# Water Disinfection

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# BASIC CRITERIA FOR SELECTING A DISINFECTANT

- ANTIMICROBIAL ACTIVITY
- SOLUBILITY
- STABILITY
- LACK OF TOXICITY
- NO OR MINIMUM INACTIVATION BY EXTRANEOUS MATERIALS
- DEODORIZING ABILITY
- EASY AVAILABILITY AND AFFORDABILITY
- ACTIVITY AT AMBIENT TEMPERATURE

# Water Disinfection Options Available (Physical)

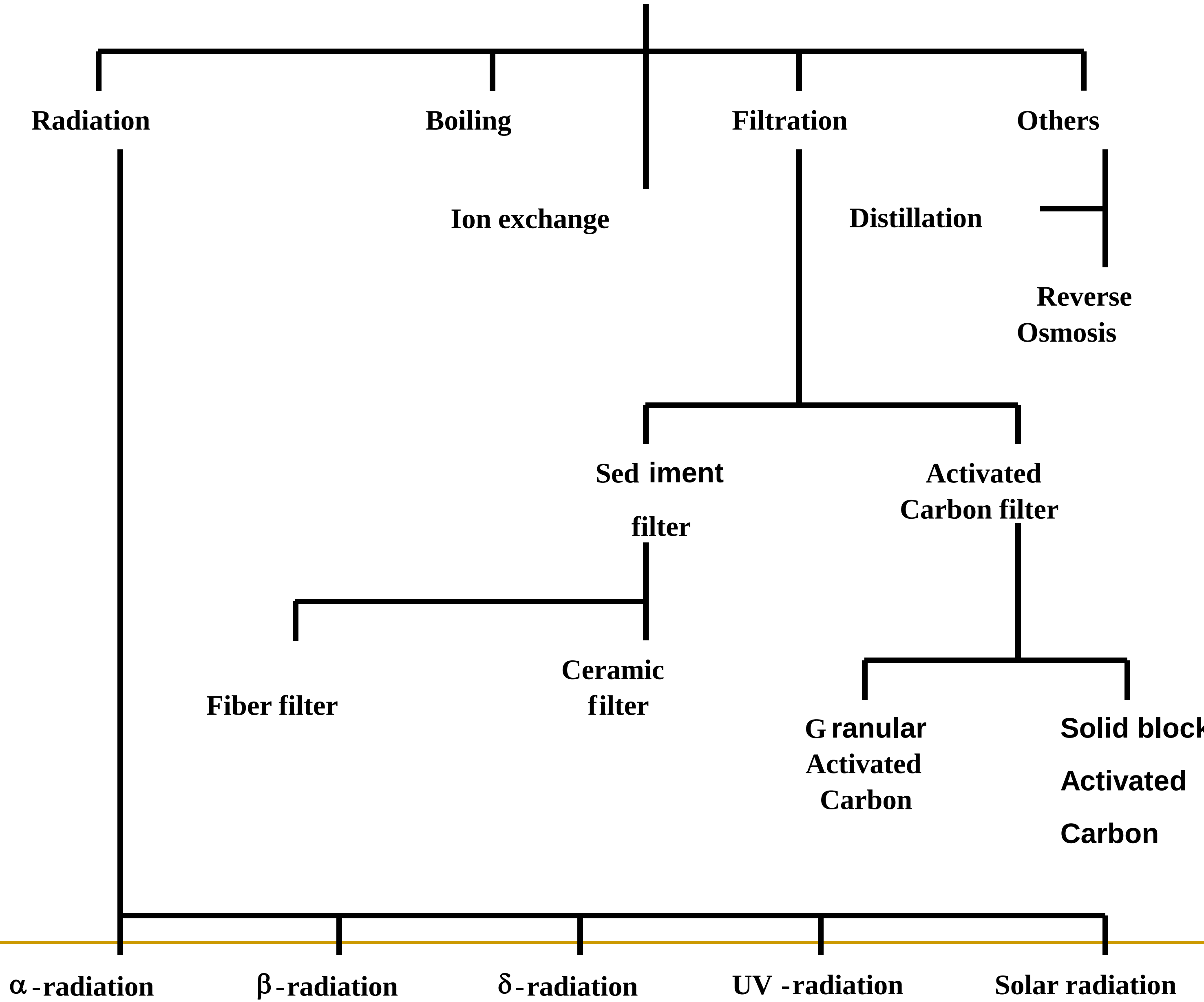
# INTRODUCTION

## DISINFECTION

- Water disinfection is the process of almost complete removal of pathogens in body of water or
- Specifically, a purification process that kills or remove biological contaminants (cyst, bacteria,viruses,protozoans)from a water source

