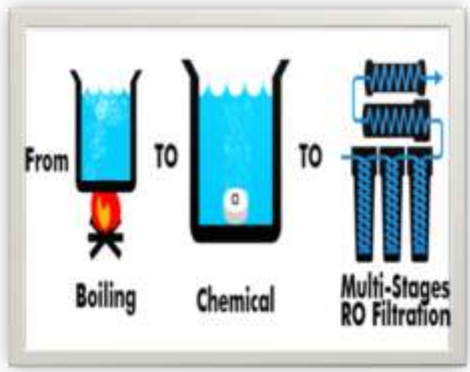
UNIT - 4



ADVANCED WATER TREATMENT

AERATOR

Aerators are various devices used for aeration, or mixing air with another substance, such as soil or water.

- **AERATION** - process in which water is brought in contact with air, where oxygen is absorbed and carbon dioxide gas is removed.
- Kills bacteria to a certain extent.
- Also removes H_2S gas, iron and manganese to some extent from treated water.

Types of Aeration

Spray Nozzles

- Breaks water into droplets
- Dissolved gases escape
- CO_2 – 90% removed

Cascade Aerator

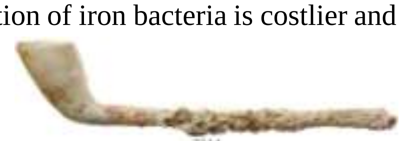
- Water fall height – 1 to 3m
- Step fall – 0.15 to 0.3m
- Also called *Freefall aerator*
- Large quantity – Small area
- Simple to clean – durable
- Must be in open air
- Efficient in raising DO
- CO_2 – 60 to 70% removal

Diffused Aerator

- Compressed air is bubbled
- Perforated pipes
- Placed at the tank bottom
- Pressured air mixes with water

IRON AND MANGANESE REMOVAL

- Iron and Manganese – dissolved together in well water or anaerobic reservoir water – invisible dissolved form.
- Permissible limit – Iron: 0.3 mg/l, Manganese: 0.1 mg/l
- Effects when limit exceeds in water,
  - Discoloration of clothes
  - Encrustation of water mains – deposition of ferric hydroxide and manganese oxide
  - Unpleasant taste of water
  - Growth of autotrophic bacteria on reduced iron content
  - Periodic flushing helps in removing accumulated rust particles
  - But elimination of iron bacteria is costlier and difficult



- Iron and manganese may present in combination with organic matter or without.
- When present in free form it can be removed by *aeration* process followed by coagulation, sedimentation and filtration.
- **Aeration** – soluble ferrous and manganous compounds in water gets oxidized and settles down as ferric and manganic salts.
- When present in combination, it is difficult to break and if it is done, above process is continued to remove them from water.

Breaking of bond

Addition of *Lime*

thereby pH increased

till 8.5 to 9

Or

Addition of *Chlorine* or *Potassium permanganate*

Or

Manganese zeolite – natural green sand coated with manganese dioxide

Defluoridation

- F Source – drinking water – PL: 1 mg/l
- 96 – 99% combines in bones – becoz fluoride has affinity to Calcium phosphate in bones
- Excess fluoride intake – *Dental fluorosis, Skeletol fluorosis and Non-skeletol fluorosis*

  Dental – Discoloured, blackened or chalky white teeth

  Skeletol – Bone & joint deformation

  Non-skeletol – Intestine & Neurological disorders
- Fluoride – Damages foetus and children IQ
- Excess fluoride – India & Bangladesh

Defluoridation mechanisms

1. Prasanti Technology – Adsorption by Activated Alumina
2. Ion Exchange Adsorption method
3. Nalgonda Technique
4. Reverse Osmosis Process

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Department of Civil Engineering

Prasanti Technique

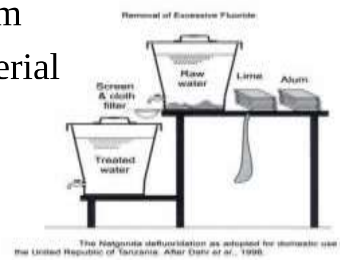
- Water passed into insoluble granular beds (AA)
- Activated Alumina – Excellent medium – Uneconomical
- Adsorption takes place in slight acidic condition
  pH – 5 to 7
- AA – regenerated by backwashing with caustic soda solution (NaOH – 1%)

