barrier, a chemical process or a biological process to cleanse water to the extent necessary for compliance of end use.

  - Natural filtration occurs in ground water as the water percolates through soil
  - Treatment plant filtration is used for iron, manganese, arsenic, etc. removal in groundwater
  - Treatment plant filtration is used for surface water for removal of suspended materials.

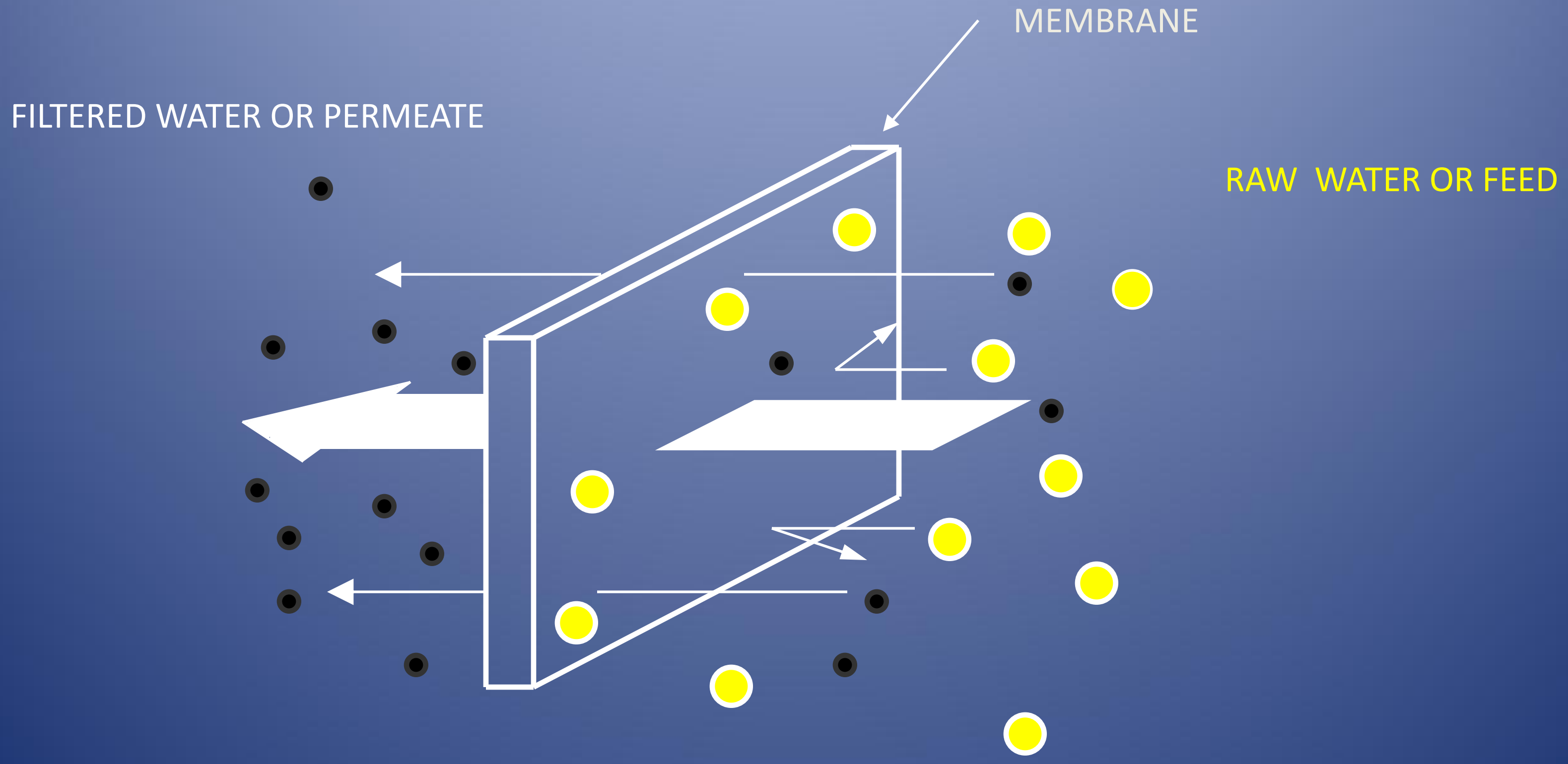
FILTRATION



Large particles become lodged and cannot continue downward through the media.

Particles stick to the media and cannot continue downward through the media.

FILTRATION



FILTRATION

- Common Filter Media may include the following:
  - Sand
  - Anthracite Coal
  - Granular Activated Carbon
  - Garnet Sand
  - Glauconite "Green" Sand or (oxidized impregnated media)
  - Membrane Filters
  - Combination of above

FILTRATION TECHNIQUE SELECTION

- The selection of the filter type and/or filter media is paramount to the contaminant(s) of concern for which the system is removing.
- The following is a basic overview of filter types and associated contaminants removed therewith.

FILTRAITON
ORGANICS REMOVAL

- Treatment Options:
  - Granular Activated Carbon (GAC) filters. Use a minimum of two (2) filters in series
  - Aeration
  - Combination of GAC and Aeration

ORGANICS REMOVAL
<u>AERATION</u>

AERATION CONTINUED

- Aeration is the process by which liquid is brought into intimate contact with a gas, typically air, so that the undesirable volatile substance present in the liquid phase can be released and carried away by the gas. Processes such as mechanical surface aeration, diffused aeration, spray or tray towers, and countercurrent packed towers are encompassed by the term aeration or "air stripping."
- These procedures produce a condition in which a large surface area of the water to be treated is exposed to the air, which promotes transfer of the contaminant from the liquid phase to the gaseous phase.
- Oxidation can occur via aeration or chemical addition.
- Iron is easily oxidized by atmospheric oxygen.
- Aeration provides the dissolved oxygen needed to convert the iron and manganese from their ferrous and manganous forms to their insoluble oxidized ferric and manganic forms.
  – It typically takes 0.14 ppm of dissolved oxygen to oxidize 1 ppm of iron
  – It typically takes 0.27 ppm of dissolved oxygen to oxidize 1 ppm of manganese

GRANULAR ACTIVATED CARBON (GAC)

- GAC is used for the removal of organic chemicals
- GAC can also be used for taste and order control
  - Chlorine removal
  - Sulfur Odor (rotten egg smell)
- When using GAC filters, a minimum of two (2) units are installed in series.

