WATER PURIFICATION

K. M.ahdiuzzaman Sayed
Lecturer

Nutrition & Food Engineering

Daffodil International University

Water Purification Methods

Backpackers Guide To Making Water Safe For Drinking

1 Boiling

The longer the water stays at a "rolling boil" the more likely it is that any dangerous bacteria will be killed off. The minimum suggested period of rolling boil is one minute but 10 is Recommended to be safe

Recommended
Highly effective at filtering Protozoat-Cryptosporidium, Protozoa Giardia intestinalis, Bacteria and Viruses

2 Filtration

Filters require you to manually pump water through a filtration device. They can be clunky and a little fiddly due to the number of parts they contain, but, if used effectively, can filter upwards of 1.5 liters per minute.

Effective at filtering Protozoa-Cryptosporidium, Protozoa Giardia intestinalis but not as effective with bacteria and viruses.

3 Chlorine

Chlorine can be found in house hold bleach. Eight drops of bleach with a 5-6% concentration of sodium hypochlorite will purify one gallon of warm, clear water

Effective at filtering Bacteria, Viruses and Protozoa Gi-ardia intestinalis but not Protozoa-Cryptosporidium

4 Iodine

Five drops of 2% tincture of iodine should be added per quart of clear water to purify it; ten drops should be used if the water is cloudy

Effective at filtering Bacteria and Viruses but not Protozoa-Cryptosporidium or Protozoa Giardia intesti-nalis

5 Purification Tablets or Drops

Water purification tablets and drops make use of chemicals to kill off bacteria lurking in your water. Iodine, chlorine and chlo-rine-dioxide are the most common chemi-cals used.

Effective at filtering Bacteria, Viruses and Protozoa Gi-ardia intestinalis but not Protozoa-Cryptosporidium

6 Combination of Filtering and Disinfection

Other than boiling, filtration and disinfec-tion used in combination provide the most effective pathogen reduction in untreated water.

Recommended
Highly effective at filtering Protozoa-Cryptosporidium, Protozoa Giardia intestinalis, Bacteria and Viruses

Water and its impurities

Waters are classified according to hardness grades as follows.

(mg/L) $CaCO_3$	Degree of Hardness
0-75	Soft
75-150	Middle
150-300	Hard
300 and over	Very hard

Temporary hardness is caused by calcium and/or magnesium hydrogen carbonate. These are formed as carbonated rain water passes over rocks containing carbonate ions, for example

H2O(l) + CO2(g) + CaCO3(s) → Ca(HCO3)2(aq)

H2O(l) + CO2(g) + MgCO3(s) → Mg(HCO3)2(aq)

Temporary hardness can be removed simply by boiling the water.

Permanent hardness is caused by calcium and/or magnesium sulphate. These are formed as water passes over rocks containing sulphate ions, for example

aq. + CaSO4(s) → Ca2+(aq) + SO42-(aq)

aq. + MgSO4(s) → Mg2+(aq) + SO42-(aq)

Permanent hardness cannot be removed by boiling but can often be removed by chemical treatment (see later).

The aim of softening:

Hard water can cause various problems. The problems created by hard waters are as follows;

- They cause excessive soap consumption.
- They cause to skin irritation.
- They cause lime accumulation in boilers, hot water pipes and heaters.
- They cause discoloration in porcelain. Especially in homes, the white color of the sinks and bathtubs are discolored.
- They reduce the life of fabrics and cause them to wear out.
- They cause problems in canned food industry.

Specifications of process water

Minimum standard	Permissible standard
Color	Colorless
Smell	Odorless
p^H value	7-8
Water hardness	$<5^O$dH
Dissolved solids	<1mg/L
Solid deposits	< 50 mg/L
Inorganic salt	< 500 mg/L
Organic substance	<20 mg/L
Iron (Fe)	<0.1 mg/L
Copper (Cu)	<0.005 mg/L
Mn	< 0.05mg/L
Nitrate	< 50 mg/L
Nitrite	<5mg/L

Quality of water used in industrial boiler

Properties	Acceptable limits
Appearance	Clear, without residue.
Residual hardness	$<0.05^0$ dh
Oxygen	<0.02 mg/L
Temporary CO_2	0 mg/L
Permanent CO_2	<25 mg/L
Iron (Fe)	<0.05 mg/L
Copper(Cu)	<0.01 mg/L
Phosphate(PO_4)	4-5 mg/L
P^H(at 25^OC)	≈9 (generally 8-9)
Conductivity	2500us/cm
Temp of boiler feed water 90^0C	$\approx 90^OC$

Method to soften hard water

Hardness removal (chemical softening) is a process that removes all or part of the hardness by adding various chemical substances into the water. The processes used for water softening are chemical sedimentation and ion exchange methods. Chemical sedimentation can be carried out in 3 ways.

1-Lime-soda process

2-Caustic-soda process

3-Sodium phosphate process

Soda lime process: In this process, hydrated lime & Sodium Carbonate are added to precipitate calcium & Magnesium ions as compounds of low solubility.

For temporary hardness,

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow 2MgCO_3 + 2H_2O$$

$$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCO_3$$

Permanent Hardness

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 + Na_2SO_4$$

$$MgSO_4 + Na_2CO_3 \longrightarrow MgCO_3 + Na_2SO_4$$

Lime soda process: In lime-soda process, hard water is treated with lime (CaO or Ca $(OH)_2$) firstly, after that with soda. In this process, the hardness is removed by sedimentation as calcium carbonate or magnesium hydroxide. Lime is added either as calcium hydroxide or calcium oxide, and soda is added as sodium carbonate. The substances form hardness in water and the reactions of lime and soda can be written as follows.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_20$$

$$Ca(OH)_2 + Ca(HCO_3)_2 \longrightarrow 2CaCO_3 + 2\ H_20$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow MgCO_3 + CaCO_3 + 2\ H_20$$

