# COMPENDIUM OF WATER TREATMENT TECHNOLOGY

**A thesis submitted towards partial fulfillment of the requirements for the degree of**

**Master of Engineering in**
**Water Resources and Hydraulic Engineering**
Course affiliated to Faculty of Engineering & Technology
Jadavpur University

**Submitted by**

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## CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"COMPENDIUM OF WATER TREATMENT TECHNOLOGY''** is bonafied work carried out by **Rabindra Nath Samanta** under my supervision and guidance for partial fulfillment of the requirement for Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2018-2019

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**This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a pre-requisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.**

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as a part of my Master of Water Resources & Hydraulic Engineering degree during academic session 2018-2019.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred all material and results that are not original to this work.

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# ABSTRACT

The other name of water is life. Water not only essential for human being but also for all living body animals and plants also. For modern civilization not only sufficient quantity of water necessary and good quality and should not contain impurity, harmful chemical and bacteria also. So, human treated the natural sources of water at their need. So from the ancient time scientists and researchers invented lots of process and method according to the raw water quality. There are several unit of operation for each treatment process. In this paper all of the process discusses the salient features in brief. A small discussion kept about the scenario of water available in world and in India. The quality scenario in India of different sources in ground water and surface water also discussed. A brief list and methodology of each unit of process incorporated in this paper. There are several special technique invented and applied now a days for removing and reducing the impurity such as arsenic and floride content in the water. To meet up the industrial need several special treatment invented to improve the water quantity such as different membrane filtration micro filtration (MF),ultra filtration(UF), nano filtration (NF), reverse osmosis( RO), electro dialysis (ED/EDR) demineralization (DM) etc . also discuss a small area. All the method collected as compendium of water treatment in this paper and will be helpful.

# Index of Thesis

## CONTENTS

# CHAPTER – 1

## Introduction / Background

Water is absolutely not only essential for survival for human beings but also for animals, plants and all other living beings. Furthers more it is necessary that the water requires for their needs must be good and it should not contains unwanted impurities or harmful compounds, minerals or bacteria in it. So, from the ancient time to modern days humans collect the water from different sources make it suitable for the society as per need. So, human are developing different method / process by applying natural, or using different chemicals. Each process has merit/demerits, different time, and cost accepts. Therefore I try to concise the different information of water treatment.

The total quantity of water in the world is about 1386 BCM. Out of this 96.5% water are saline and contained at sea. Some water in land also saline. Only 2.5% water are fresh water. Out of the total fresh water 30% from the groundwater, while the rest is stored in distant glaciers, ice sheets, mountainous areas, places that we can hardly access. So, the fresh water scenario is at ice stage in mountain and glacier 68.9%, Ground water 29.9%, river and lake 0.3%, soil moisture 0.9%. This is the scenario of global water distribution when no intervention is anticipated. It is also observed that only 0.047 BCM water is the runoff overflow the land mass to ocean and ground water outflow to ocean. Only 4 % of the river water utilized for irrigation and rest flow to the ocean. Even the usable water also very scatter way in place and season also. Though the earth is called blue planet, a very small part we can used for our daily need.

By 2025, an estimated 1.8 billion people will live in areas plagued by water scarcity, with two-thirds of the world's population living in water-stressed regions. 780 million people live without clean drinking water. More than one-third of Africa's population lacks access to safe drinking water. Compared to today, five times as much land is likely to be under "extreme drought" by

2050.More than two billion people worldwide rely on wells for their water.25-33% of Chinese do not have access to safe drinking water.

Water pollution is a serious problem in India as almost 70 per cent of its surface water resources and a growing percentage of its groundwater reserves are contaminated by biological, toxic, organic, and inorganic pollutants. In many cases, these sources have been rendered unsafe

for human consumption as well as for other activities, such as irrigation and industrial needs. This shows that degraded water quality can contribute to water scarcity as it limits its availability for both human use and for the ecosystem. Besides a rapidly depleting groundwater table in different parts, the country faces another major problem on the water

front—groundwater contamination—a problem which has affected as

many as 19 states, including Delhi. Salinity, iron, fluoride, and arsenic have affected groundwater in over 200 districts spread across 19 states. So, treated water is necessary for the society for human, animals and for industry also. The treatment method and size may vary according to demand of quantity and quality. A major part of people lives in village and the method should be suitable for domestic use.

## CHAPTER – 2
# Literature Review

- Details information data in all the matter available and helpful in Wikipedia.

- Central Water Commission Report enriches details information of water in India including sources catchment area. The map of rivers basin guided in this paper.

- DYNAMIC GROUNDWATER RESOURCES OF INDIA Report enriches details information of ground water in India including the ground water level. The map of ground water sources available and helpful.

- In the Handbook for the Operation of Water Treatment Works, SCHUTTE 2007 the detail unit of operation and others information help me to prepare the paper.

- In this book Water Supply Engineering, S.K.Garg the different process and detail design criteria drawing also help very much.

# CHAPTER – 3
# Objective / Scope of Work / Methodology

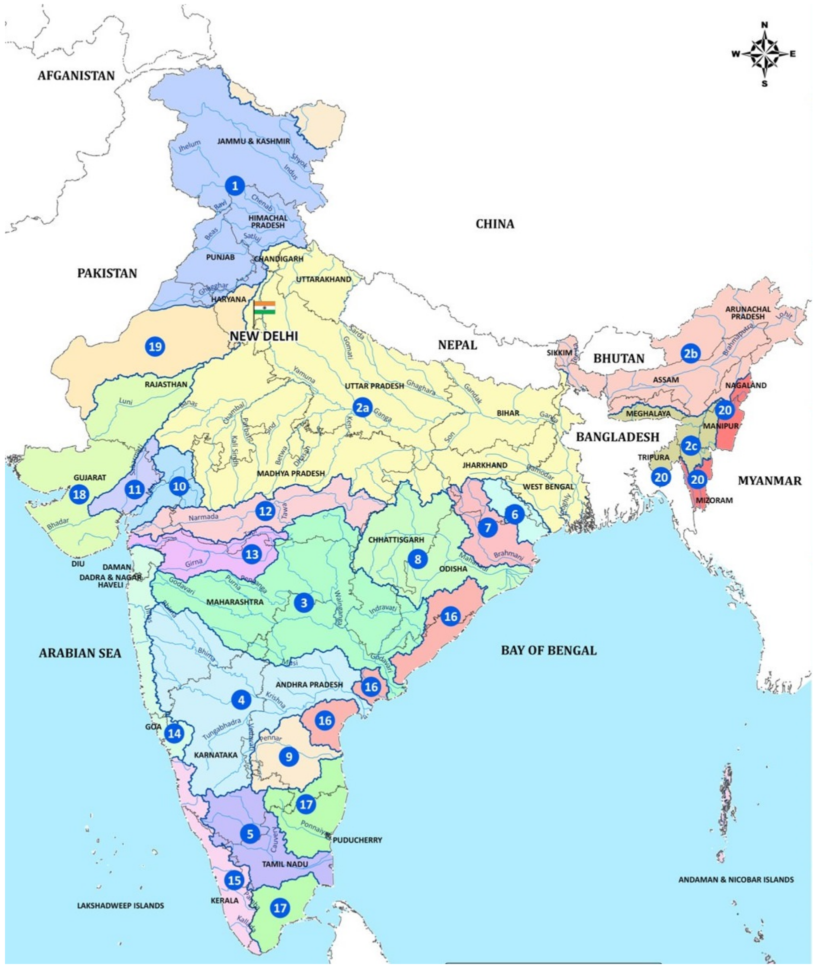
There are several method/process for treatment the raw water. The sources of water supplied for treatment mainly surface water and other is ground water. The unit process for treatment mainly depends upon the characteristics and quality of water. The quality of treated water also have a great role in the treatment process. As the raw water quality characteristics varies a wide range in season even in day time also and the demand of treated water also varied as required quality the treatment process also varied. Therefore it is necessary to concise the different method/process according to their suitability, quality, quantity, and cost. The document's popularity lies in its brevity – structuring and presenting a huge range of information on tried in a single document.

There is a huge scope to work in this field as a large nos of method /process and research paper available in this purpose. All of are suitable for the specific purpose and raw water condition and quality necessary. More over regular invention is doing regularly. Here I try to collect the data of different process and brief discussion in this paper.

Collect all the data from different book, research paper, and internet and synchronies the information and written in this paper.

## CHAPTER – 4

# Water Quality: Scenario in India




India is situated north hemisphere between 8°04' to 37°06' north latitude and 68°07' to 97°25' east longitude India is the 7th. Largest country but 2nd. most populated country in the world of area 328.73 M ha. India measures 3,214 km from north to south and 2,933 km from east to west. It has a land border of 15,200 km and a coastline of 7,516.6 km. India is bounded by the Arabian Sea on the west, the Bay of Bengal on the east, and the Indian Ocean proper to the south. In north the Himalayan mountain range, where the country borders China, Bhutan, and Nepal ,Pakistan In east, its border divided with Bangladesh Mayanmar.

In India there are twenty two major river basins (CWC, 2015) flowing surface water. Out of these twenty two twelve are major river basin (catchment area more than 20,000 sq. km.) spreads over 81% of geographical area of India of 2600 M ha. There are 46 medium river basins (catchment area less than 20,000 sq. km.) in India comprising 24.6 M ha.

As per Central Ground Board of India the dynamic ground water resources in India as reported on 31$^{st}$. march 2013 publish in June 2017 are as follows.

1. Total Annual Replenishable GroundWater Resources447 bcm

2. Net Annual Ground Water Availability 411 bcm

3. Annual Ground Water Draft 253 bcm

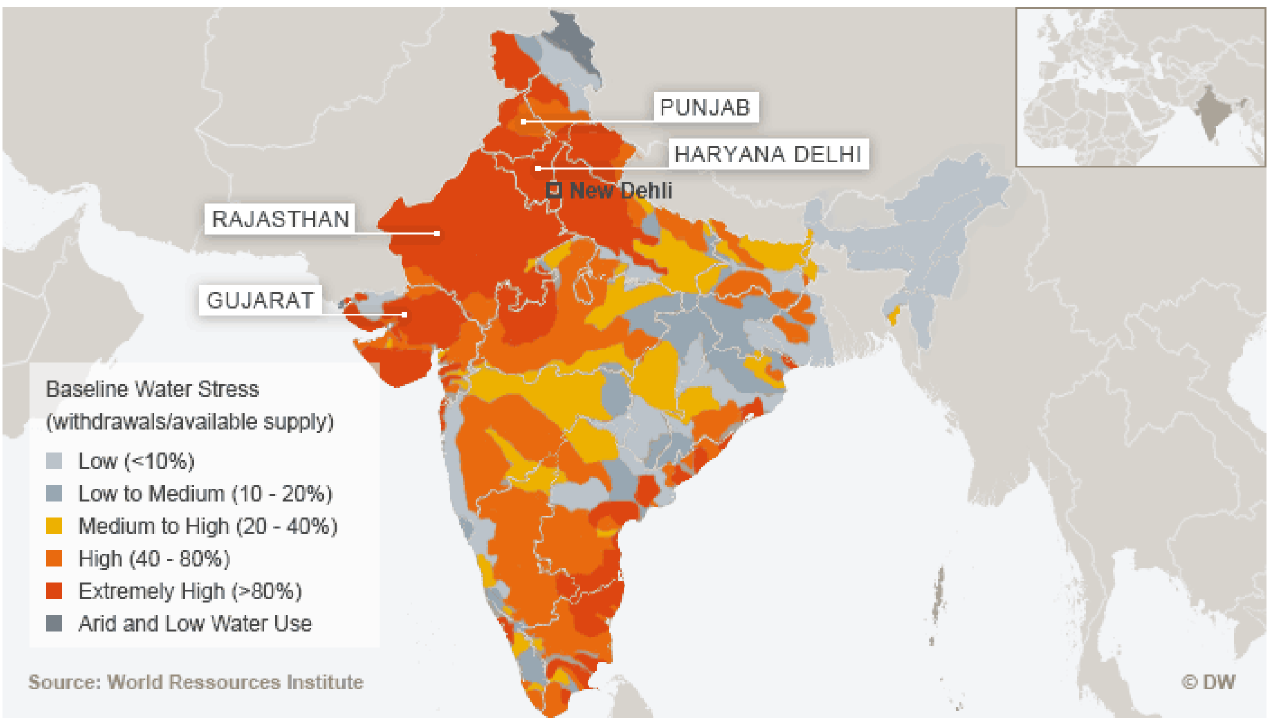
The total consumption of water is one third of ground water even more than 50% in rural area.

**Water Quality**

Water quality is the most important criteria for water supply to the consumer of basic requirements for potable purposes(safe for human consumption).So one must consider both a precise analysis of the raw water supply and the end use of the water. The raw water must be analysis the water in physical characteristics i.e. turbidity, color, taste and odor, chemical impurities i.e. dissolved minerals, gases , organic and inorganic matters and Microbiological Impurities. Whether any of these impurities could be harmful or undesirable depends on the nature and amount of the impurities. There are tremendous variations in the quality of water depending upon source, geography and season (time) of the year. In some cases there are variations in quality even on a day to day basis.