Ion Exchange Adsorption

- Same as hardness removal process
- Zeolite – strong base anion exchange resin
- Water is passed through anion bed
- Fluorides, arsenic, nitrates etc., gets exchanged with chloride ions in the resin
- Thus chlorides are released and fluoride is adsorbed into resin
- Bed is regenerated by backwashing with 5 to 10% brine (Sodium chloride) solution
- Plant capacity range: 500 l/h – 5000 l/h

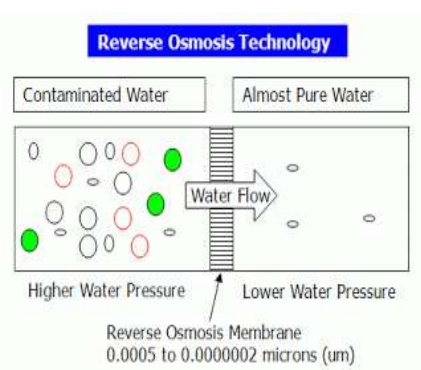
Nalgonda Technique

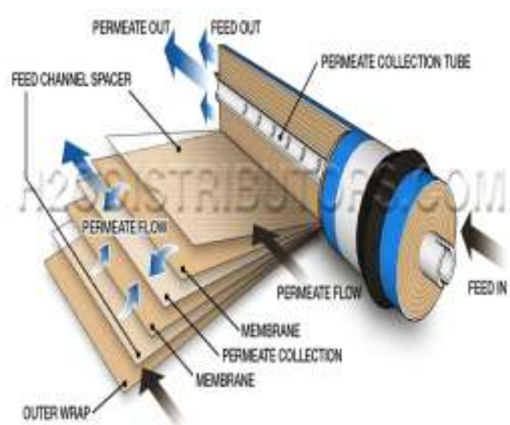
- Adopted in Indian rural areas
- Simpler and economical – No regeneration
- Removes fluoride with colour, odour, turbidity, bacteria and organic contaminants in water
- Defluoridation material – Aluminium salt (alum)
- Addition of lime followed by Alum
- 10 min stirring – precipitated material is discarded

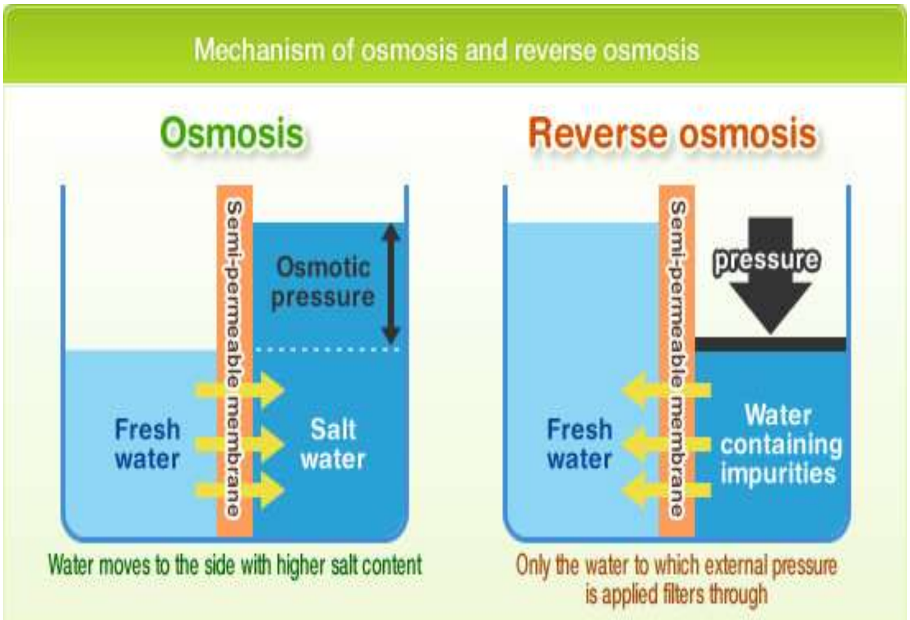


Reverse Osmosis

- Mostly used for *Desalination*







Demineralization

- Removal of *Minerals* - Also called *de-ionised water*
- Water passes – cation exchange resin – Anion exchange resin

<u>Cation Exhange Resin</u> process

$Ca(HCO_3)_2 + H_2R \longrightarrow CaR + 2H_2O + 2CO_2$

(Fresh cation) (Exhausted resin)