$$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCO_3$$

$$MgCl_2 + Ca(OH)_2 \longrightarrow CaCl_2 + Mg(OH)_2$$

$$MgSO_4 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaSO_4$$

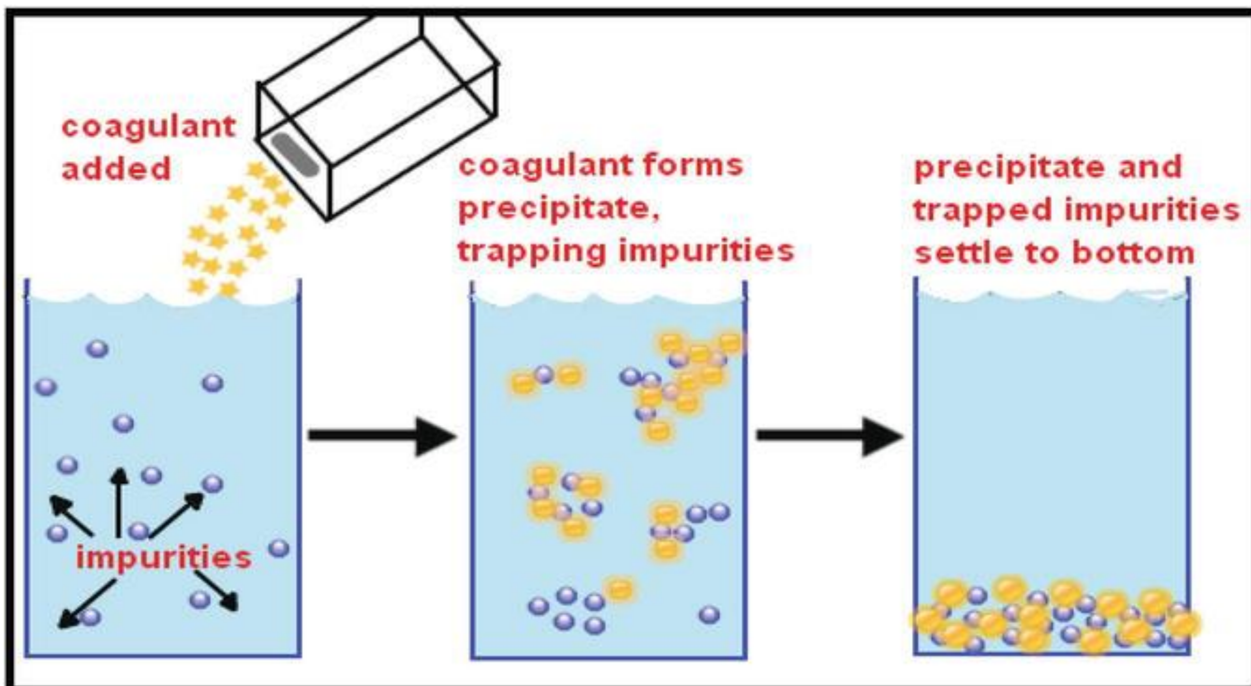
$$2NaHCO_3 + Ca(OH)_2 \longrightarrow CaCO_3 + Na_2CO_3 + 2H_20$$

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + NaCl$$

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 + Na_2CO_3$$

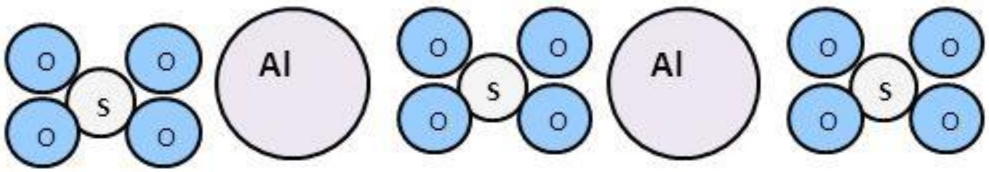
Coagulation and Flocculation:

In water treatment, coagulation flocculation involves the addition of compounds that promote the clumping of fines into larger floc so that they can be more easily separated from the water. Coagulation is a chemical process that involves neutralization of charge whereas flocculation is a physical process and does not involve neutralization of charge. The coagulation-flocculation process can be used as a preliminary or intermediary step between other water or wastewater treatment processes like filtration and sedimentation. Iron and aluminium salts are the most widely used coagulants but salts of other metals such as titanium and zirconium have been found to be highly effective as well.

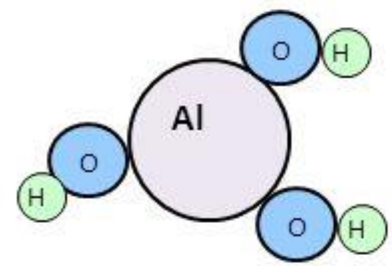


Aluminum Coagulants

- Alum $Al_2(SO_4)_3 \cdot 14\ H_2O$



- Minimum solubility – pH 5.5
- Precipitates as $Al(OH)_3$ ~(10^{-8} M)

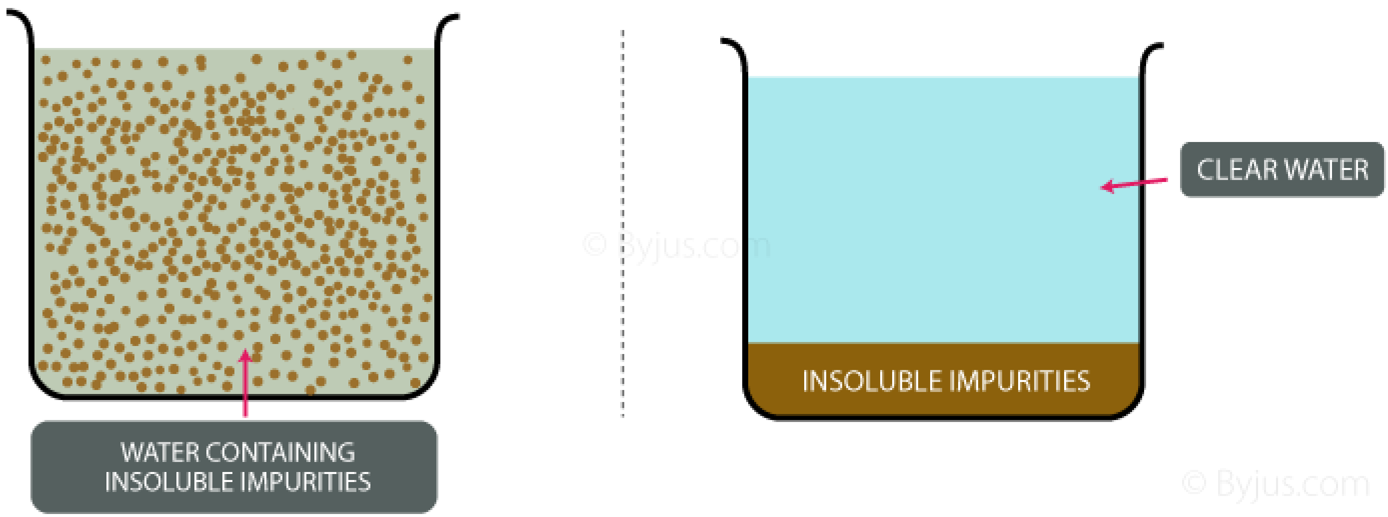


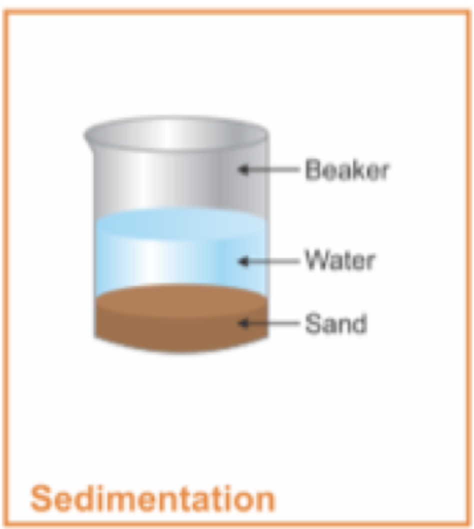
- Process works best at lower pH (6-7)