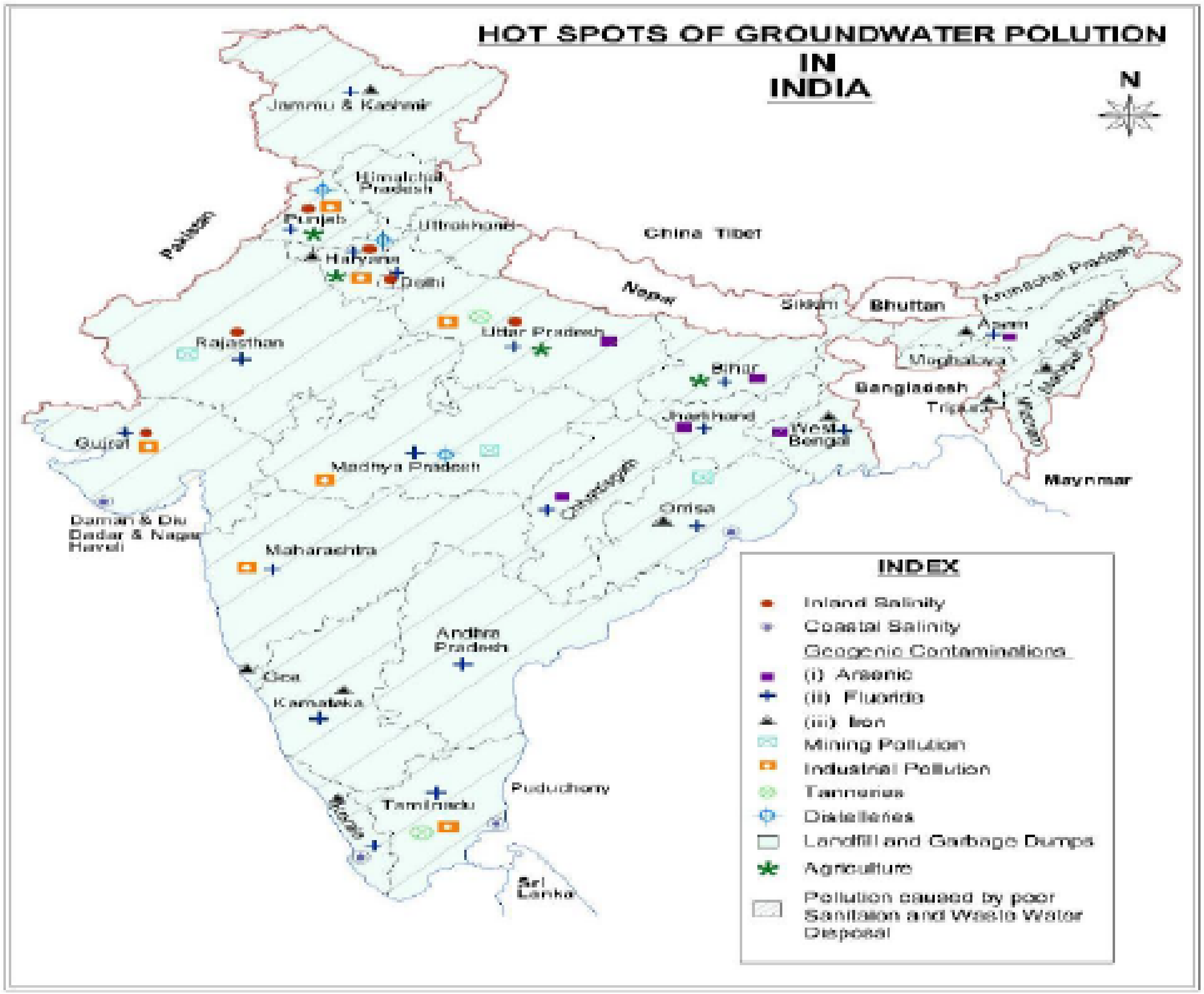
A given quality of water that is unacceptable for one function may prove satisfactory for another.

## Surface Water




The sources of surface water are lakes, reservoir, ponds, rivers, sea. Normally when water reaches on the earth through rain , snow, slit etc. it is slightly acidic, corrosive and relatively soft. Surface waters contain many impurities such as silt, sand and clay –which give them a muddy or muddy appearance. Surface waters are relatively low in mineral content, but normally possess a high degree of physical& microbiological contamination, and may require treatment to make them potable.

## Ground Water




Ground water must pass through various strata in sub surface as groundwater. The surface water moves sub soil and different layer through pores of strata and stored in under ground. It is usually clear and colorless due to filtration through rock and sand. Ground water supplies are usually higher in mineral content than surface waters in the same area.

The nature and kinds of impurities vary widely in different sections of the country as the rocks and sand in the soil consists of many kinds of minerals and chemical substances. Usually, shallow wells will not contain as high an amount of hardness and other dissolved materials as deep wells. Groundwater lifted from deep strata generally contains high concentrations of dissolved minerals like calcium, iron, magnesium etc. Many ground waters are contaminated with disease causing minerals like fluoride, arsenic, nitrate also. Water from springs a source of ground water is generally clear, sparkling and absolutely pure. In reality spring waters may contain large amounts of mineral matter considerable turbidity.

## Water Quality Scenario in India

Pollution of water both surface and ground is the major concern which is affecting the water supply as well as human health conditions. All most all sewerage effluent from different municipality discharged in the river without proper treatment and polluted the surface water. The industrial effluent does same thing. Excessive fertilizer and pesticide also and polluted both the surface water and ground water. It is reported that over 70% of the water consumed by rural population in India does not meet the WHO standards. It has been reported that 80% of rural illnesses,21% of transmissible diseases and 20% of deaths among children in the age group of 5 years, are directly linked to consumption of unsafe water. The different mineral, fluoride, nitrates metal iron, magnesium and harmful heavy metal arsenic level in ground water which can spell disaster on the human body with long term usage are typical problems faced in some parts of our country. Fluoride above permissible limit in ground water has been reported from parts of 20 States (Andhra Pradesh, Assam, Bihar, Chhattisgarh, Delhi, Gujarat, Haryana, Jharkhand, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh and West Bengal. Arsenic in ground water was reported in sever to very sever in different parts of 10 States of West Bengal, Assam, Bihar, Jharkhand, Uttar Pradesh, Punjab, Haryana, Chhattisgarh, Karnataka & Manipur and excess limit of permissible limit in another additional 11 States in India.

**CHAPTER – 5**

# Unit of Operation

The raw water supplied for treatment invariably contains different organic and inorganic substances and also harmful pathogens. All of the impurity must be removed during the treatment process to make it fit for domestic use. For industrial purpose it must be treated and make it for particular special purpose for which it will be utilize. In the same time the raw water also contain some also some living organism which is very much harmful for the society. The main aim of treatment is to supply the society safe and potable water at minimum cost. To achieve this goal a several variety treatment process employed various physical and chemical and biological phenomena to remove or reduce the undesirable constitutes from the water.

For successful performances of the plant the selection of appropriate and effective individual process or combination of process is very much important. The appropriate has a great impact of plant future and project cost and environment also. The combination of the processes remove the turbidity, odour, taste and to disinfect the water and demineralization up to desire quality. There are great influence for selection of process are the raw water and treated water quality, quantity of water treated, seasonal variation topography and site condition, hydraulic requirement, land availability, financial support etc. A summary of several process generally used and their function listed in a tabular from below.

| Sl. No. | Unit Process | Description and Application |
|---|---|---|
| 1 | Trash rack / Coarse Screening | Trash rack/ coarse screening are provided at the intake gate for removal of floating debris Coarse screen Mechanically cleaned screens provided at the intake gate or in the sump well ahead of pumps. The coarse screening are consists of parallel iron rods placed in front of fine screens vertically or at slight slope at about 2.5 to 5 cm apart. |
| 2 | Fine Screening | The fine screen is made of woven wire mesh. It remove small solids |
| 3. | Microstrainer | Removes algae and plankton from the raw water |
| 4. | Aeration | Remove and oxidises taste- and odour-causing volatile organics and gases and oxidises iron and manganese. Aeration systems include gravity aerator, spray aerator, diffuser and mechanical aerator |
| 5 | Mixing | Provides uniform and rapid distribution of chemical and gases into the water |
| 6 | Pre-oxidation | Application of oxidising agents such as chlorine, potassium permanganate and ozone in raw water and in other treatment units to limit microbiological growth and to oxidise taste, odour and colour causing compounds as well as iron and manganese compounds. |
| 7. | Coagulation | Coagulation is the addition and rapid mixing of coagulant with the water to destabilise colloidal particles and form small flocs. |
| 8 | Flocculation | Flocculation causes aggregation of destabilised colloidal particles to form rapid-settling flocs. |
| 9 | Sedimentation | Gravity separation of suspended solids or flocs produced in treatment processes. It is used after coagulation and flocculation and chemical precipitation. |

| | | |
|---|---|---|
| 10 | Rapid Sand filtration<br><br>Slow sand filter<br><br>Pressure filter<br><br>Duel media filter | Removal of flocculated and particulate matter by filtration through granular media (normally filter sand). Multimedia may also be used (sand and anthracite, or sand and activated carbon, or a third layer may also be incorporated).<br><br>To remove of all micro organism and collide material from the water very high rate filtration passing through multilayer of granular materials at high pressure.<br><br>The Dual Media Filter utilizes combination of Filter Media and Anthracite for higher flow rates with a smaller footprint. High filtration velocities are achieved by proper selection of media, and designing of distribution and collection systems. |
| 11 | Recarbonation / Activated carbon adsorption | Addition of carbon dioxide to reduce pH of water after addition of lime for coagulation or softening. Removes dissolved organic substances such as taste and odour causing compounds and chlorinated compounds. It also removes many metals. It is used as powdered activated carbon (PAC) at the intake or as a granular activated carbon (GAC) bed after filtration. |
| 12 | Disinfection | Destroys disease-causing organisms in water. Disinfection is achieved mainly by chlorine, but ultraviolet radiation and other oxidising chemicals such as ozone and chlorine dioxide are also used Chloramination Ammonia converts free chlorine residual to chloramines. In this form, chlorine is less reactive, lasts longer and has a smaller tendency to combine with organic compounds, thus limiting taste and odour. |
| 13 | Fluoridation / Deflori dation | Addition / reduction of sodium fluoride, sodium silicofluoride or hydrofluosilicic acid to produce water that has optimum fluoride level for prevention of dental caries. |
| 14 | Softening | To remove or reduces the permanent hardness a special type of treatment employed generally called softening. The main three process are<br>i)Lime soda process<br>ii) Base exchange process ( Zeolite process )<br>iii) Demineralization process |

| | | |
|---|---|---|
| 15 | Desalination | Involves removal of dissolved salts from the water supply. Desalination may be achieved by membrane processes, ion exchange and distillation. |
| 16 | Reverse osmosis (RO) | High-quality water permeates very dense membrane under pressure while dissolved solids and some organics are prevented from permeating the membrane. RO is also used for nitrate and arsenic removal. |
| 17 | Nanofiltration (NF) | Less dense membranes (than RO) are used for removal of divalent ions (softening), micro-organisms and organics from water under pressure. |
| 18 | Ultrafiltration (UF) | Removal of colloidal material and some micro-organisms from water by membranes under pressure. |
| 19 | Microfiltration (MF) | Removal of all particulate matter and some colloidal matter |
| 20 | Electrodialysis (ED / EDR) | An electrical potential is used to remove cations and anions through ion-selective membranes to produce desalinated water and brine. Distillation Used mostly for desalination of seawater. |
| 21 | Ion exchange (IX) | The cations and anions in water are selectively removed when water is percolated through beds containing cation and anion exchange resins. The beds are regenerated when the exchange capacity of the beds is exhausted. Selective resins are available for hardness, nitrate and ammonia removal. |
| 22 | Arsenic Removal | To remove the heavy metal arsenic from water this causes carcinogenic affect. There are many process for this purpose mainly i) coagulation and flocculation ii) oxidation iii) ion exchange iv ) membrane filtration v) adsorption |

## CHAPTER – 6
## Surface Water Based Water Treatment Technologies

The raw water collected from different sources for treatment to make suitable for desired purpose. The sources mainly divided in two types.

a) Surface water sources
b) Underground sources

Sometimes the both surface and ground water can be used at same time to control quaintly and quality.

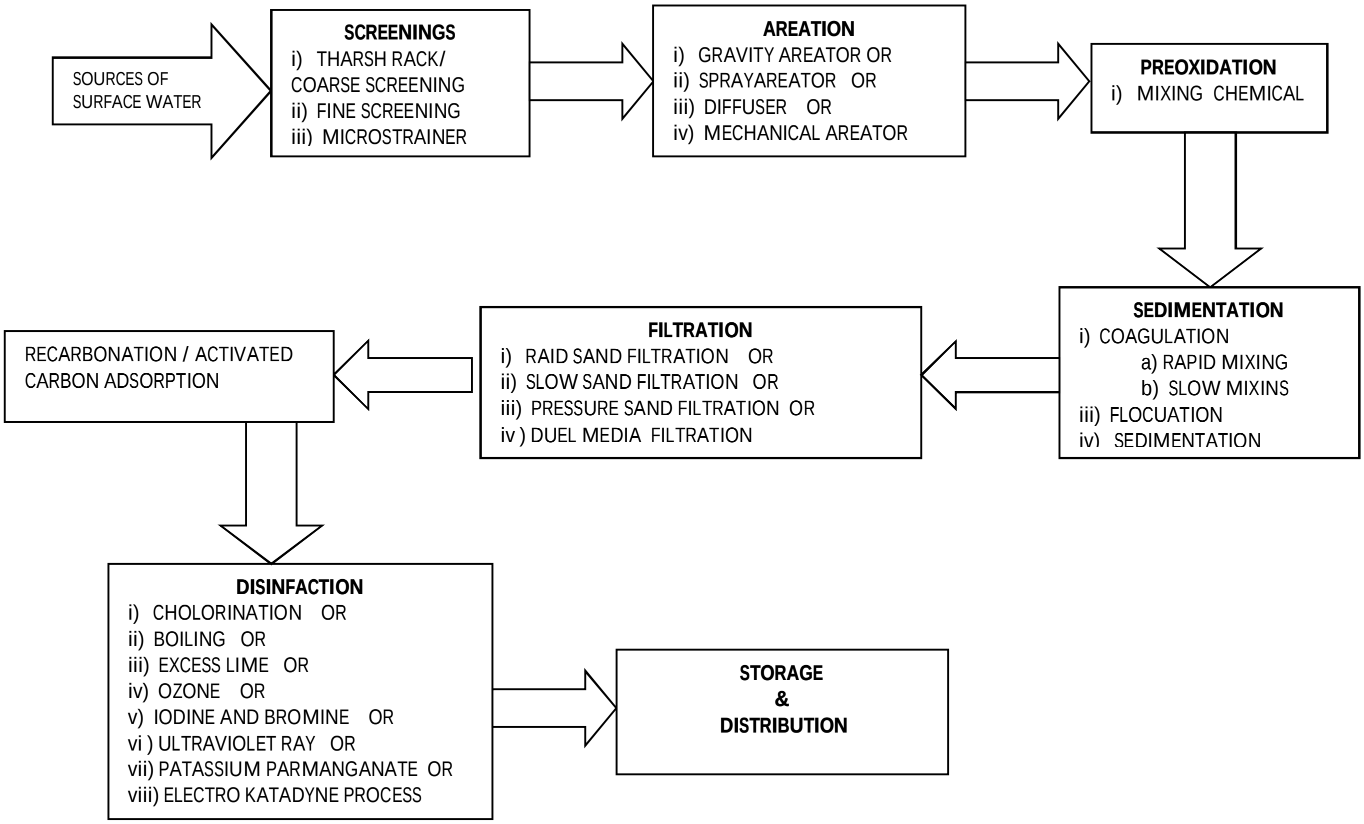
The surface water may be available different sources :-

i) Rivers and streams
ii) Lakes and pond
iii) Storage reservoir
iv) Oceans

The raw surface water supplied for treatment contains different organic and inorganic substances as follows.

a) Floating debris like trees, branches, sticks vegetation, fish, animal life, dead body etc.
b) Coarse suspended solids.
c) Finer suspended particle)
d) Collide particle
c) Algae
d) Living organism, pathogenic bacteria etc.