$CaCl_2 + H_2R \longrightarrow CaR + 2HCl$

$MgSO4 + H_2R \longrightarrow MgR + H_2SO_4$

$2NaCl + H_2R \longrightarrow Na_2R + 2HCl$

Anion Exhange Resin process

$ROH + HCl \longrightarrow RCl + HOH$

(Fresh anion) (Exhausted resin) (water)

$2ROH + H_2SO_4 \longrightarrow R_2SO_4 + 2HOH$

(Fresh anion) (Exhausted resin) (water)

Regeneration of Cation Exhange Resin process

$Ca/Mg/Na_2\{ R + 2HCl \longrightarrow H_2R + Ca/Mg/Na_2\{ Cl_2$

(Exhausted Cation resin) (Regenerated Cation resin)

OR

$Ca/Mg/Na_2\{ R + H_2SO_4 \longrightarrow H_2R + Ca/Mg/Na_2\{ SO_4$

(Exhausted Cation resin) (Regenerated Cation resin)

Regeneration of Anion Exhange Resin process

$RCl + Na_2CO_3 + 2H_2O$

(exhausted anion resin)

$\searrow$

$2ROH + 2NaCl + CO_2\uparrow + H_2O$

(Regenerated anion resin)

Water Softening

- Removal of *Hardness*
- Merits – reduction in soap consumption, lowers plumbing equipment maintenance cost, improves food taste.
- Mainly carried out in industrial sector to reduce scale formation
- Types: Temporary & Permanent hardness
- Temporary – caused by Carbonates & bi-carbonates of Calcium & Magnesium
- Permanent - caused by Sulphates, Nitrates & Chlorides of Calcium & Magnesium

Temporary hardness removal methods

Boiling of Water

Calcium carbonate – slightly soluble in water – present in the form Calcium bicarbonate becoz, it easily dissolves in water containing CO_2.

$$Ca(HCO_3)_2 + Heat \longrightarrow CaCO3\downarrow + CO_2\uparrow + H_2O$$

Magnesium bicarbonates & carbonates – unsatisfactory in removing by this method – Not suitable for large scale boiling – removes only temporary hardness – not adopted for softening

Addition of Lime (CaO)

Hydrated lime [$Ca(OH)_2$] is added to water

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

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Ca(HCO_3)_2 + Mg(OH)_2\downarrow$$

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

Suitable only for Temporary hardness removal process

Permanent hardness removal methods

1. Lime-Soda process

2. Base-Exchange process, generally called *Zeolite process*

3.Demineralization process

Lime-Soda process

Lime [$Ca(OH)_2$] & Soda ash [Na_2CO_3] added to hard water

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Ca(HCO_3)_2 + Mg(OH)_2\downarrow$$

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

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

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

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

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O$$

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaCl$$

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

Recarbonation process

Little amount of sediments – causes enlargement of sand grain in future – *Incrustation of filter media* – Recarbonation – insoluble carbonates converted to soluble carbonates

$$CaCO_3 \downarrow + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$$

$$Mg(OH)_2 + CO_2 \longrightarrow MgCO_3 + H_2O$$

$$MgCO_3 + CO_2 + H_2O \longrightarrow Mg(HCO_3)_2$$

Zeolite or Base-Exchange or Cation exchange process

Zeolite – termed as *Green sand* – $Na_2O\ Al_2O_3\ x.SiO_2\ y.H_2O$

Zeolite or Resins have excellent property of exchanging their cations and hence during softening operation, the sodium ions of the zeolite get replaced by the calcium and magnesium ions present in hard water.

$$\begin{bmatrix} Ca \\ Mg \end{bmatrix} \cdot \begin{bmatrix} SO_4 \\ 2Cl \\ 2HCO_3 \end{bmatrix} + Na_2 \cdot Z \longrightarrow Z \cdot \begin{bmatrix} Ca \\ Mg \end{bmatrix} + \begin{bmatrix} Na_2SO_4 \\ 2NaCl \\ 2NaHCO_3 \end{bmatrix}$$

$$CaCl + Na_2Z \text{ --------->} CaZ + 2NaCl$$

$$MgCl + Na_2Z \text{ --------->} MgZ + 2NaCl$$

$$CaSO_4 + Na_2Z \text{ --------->} CaZ + Na_2SO_4$$

$$Mg_2SO_4 + Na_2Z \text{ --------->} MgZ + Na_2SO_4$$

$$Ca(HCO_3) + Na_2Z \text{ --------->} CaZ + 2NaHCO_3$$

$$Mg(HCO_3) + Na_2Z \text{ --------->} MgZ + 2NaHCO_3$$

- Used as filter media in sand filter (Zeolite sand bed)
- When Sodium is replaced by Calcium & Magnesium – backwashing is done – Again brine is added to regenerated the filter bed – excess brine is removed by back washing with water
- Filters – Gravity or Pressure (more common)
- Rate of filtration: 300 l/m^2/min
- Zeolite process results in *Zero hardness* – not suitable for public supplies – small amount is processed and mixed with unsoftened water to obtain standard limits