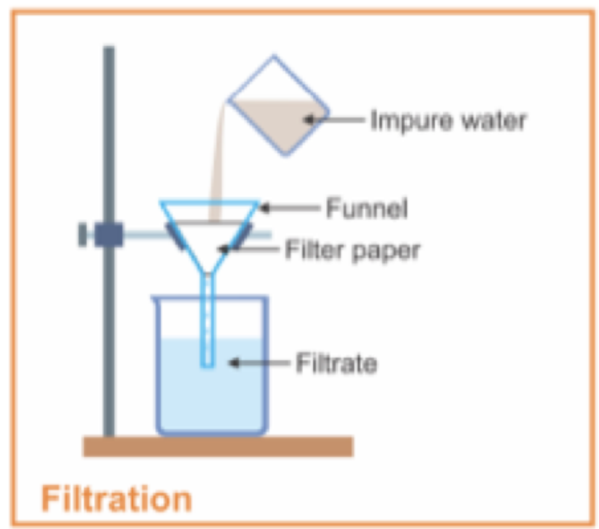
$$Al_2(SO_4)_3 + 14H_20 + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3Ca(SO)_4 + 14H_2O + 6CO_2$$

- Each mg/l alum consumes 0.5 mg/l alkalinity

SEDIMENTATION







Ultrafiltration

Sols pass through an ordinary filter paper, Its pores are too large to retain the colloidal particles. However, if the filter paper is impregnated with collodion or a regenerated cellulose such as *cellophane* or *visking*, the pore size is much reduced. Such a modified filter paper is called an **ultrafilter.**

The separation of the sol particles from the liquid medium and electrolytes by filtration through an ultrafilter is called ultrafiltration.

Ultrafiltration is a slow process. Gas pressure (or suction) has to be applied to speed it up. The colloidal particles are left on the ultrafilter in the form of slime. The slime may be stirred into fresh medium to get back the pure sol. By using graded ultrafilters, the technique of ultrafiltration can be employed to separate sol particles of different sizes.

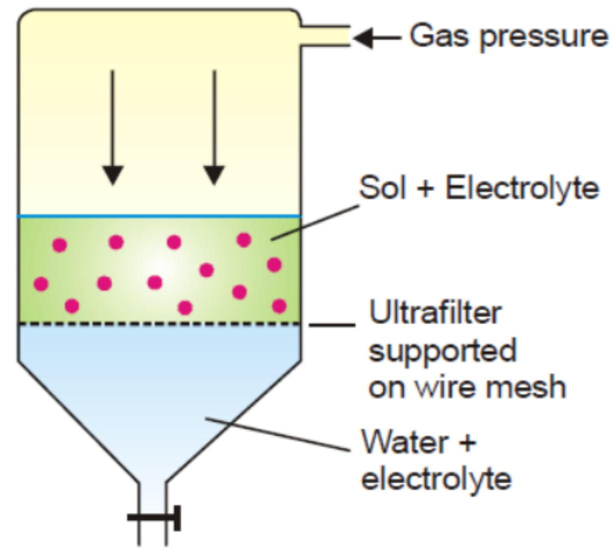
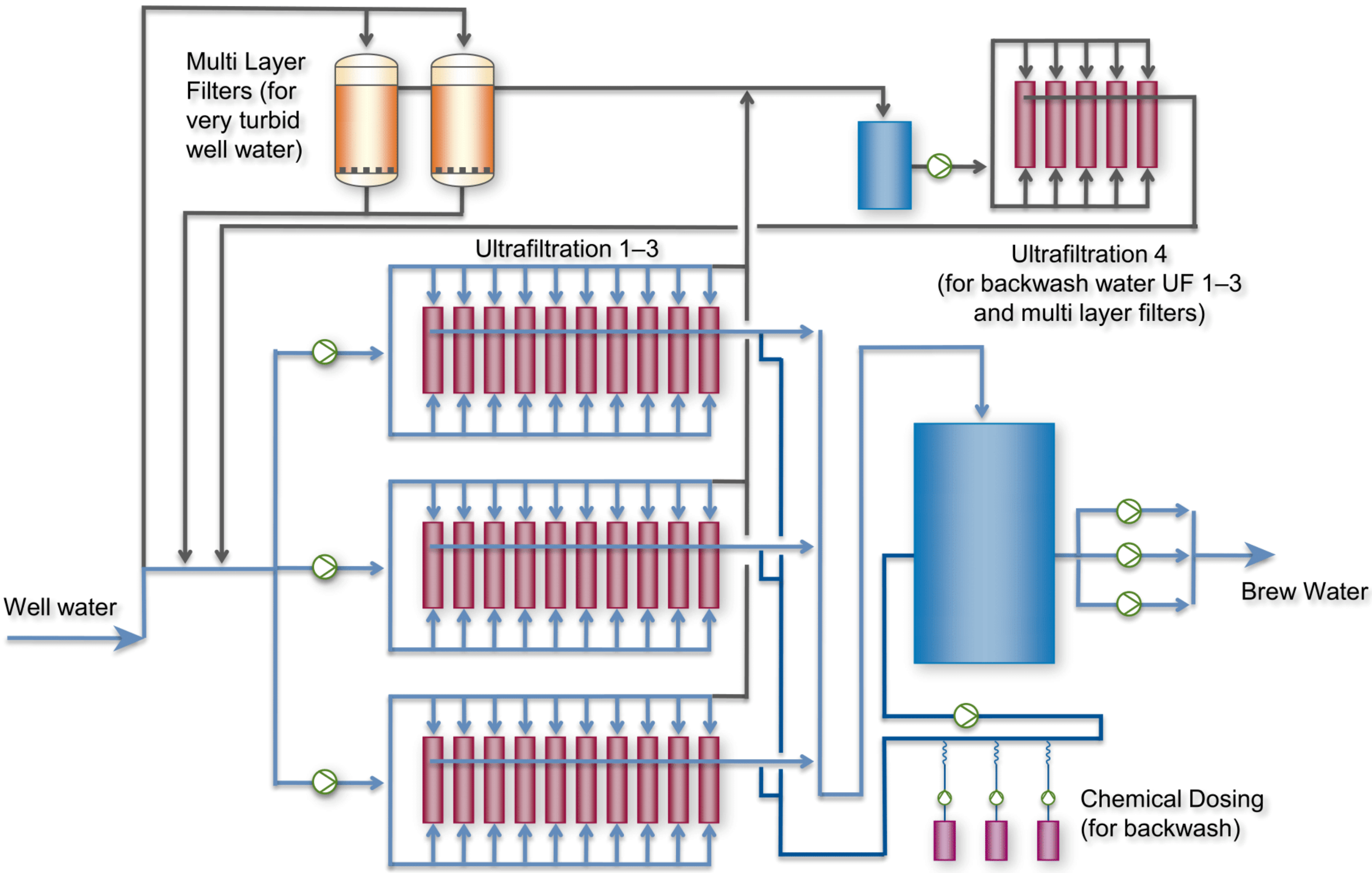


Figure 22.9
Ultrafiltration.