FILTRATION
COULPED WITH OXIDATION

IRON AND MANGANESE REMOVAL

- Iron (Fe) and Manganese (Mn) can be present in water in one of three (3) basic forms:
  - Dissolved: Ferrous (Fe_2^+) and Manganous (Mn_2^+)
  - Particulate: Ferric (Fe_3^+) and Manganic (Mn_3^+)
  - Colloidal: very small particles, being difficult to settle and filter
- The predominance of one form over another is dependent on the pH, redox potential, and temperature of the water
- Knowledge of the forms or states of iron and manganese are essential in determining and fine tuning a given treatment practice for these metals.

IRON AND MANGANESE REMOVAL

- Iron in its simplest form, the form most often encountered in raw well water or raw impounded water, is ferrous iron in a soluble state.
- Manganese in its simplest soluble form is manganous manganese.
- In order to convert these metals to a filterable form, an oxidizing agent needs introduced

IRON AND MANGANESE REMOVAL

- Lab Analysis of Iron and Manganese
  - Operators need to determine the amount of soluble vs. insoluble forms of Fe and Mn.
  - Should always perform two sets of analyses.
    - One of the raw water (total Fe & Mn).
    - One after filtration (soluble).

IRON AND MANGANESE REMOVAL

- Lab Analysis of Iron and Manganese

- Difference between the two is the insoluble or particulate form of Fe and Mn.

    - Example: If the raw water has a total iron concentration of 1.0 mg/l and the filtrate iron is 0.6 mg/l, it means 0.4 mg/l is soluble.

IRON AND MANGANESE REMOVAL

- Filtration is typically combined with pre-oxidation
  - Potassium permanganate
  - Sodium permanganate
  - Chlorine
  - Chlorine Dioxide
  - Ozone
  - Air injection
- Manganese is typically oxidized at a higher pH therefore, pH adjustment may be required.

IRON AND MANGANESE REMOVAL

- Dependent upon the conditions, type and concentrations of iron and manganese present within your water source, various treatment methods can be employed

- Types of Treatment:
  - Oxidation
  - Ion Exchange
  - Sequestration
  - Lime-Soda Ash Softening

  Filtration

- The basic and most common approach to remove iron and manganese from ones source water employs the process of oxidation coupled with filtration.

OXIDATION STOICHIOMETRY

- Chlorine
  - 0.64 mg of HOCL to oxidize 1 mg of Iron
  - 1.30 mg of HOCL to oxidize 1 mg of Manganese

- Potassium Permanganate
  - 0.94 mg of KMnO4 to oxidize 1 mg of Iron
  - 1.92 mg of KMnO4 to oxidize 1 mg of Manganese

- Ozone
  - 0.43 mg of O3 to oxidize 1 mg of Iron
  - 0.88 mg of O3 to oxidize 1 mg of Manganese

- “Rule of Thumb, one part chemical to one part iron, two parts chemical, to one part manganese

OXIDATION REACTIONS

- Effect of pH on reaction time.
  - Optimum pH for iron oxidation/removal is 7.5 – 8.5.
  - Optimum pH for manganese oxidation/removal is 8 – 9.
  - pH adjustment is common to facilitate oxidation reaction.
  - Typically use caustic soda, soda ash or lime.

IRON AND MANGANSE REMOVAL – ALTERNATE TECHNIQUES (SEQUESTRATION)

- Sequestration is the addition of chemicals to groundwater aimed at controlling problems caused by iron and manganese without removing it.
- The chemicals are added to groundwater at the well head or at the pump intake before the water has a chance to come in contact with air or chlorine.
- This ensures that the iron and manganese stays in soluble form.
- If the water contains less than 1.0 mg/L iron and less than 0.3 mg/L manganese, using polyphosphates followed by chlorination can be an effective and inexpensive method for mitigation iron and manganese problems.
- No sludge is generated in this method
- Below these concentrations, the polyphosphates combine with the iron and manganese preventing them from being oxidized.

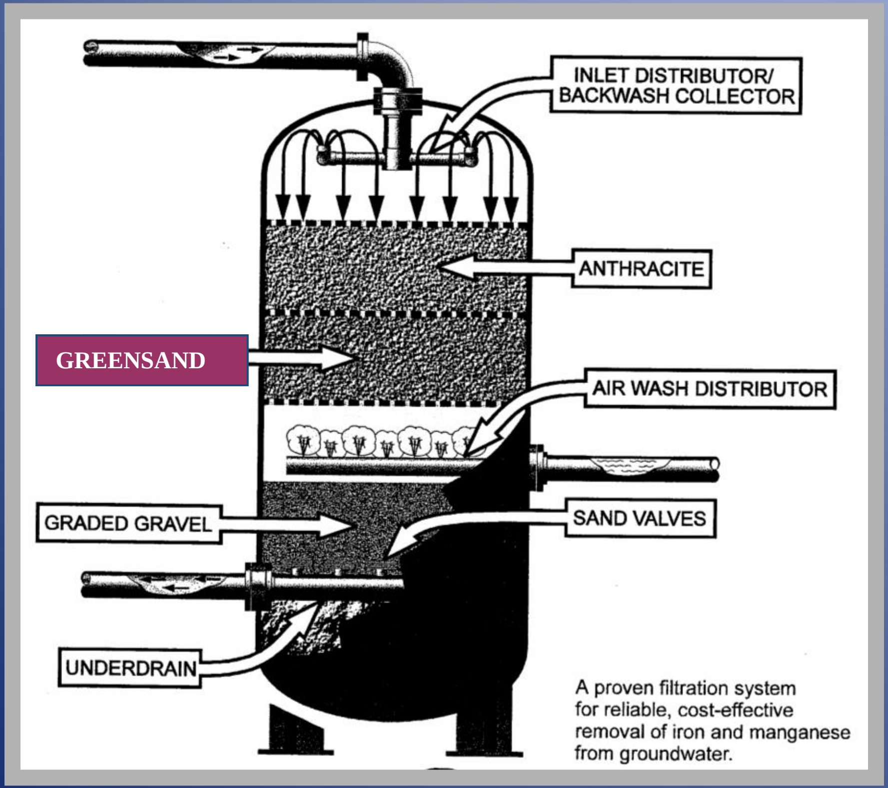
IRON AND MANGANSE REMOVAL – ALTERNATE TECHNIQUES (FILTRATION)