Desalination

- Water with common salt or sodium chloride – named as *Salt water or Brackish water*

Process of removing salt from water is called ***Desalination***

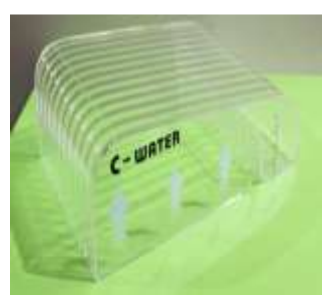
Water free from salt content is termed as *fresh water*

Salinity is described as TDS , unit is mg/l.

S.NO	Type of Water	TDS valve in mg/l
1	Sweet waters	0 – 1000
2	Brackish waters	1000 – 5000
3	Moderately saline	5000 – 10,000
4	Severely saline	10,000 – 30,000
5	Sea water	> 30,000

Methods of Desalination

1. Desalination by evaporation & distillation
2. Electro dialysis method
3. Reverse Osmosis method
4. Freezing process
5. Solar distillation method
6. Other methods



Choice of Desalination Process

S.NO	Desalination process	TDS valve of salt water to be treated in mg/l
1	Ion exchange	Up to 500
2	Electro dialysis	500 - 3000
3	Low pressure osmosis including UF	1000 – 10,000
4	High pressure reverse osmosis	10,000 – 30,000
5	Distillation	> 30,000

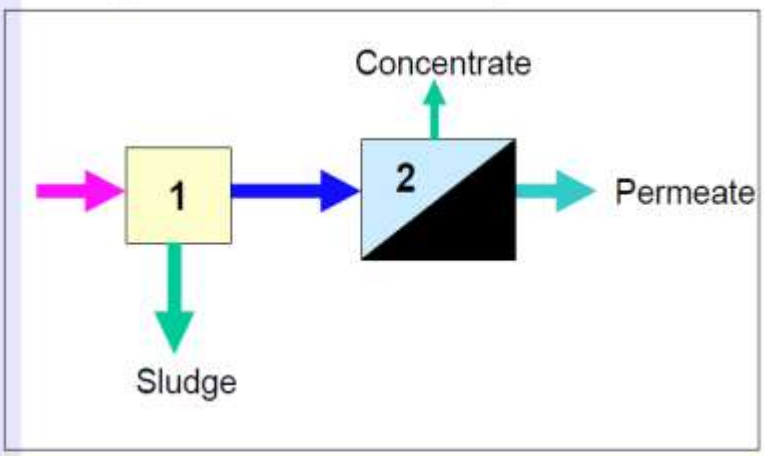
MEMBRANE SYSTEMS

- Micro filtration
- Ultra filtration
- Nano filtration
- Reverse osmosis

Physical separation

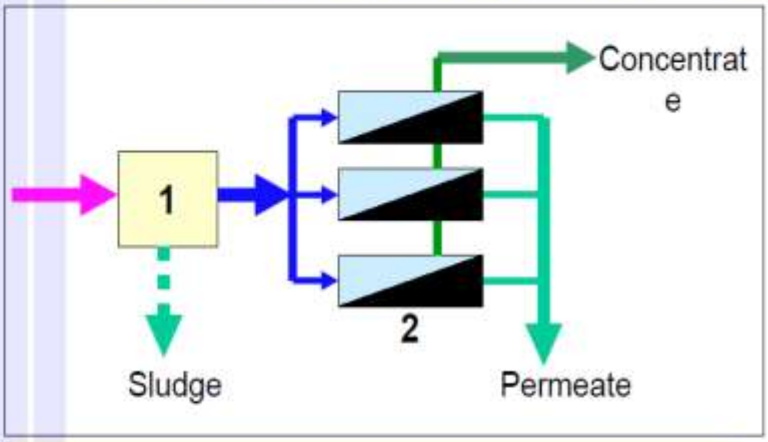
- Single membrane operation
- Multiple membrane operations
- Hybrid conventional treatment system + membrane operation