Ultrafiltration with Backwash Water Recycling



Dialysis

Animal membranes (bladder) or those made of parchment paper and cellophane sheet, have very fine pores. These pores permit ions (or small molecules) to pass through but not the large colloidal particles. When a sol containing dissolved ions (electrolyte) or molecules is placed in a bag of permeable membrane dipping in pure water, the ions diffuse through the membrane. By using a continuous flow of fresh water, the concentration of the electrolyte outside the membrane tends to be zero. Thus diffusion of the ions into pure water remains brisk all the time. In this way, practically

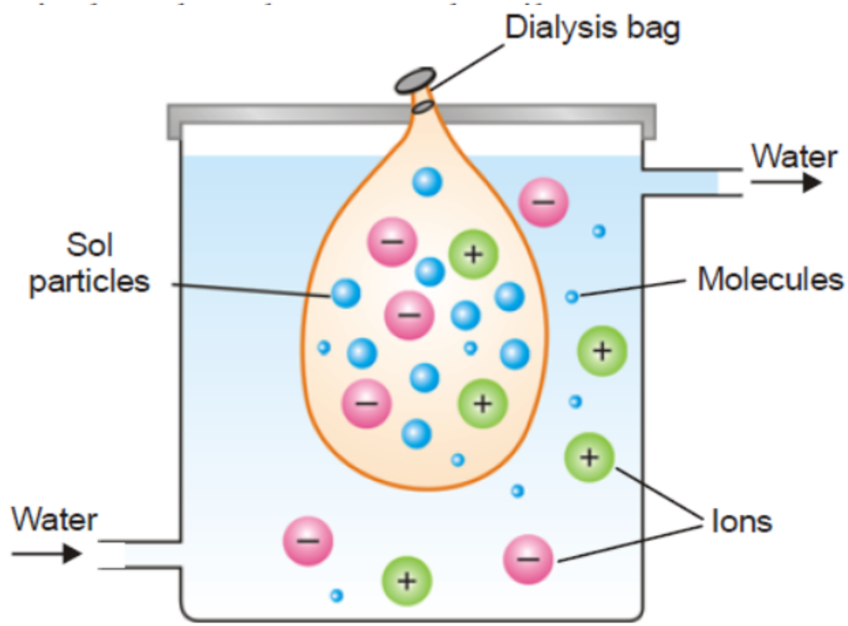
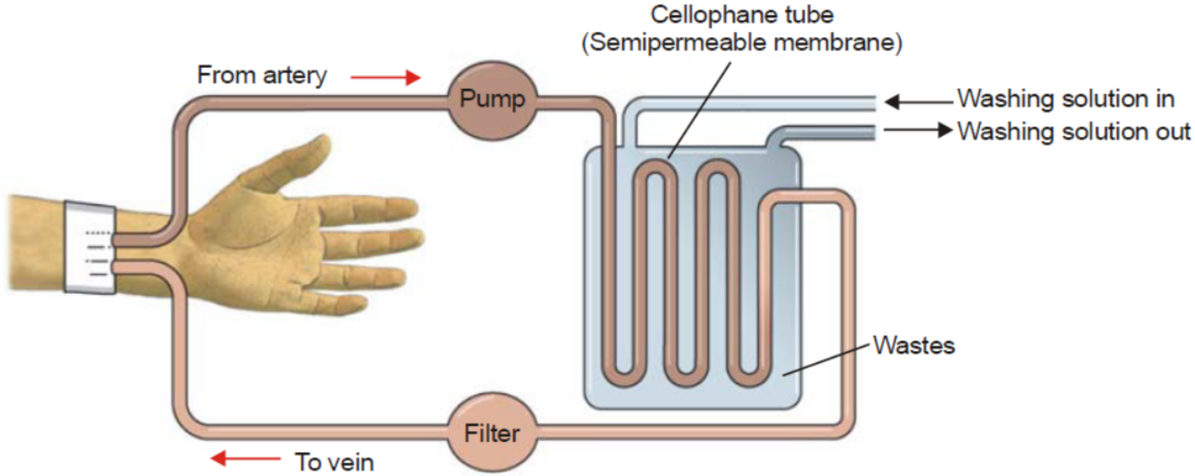


Figure 22.7
Dialysis of a sol containing ions and molecules.

The process of removing ions (or molecules) from a sol by diffusion through a permeable membrane is called Dialysis. The apparatus used for dialysis is called a **Dialyser.**

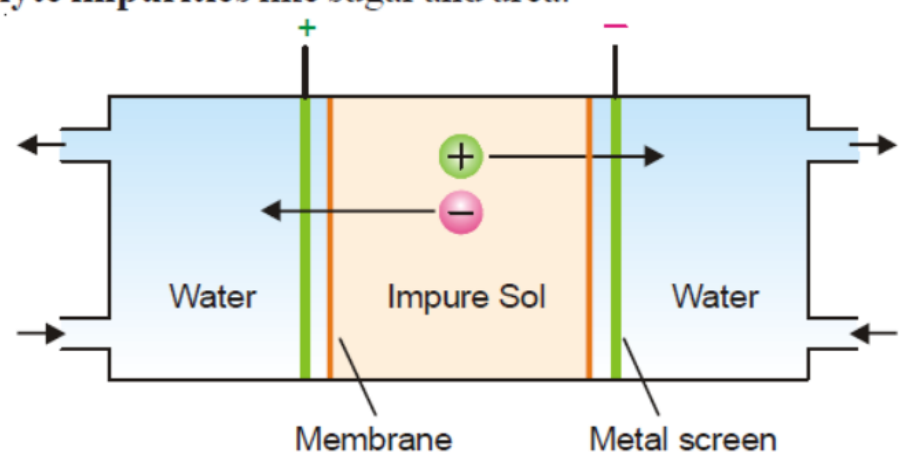
Example. A ferric hydroxide sol (red) made by the hydrolysis of ferric chloride will be mixed with some hydrochloric acid. If the impure sol is placed in the dialysis bag for some time, the outside water will give a white precipitate with silver nitrate. After a pretty long time, it will be found that almost the whole of hydrochloric acid has been removed and the pure red sol is left in the dialyser bag.



■ Figure 22.32
An artificial kidney machine for purification of blood by dialysis.

Electrodialysis

In this process, dialysis is carried under the influence of electric field (Fig. 22.8). Potential is applied between the metal screens supporting the membranes. This speeds up the migration of ions to the opposite electrode. Hence dialysis is greatly accelerated. Evidently **electrodialysis is not meant for nonelectrolyte impurities** like sugar and urea.



■ Figure 22.8
Electrodialysis.

ION–EXCHANGE ADSORPTION

In recent years, many synthetic resins have been made which function as ion-exchangers. In effect, the resin has one ion adsorbed on it. The resin releases this ion and adsorb another like ion. The process is called **ion-exchange adsorption**. When cations are exchanged, the resin is known as **cation exchanger**. When anions are exchanged, it is referred to as **anion exchanger** .

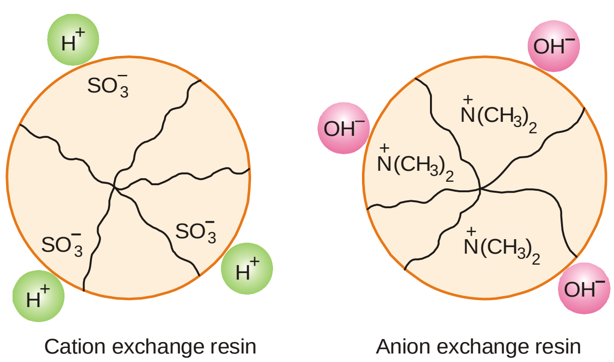


Figure 23.12
Macromolecules of ion-exchange resins.