By removing or reducing the desirable compound and the water make safe, good in appearance, attractive to human taste and tongue. It also be suitable for industrial purpose like steam generator, dyeing, brewing etc. Hence a series of unit process adopted required upon the characteristics and quality of raw water available.




## OVERVIEW OF SURFACEWATER TREATMENT PROCESSES

For water treatment from a surfacewater source a series of unit processes adopted to chive the desirable quality water.

## A. SCREENING

The aimedto removing the floating debris such wooden log, branches of trees coarse particle algae etc.

I) TRASH RACK / COARSE SCREENINGS:

Trash rack / coarse screens are provide in front pump or intake structure to restrict the entering the large debris like wooden log, branches of tree, animals bushes etc. into the pump. A series of iron rods welded and provided vertically or slightly sloped position to resist the bigger floating bodies and Organic solids. The screens should sufficient area so that the velocity should be sufficient more than 0.8 to 1 m/ sec to avoid sedimentation. The materials collected at up streams of the coarse screens and removed, cleaned in regular interval. The cleaning process done by mechanical or manually removed at this stage.

**ii) . FINE SCREENS:**

The fine screens usually made of woven wire mesh not more than 6 mm square used to remove the finer suspended bodies.The fine screens very often clogged are to be cleaned frequently. Therefore this process is not used now a days to avoid the problems.

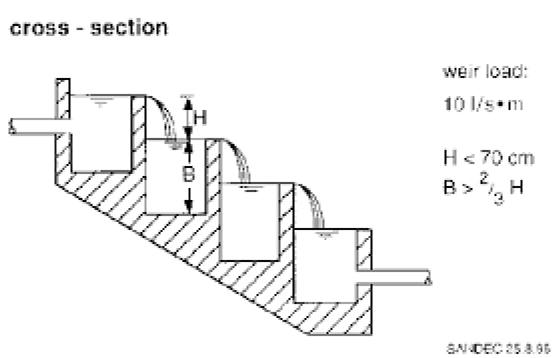
## iii) MICROSTRAINERS:

Micro strainers are provided to remove the algae and plankton from the raw water. This unit of process also not practicable and not used now a days.

## B. AEREATION

Aeration is the processes of bringing water and air into close contact in order to remove the dissolved gases such as sulpher dioxide, methane, carbon dioxide it oxidized the dissolved metal such as iron, manganese. It also removes the volatile organic chemical in the raw water. Practically it is the first step of water treatment to modify the raw water for treatment process. It increase the dissolved oxygen and remove or reduced the bad taste and odor causing compound by volatitallzation.The main aim to increase the oxygen in water for oxidizing metals and removing and volatile organic compound. There are manly four methods.

### GRAVITY AERATOR



In this method the water allowed to fall from height through a series of steps and air oxygen accompanied in the water. It oxidized the iron and partially removed the dissolve the gases like sulpher dioxide, carbon dioxide.

## SPRAY AERATOR



This type of aerator has one or more spray nozzle connected to a pipe manifold. Moving through the pipe under pressure the water leaves each nozzle in a fine spray and fall through the surrounding air creating a fountainer affect. It successfully oxidized the iron and manganese.

## DIFFUSER

In this method compressed air is bubbled through the water so, as to mix thoroughly mix it with water. Perforated pipes are installed at the bottom of the settling tank and compressed air blown through the pipe. During the upward movement the air mixes with the water and completing the aeration process.

**MECHANICAL AERATOR**

In this method the water allowed to trickle down the bed of coke and supported a layer of perforated bottomed trays and arrange vertically in series. This method gives a better result but less output.

## C. PREOXIDATION

**MIXING CHEMICALS**

Some times the raw water contains very large quantity of algae and micro biological organism which is very harmful to the efficiency of the plant. Hence some oxidizing agent such as chlorine, potassium permanganate and ozone mixed with raw them. It also oxide the taste, odour and colour causing compounds as well as iron and manganese compound.

## D. SEDIMENTATION

In the raw surface water contained much more suspended particle and collide particle. The total suspended solid (TSS) may vary not only source to source it large varied season to season even tidal time also. Though the specific gravity greater than water (1.0 gm / cc) they remain suspense in the waterbecause of the turbulence of water. As soon as the turbulence retarded by offering storage to the water this impurity tend to settle down at the bottom of the tank. This is the principle of sedimentation. But a extended quantity of TSS are in collide state and settling time much lengthy which is not desirable. Hence to reduces the detention period (period of stay at settling tank) the sedimentation process accelerated by adding and mixing some gelatinous chemical and make flock with suspended solid. The total happen through coagulation-flocculation – sedimentation.

## COAGULATION

A very fine suspended particle and colloidal matter present in the water can not settle down in plain sedimentation tank in ordinary detention period. These particles can be removed easily in a reasonable time by increasing their size into flocculated particles. Certain chemical of compound of their gelatinous nature called coagulants are mixing with the raw water form a gelatinous precipitation called floc. The very fine particle in the water get attracted and absorbed in these flocs, forming the bigger sized flocculated particle. Actually the colloidal particles are negative charged and repel each other. Coagulation is the process by means of which the colloidal particles in water are destabilized by changing the nature of collided particle, so that they form flocs through the process of flocculation that can be readily separated from the water. The destabilization is achieved through the addition of chemicals (called coagulants) to the water.

Many chemical can be used as coagulants considering the factor of raw water . The most common coagulants are:

**Alum or Aluminium sulphate, $Al_2(SO_4)_3.14\ H_2O$.**

The alum is dissolved in water and the aluminium ions, Al3+ that form, have a high capacity to neutralise the negative charges which are carried by the colloidal particles and which contribute to their stability. The aluminium ions hydrolise and in the process form aluminium hydroxide, Al(OH)3 which precipitates as a solid. During flocculation when the water is slowly stirred the aluminium hydroxide flocs enmesh the small colloidal particles. The flocs settle readily and most of them can be removed in a sedimentation tank. Complete precipitation is a function of the ph of the water and the ph must therefore be closely controlled between 6.0 and 7.4.

$Al_2(SO_4)_3.14H_2O + 6\ HCO^{3-}$

$2\ Al(OH)_3(s) + 6CO_2 + 14\ H_2O + 3\ SO_4^{2-}$

**Copperas $FeSO_4$**

It also commonly used as coagulant. When added to raw with lime ferus hydroxide formed which is precipitates as ferric hydroxide, Fe(OH)3 and the effective done at ph value above 8.5 and above.

$FeSO_4 + 3\ HCO^{3-}$

$Fe(OH)_3(S) + 3\ CO_2 + 3\ Cl^-$

**Cholorinated Copperas chloride, $FeCl_3$**

It also commonly used as coagulant. When added to water, the iron precipitates as ferric hydroxide, Fe(OH)3 and the hydroxide flocs enmesh the colloidal particles in the same way as the aluminium hydroxide flocs do. The optimum pH for precipitation of iron is not as critical as with aluminium and pH values of between 5 and 8 give good precipitation.

$FeCL_3 + 3\ HCO^{3-}$

$Fe(OH)_3(S) + 3\ CO_2 + 3\ Cl^-$

## Sodium Aluminate

Besides aluminium and iron sulphate salts sodium aluminate is also sometimes used as a coagulant. This chemical when dissolved and mixed in water reacts with the salts of calcium and magnesium present in the raw water, resulting in the formation of precipitation of calcium and magnesium aluminate. This is about 50% costlier than alums and copears and avoided to use.

## Polymeric coagulants

Polymeric coagulants including Dadmacs and polyamines which form white or brown flocs when added to water.

## Polyelectrolytes

Polyelectrolytesare mostly used to assist in the flocculation process and are often called flocculation aids. They are polymeric organic compounds consisting of long polymer chains that act to enmesh particles in the water.

## Aluminium polymers

Aluminium polymers such as poly-aluminium chloride that provide rapid flocculation, efficient removal of organics, and less sludge than alum under certain conditions, but at a higher cost.

## Hydrated lime

Hydrated lime is also used as coagulant, but its action is different to that of alum and ferric chloride. It added to maintain the correct pH suitable for alum or copears. These results in the formation of carbonate ions from the natural alkalinity in the water. The increase in carbonate concentration together with calcium added in the lime results in the precipitation of calcium carbonate,

$CaCO_3$. The calcium carbonate crystals also enmesh colloidal particles and facilitate their removal.

**Activated silica**

Activated silicais sometimes used as a flocculant together with alum or hydrated lime as coagulant.

**Bentronite and/or kaolin**

Bentronite and/or kaolin are sometimes added to water when the water to be flocculated contains too few particles for effective flocculation.

## FLOCCULATION

In the coagulation plant first the coagulant feed and mixed properly for effectively sedimentation of suspended solids. The chemical first fed either dry or in solution into the raw water through the feeding devices.

## RAPID MIXING

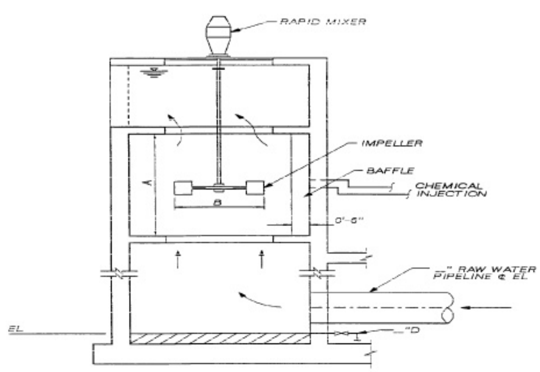



Figure 3.7 : Rapid mixer

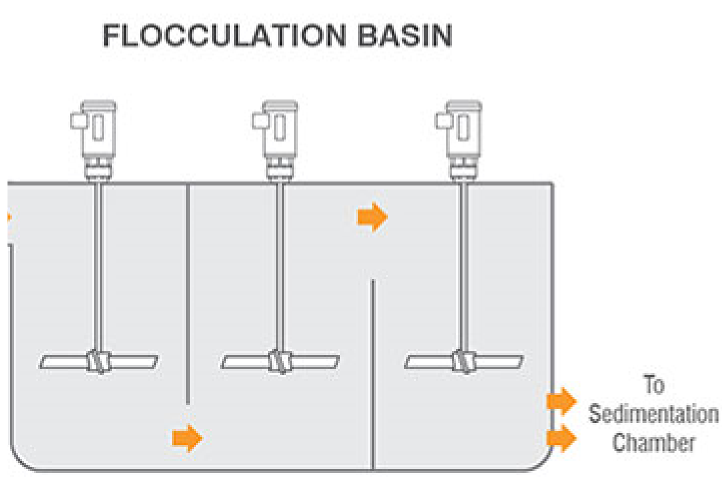
20

The mixture is then thoroughly and vigorously mixed, so that the coagulant gets fully dispersed into the entire mass of water. This violent agitation of water compressed air, by means of mixing devices. Out of these devices mixing basins are most important and normally adopted are two types. Mixing basins with basin and baffle walls and mixing basin equipped with mechanical devices.

The rapid mixing stage is possibly the most important component of coagulation-flocculation processes, since it is here that destabilization reactions occur and where primary floc particles are formed, whose characteristics markedly influence subsequent flocculation kinetics. In general it is likely that the metal coagulant hydrolysis products that are formed within the time range 0.01 to 1.0 seconds are the most important for effective destabilization. In many instances, traditional 30 to 60 second retention times during rapid mixing are necessary and flocculation efficiency may not improve beyond rapid mix times of approximately 5 seconds or less. Indeed, beyond a certain optimum rapid mix time, a detrimental effect on flocculation efficiency may result.

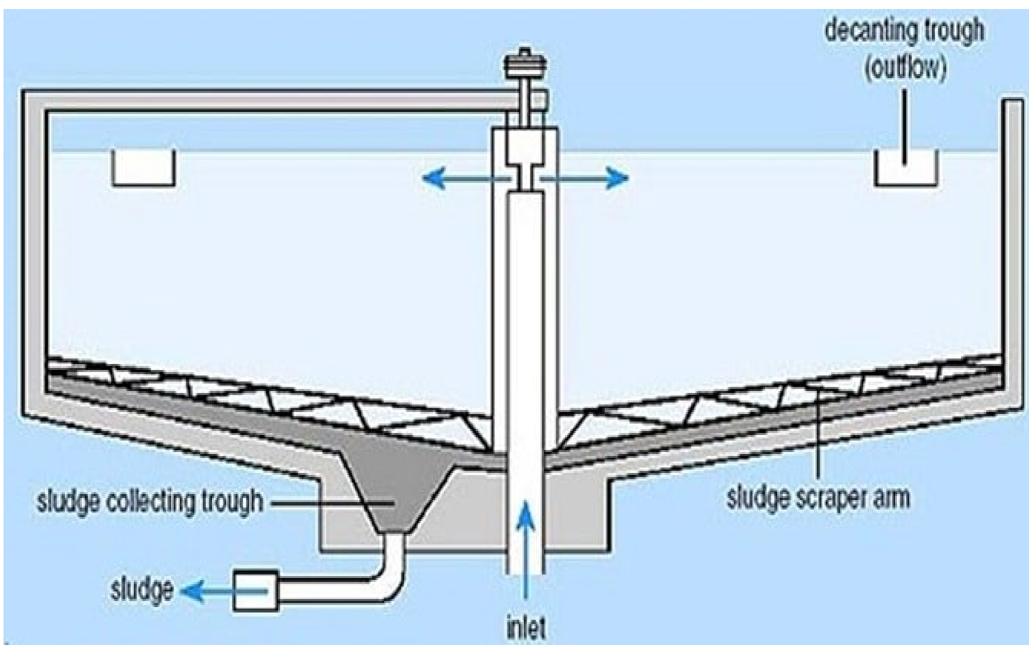
The type of rapid mixer often installed in practice is given the general name back-mix reactors. These are often designed to provide a 10 to 60 second retention time with a root mean square velocity gradient, G, of the order 300 s-1. Back-mix reactors normally comprise square tanks with vertical impellers. In many instances these back-mix reactors have been abandoned or not used extensively due to the poor results often attained.