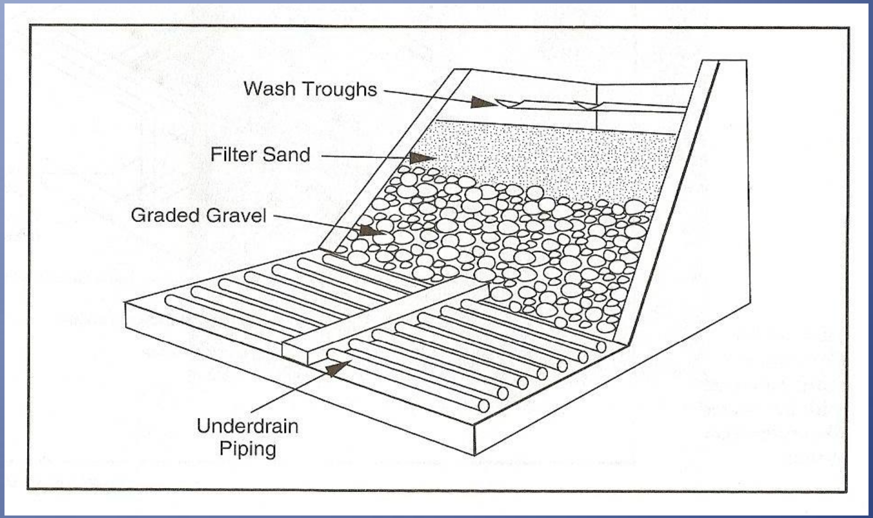
- Removing iron and manganese from drinking water versus sequestration is recommended if the water contains over 1.0 ppm iron and over 0. 3 ppm of manganese.
- Most commonly, iron and manganese removal is accomplished by filtration after oxidation.
- Filtration is an essential process in the overall treatment of iron and manganese.
- It is the supplemental sequence to oxidation or ionization that physically removes the insoluble form of metals from the water source, serving as the final process step.

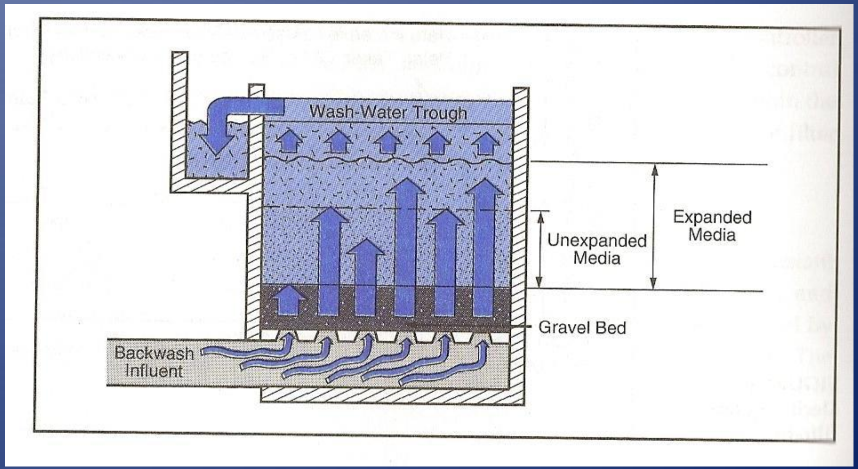
FILTRATION METHODS

- Basic Types of Filtration Used:
  - Pressure Filters
    - Applied water pressure forces the water through the filter
    - More common in smaller water systems
  - Gravity Filters
    - Force of gravity moves the water through the filter
    - More common in larger systems
  - Membrane Filtration
    - A type of pressure/vacuum filter system using a membrane material (absolute pore size) to capture and restrict the contaminant from passing through the membrane.
    - Has rapidly gained popularity over the last decade as an effective filtration device, especially when multiple contaminants of concern exist within the raw water source.

PRESSURE AND GRAVITY FILTRATION







PRESSURE FILTRATION

- **Drinking Water:**
  - Iron and Manganese Removal
  - Arsenic Removal
  - Groundwater Under the Influence
  - Pretreatment to other filtration types
  - Granular Activated Carbon
  - Fluoride Removal
  - Ion Exchange
- Media options and arrangements are several and depend on the application and internal piping arrangement but often consist of a dual-media sand-and anthracite arrangement (to minimize bachwash frequency) above a gravel support bed.

PRESSURE FILTRATION

- Pressure filtration System Applications:
  - Community Drinking Water Systems
  - Non-Transient, Non-Community Systems
  - Remediation and Industrial Treatment
  - Small Utilities
  - Subdivisions
  - Schools
  - Mobile Home Communities
  - Parks and Recreation Facilities
  - Retirement / Day care Facilities
  - Commercial Facilities

PRESSURE FILTRATION

- ***Features and benefits include:***
  - Completely pre-packaged, pre-designed modular system for ease of use
  - Minimal site engineering for simple permitting and "plug and play" installation
  - Ability to utilize high performance granular media for a large area of contaminant removal
  - High percent removal rate of contaminants, often times without chemical addition
  - Custom options for adsorbers available in composite or carbon steel
  - Automatic controls with LCD display/readout or optional PLC and touch screen interface
  - Proven, reliable treatment without the hassle of chemicals or brine; and long product life for economical performance.

GRAVITY FILTRATION

- Gravity filtration is a physical process for the separation of solids from liquids.

- The underdrain is the heart of every gravity filter.
  - If the underdrain is well designed, durable and efficient, the filter will provide many years of continuous service.