Cationic exchange

The cationic exchangers are high polymers containing acidic groups such as sulphonic acid group, $–SO_3$, H. The resulting macro-anion has adsorbed H^+ ions. When solution of another cation (Na^+) is allowed to flow over it, H^+ ions are exchanged for Na^+ ions. This process in fact, consist of desorption of H^+ ions and adsorption of Na^+ ions by the resin.

$$\underset{\text{cationic resin}}{R^-H^+} + Na^+ \rightleftharpoons \underset{\text{sodium 'salt'}}{R^-Na^+} + H^+$$

Since the above cationic exchange is reversible, the sodium 'salt' upon treatment with an acid regenerates the original resin.

Anionic exchange

A resin containing a basic group such as quaternary ammonium hydroxide, $-N^+R_3O^-H$, will act as anion exchanger. It will, for example, exchange OH^- ion for Cl^-.

$$\underset{\text{anionic resin}}{R^+OH^-} + Cl^- \rightleftharpoons \underset{\text{resin 'chloride'}}{R^+Cl^-} + OH^-$$

The original anion exchanger resin can be regenerated by treatment of the resin 'chloride' with a base (OH^- ions).

APPLICATIONS OF ION–EXCHANGE ADSORPTION

Ion-exchange adsorption has many useful applications in industry and medicine.

(1) Water softening

Hard water contains Ca^{2+} ions and Mg^{2+} ions. These form insoluble compound with soap and the latter does not function as detergent. Hard water is softened by passing through a column packed with sodium cation-exchanger resin, R^-Na^+. The Ca^{2+} and Mg^{2+} ions in hard water are replaced by Na^+ ions.

$$2R^-Na^+ + Ca^{2+} \longrightarrow R_2^-Ca^{2+} + 2Na^+$$

(2) Deionization of water

Water of very high purity can be obtained by removing all dissolved salts. This is accomplished by using both a cation and anion exchanger resin. The water freed from all ions (cations and anions) is referred to as **Deionized or Demineralized water**.

The water is first passed through a column containing a cation-exchanger resin, R^-H^+. Here any cations in water (say Na^+) are removed by exchange for H^+. The water is then passed through a second column packed with an anion-exchanger, R^+OH^-. Any anions (Cl^-) are removed by exchange of OH^- for Cl^-.

$$R^-H^+ + Na^+ \longrightarrow R^-Na^+ + H^+ \qquad \textit{(First Column)}$$

$$R^+OH^- + Cl^- \longrightarrow R^+Cl^- + OH^- \qquad \textit{(Second Column)}$$

The H^+ and OH^- ions thus produced react to form water.

$$H^+ + OH^- \longrightarrow H_2O$$

Thus the water coming out of the second column is entirely free from ions, whether cations or anions. The water is purer than distilled water and is called **Conductivity water**.

In another process, which is more common way, the tap water is passed into a column containing both types of resin (cation and anion exchanger). Here cations and anions are removed simultaneously.

Electrical demineralization of water

Ion-exchange resins supported on paper or fibre can be used as membranes through which only cations or anions will pass. Such membranes are used in electrical demineralization of water and they act as ionic sieves (Fig. 23.13). Upon application of the electric current, cations move through the cation-exchanger membrane to the negative electrode. The anions move in the opposite direction through the anion exchanger membrane. Thus the water in the middle compartment is demineralized.

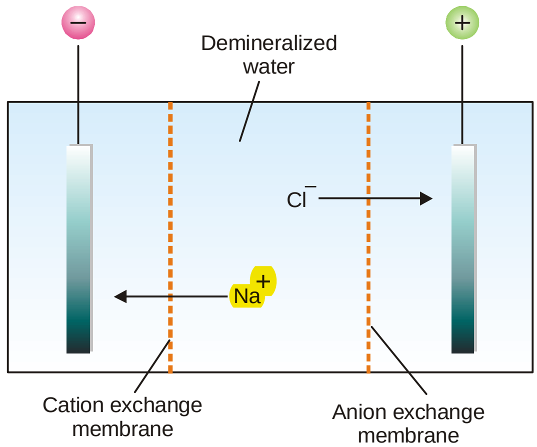
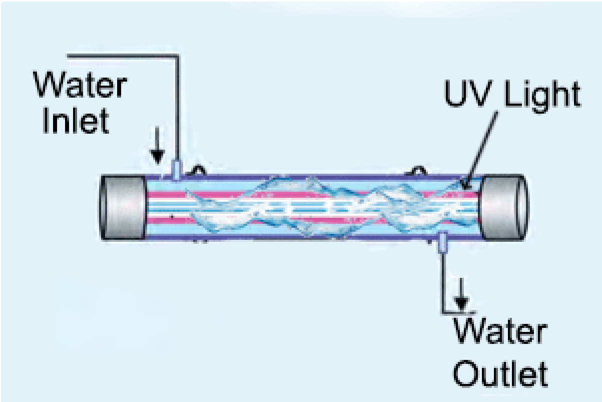
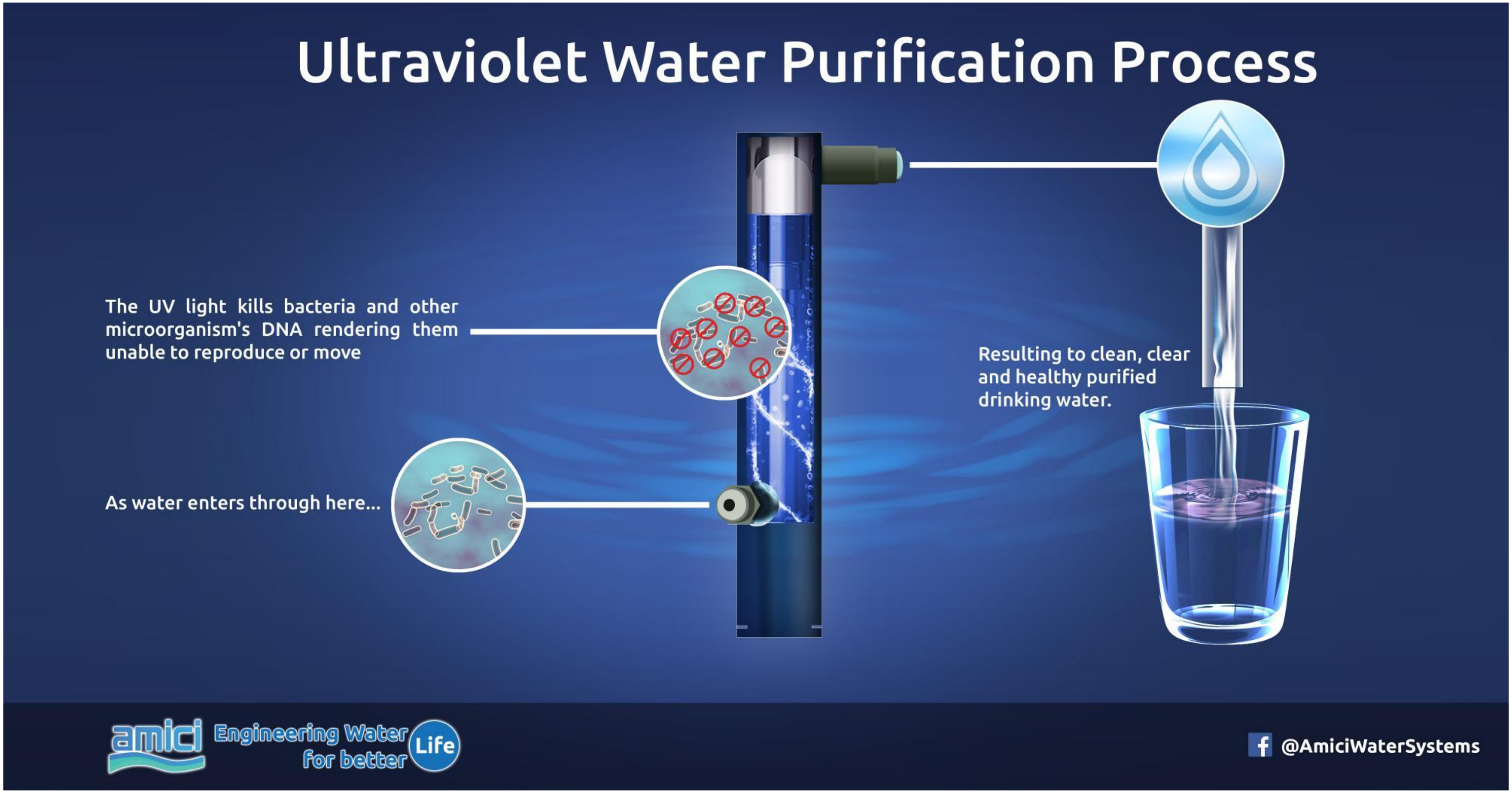