## SLOW MIXING



Ortho kinetic flocculation arises from induced velocity gradients in the liquid. At this stage the particle are induced to approach close enough together, make contact and progressively form larger agglomerates, or flocs. The degree or extent of flocculation is governed by both applied velocity gradients and time of flocculation. These two parameters influence the rate and extent of particle aggregation and the rate and extent of breakup of these aggregates. There are various ways to induce velocity gradients: baffled chambers; granular media beds; diffused air; spiral flow chambers; reciprocating blades and rotating blades of horizontal shaft and vertical shaft. In the slow mixing typically horizontal chamber slowly mechanically moving paddle fitted. The paddles usually rotated speed about 2 to 3 rpm, of detention period 20 to 60 minutes and velocity gradient 20 to 80 $s^{-1}$.

## SEDIMENTATION



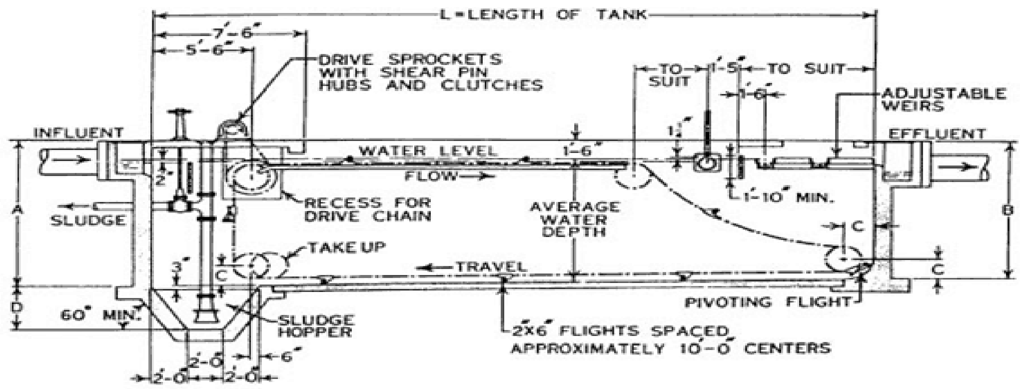


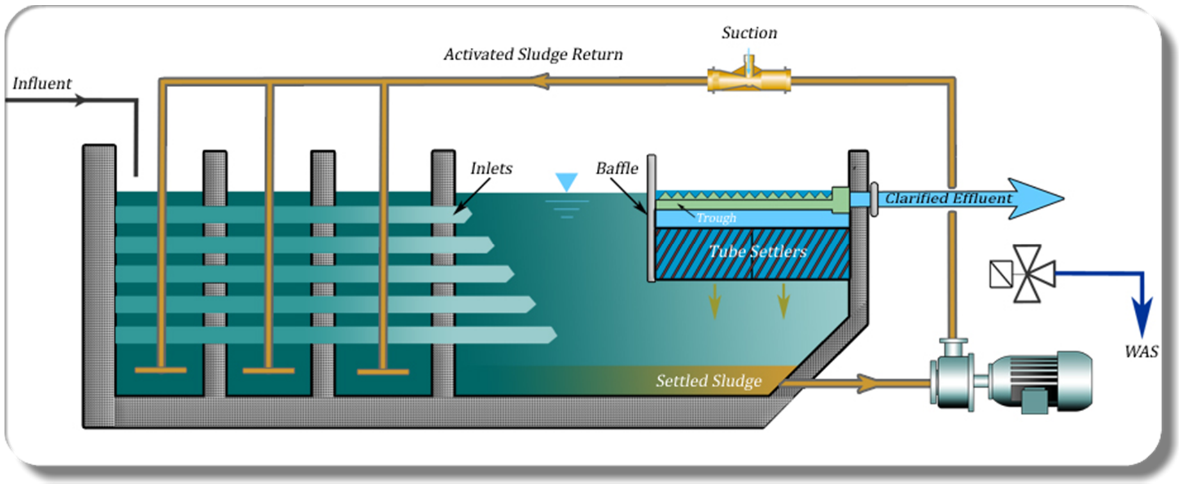

*Figure 11–3. Typical rectangular primary sedimentation tank.*

Sedimentation is the process in which the aggregates that have been coagulation and flocculation are allowed to settle from at the bottom of the tank and collected as sludge and further removed regular basis. The flocs settle to the bottom of the tank and the clean water leaves the sedimentation tank through collection troughs located at the top of the tank.

There are a variety of designs for sedimentation tanks available. These include large rectangular tanks in which the water enters one side and leaves at the other end. This type tank having uniform velocity through the tank is normally used at large conventional treatment works. Circular tanks with flat or cone shaped bottoms are also used, especially at smaller works. Flocculated water enters the tank at a central distribution section having velocity of water decreased with time ( which helpful for sediment the flock ) and clarified water leaves the tank at collection troughs at the circumference of the tank. The design and flow conditions in a sedimentation tank must be such that the minimum amount of flocs leaves with the clarified water. A sufficiently low turbidity level is required for effective filtration and further disinfection of the water . Removal of turbidity to low levels is achieved by means of sand filtration.

The normal sedimentation tank required a large area for a large scale water treatment plant. Now a days tube settler and plate settler used to solve the problem.

## TUBE SETTLER




This is a device used to treat water. It is made up of lightweight PVC tubes which are adjacently placed and joined at 60 degrees to increase the settling area. A tube settler is made up tubular channels that are placed adjacent to each other. These are placed at 60 degrees and combined to increase the effective settling area of particles. The settling area of the particles is made in such a way that it is less deep than that of the conventional clarifier. This makes it easier for the floc to settle very easily. For the tube settler to arrest the fine particles, it has to make use of the fine floc that manages to go past the clarification zone. In this case, it makes the larger particles to reach the bottom of the tank in a better shape. The tube settler now creates a sizeable mass that can go down the channel with ease.

Tube settlers work in 2 ways;

First, they provide a large surface area for settlement of particles. This is because of the angle at which they are joined.

Secondly, they are used to accumulate the smaller particles until they form larger particles that can move down the pathway uniformly.

Tube settlers are common in rectangular clarifiers, where they increase the settling surface area of particles. This works by means of increasing the vertical distance the particle will have to move before settling.

PLATE SETTLER

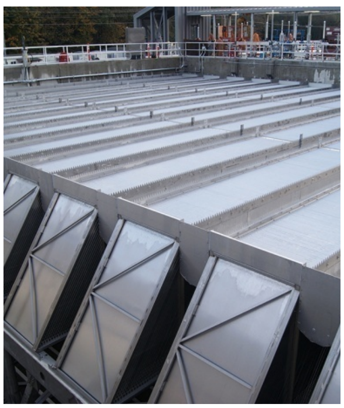


**Plate settler are** parallel inclined plates to minimize floor area occupation. The Inclined Plate Settler (IPS) consists of two main components, the upper tank containing the lamella plates inclined at 55° and the lower conical or cylindrical sludge tank y. Two basic criteria for gravity settling equipment are good clarity of the overflow liquid and maximum density of the underflow solid s discharge. The area needed to clarify a suspension is often greater than that needed for thickening. This means that in a cylindrical thickening tank, the lower section with rakes and drive mechanism can be oversized..

## Plate  Setter Advantages

The Inclined Plate Settler (IPS) consists of two main components, the upper tank containing the lamella plates inclined at 55° and the lower conical or cylindrical sludge tank.

The solids settle onto and slide down each plate pack to the sludge tank where the solids are further thickened and compressed with the assistance of the raking system.
The advantages of plate settler
They are more durable since they are made of Stainless Steel.
They require low maintenance costs. This is what makes them a darling to most people.
Easy to install. Their installation procedure is not complicated.

## Disadvantages of Plate Settlers

They will require you to observe a particular height before you install them. This is very tiresome for one.
Initial costs are relatively high. You have to buy expensive materials for the construction of the clarifiers.
A clarifier is simply a tank built with mechanical means. It is used to remove solid particles that are deposited during the sedimentation process.

## E. FILTRATION

Screening and sedimentation process remove large debris and most of the suspended solids from the water, but the water still not suitable for intake. It contains   very fine suspended solids and harmful living organism. To remove or reduced this impurities and to potable and palatable water the water further filtered through the fine granular material such as sands etc. The process of purification by passing through granular materials called filters )is known as filtration. This process also helpful to remove colour, odour, turbidity and some pathogenic bacteria from the water. Sand filtration is a simple process in which the water is allowed to filter through a layer of sand in a specially constructed container. In the filtration process the small remaining floc particles are removed by the sand grains and are retained in the bed of sand, while clean water flows out from the bottom of the sand bed.

There are three types filtration

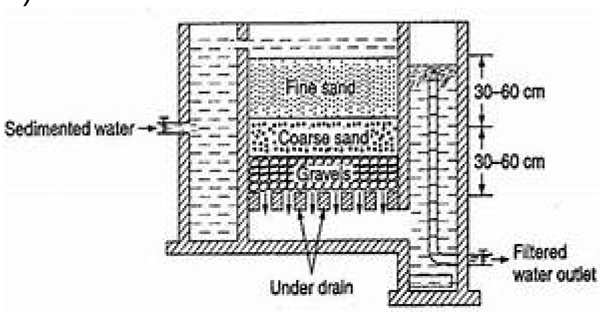
i ) Rapid Sand Filter

ii ) Slow Sand Filter

iii) Pressure Filter

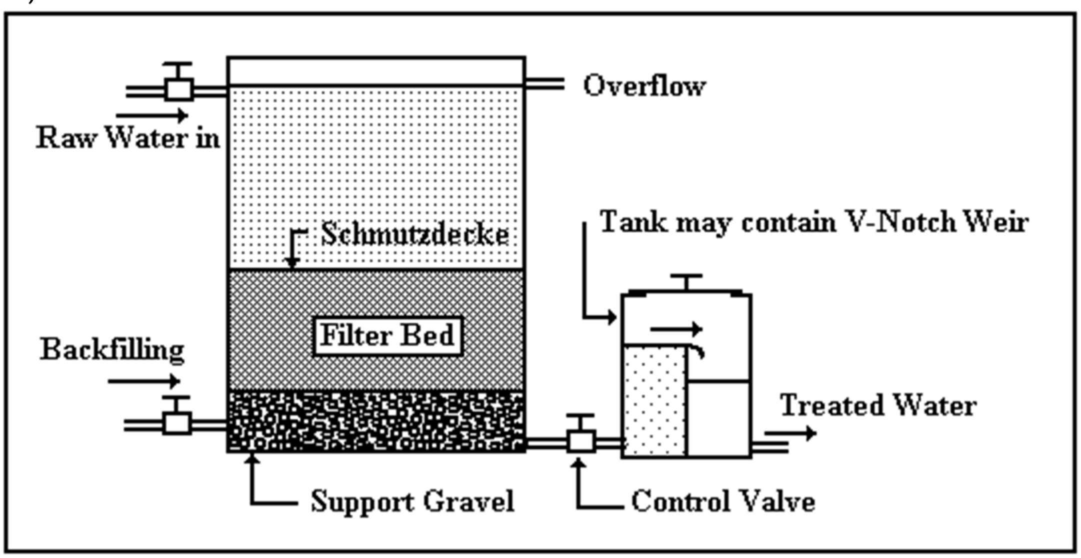
iv ) Duel media filtration

I )**RAPID SAND FILTER**



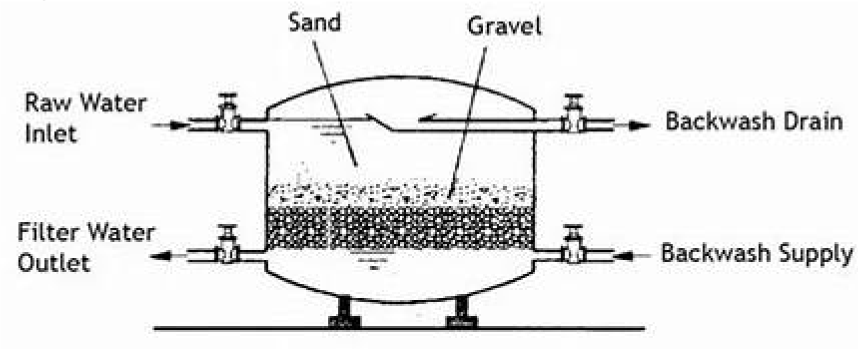

Rapid sand filtration is used in conventional water treatment following sedimentation. The filters are open to the atmosphere and flow through the filter is achieved by gravity. Flow is normally downward at rates of about 5 m/h and the filters are cleaned by backwashing at intervals that vary from 12 to 72 hours. During filtration, solids are removed from the water and accumulate within the voids and on the top surface of the filter medium. The filter medium normally consists of multilayer gravel and coarse sand of different size and uniformity co-efficient. The size of gravels 3 to 40 mm,depth 60 to 90 cm and the size of sand 0.35 to .55 mm of depth 0.80 m and uniformity co-efficient 1.2 to 1.8, sand placed over a layer of coarse medium (gravels). This process has large discharge capacity of 3000 to 6000 liters per hour per sq.m. with low initial cost but higher operational cost. The fact that flocs are retained in the filter bed means that the filter will become saturated or clogged with the retained flocs at some stage. The sand has then to be cleaned in regular basis by means of back washing to remove the accumulated flocs in order to restore the filtering capacity of the sand. The frequency of back washing is determined by the amount of flocs that has to be removed. Backwashing can be controlled on a time basis or on the basis of the pressure drop across the filter.