- Gravity Filters or rapid sand filters are typically designed as part of multi-stage treatment systems used by large municipalities. These systems are complex and expensive to operate and maintain, and therefore less suitable for small communities.

GRAVITY FILTRATION

- Advantages include:
  - Much higher flow rate than a slow sand filter (about 150 to 200 million gallons of water per acre per day.
  - Requires relatively small land area.
  - Less sensitive to changes in raw water quality, e.g. turbidity.
  - Requires less quantity of sand.

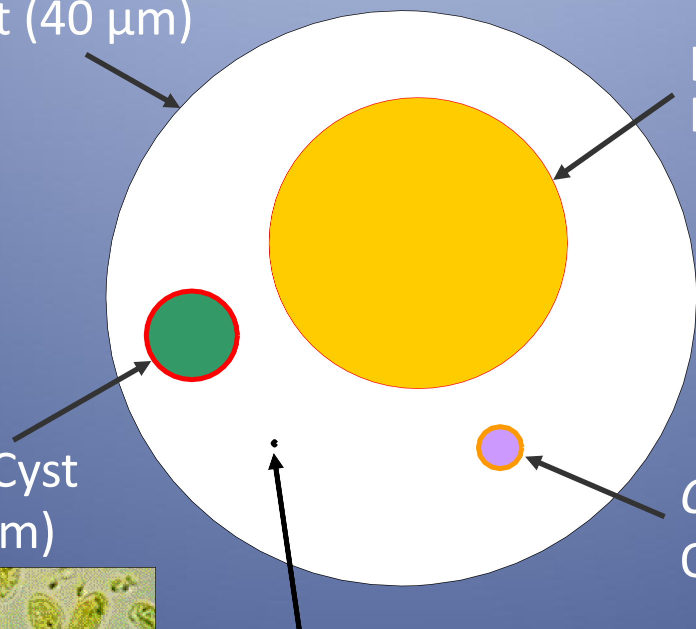
- Disadvantages include:
  - Large pore size will not, without coagulant or flocculent, remove pathogens smaller than 20 µm, like Cryptosporidium.
  - Requires greater maintenance than a slow sand filter.
  - Generally ineffective against taste and odor problems.
  - Produces large volumes of sludge for disposal.
  - Requires ongoing investment in costly flocculation reagents.
  - Treatment of raw water with chemicals is essential.
  - Skilled supervision is essential.
  - Cost of maintenance is higher.