# Options Available (Physical)

# Physical Methods

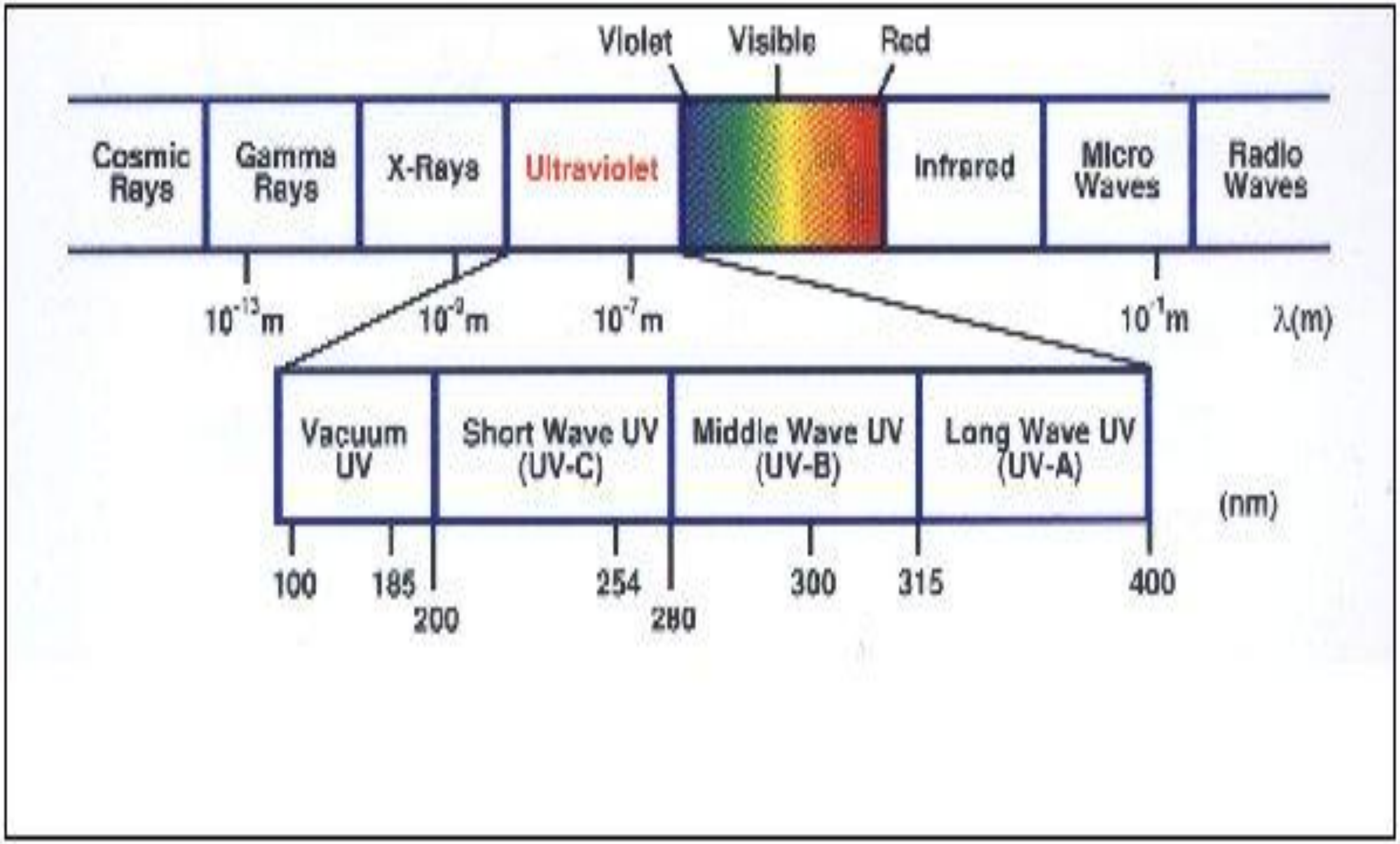


# Characteristics of Ultra Violet Light

- UV radiations are energy-rich electromagnetic rays

- UV radiation is light energy between 100 and 400 nm wavelength

# Characteristics of Ultra Violet Light



# UV Uses As Disinfectant

- UV disinfection is a purely physical process
- The effectiveness of this technology is directly related to the amount of UV radiation received by the target organisms
- The specific wavelength responsible for the bactericidal effects are situated between 200-280nm, with 254nm known as UV-C as the most suitable and effective wavelength

# UV-C Production

- The UV source is a fused silica quartz tube, typically 15mm- 25mm diameter ranging from 100-1200mm long.
- The inert gas filled in the tube provides primary discharge and the necessary action

# UV Uses As Disinfectant

- Drinking water
- Wastewater
- Aquaculture industries

# Mechanism of Action
# Inactivation of All Pathogens

- UV disinfects primarily by interacting with the nucleic acids of the pathogens and by inducing damage
- The nucleotide bases are the major UV absorbing species responsible for microbe inactivation
- UV absorption may vary somewhat from organism to organism

- UV absorbing compounds within the cell could account for some reduction of light intensity as UV passes through the cell on its way to nucleic acids

- Proteins are the most abundant UV absorbing molecules

- A typical bacterium consists of 12% protein, 6% nucleic acids (all types), 1% carbohydrate and 80% water

- About 85% of the UV light entering the bacterium exits from the other side and can pass into an adjacent microbe

# Ultraviolet Dose

UV dose = intensity X exposure time

(Expressed as energy per unit surface area

1mj/ $cm^2$=1000 $\mu$w-s/$cm^2$ micro watt seconds /square centimeter)