II )**SLOW SAND FILTER**



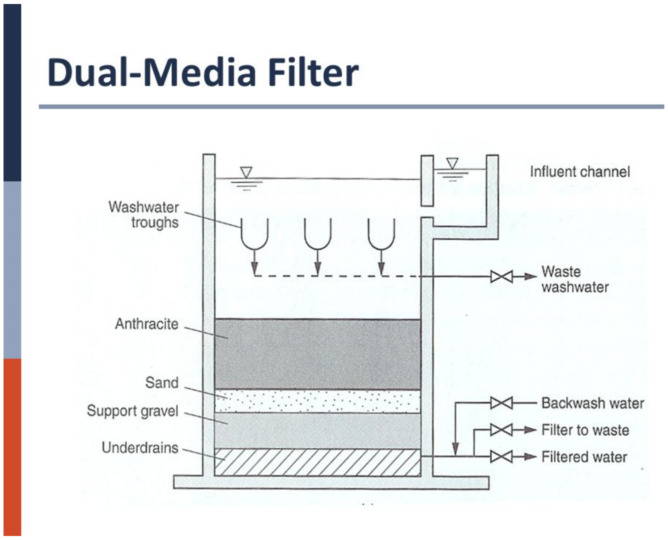

In the Slow sand filtration has a very slow rate of filtration(compared to rapid sand filtration). The filter media in slow sand filter similar to rapid sand filter but size and uniformity co-efficient and depth is different. The size of sand is 0/2 to 0.4 mm uniformity co-efficient 1.8 to 3.0. It cannot clean by back-washed at all, but the filter is cleaned by removal of the top layer of sand at long intervals of 1 to 3 months. This process has low capacity 100 to 200 liters per sq.m. This process required high initial but low operational cost. The filter received much better quality and remove suspended solid and bacteria.

III )**PRESSURE FILTER**




Sometimes for portable filter a special type of rapid sand filter used. The sand filters are not open to the atmosphere, but operate under pressure300 to 700 kN per sq.m. These types of filters are often used in package treatment plants. It high very discharges capacity of 6000 to 15000 liters per hour per sq.m. These types of filters are often used in package treatment plants.

IV ) **DUEL MEDIA FILTRATION**




The sewage water treatments plant and dual media filter is the most commonly used household water treatment plant that is utilized by many household and commercial units. These types of plants are used to clean the waste water in an efficient way. While using these plants, the effluents from the disposable water are removed or recycled in an excellent way without spreading any sort of illness. Even the recycled water can further be used for different purposes such as drinking, agriculture and irrigation. The Dual Media Filter utilizes combination of Filter Media and Anthracite for higher flow rates with a smaller footprint. High filtration velocities are achieved by proper selection of media, and designing of distribution and collection systems. These filters are offered in Mild Steel, FRP or SS construction with face piping and associated Valves.

Other than the sewage water treatment plants, dual media filter is used to remove the turbidity and suspended solids from the water. It is also known as sand anthracite filter or multimedia filter that is used to follow the cleaning process. These types of filters make the use of high filtration rate that helps in performing the efficient removal of the unwanted particles from water.

The model of these sand anthracite filters is said to have layered with a bed of filter media that consists of two main parts namely: A composite pressure vessel and graded beds of sand and anthracite. The design of the filter is kept in the way to make it run for long before any necessity rose for backwash system.

The system of the filter is designed with an internal fitting done with an inlet distributor and bottom collecting system while the external fitting is done with isolation valves and frontal pipe work. Working of the filter is processed with the activities performed by the sand and the anthracite wherein sand removes the suspended particles and the odor and color is removed with the help of anthracite.

## 5.RECARBONATION/ ACTIVATED CARBON ADSORPTION

During softening of hard water in lime soda process, insoluble $CaCO_3$ and $Mg(OH)_2$ are formed which are removed by sedimenting the water in sedimentation tank. However, the effluent of the sedimentation tank may be still certain some quantity of their finally divided particles which if not removed, may cause trouble by depositing in the filter or in the pipes of the distribution system. So by addition of carbon dioxide to convert the insoluble $CaCO_3$ to soluble $Ca(CHO_3)$ and reduced the hardness. Activated carbon adsorption removes dissolved organic substances such as taste and odour causing compounds and chlorinated compounds. It also removes many metals. It is used as powdered activated carbon (PAC) at the intake or as a granular activated carbon (GAC) bed after filtration.

## F. DISINFECTION

A large fraction of bacteria and larger micro-organisms of the water are removed during clarifloccuation and sedimentation processes, especially by sand filtration. However, many bacteria and viruses still remain in clarified water even at low turbidity levels. It is therefore, essential to disinfect the water to prevent every possibility of water-borne diseases are spread by pathogens (disease-causing micro-organisms) in water. Disinfection of water by addition of the required amount of certain chemical (disinfectant) to the water and allowing contact between the water and disinfectant for a pre-determined period of time .

Physical methods of disinfection of water include irradiation with ultra-violet light and boiling. The most commonly used disinfectant is chlorine gas, $Cl_2$ that is dissolved in the water at a certain concentration for a certain minimum contact time. Other disinfectants include ozone, chlorine dioxide and other chlorine compounds such as calcium hypochlorite (HTH), sodium hypochlorite (bleach) and monochloramine, excess lime, potassium permanganate, iodine and bromine, silver. Chlorine is a very strong oxidising agent and it reacts and oxidises some of the essential systems of micro-organisms thereby inactivating or destroying them. The different forms in which chlorine is used for disinfection, have different oxidising power sand this must be taken into account to ensure effective disinfection. Chlorine can be added to water in different forms.

## CHOLORINATION

Chlorine is the mostly used as disinfectant in different large plant to domestic use. The Chlorine from in gas, liquid is delivered to the plain the in gas cylinders and the chlorine is introduced into the water by means of special dosing devices (chlorinators). Calcium hypochlorite, $Ca(OCl)_2$ (commonly known as HTH) is available in granular or solid (tablet) form and is therefore a very convenient form in which to apply chlorine, especially for smaller or rural plants. It contains between 65 and 70% of available chlorine, it is relatively stable and can be stored for long periods (months) in a cool dry environment. Sodium hypochlorite, NaOCl is available as a solution. Water treatment sodium hypochlorite contains 12 to 13% of hypochlorite available chlorine. Monochloramineis also used for water disinfection. It is formed when HOCl is added to water that contains a small amount of ammonia. The ammonia reacts with HOCl to form monochloramine, $NH_2Cl$. It is much less effective as a disinfectant than HOCl (the same order of effectiveness as chlorite ion).

The two most important factors that determine the effectiveness of disinfection by means of chlorine are the chlorine concentration and the chlorine contact time. The pH of the water also plays an important role as well as the turbidity of the water, exposure to sunlight and the water temperature. The chlorine concentration is the most important control factor to ensure effective disinfection. It is normally accepted that sufficient chlorine must be added to water to give a free chlorine residualof not less than 0,5 mg/*l* after 30 minutes contact time. One of the problems associated with chlorination is the formation of chlorinated by-products. Some of these (so-called trihalomethanes or THM's) have been shown to have negative health effects and for this reason the concentration of THM's is controlled at very low levels in drinking water. It is important therefore to control chlorination dosages and to pretreatment the water before chlorine contact to remove organic material in the water (so-called precursor material) to low levels.

## BOILING OF WATER

The boiling of water at least 10 minutes at $100^0$ C can be destroyed the bacteria present in the water .But it can be possible for small range and costly. More over the natural taste omitted by this process. This system is used in domestic purpose only.

## LIME

Lime is generally used at a water purification plant for softening (reducing hardness ) But it is found that excess lime 14 to 44 ppm lime can kill the bacteria upto 99.3 to 100 %.

## OZONE

Ozone gas is a faintly blue gas of pungent odour and excellent disinfectant. Ozone gas is nothing but an unstable allotropic of three nascent oxygen and these atoms acts as very high effective disinfectant. The ozone treatment gives superior quality of water.

$O_3$ ( Ozone ) $\longrightarrow$ $O_2$ ( Oxygen ) + O ( Nascent Oxygen )

The nascent oxygen so produced is a powerful oxidising agent and removes the organic matter as well as bacteria from the water.

Some advantages of ozone are :

i) Ozone are unstable and nothing remains in water

ii ) Ozone removes colour, odour causing compound in addition and it make free from bacteria.

iii ) Ozonised water tasty and pleasant.

Some disadvantages of ozone are:

i) It is costly

ii) Electricity necessary at treatment site.

iii) No residual in water and not ensure pathogen free at consumer end

iv) Complicated process to manufacture.

v) Less efficient than chlorination process.

## IODINE AND BROMINE

The addition of iodine or bromine can help in killing the pathogenic bacteria. The quantity of these disinfectants may be limited to about 8 ppm and contact period of 5 minutes is generally enough.

## POTASSIUM PERMANGANATE

Potassium permanganate used as a popular disinfectant for disinfecting the well water supplies. It is cheap handy and quite useful. This process is not so much effective to remove the bacteria.

## SILVER OR ELECTRO- KATADYN PROCESS

In this method of disinfection metallic silver ions are introduced into the water by passing it through a tube containing solid silver electrodes which are connected to a D.C. supply of about 1.5 volt.

## ULTRAVIOLET RAY

Disinfection by means of ultra-violet (UV) irradiation is becoming more and more popular now a days. In this process used in large plant and also in domestic purpose. Moreover no by product from is the more advantageous. UV radiation kills or inactivates micro-organisms provided each organism with minimum amount of irradiation. UV irradiation functions on the principle that each unit of water must be exposed to the irradiation for a minimum amount of time at minimum dosage intensity (fluence).

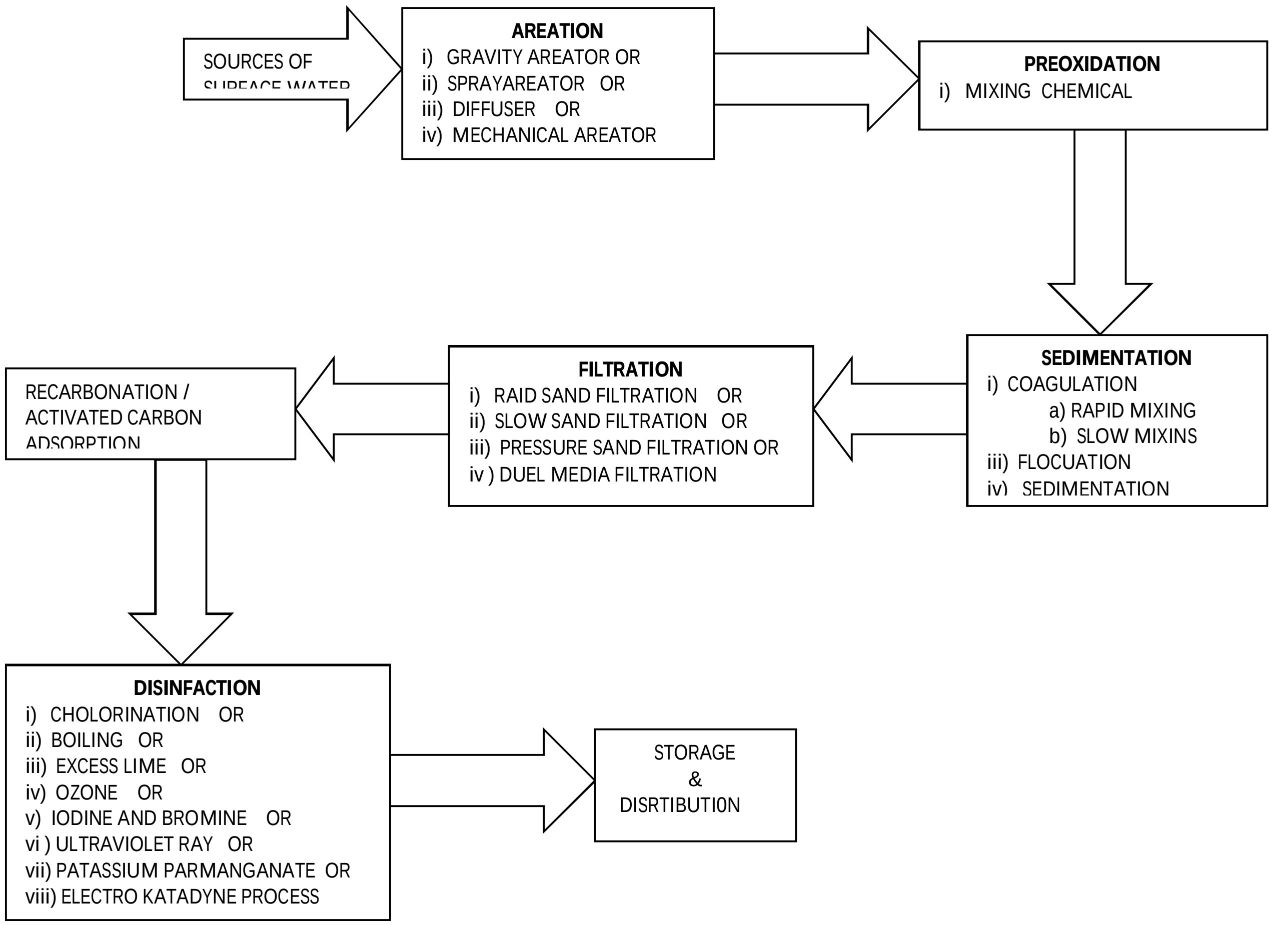
# CHAPTER – 7
## Ground Water Based Water Treatment Technologies

The ground water are the important sources for entire living world—plants, animals, and humans. Human cultures and societies have rallied around water resources for tens of thousands of years—for drinking, for food production, for transportation, and for recreation, as well as for inspiration. Worldwide, more than a third of all water used by humans comes from ground water. In rural areas the percentage is even higher: more than half of all drinking water worldwide is supplied from ground water.