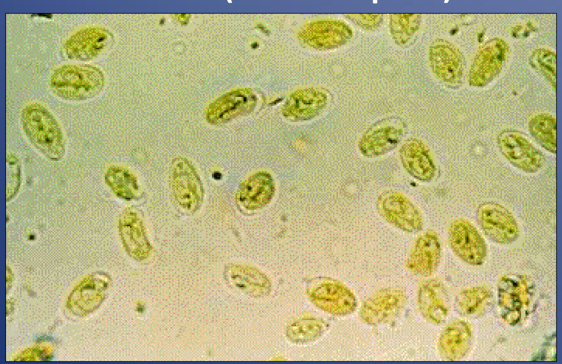
FILTRATION - MEMBRANES

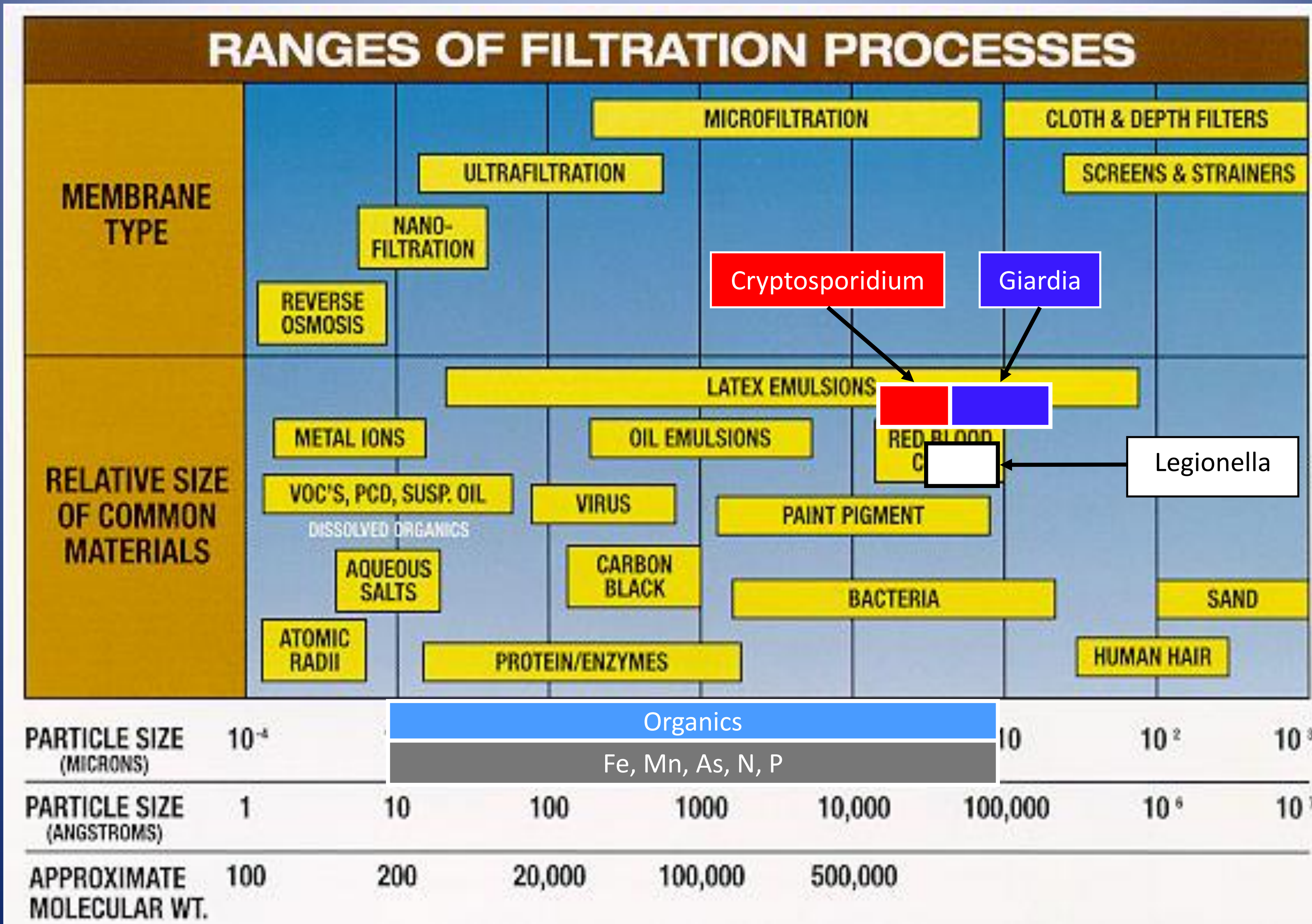
MEMBRANE FILTRATION

- Filtration via the use of membranes occurs as water is forced through a porous membrane under pressure or vacuum, while suspended solids, larger molecules or ions are held back or rejected.
- Membranes are classified by the size of their pores, and is often referred to as “absolute” filtration.
- Four (4) general membrane processes that operate by applying pressure
  - Microfiltration (Pore size of approximately 0.1 micron)
  - Ultrafiltration (Pore size of approximately 0.01 micron)
  - Nanofiltration (Pore size of approximately 0.5 nm or 0.0005 um)
  - Reverse Osmosis (Pore size of approximately 0.1nm or .0001 um)

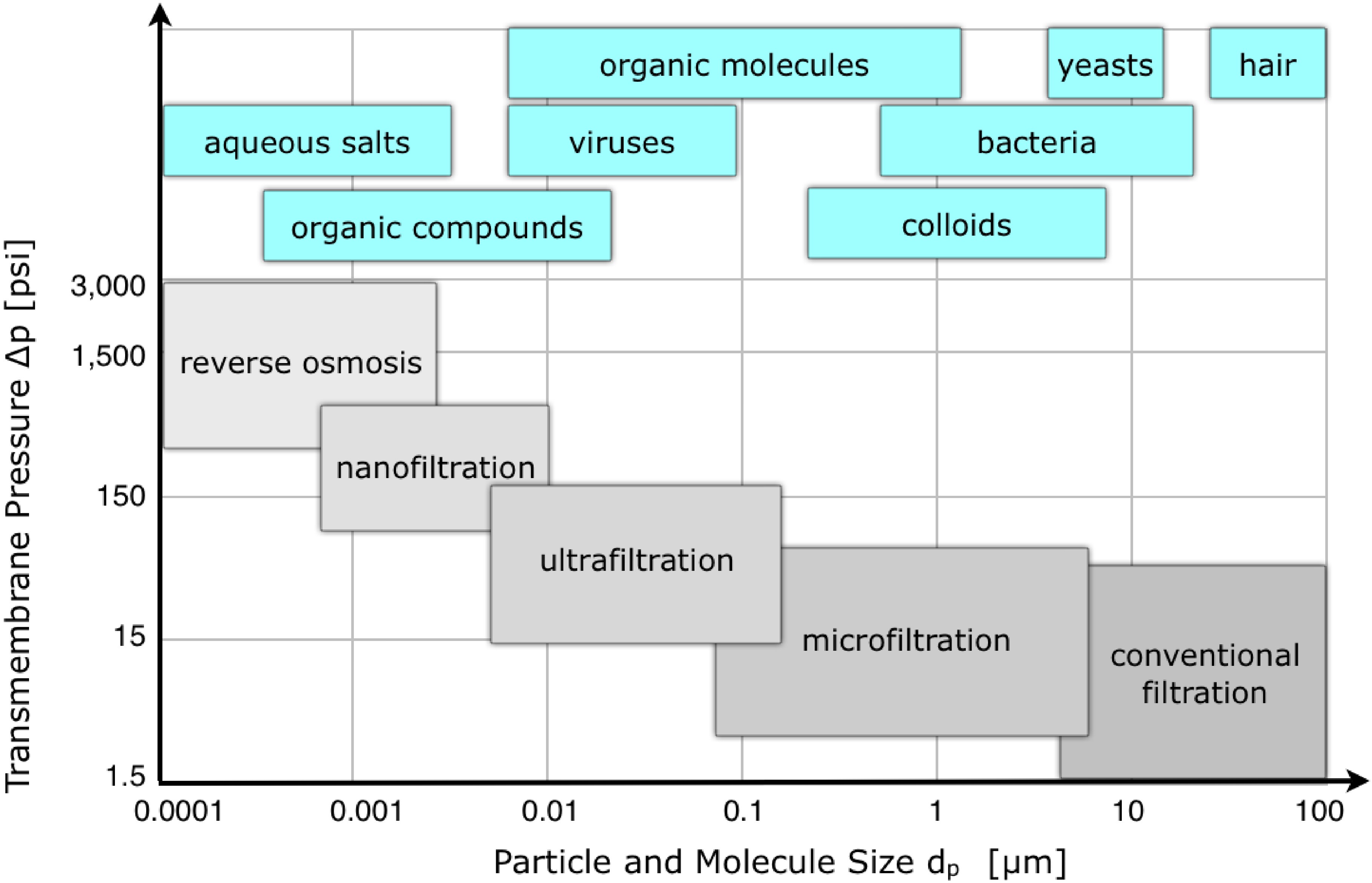
RELATIVE PARTICLE SIZE






RANGES OF FILTRATION PROCESSES
MEMBRANE TYPE
MICROFILTRATION
CLOTH & DEPTH FILTERS
ULTRAFILTRATION
SCREENS & STRAINERS
NANO-FILTRATION
REVERSE OSMOSIS
Cryptosporidium
Giardia
RELATIVE SIZE OF COMMON MATERIALS
LATEX EMULSIONS
METAL IONS
OIL EMULSIONS
Legionella
VOC'S, PCD, SUSP. OIL
VIRUS
PAINT PIGMENT
DISSOLVED ORGANICS
AQUEOUS SALTS
CARBON BLACK
BACTERIA
SAND
ATOMIC RADII
PROTEIN/ENZYMES
HUMAN HAIR
Organics
Fe, Mn, As, N, P
PARTICLE SIZE (MICRONS) 10⁻⁴ 10 10² 10³
PARTICLE SIZE (ANGSTROMS) 1 10 100 1000 10,000 100,000 10⁶ 10⁷
APPROXIMATE MOLECULAR WT. 100 200 20,000 100,000 500,000