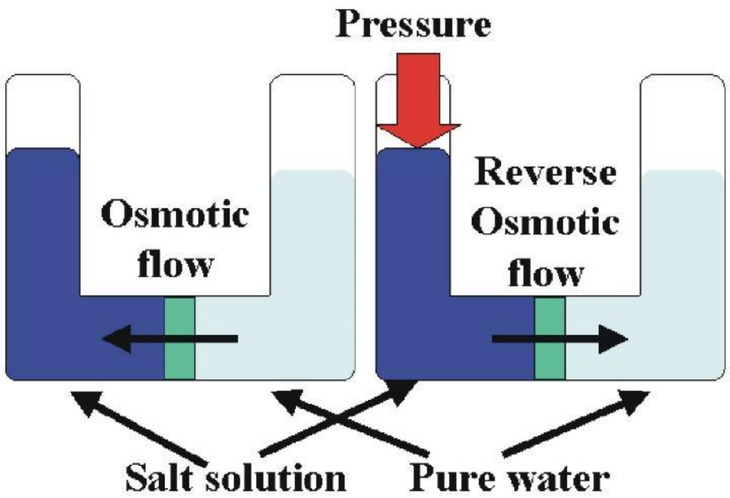
Figure 23.13
Electrical demineralization of saline water.

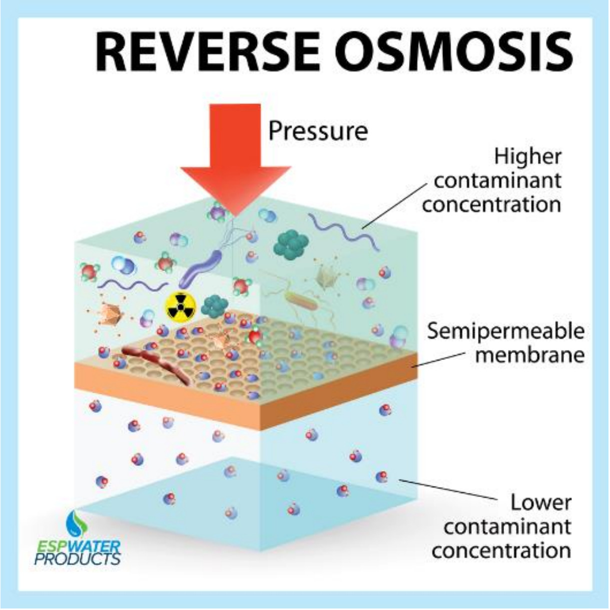
(3) Medical uses

Excess sodium salts can be removed from the body fluids by giving the patient a suitable ion-exchanger to eat. Weakly basic anion-exchangers are used to remove excess acid or ‘ acidity’ in the stomach.


Water Inlet
UV Light
Water Outlet

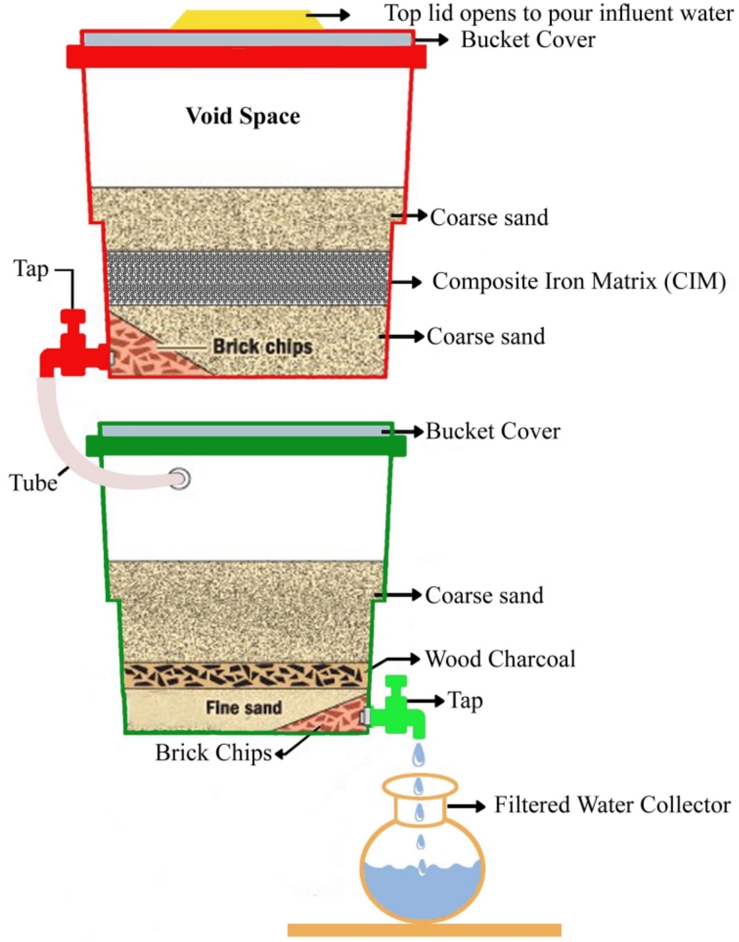

Ultraviolet Water Purification Process
The UV light kills bacteria and other microorganism's DNA rendering them unable to reproduce or move
As water enters through here...
Resulting to clean, clear and healthy purified drinking water.
amici Engineering Water for better Life
@AmiciWaterSystems