The characteristics and quality of ground water are different than surface water available. Generally the main characteristics of the water are much more pure i. e. it contain less turbidity, pathogenic bacteria, essential minerals. At the same it may enriched with hardness, metal like iron magnesium, manganese and several gases. At the same times the water may be contaminated with harmful arsenic and floride. The quality of water varies in place to place even in season to season also. The depth of tube well has a great role in quality. Most of the villages the deep tube well water used as drinking water directly or minor treatment. Hence, the water required different unit of operation process as per the characteristics and quality of ground water. The main sources of ground water are:

1. Springs
2. Infiltration galleries
3. Infiltration wells
4. Wells and tube- wells

The unit of operation shown in a flow chart below :-




## OVERVIEW OF GROUND WATER TREATMENT PROCESSES

For water treatment from a ground water source a series of unit processes adopted to chive the desirable quality water.

## A. AREATION

In fact aeration is the first step for ground water treatment. The water contains more dissolve gas and organic compound minerals salt etc. The aeration process is helpful to remove or reduced the dissolve gas and oxidized the metal like iron, magnesium. It also removes the bad odour due to sulpher di oxide. The aeration process as same as surface water treatment any of the four method i.e. gravity aerator, spray aerator, diffuser or mechanical aerator best suited with the characteristics of raw water.

## B. PREOXIDATION

### MIXING CHEMICALS

Some times the raw water contain very large quantity iron, magnesium, manganese and these metal reduced by oxidizing agent such as chlorine, potassium permanganate and ozone mixed with raw them. It also oxide the taste, odour and colour causing compounds.

## C. SEDIMENTATION

Generally the ground water contains less turbidity. Hence the turbidity and other impurity can be removed or reduced by the same process as in described in surface water treatment. The unit of operation for the phase are coagulation-flocculation-sedimentation. For coagulation process the coagulant such alum, copears etc. rapidly and thoroughly mix with the raw water as and then agitate slowly with mechanical agitator to agglomerate and become big and bigger flocs. The flocs then precipitate at the bottom of the sediment tank. Then the sediment removed regularly from the tank to maintain the efficiently. Special care should be taken for the water velocity, detention time and velocity gradient specifically mention in surface water treatment. The fresh water collected at the top of the tank and supplied for next unit of operation i.e. disinfection.

## D. FILTRATION

Filtration is one of the most units of process in water treatment. After sedimentation most of the suspended solids and the colloidal matter formed flocs and removed from the water. Some finer particles and the micro organism still contain in the water. To remove these particles the water passes through a granular bed and these impurities arrest in the bed and this process is called filtration. There are mainly three process i.e slow sand filter, rapid sand filter and pressure filter. Each of process has merits and demerits and quality of filter water also different. Considering the cost and other peripheral condition and desired quality the appropriate process choose. The details described in surface water treatment.

## E. RECARBONATION / ACTIVATED CARBON ADSORPTION

After filtration the water may contain high pH value and taste and odour causing compound. Addition of carbon dioxide to reduce the pH of water . Activated carbon adsorption removes dissolved organic substances such as taste and odour causing compounds and chlorinated compounds. It also removes many metals. It is used as powdered activated carbon (PAC) at the intake or as a granular activated carbon (GAC) bed after filtration

## F. DISINFECTION

Disinfection is the most important process in the water treatment. Though the water treated in several process and remove or reduced the impurity, but a threat is always because the presence of micro organism, harmful pathogenic bacteria. A very small amount of pathogenic bacteria spreads epidemic in the society. So treated water at the end of consumer the water should be free from bacteria. There are several process and several materials used for this purpose. Some are using chemical and others are phenomena, (boiling of water passing through , ultraviolet ray, electro katadyne process ) to kill the germs. Chlorine in different from ( liquid gas and compounds are the mostly used effectively in this purpose. Others chemicals are such as ozone, excess lime, iodine, bromine, potassium permanganate etc. are also remove or reduced the harmful germ from treated water. The details are described in the surface water treatment.

## CHAPTER – 8

# Advanced Water Technologies

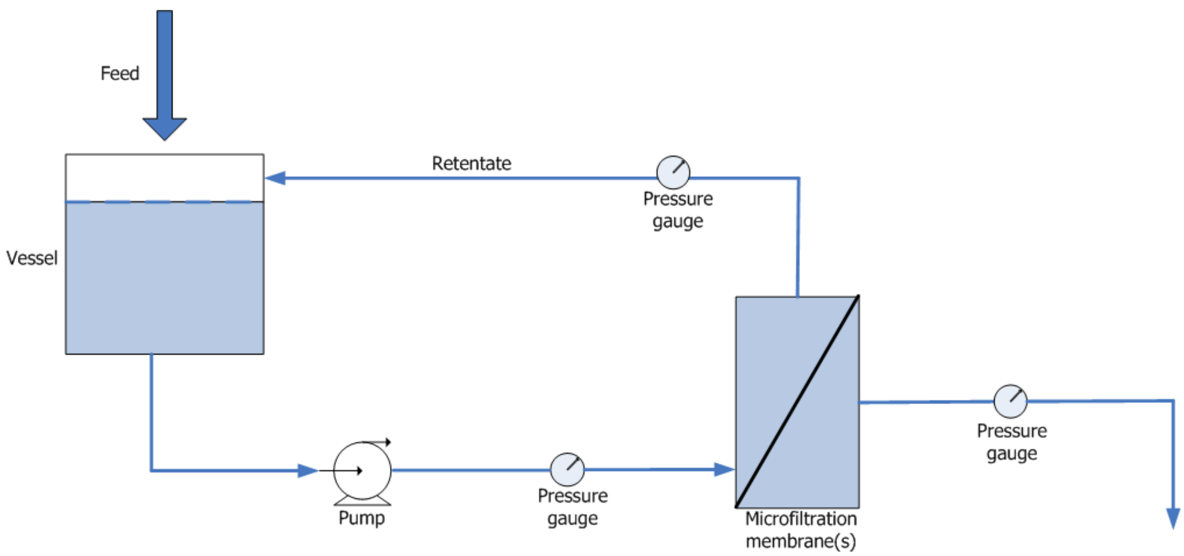
Earlier the different unit of operation mention for surface water and ground water. The conventional water treatment process are aeration, sedimentation, filtration and disinfection. The term advanced treatment processes refers to processes other than conventional processes, i.e. coagulation-flocculation, sedimentation, filtration, chlorination and stabilisation. Processes normally considered as advanced processes are membrane processes ((reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and electrodialysis (ED)), activated carbon adsorption, ozonation, oxidation processes for arsenic iron and manganese removal and processes for removal of specific substances such as fluoride.

### MEMBRANEPURIFICATION PROCESS

A membrane is a thin layer of semi-permeable material. When driving force is applied across the membrane it separates the impurities in the water. In the modern days the membrane processes are increasingly used for removal of bacteria, microorganisms, and bad tastes, and odors causing natural organic material. As advancements are made in membrane purification technology it largely used as disinfection desalination purpose in large plant and in domestic scale also. The membrane processes discussed as per pore size here are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) is given a table below.

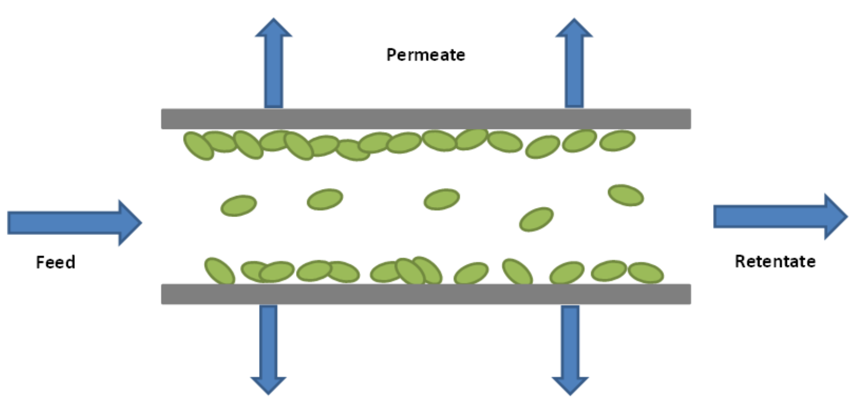
| PORE SIZE | MOLECULAR MASS | PROCESS | FILTRATION | REMOVAL OF |
|---|---|---|---|---|
| 0.1 -5µm | >5000 k Da | Microfiltration | <2 bar | Larger bacteria, yeast, particle |
| 0.1 - 0.01 µm | 5-5000 k Da | Ultrafiltration | 1-10 bar | Bacteria, micromolecule, proteins, larger virus |
| 0.01 - 0.001 µm | 0.1-5 k Da | Nanofiltration | 3-20 bar | Virus, valent ions |
| >0.001 µm | < 100 Da | Reverse osmosis | 0-80 bar | Salts, small organic molecules |

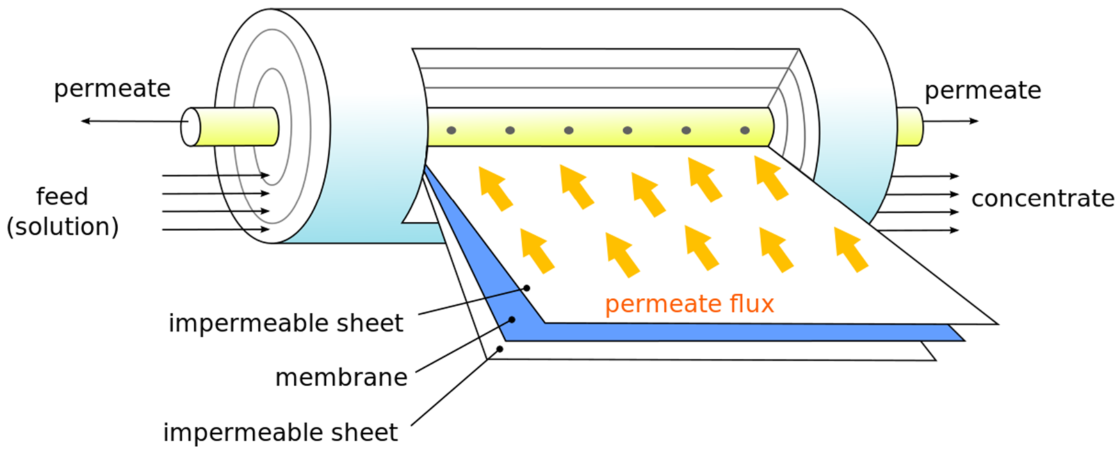
**MICROFILTRATION(MF)**




Microfiltration is the process of physically remove the suspended solids from water 0.1 to 10 micron range, including bacteria using membranes with a pore size of 0.1 – 10 µm. Micro filtration can be implemented in many different water treatment processes when particles with a diameter greater than 0.1 mm need to be removed from a liquid. Usually, water microfiltration is performed by cross-flow separation, which involves a feed stream being introduced into the membrane under pressure and passed over a membrane surface in a controlled flow path. This process is economical, effective long-term operation. The principle of micro filtration is larger size substances of the water than the pore size of the membrane that passes through the membrane and arrested by the membrane. Micro filtration and ultra filtration are pressure-dependent processes, and the efficiency depend upon the size of the pores in the membranes and dissolved solids, turbidity and micro organisms and pressure. The use of MF membranes presents a physical means of separation (a barrier) as opposed to a chemical alternative. In that sense, both filtration and disinfection take place in a single step, negating the extra cost of chemical dosage and the corresponding equipment. The materials which constitute the membranes used in microfiltration systems may be either organic or inorganic depending upon the contaminants that are desired to be removed, or the type of application .The organic membranes are a wide range of polymer cellulose acetate(CA), polysulfone, polyvinylidene fluoride, polyethersulfone and polyamide and the inorganic membranes are usually composed of sintered metal or porous alumina. They are able to be designed in various shapes, with a range of average pore sizes and permeability.