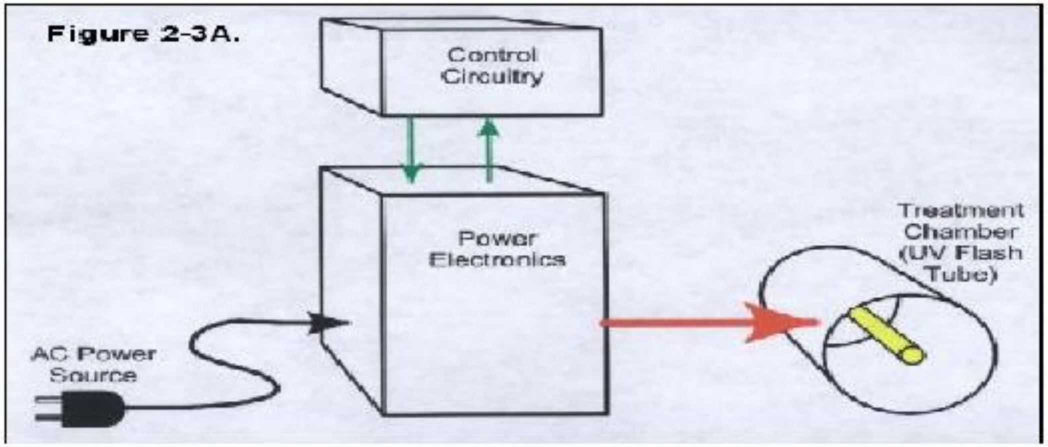
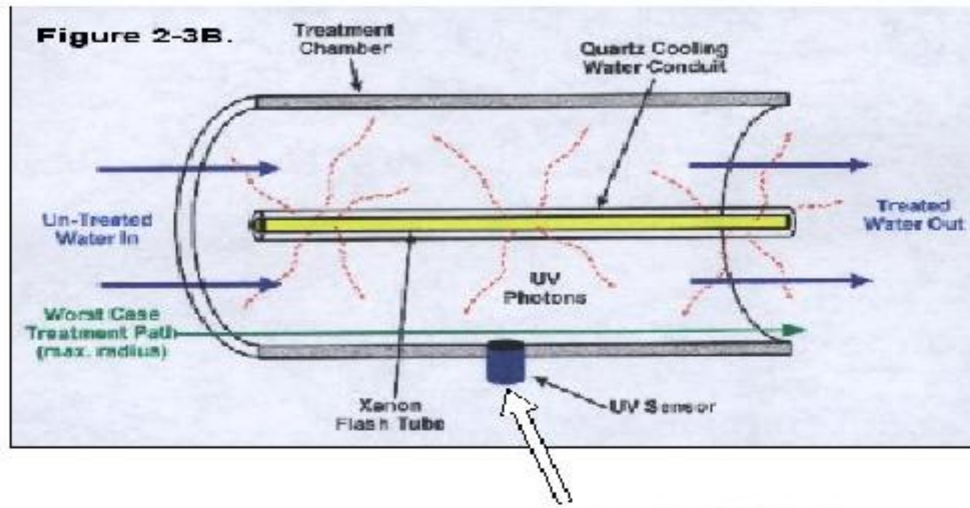



Figure 2-3A.
**Schematic of a Pulsed UV Treatment System**

Figure 2-3B.
**Detailed Schematic of Treatment Chamber**




"UV Sensor" adjusts radiation energy emitted from Flash Tube to maintain a predetermined minimum of radiation throughout the Treatment Chamber

# Advantages

- No chemicals added with and hence no environmental problems
- The water retains its natural taste, smell and pH
- Normally no hazardous by products are formed
- No corrosion problems
- Pathogens are easily killed
- Require less maintenance and easy handling, as system is compact and easy to install
- Maximum operating safety with minimum operating costs

# Disadvantages

- Water clarity, exposure period, and radiation energy are the three factors that affect the performance of a UV disinfection plant

- Water clarity and the depth of UV transmittance through water in the treatment chamber are inversely related

- Optimal treatment effectiveness is achieved when the transmissivity of the water approaches 100 percent

- Suspended matter absorbs and deflects UV energy, thereby decreasing the effectiveness of the treatment process to kill microorganisms

- Iron in the treatment water also reduce UV treatment efficacy by absorbing UV radiation and forming a film on the light/water interface

# Environmental Concerns
# Mercury

- Accidental release of low-level mercury if mercury-containing lamps are broken or improperly disposed

# Environmental Concerns
# Genetic Mutation Risk

- Aquatic microorganisms that survive the UV treatment process could be genetically mutated

- It is expected that most or all of the surviving organisms with damaged genetic material will fail to procreate

# Dose Requirements- Common Organisms

| **Species** | **Dose ($mj/cm^2$)** |
|---|---|
| *Bacillus subtilis* | 12 |
| *Legionella pneumophilla* | 2.04 |
| *Pseudomonas aeruginosa* | 5.5 |
| *Streptococcus faecalis* | 4.5 |
| *Hepatitis A virus* | 11 |
| *Polio virus* | 12 |
| *Sacchromyces cervisiae* | 6 |

mj =milli-joules

# *E .Coli* (Water Borne Indicator of Pathogen)

| Dose (mj/cm$^2$) | Reduction in number of live organisms % |
|---|---|
| 5.4 | 90 |
| 10.8 | 99 |
| 16.2 | 99.9 |
| 21.6 | 99.99 |
| 27 | 99.999 |

mj = moles-joules

# SOLAR RADIATION

## Mechanism of Action

The mode of action of solar disinfection depends upon:

- UV radiation
- High temperature

# Destruction of Bacteria

Important considerations:

- The intensity of sunlight at the time of exposure, which in turn depends upon:
  - geographic location (i.e Latitude)
  - seasonal variations
  - cloud cover
  - the effective range of wavelengths of light
  - the time of day

# Destruction of Bacteria

- The kind of bacteria being exposed
- The nature and composition of the medium
- The presence of nutritive elements capable of supporting the growth
- Multiplication of the various microorganisms

# Destruction of Bacteria

- The characteristics of the containers (e.g. Colour, shape, transparency to sunlight, size, and wall thickness)
- Clarity of the water (i.e. degree of turbidity), and its depth

# ION EXCHANGE

- Used especially for the removal of iron, manganese, nitrates which cause taste and taint problems

- Specialized ion exchange units can be purchased to replace the toxic or undesirable ions with safer ions

# BOILING

- This method works well to make water that is contaminated with living organisms safe to drink
- Boiling will also drive out some of the volatile organic compounds (vocs) that might also be in the water

# BOILING

- Water should be placed in a clean container and allow to achieve boiling and continue for at least 3 minutes (maximum 10 minutes)

- At 5,000 feet above sea level, increase the boiling time to at least 5 minutes (plus about a minute for every additional 1,000 feet).

# BOILING

- Boiling also does not remove many other water contaminants

- In fact boiling is liable to concentrate contaminants (like lead, asbestos, mercury, and many toxic organic chemicals) that do not vaporize as the relatively pure water vapor boils off.

# BOILING

Undesirable effects can be removed by:

- Aeration

- By allowing it to stand for a few hours

- By adding a small pinch of salt for each quart of boiled water

# FILTRATION

- The contaminants are physically prevented from moving through the filter either by screening them out with very small pores

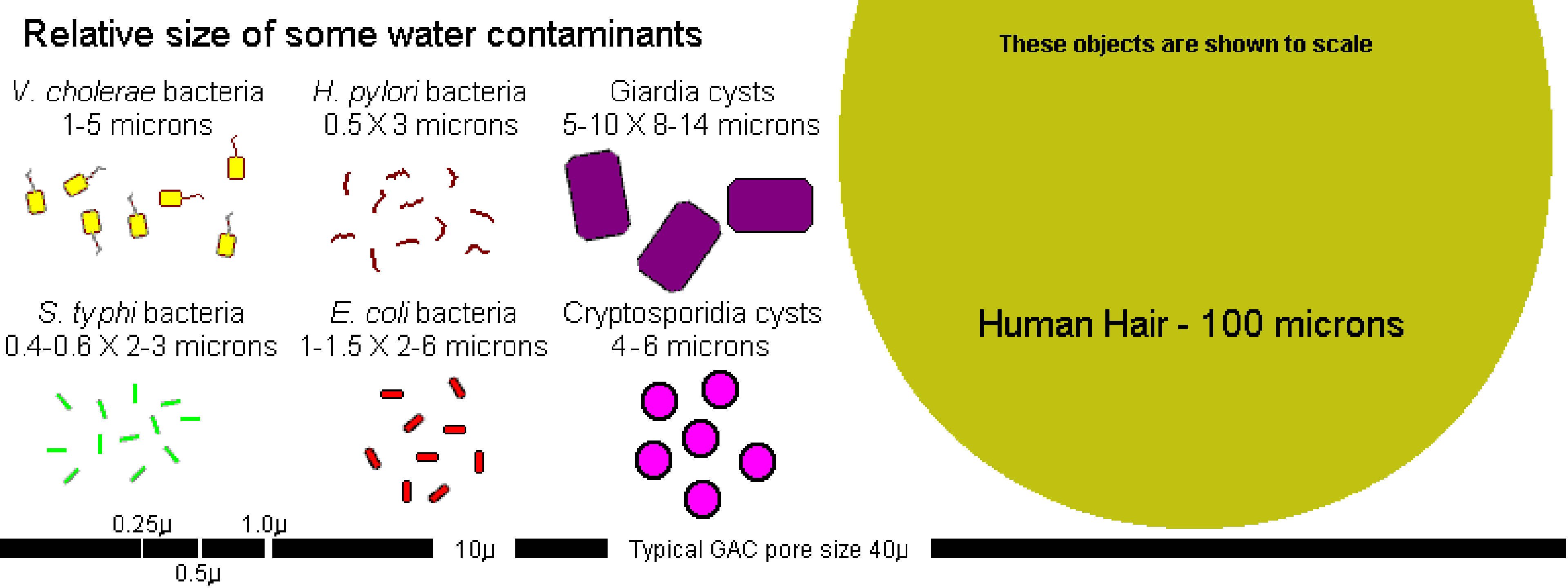
- By trapping them within the filter matrix by attracting them to the surface of carbon particles (the process of adsorption)