Membrane & Contaminant Classifications



MEMBRANE MATERIAL CLASSIFICATION

1. **Organic**

   A. Hydrophilic polymers
      1. Cellulose diacetate
      2. Cellulose triacetate
      3. Polyamides
      4. Polyacrylonitril (PAN)

   B. Hydrophobic
      1. Polytetraflouroethylene (PTFE)
      2. Polyvinylidene Fluoride (PVDF)
      3. Polyethylene (PE)
      4. Polycarbonate (PC)
      5. Isotactic Polypropylene (PP)

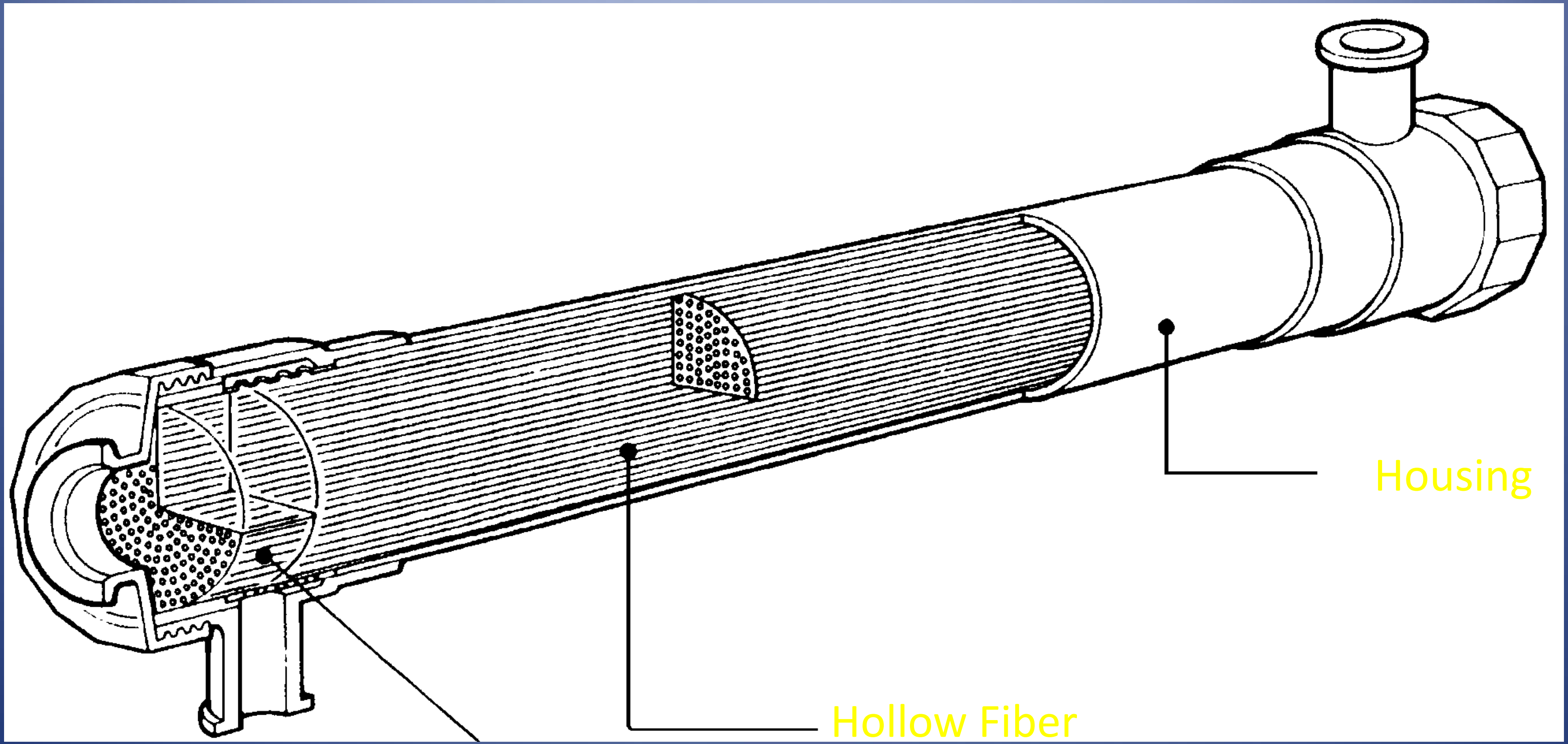
   C. Hydrophobic/Hydrophilic Blends
      1. Polysulphone (PS_F)
      2. Polyethersulphone (PES)