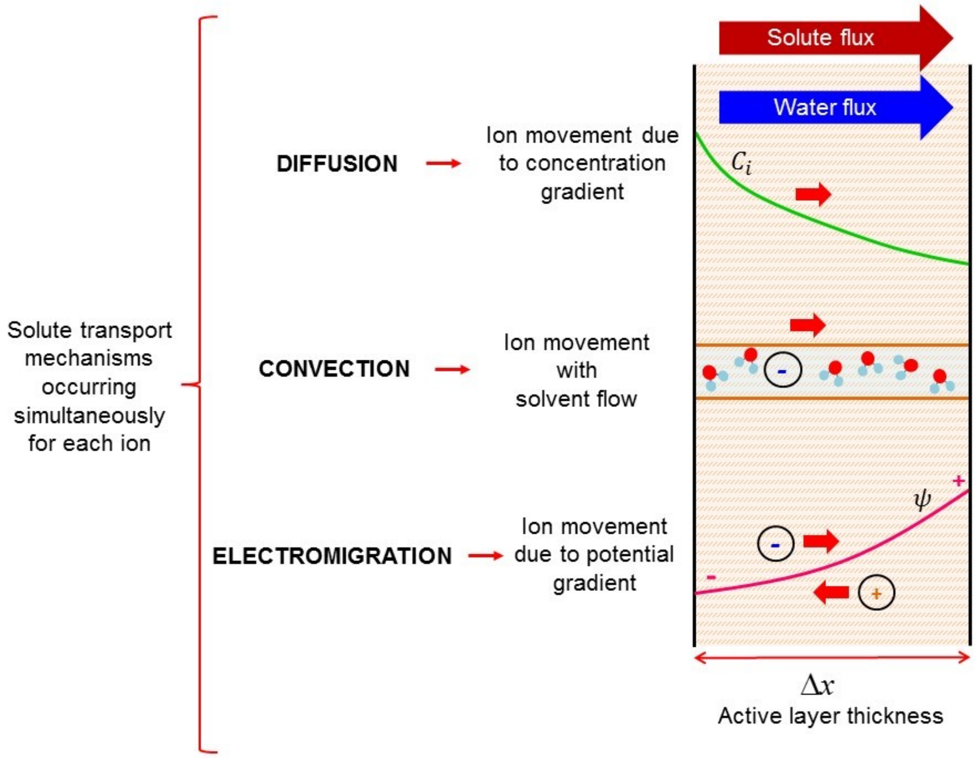
**ULTRAFILTRATION (UF)**

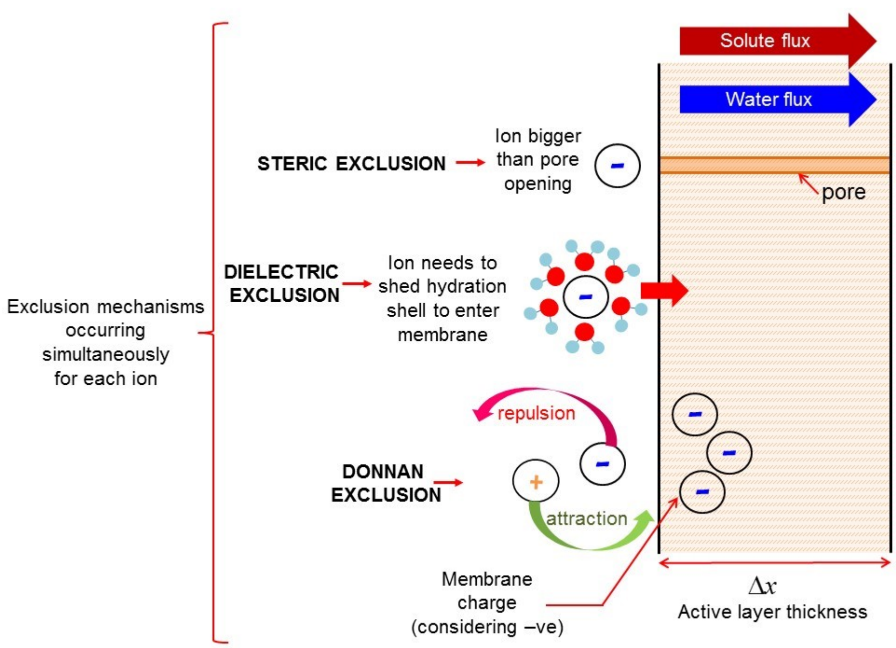





Ultrafiltration membranes have pore sizes ranging from 0.1 µm to 0.01 µm. Ultrafiltration can be used for the removal of particulates and macromolecules from raw water to produce potable water. It has been used to either replace existing secondary (coagulation, flocculation, sedimentation) and tertiary filtration (sand filtration and chlorination) systems employed in water treatment plants or as standalone systems in isolated regions with growing populations. When treating water with high suspended solids, UF is often integrated into the process, utilizing primary (screening, flotation, filtration) and some secondary treatments as pre-treatment stages. UF processes are currently preferred over traditional treatment methods because its compact size, quality of product and no chemicals required.

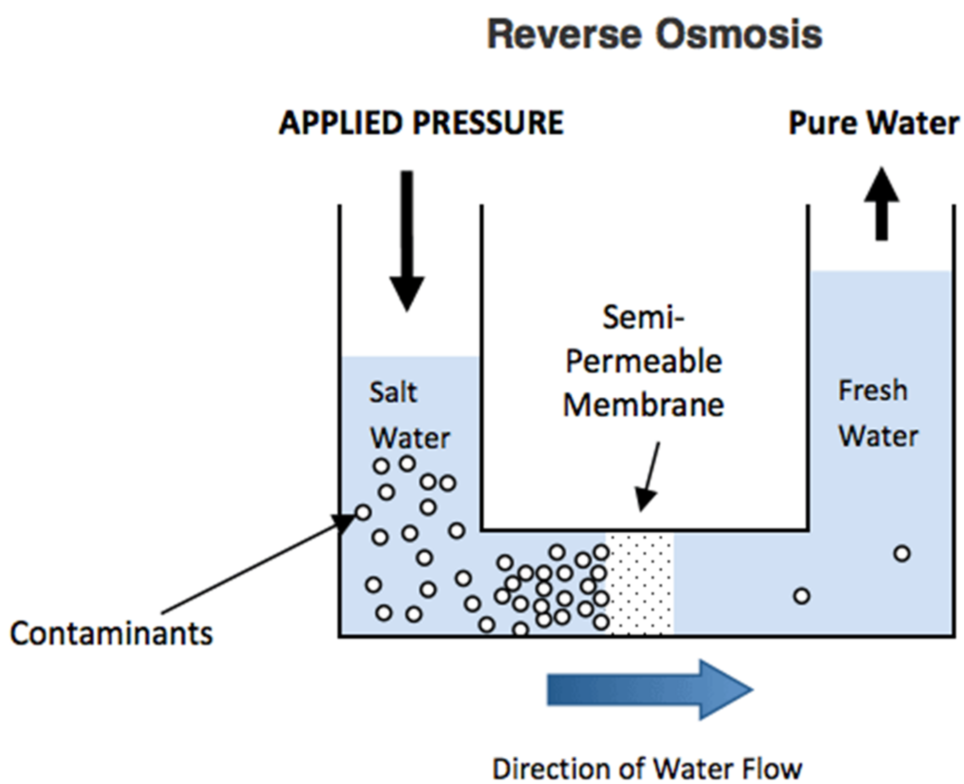
## NANOFILRATION (NF)



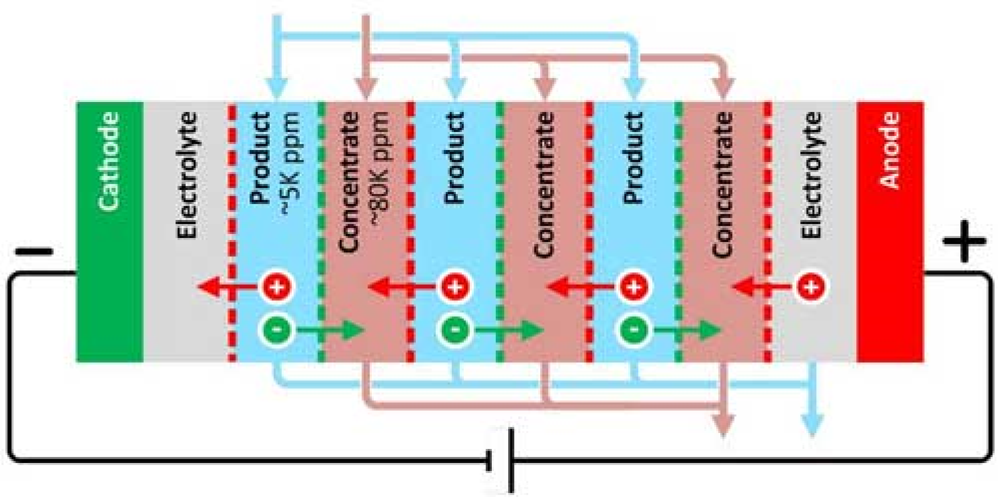
Nanofiltrationis often used to filter water with low amounts of total dissolved solids, to remove organic matter and soften water. It is also a desalination process since it separates dissolved salts from solution. However, NF membranes contain very small pores sizes (0.01 -0.001 µm) and therefore allow substances to pass that are retained the virus and valent ions. Main advantage of NF is it removes monovalent ions such as Na+ and Cl- readily permeate the NF membrane, while divalent ions such as $Ca_2$+ and$SO_4$ 2- are rejected to a larger degree by NF membranes. It is therefore effective to soften water (remove Ca, Mg and other hardness causing ions). Another advantage is it operates in room temperature and reduced cost. But the cost of filter membrane and its maintenance cost is much more.

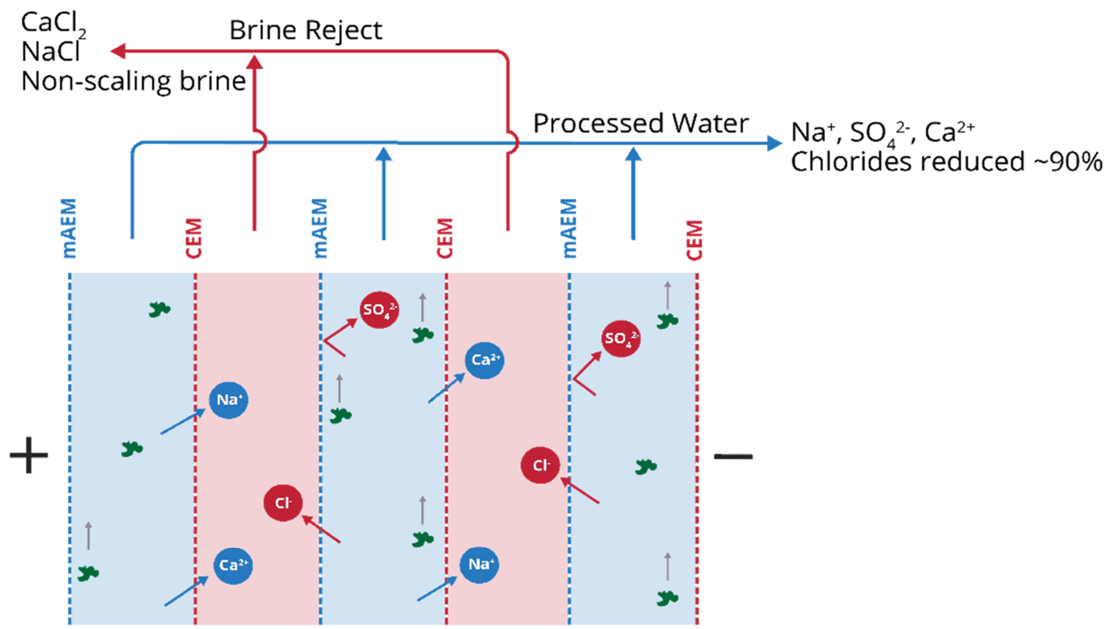
**REVERSE OSMOSIS (RO)**



Reverse osmosis ( RO) is a filtration method that is used to remove ions and molecules from a solution by applying pressure to the solution on one side of a semi permeable or selective membrane. The pore sizes are extremely small less than 0.001 µm. The molecules (solute) can't cross the membrane, so they remain on one side. Water( solvent ) can cross the membrane. The result is that solute molecules become more concentrated on one side of the membrane, while the opposite side becomes more dilute. The main application of RO is to remove dissolved substances, including ions such as Na+ and Cl- from solution. RO is a general desalination process being used to desalinate seawater, brackish water and high-TDS effluents. The pore size is too small that RO removes all particulate matter including all bacteria and viruses, all organic macromolecules and most organic molecules with molecular mass of larger than about150 Daltons (mol mass units). RO therefore produces product water of extremely good quality

**ELECTRODIALYSIS (ED / EDR)**





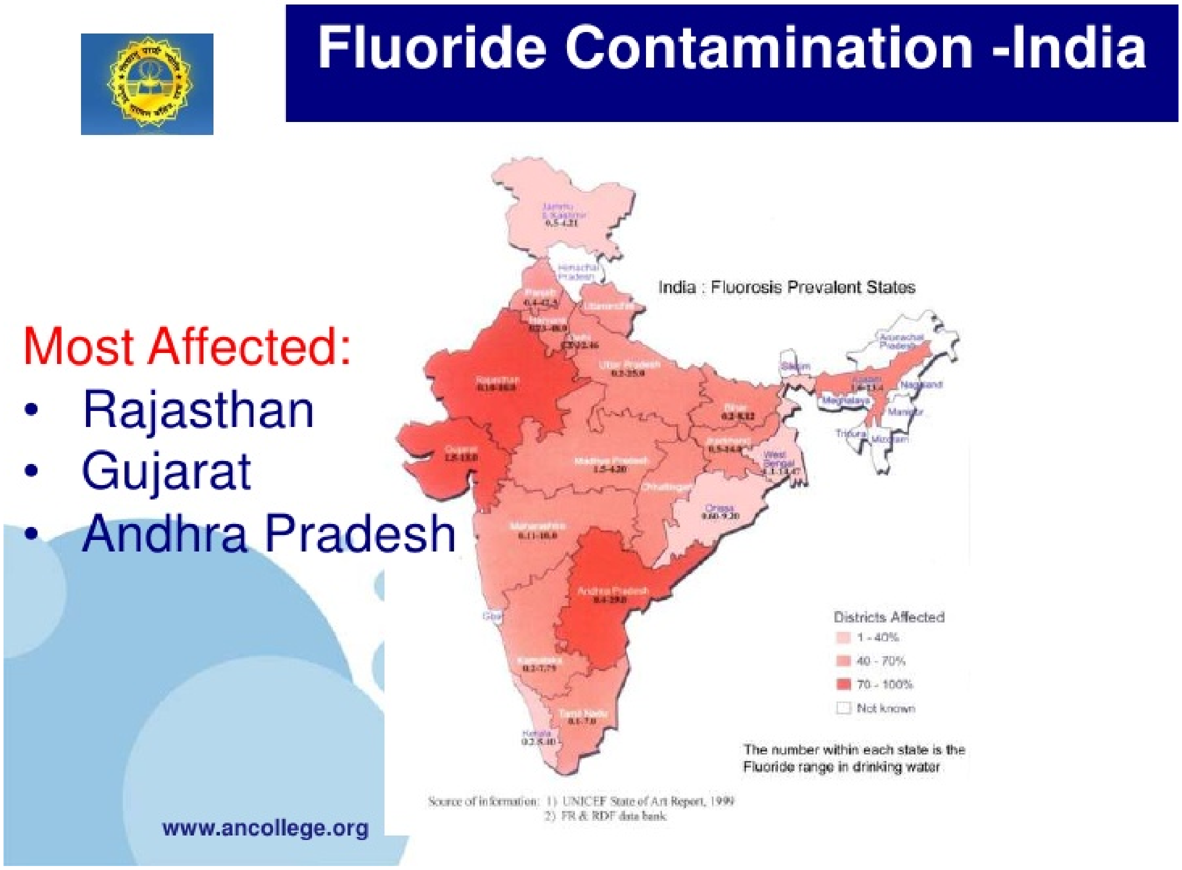

**Monovalent Electrodialysis (mEDR) with FlexEDR Selective**

Remove chlorides at high recovery with minimal pre-treatment

**mAEM** Monovalent anion exchange membrane (blocks sulphate, passes chloride)
**CEM** Cation exchange membrane
Organics do not transit or foul membranes

Electrodialysis is a membrane separation process. Here the driving force is an electrical potential across the membrane and the charged ions are separated from the feed water. So, the product water contains less dissolved salts but that all non-charged compounds such as organic molecules and all particulates including bacteria and viruses will remain in the product water. This is a disadvantage of ED compared to RO but the process has certain other advantages which makes it competitive with RO in many applications. Electrodialysisis mainly used for desalination of water. The growing popularity among municipalities of the EDR systems is related with its capacity to reduce TDS and some inorganics elements like nitrates, sulphates, radon, bromides and others, with high water recovery and easily operation and control by adjusting amount of electricity applied to membrane stack.