# Filtration

- There are two main types of filters
  - Sediment filter
  - Activated carbon filter

  or combination of both

# Relative size of some water contaminants




Sub-micron filters can be found in ceramic and carbon block filtration systems

10μ to 20μ pores are the lower limit for most whole house filtration systems

## Relative pore size of some common filtration media

Pore size is often measured in microns (appreviated μ).
There are 1,000,000 μ in 1 meter.

The scale of the diagram above is 4 pixels = 1 micron

Although a good sub-micron filter will remove most bacteria from drinking water, it is a good idea not to rely on them for your primary disinfection method. A crack in the filter medium will allow pathogens to flow unfiltered into the output stream. They are best employed in emergencies and when other disinfection methods are not available.

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This scale is ok for showing the relative size of "fairly large" microscopic contaminants.
At this scale, however, a virus would be about 10 times smaller than the period at the end of this sentence (0.025μ).

On the scale of this diagram, Reverse Osmosis filter membranes have a pore size of about 1,000 times smaller than the period at the end of this sentence (0.00025 μ). This ultra-filtration is able to filter larger single molecules from the water (or exclude them electrically) leaving nearly pure water.

# Sediment Filters

- Fiber filter
- Contain cellulose, rayon or some other material
- Suspended matter (or turbidity) is removed as water pressure forces water through tightly wrapped fibers

# Sediment Filters

- Fiber filters will not remove contaminants that are dissolved in the water, like lead, mercury, trihalomethanes or other organic compounds

# Sediment Filters

## Ceramic Filters

- Water is forced through the pores of a ceramic filtration media
- This provides mechanical filtration
- This type of filter can reduce:
  - Asbestos fibers
  - Cysts (if the pores are one micron or smaller)

## Sediment Filters
## Ceramic Filters

- Ceramic filters will not remove contaminants that are dissolved in the water, like lead, mercury, trihalomethanes or other organic compounds

# Sediment Filters

- These filters may be used as a back-end to an activated carbon filter to provide a more thorough removal of contaminants

# Activated Carbon Filters

- Activated carbon is particles of carbon that have been treated to increase their surface area
- Activated carbon is particularly good at adsorbing organic compounds

# Activated Carbon Filters

- There are two basic kinds of carbon filters:
  - Granular activated carbon (GAC)
  - Solid block activated carbon (SBAC)
- It is important - that **hot water should NEVER be run through a carbon filter**

# Granular Activated Carbon (GAC)

- In this type of filter, water flows through a bed of loose activated carbon granules, which trap some particulate matter

- Remove some chlorine, organic contaminants, and undesirable tastes and odors

# Granular Activated Carbon (GAC)

- The three main problems associated with GAC filters are:
  - **Channeling**
  - **Dumping**,
  - **Large pore size**

# Granular Activated Carbon (GAC)

- The carbon granules are fairly large (0.1mm to 1mm in one popular pitcher filter), the effectively pore size **of the filter is relatively large** (20 - 30 microns or larger).