2. Inorganic

   A. Ceramic
      1. Oxides
      2. Nitrides
      3. Carbides

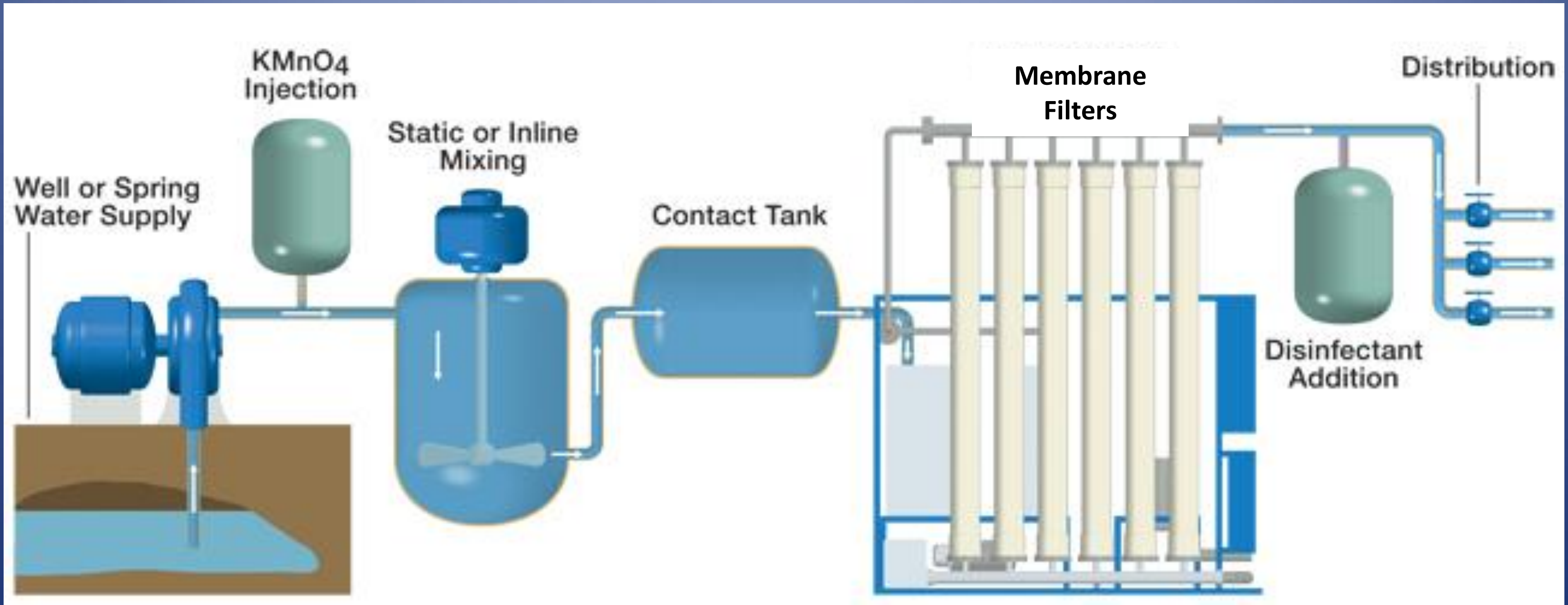
MEMBRANE CONFIGURATIONS

- A membrane module is the smallest functional unit of membrane material.
  - ✓ Plates
  - ✓ Spiral Wound
  - ✓ Tubular
  - ✓ Hollow Fiber
  - ✓ Rotating Disc/Cylindrical
  - ✓ Cassette



Example of Cartridge Style Hollow Fiber Membrane Module

MEMBRANE FILTRATION



DRINKING WATER APPLICATIONS
MICROFILTRATION & ULTRAFILTRATION SYSTEMS

- Widespread use in potable water treatment
- Direct filtration of high quality surface water sources (turbidity <100 NTU)
- Direct filtration of groundwater (GUDI) and spring sources
- Filtration following clarification of poor quality surface water sources (turbidity >100 NTU)
- Filtration of iron/manganese following oxidation
- Filtration of organics following EC pretreatment
- MF/UF used for pretreatment filtration for nanofiltration & Reverse Osmosis systems.

FILTRATION - ION EXCHANGE

ION AND CATION EXCHANGE SYSTEMS

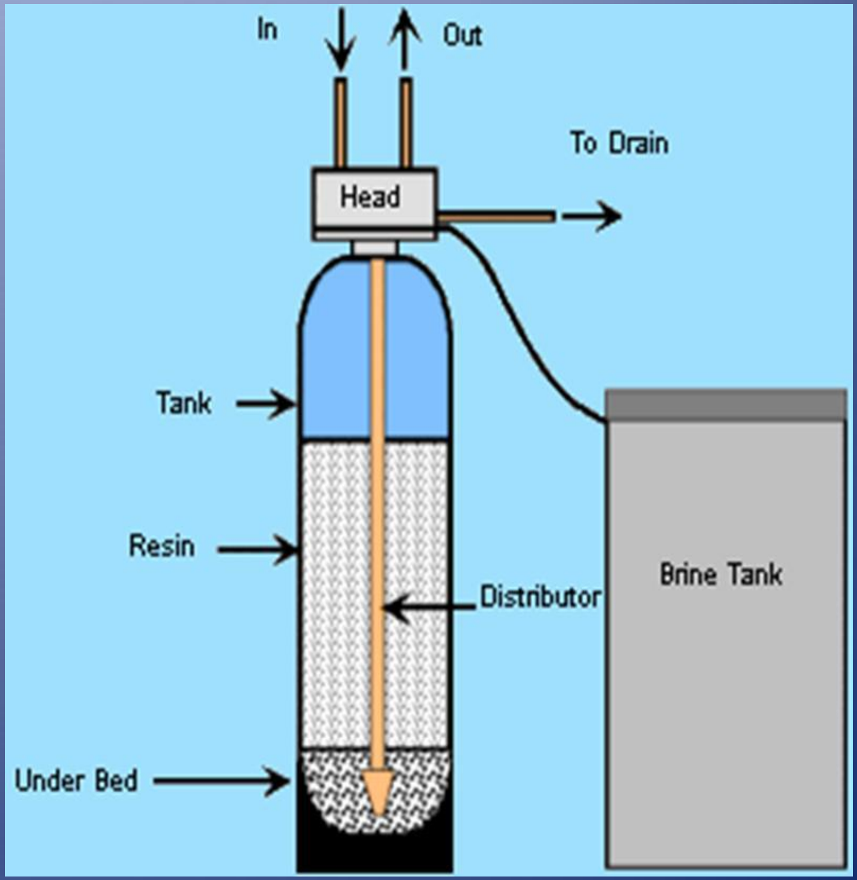
- This process involves the exchange of positively charged ions (cations) or negatively charged ions (anions) in water.
- Ion exchange should be considered only for the removal of small quantities of iron and manganese because there is a risk of rapid clogging.
- Ion exchange involves the use of synthetic resins where a pre-saturant ion on the solid phase (the “adsorbent,” usually sodium) is exchanged for the unwanted ions in the water.
- One of the major difficulties in using this method for controlling iron and manganese is that if any oxidation occurs during the process, the resulting precipitate can coat and foul the media. Cleaning would then be required using acid or sodium bisulfate.