Pressure
Osmotic flow
Reverse Osmotic flow
Salt solution
Pure water

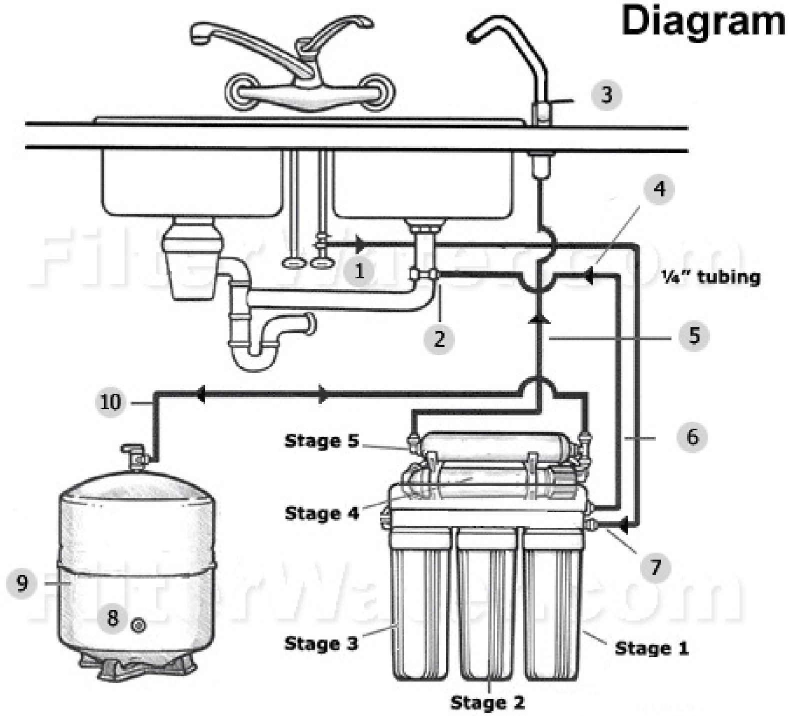

REVERSE OSMOSIS
Pressure
Higher contaminant concentration
Semipermeable membrane
Lower contaminant concentration
ESPWATER PRODUCTS


SEDIMENT FILTER
Raw Water
ACTIVATED CARBON FILTER
RO
Dirty Water
Reduces Dissolved Impurities
UF
TDS Controller
Reduces Bacteria & Cysts
Retains Essential Minerals
Purer Water
UV
Reduces Bacteria & Viruses
KENT

Schematic Diagram of SONO™ Filter



FilterWater.com **RO Installation Diagram**

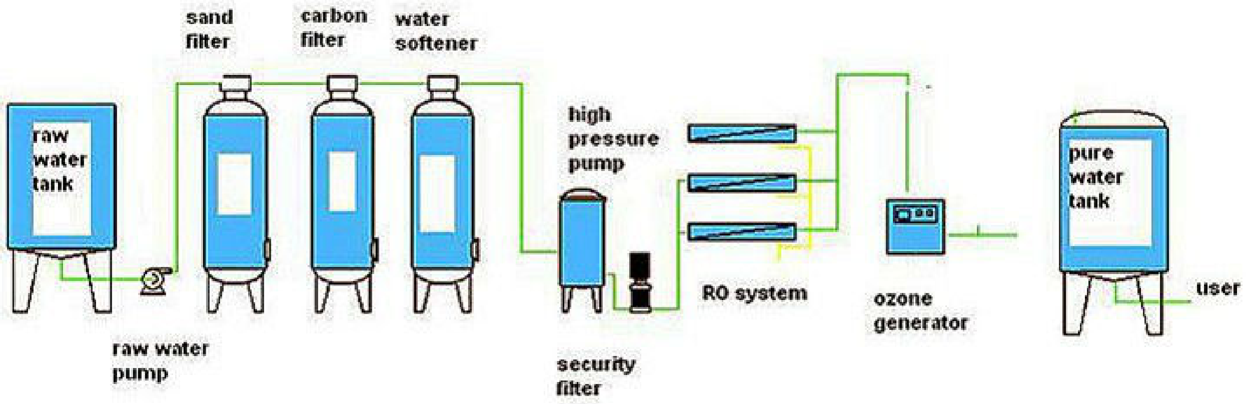


System Installation:
1. Self-piercing valve supplies feed water to RO unit.
2. Drain Connector
3. Drinking Faucet.
4. line to drain
5. line to faucet
6. black tube with flow restrictor to drain
7. line from feed
8. Schrader pressure valve
9. Storage Tank
10. line to tank

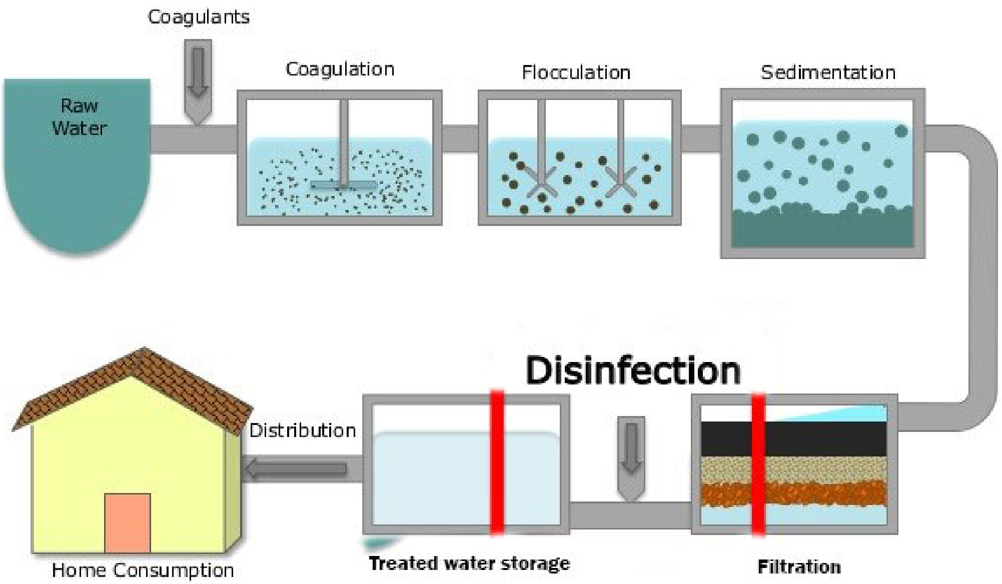
System Stages:

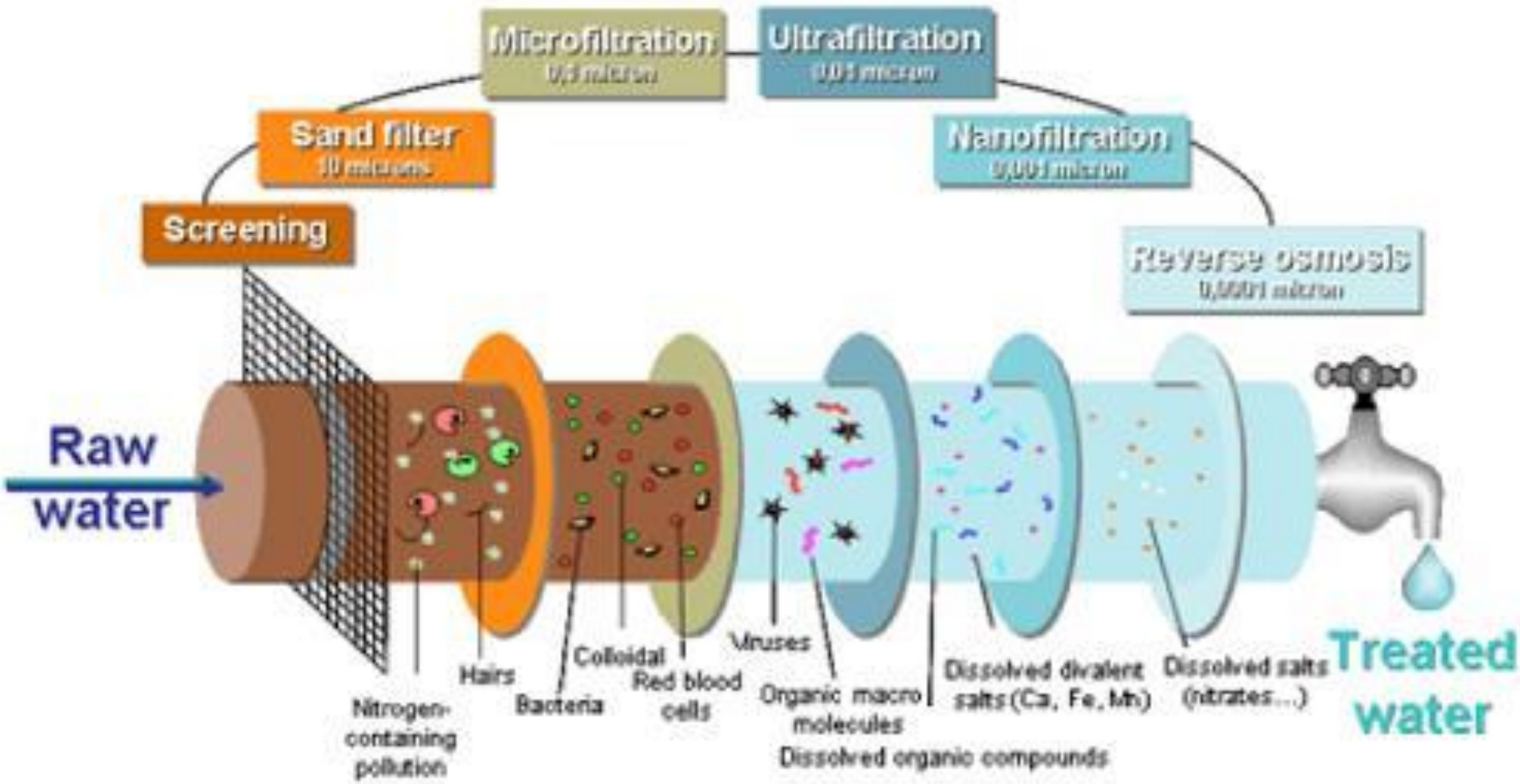
Thunder RO system:
1. Carbon Block Filter
2. Ultrafiltration membrane or optional specific contaminant removal filter
3. Multi-stage cartridge
4. Reverse Osmosis Membrane
5. Carbon Postfilter and optional other Post-Filters

Typical RO system:
1. Sediment Filter
2, 3. Carbon Block
4. Reverse Osmosis Membrane
5. Carbon Postfilter

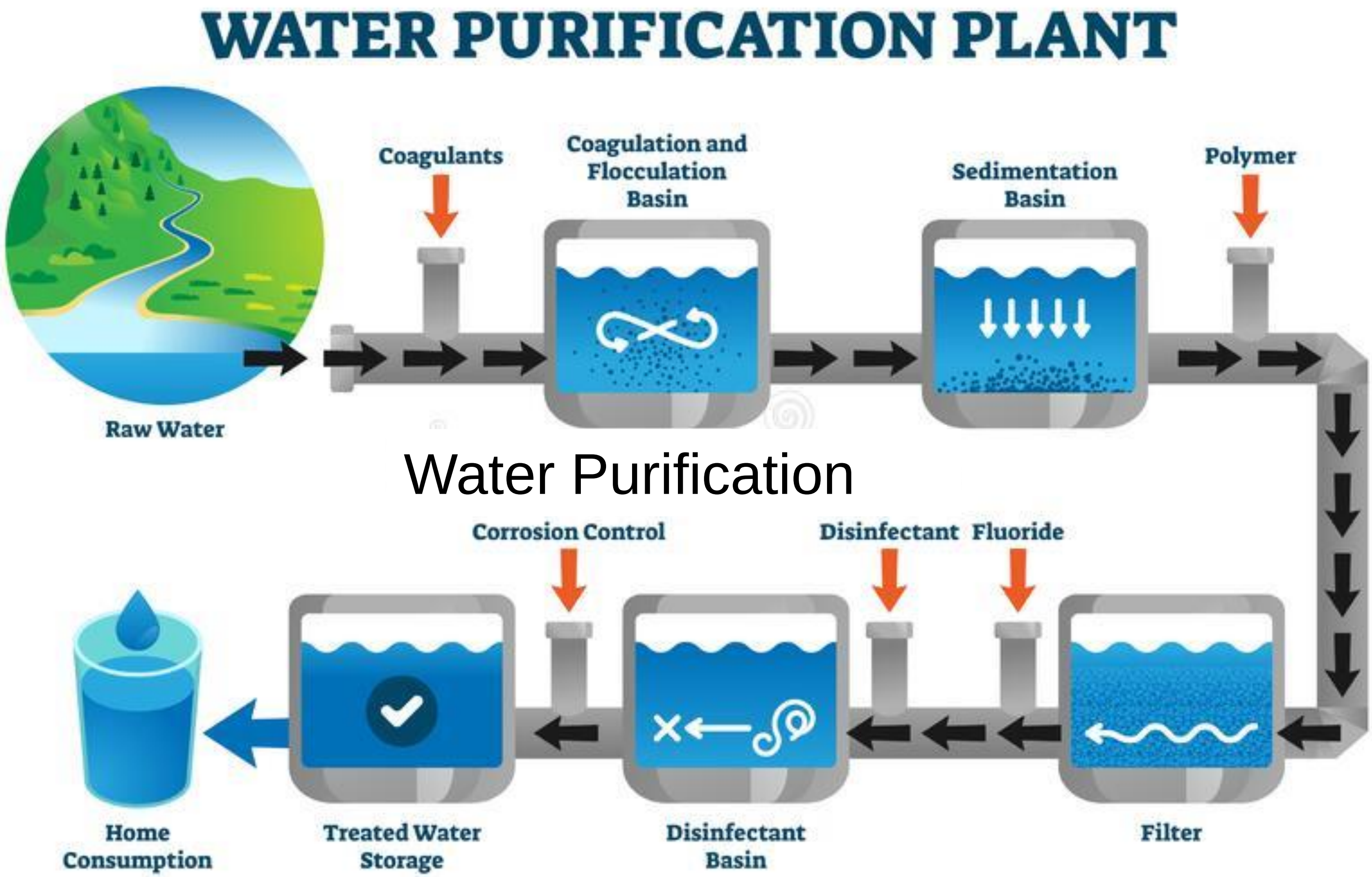


Water Treatment Process





Drinking Water Purification Process in Filter



Water Purification