Single Membrane Operation



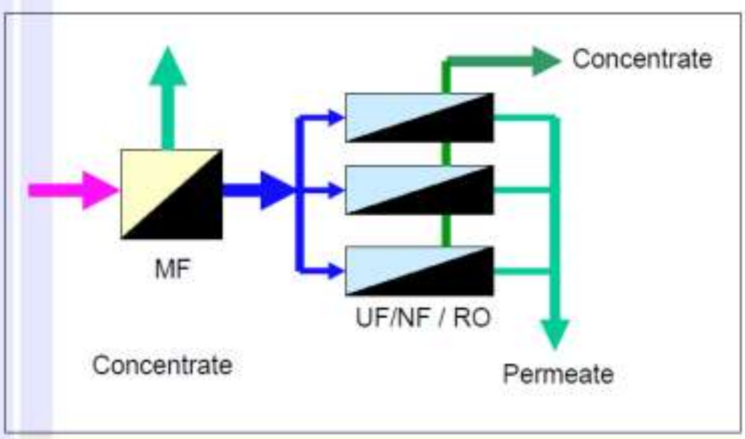
(1) Pretreatment unit (2) Membrane unit (s)

Single Membrane Operation



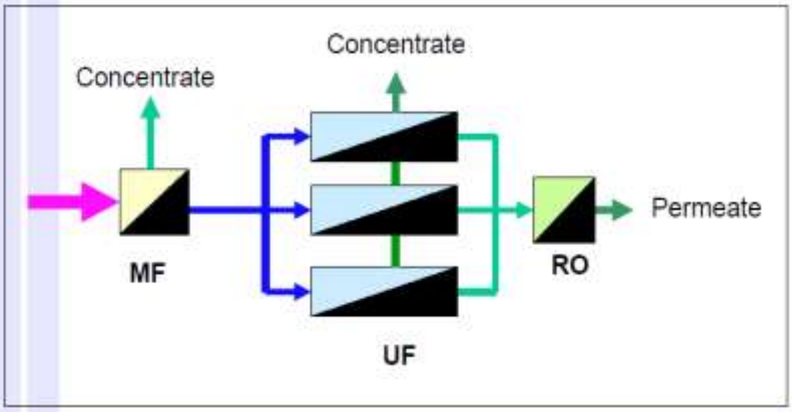
(1) Pretreatment unit (2) Membrane unit (s)

Multiple Membrane Operations



Normally, first with UF, followed by UF, NF and RO

Multiple Membrane Operations



Normally, first with UF, followed by UF, NF and RO

Microfiltration

- Exact pore size is a matter of debate
- Generally – filterable of *0.02-10* micron
- Particles, colloids, microorganisms (incl. *bacteria and virus*)
- Larger flux compared to UF, NF or RO
- Separation based on *sieving process* (or also known as surface filtration)
- Opposite to surface is depth filtration
- Operation pressure: 50 to 500 KPa

Membrane permeability

Permeability = (filtration rate ÷ area) × pressure difference

Microfiltration systems

Components

- Piping systems
- Pumps
- MF modules
- Pressure gauges
- Feeding and permeate tanks
- Control systems
- Pretreatment facilities

Ultrafiltration

Introduction

- Sieving process for separation (similar to MF)
- Almost similar pressure range as MF
- Major difference with MF: pore size (MF > 0.1μm)
- For water treatment, UF is used as clarification and disinfection operation, MF as treatment
- Remove all types of bacteria and virus
- Operating pressure: 50 to 500 KPa

Reverse Osmosis

- RO is a pressure-driven operation in which the solvent of the solution is transferred through a dense membrane tailored to retain salts ad low-molecular-weight solutes.
- If a concentrated saline solution is separated from pure water by RO, the difference in chemical potential tends to promote the diffusion of water from the diluted compartment to the concentrated compartment in order to equalize the concentrations.