ION AND CATION EXCHANGE SYSTEMS

- Commonly referred to as water softeners
  - Effective at removal of calcium and magnesium
  - Removal of Barium or Radium requires longer treatment times for removal.
  - Typically associated with low flow systems (i.e. non-community, systems)

ION AND CATION EXCHANGE SYSTEMS

- Components and Purpose
  - Tank
    - Water pressurized vessel that holds resin in place
  - Head
    - Determines frequency for backwash
    - Controls flow of water during service, backwash, brine cycle, brine refill and rinse cycle
  - Distributor and Riser
    - Provides return route to the head for the treated water
  - Resin
    - Provides sites for ion exchange
  - Underbed Gravel
    - Supports Media
    - Provides a collection area for the treated water
  - Brine Tank
    - Stores salt used to regenerate the media



ANION EXCHANGE

- Anion Exchange systems look like a typical ion exchange “softener” system, however use a different resin.

- Several different types of anion exchange resins exist which are designed to remove specific contaminants
  - Nitrate-selective resin to reduce nitrates
  - Sulfate-selective resin to reduce arsenic

BREAK

COMPARISON OF FILTRATION SYSTEMS:

- Slow Sand Filtration
  - A filter consisting of a bed of fine sand approximately 3 to 4 feet deep supported by a 1-foot layer of gravel and an underdrain system.
- Advantages
  - Low cost, simple operation, reliable and able to achieve high (99.9 %) percentage removal of *Giardia* cysts. Does not require extensive active control by an operator.
- Limitations
  - Not suitable for water with high turbidity. Filter surface area requires maintenance. Larger land area is needed as a result of the filters low-flow operation (0.03 to 0.10 gpm/ft^2).

SLOW SAND FILTRATION CONTINUED

- Process
  - Filters are operated under continuous, submerged conditions maintained by adjusting a control valve located on the discharge line from the underdrain system. Biological processes and chemical/pysical processes common to various types of filters occur at the surface of the filter bed. A biological slim or mat referred to as “schmutzdecke” forms on the surface of the bed, which traps small particles and degrades organic material present in the raw water.
  - Slow sand filters do not require coagulation/flocculation and may not required sedimentation.
  - Water applied to slow sand filters is not pre-chlorinated as the chlorine would destroy organisms in the schmutzdecke.

Diatomaceous Earth Filtration

- Diatomaceous earth filtration
  - Also know as precoat or diatomite filtration, relies on a layer of diatomaceous earth approximately 1/8 inch thick placed on a septum or filter element. Septum's must be placed in pressure vessels or operated under a vacuum in open vessels.
- Advantages
  - Filters are simple to operate and effective in removing cysts, algae and asbestos.
  - Such filters have usually been chosen for projects with limited initial capital, and for emergency or standby capacity to service large seasonal increases in demand.
- Limitations
  - Most suitable for water with low bacteriological counts and low turbidity (less than 10 NTU). Coagulant and filter aids are required for effective virus removal.
  - Potential difficulties in maintaining complete and uniform thickness of diatomaceous earth on the filter septum

DIRECT FILTRATION

- Direct Filtration systems are similar to conventional systems, however omit sedimentation
- Advantages
  - Effective direct filtration performance ranges from 90 to 99 percent for virus removal and from 10 to 99.99 percent for *Giardia* removal. The most effective direct filtration configurations for *Giardia* removal must include coagulation.
  - Direct filtration consists of several combinations of treatment processes. It always includes coagulation and filtration, and may require flocculation after the coagulation addition.
- Limitations
  - Direct filtration is only applicable for systems with high quality and seasonally consistent influent supplies. The influent generally should have a turbidity of less than 5 to 10 NTU and color of less than 20 to 30 units (water with 15 or more units of color causes aesthetic problems, such as staining)

PACKAGED FILTRATION

- Packaged Filtration
  - Simply all of the features of filtration (chemical addition, flocculation, sedimentation, filtration) mounted as a unit on a frame for simple hookup of pipes and services. Most widely used to treat surface water supplies for removal of turbidity, color and coliform organisms with filtration processes.
  - Packaged filtration is often used to treat small community water supplies, as well as supplies in recreational areas, ski areas and military installations, among others.
- Advantages
  - The four (4) major advantages of package plants are their compact size, cost effectiveness, relative ease of operation, and design for unattended operations (where permissible).

PACKAGED FILTRATION CONTINUED

- Limitations
  - When the turbidity of the raw water varies a great deal, these package plants require a high level of operator attention and skill.
- Other
  - The most important factor to consider in selecting a package plant is the influent characteristics, such as temperature, turbidity, and color levels. Pilot testing is recommended.
  - Chemical feed controls are especially important for plants without full-time operators or with variable influent characteristics. Even with automated devices, the operator needs to be properly trained and well acquainted with the process and control system.

MEMBRANE FILTRATION

- Membranes
  - A membrane is a thin layer of material capable of separating substances when a driving force is applied across the membrane.
- Advantages
  - Membrane filtration can be a very attractive option for systems because of its small footprint and automated operations. Membrane processes are increasingly employed for removal of bacteria and other microorganisms, particulate material and natural organic mater, which can impact color, taste and odors to water.
  - Minimal Chemical usage, and less reliance on coagulation chemistry
- Limitations
  - Fouling of the membrane is the major problem preventing widespread application of this technology
  - Limitations on source water quality
  - Requires Pilot Testing (min. 90 days typical)

MEMBRANE FILTRATION CONTINUED

- Membrane technologies are relatively simple to install and for groundwater sources that do not need pretreatment, require little more than a feed pump, cleaning pump, membrane modules and some holding tanks.
- Periodic backwashing (w/ air scour) and occasional chemical cleaning is necessary to maintain the membrane.
- Care should be taken in selecting the membrane material, especially for durability, chemical resistance, etc.
- Provide an absolute filtration barrier versus that of the probable filtration of conventional filtration.

SUMMATION

- It is vital to know your source's qualities to select the best approach to groundwater treatment

THANK YOU FOR YOUR TIME AND ATTENDANCE!

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