# Solid Block Activated Carbon (SBAC)

- The effective pore size can be very small (0.5 - 1 micron)

Advantages

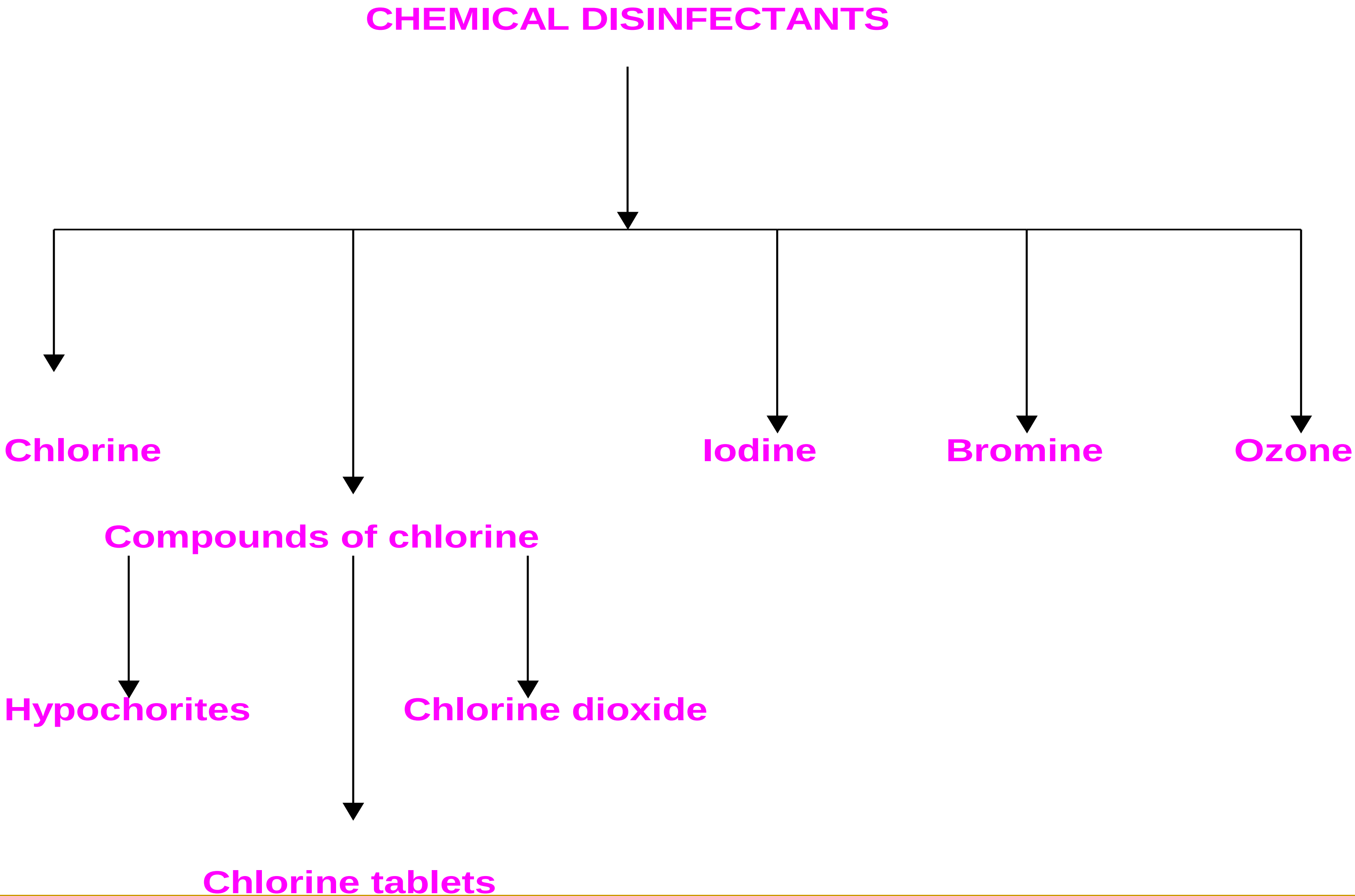
- Carbon block filters provide:
  - A large surface area
  - A longer contact time