Reverse Osmosis

- At equilibrium, the difference in the levels between the 2 compartments corresponds to the osmostic pressure of the saline solution.
- To get economical and viable flow, at least twice the osmotic pressure must be exerted
- For sea water, pressures of 5 to 8 MPa are used

Nanofiltration

(Also known as low-pressure RO)

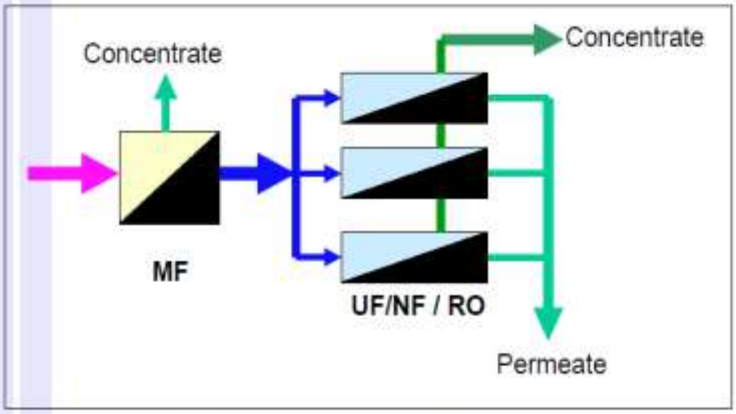
- Lies between RO and UF in terms of selectivity
- Removal of multivalent ions and organics
- Monovalent are poorly rejected (requires RO)
- NF leads to osmotic backpressure which is much lower than RO
- Pressure: 0.5 to 1.5 MPa

Applications of Nanofiltration

(Also known as low-pressure RO)

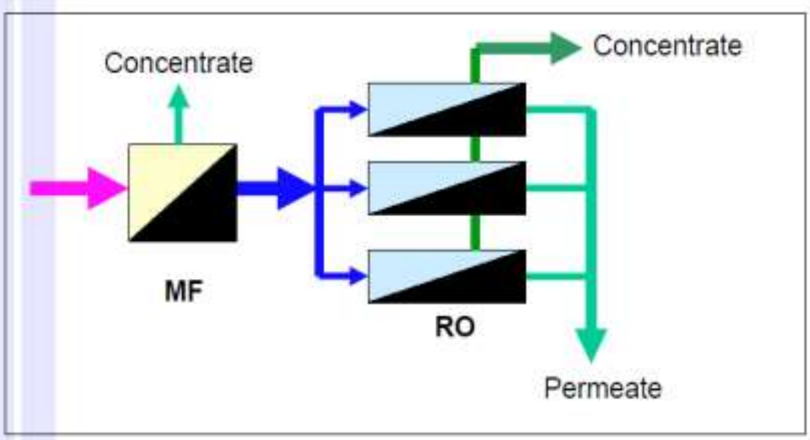
- Water softening
- Removal of organic matters, esp. NOM
- Removal of multivalent ions
- Desalting of organic reaction products
- Removal of arsenic and other metals
- Removal of endocrine disrupting chemicals

Multiple membrane operations for surface water



Normally, first with MF, followed by UF, NF and RO
(depends on the treatment objectives and quality of feed water)

Multiple membrane operations for seawater



Normally, first with MF, followed RO

Conclusions

- Membrane technology is well accepted in high quality of drinking water production
- Membrane technology is growing fast and very instrumental for the protection of public health and consumers' needs

Construction, Operation and Maintenance Aspects of water treatment plant

Construction aspect:

- **Must follow building code of practice when installing**
- **Use of materials is also need to followed as per standards**
- **Proper material and workmanship**
- **Pipe diameter, threads, wall thickness, pressure class, corrosion protection, hoop stress, buried depth, surge protection, thrust restraint, pipe bedding, and jointing should all be considered.**

Construction, Operation and Maintenance Aspects of water treatment plant

O & M aspect:

Tasks can be broken down into daily, weekly, monthly, and seasonal repeats.

Daily Tasks

- Check water meter readings and record water use.
- Check and record water level indicators in reservoir/storage tanks.
- Check and record chlorine level in the distribution system.
- Inspect chemical feed pumps for proper operation.
- Inspect well pumps, motors, pressure gauges, and controls. Record well pump running times and pump cycle starts.
- Record and investigate customer complaints.
- Inspect heater operation during winter months.

Construction, Operation and Maintenance Aspects of water treatment plant

Weekly Tasks

- Inspect chlorine testing equipment.
- Check chemical solution tanks and record use.
- Clean pump house and grounds.
- Make sure fire hydrants are accessible.
- Record pumping rate for each well or source water pump.
- Inspect pump house plumbing for leaks.
- Take bacteriological sample in for testing (required testing frequency may vary —check with your local health authority).

Construction, Operation and Maintenance Aspects of water treatment plant

Monthly, Seasonal, or Annual Tasks

- Take and record electrical meter readings at pump house.
- Inspect well head or intake structure.
- Inspect reservoir.

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