# DISTILLATION

- Distillation is the reverse of boiling
- The water is boiled causing the pure (or mostly pure) steam to vaporize leaving the non volatile contaminants behind

# REVERSE OSMOSIS (RO)

- Water pressure is used to force water molecules through a membrane leaving the contaminants behind


CHEMICAL DISINFECTANTS
Chlorine
Compounds of chlorine
Iodine
Bromine
Ozone
Hypochorites
Chlorine dioxide
Chlorine tablets

# CHLORINE METHODS

i. Chlorine Bleach

Common household bleach contains a chlorine compound that will disinfect water. The procedure to be followed is usually written on the label. When the necessary procedure is not given, find the percentage of available chlorine on the label and use the information in the following tabulation as a guide.

| Available Chlorine | Drops per Quart of Clear Water (Quarter of gallon) |
|---|---|
| 1% | 10 |
| 4-6% | 2 |
| 7-10% | 1 |

# CHLORINE TABLETS

Chlorine tablets containing the necessary dosage for drinking water disinfection can be purchased in a commercially prepared form.

These tablets are available from drug and sporting goods stores and should be used as stated in the instructions. When instructions are not available, use one tablet for each quart of water to be purified.

# Chlorine dioxide

- **Like ozone and chlorine, chlorine dioxide is an oxidizing biocide. This means that chlorine dioxide kills microorganisms by disruption of the transport of nutrients across the cell wall, not by disruption of a metabolic process.**

- **Of the oxidizing biocides, chlorine dioxide is the most selective oxidant. Both ozone and chlorine are much more reactive than chlorine dioxide, and they will be consumed by most organic compounds.**

# Amount of chlorine compounds needed to disinfect water for drinking

| Water ($m^3$) | Bleaching powder (25-35%) gm | High strength Calcium hypochlorite (70%) gm | Liquid bleach (5% sodium hypochlorite) ml |
|---|---|---|---|
| 1.0 | 2.3 | 1.0 | 14 |
| 5.0 | 12 | 5 | 70 |
| 10 | 23 | 10 | 140 |
| 50 | 120 | 50 | 700 |
| 100 | 230 | 100 | 1400 |

# IODINE

## i. Tincture of Iodine

Common household iodine from the medicine chest or first aid kit may be used to disinfect water. Add five drops of 2 percent United States Pharmacopeia (U.S.P.) Tincture of iodine to each quart of clear water. For cloudy water add ten drops and let the solution stand for at least 30 minutes.

## ii. Iodine Tablets

Commercially prepared iodine tablets containing the necessary dosage for drinking water disinfection can be purchased at drug and sporting goods stores. They should be used as stated. When instructions are not available, use one tablet for each quart of water to be purified.

# OZONATION

Ozone is a colourless gas at all concentrations experienced in industry. It has a pungent characteristic odour usually associated with electrical sparks and thunder storms.

The odour is generally detectable by the human nose at concentrations between 0,02 and 0,05 ppm or approx. 1/100$^{th}$ of the recommended 15 minute exposure level.

- The ozone molecule contains three oxygen atoms whereas the oxygen molecule contains only two .
- Ozone is a very reactive and unstable gas with a short half-life before it reverts back to oxygen.

# Advantages

- While ozone is very powerful, it has a very short life cycle.
- When it is faced with odors, bacteria or viruses, the extra atom of oxygen destroys them completely by oxidation.
- In so doing, that extra atom of oxygen is destroyed and there is nothing left...no odor...no bacteria...no extra atom, only oxygen.

Ozone is safe because we notice it's unpleasant odor at very residual levels