**DEFLORIDATION**




In India it is reported that in ground water 20 States has been suffering due to above permissible limit floride limit( maximum limit of floride as per BS standard 1 mg / lit ) the excess floride causes of flurosis and dental caries. Hence the excess floride removal done by mainly three process.

i) Based on some kind of chemical reaction with fluoride: Nalgonda technique, addition of Lime etc.

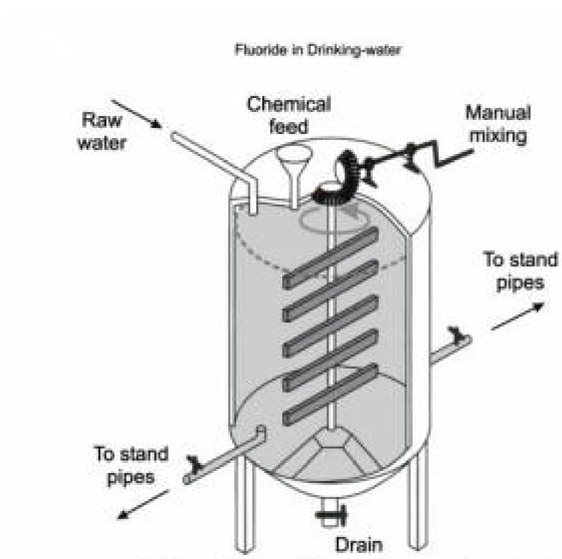
ii) Based on adsorption process: Bone charcoal, processed bone, tricalcium phosphate, activated carbons, activated magnesia, tamarind gel, serpentine, activated alumina, plant materials, burnt clay .

iii) Based on ion-exchange process: Anion/Cation exchange resins

Nalgonda technique is a combination of several unit operations and the process involves rapid mixing, chemical interaction, floculation, sedimentation, filtration, disinfection and sludge concentration to recover waters and aluminium salts. Alum (hydrated aluminium salts) - a coagulant commonly used for water treatment is used to flocculate fluoride ions in the water. Since the process is best carried out under alkaline conditions, lime is added. For the disinfection purpose bleaching powder is added. After thorough stirring, the chemical elements coagulate into flocs and settle down in the bottom. The reaction occurs through the following equations

$$2\ Al_2\ (SO_4)_3\ 18H_2\ O + NaF + 9Na2CO_3 \rightarrow [5Al(OH)_3.Al(OH)_2F] + 9Na_2SO_4 + NaHCO_3 + 8\ CO_2 + 45\ H_2O$$

$$3\ Al_2\ (SO_4)_3\ 18H_2\ O + NaF + 17NaHCO_3 \rightarrow [5Al(OH)_3.Al(OH)_2F] + 9Na_2SO_4 + 17\ CO_2 + 18\ H_2O$$




The fill and draw type Nalgonda technique for domestic and community defluoridation. After Bulusu *et al.*, 1993.

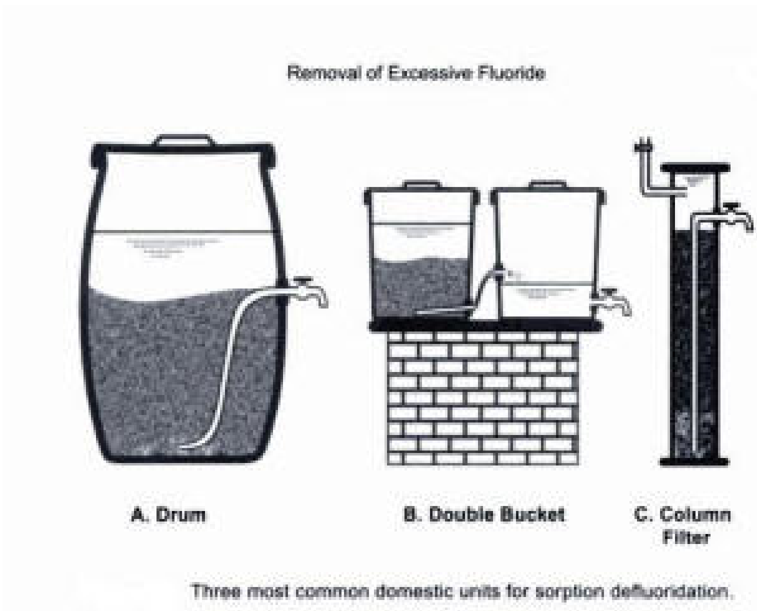
## ACTIVATED ALUMINA

Activated alumina is a granular, highly porous material consisting essentially of aluminum trihydrate. It is widely used as a commercial desiccant and in many gas drying processes.

The studies, perhaps the earliest, have demonstrated the high potential of activated alumina for fluoride uptake. An initial concentration of 5 mg/L was effectively brought down to 1.4 mg/L before regeneration and to 0.5 mg/L on regeneration with 2N HCl. The bed was regenerated with a solution of 2% Na OH,5% NaCl,2N HCl,5% NaCl and 2N HCl. The removal capacity of the medium was found to be about 800 mg/L of fluorid e/L of Alumina. Many modifications of process was suggested by subsequent workers, several patents based on the use of Aluminum oxide for fluoride removal were issued 1. Filter alum was used to regenerate activated alumina bed. The capacity of alumina to remove fluoride was reported to be proportional to the amount of filter alum used for regeneration up to a level of about 0.2kg of alum per litre of alumina. At this level the fluoride removal capacity was approximately 500 mg of fluoride per litre of alumina. Similar studies employing activated alumina was later conducted by many workers and all these works confirmed the ability of activated alumina for higher uptake of fluoride from water. Some researchers have concluded that removal was the result of ion exchange, but investigations by others have shown that the process is one of the adsorption and follows the Langmuir isotherm model.

Bone Char

The uptake of fluoride onto the surface of bone was one of the early methods suggested for defluoridation of water supplies. The process was reportedly one of the ion exchange in which carbonate radical of the apatite comprising bone, $Ca(PO_4)6.CaCO_3$, was replaced by fluoride to form an insoluble fluorapatite. Bone char produced by carbonizing bone at temperature of 1100-1600ºC had superior qualities than those of unprocessed bone and hence replaced bone as defluoridating agent



Three most common domestic units for sorption defluoridation.

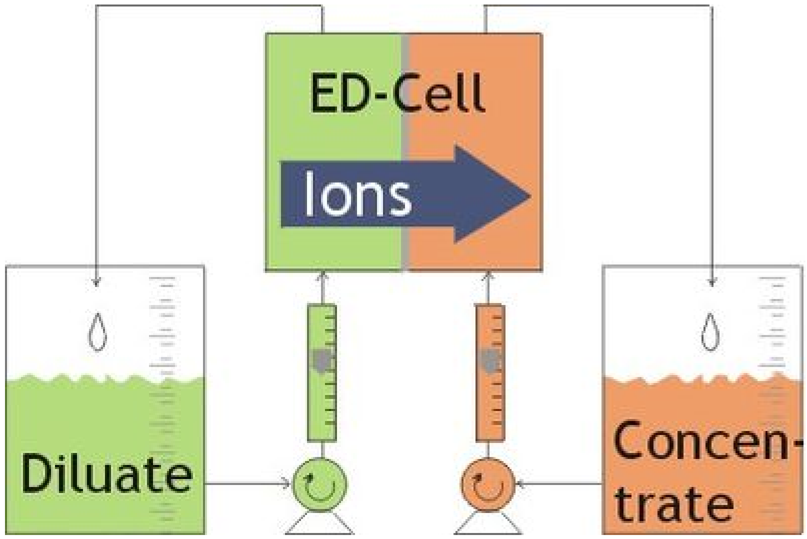
## ION EXCHANGE RESINS

Strong base exchange resins remove fluorides either on hydroxyl cycle or chloride cycle along with anions. Since the proportional quantity of fluoride as compared to other anions is very small, the effective capacity of such resins works out quite low. Some inorganic ion exchangers, eg. complex metal chloride silicates, formed from barium or ferric chloride with silicic acid, also exchanged fluoride for chloride.

Cation exchange resins impregnable with alum solution have been found to act as defluoridating agents. Alum treated cation exchange resins were used for defluoridation. 'Avaram Bark' based cation exchange resins, had been reported to work effectively in removing fluoride from water

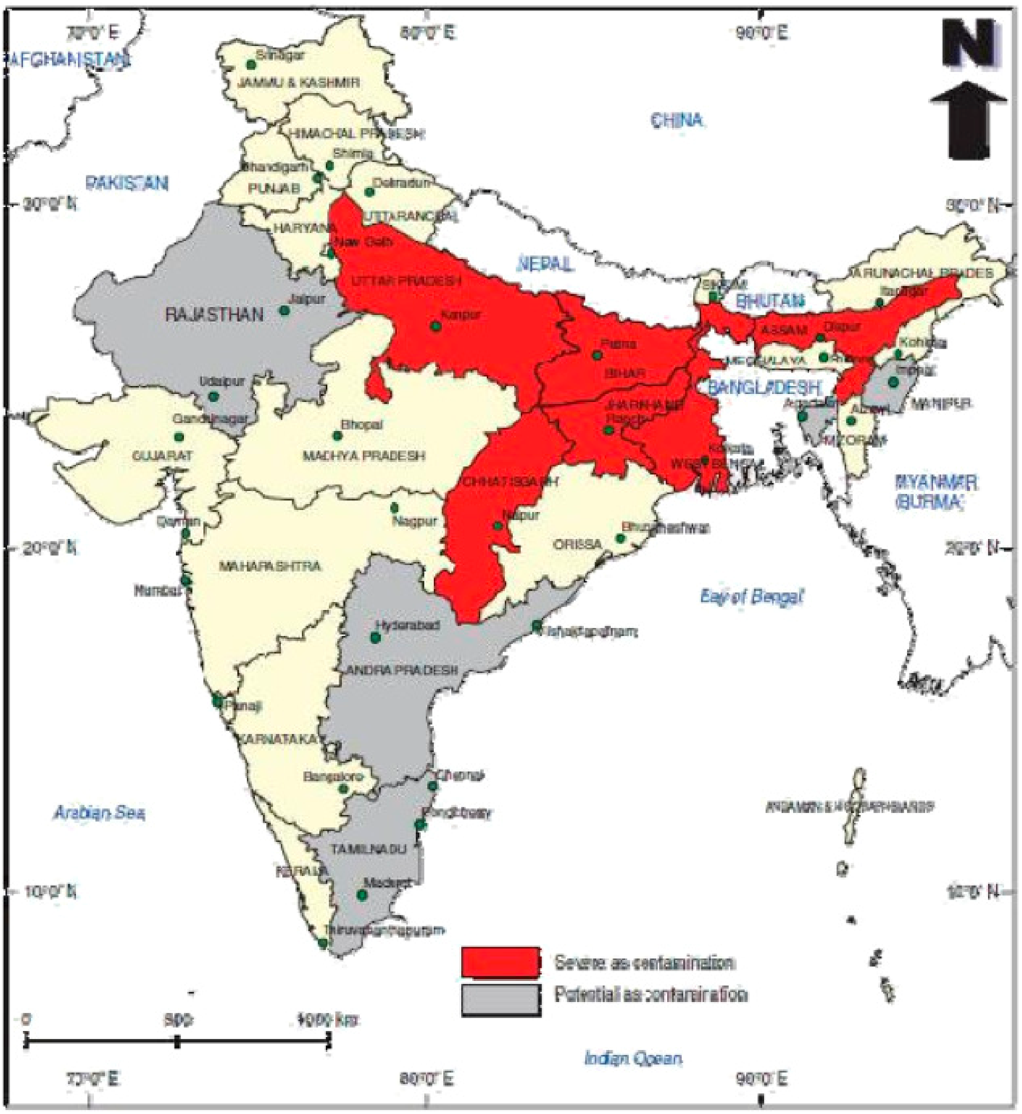
Polystyrene anion exchange resins in general and strongly basic quaternary ammonium type resins in particular are known to remove fluorides from water along with other anions.

**ION EXCHANG (IE)**




Ion(IE) is a water treatment method where one or more undesirable contaminants are removed from water by exchange with another non-objectionable, or less objectionable substance. Both the contaminant and the exchange exchanged substance must be dissolved and have the same type (+,-) of electrical charge. Ion exchange is a water treatment process commonly used for water softening or demineralization, but it also is used to remove other substances from the water in processes such as dealkalization, deionization, and disinfection. The charged particle may be positively charged cation and removed by IE media a cation exchange resin and the negatively charged particle anion removed by IE media a anion exchange resin. Resin materials have a finite exchange capacity. Each of the individual exchange sites will become full with prolonged use. When unable to exchange ions any longer, the resin must be recharged or regenerated to restore it to its initial condition. The substances used for this can include sodium chloride, as well as hydrochloric acid, sulfuric acid, or sodium hydroxide. The efficacy of ion exchange for water treatment can be limited by mineral scaling, surface clogging, and other issues that contribute to resin fouling. Pretreatment processes such as filtration or addition of chemicals can help reduce or prevent these issues.

**ARSENIC REMOVAL PROCESS**




Arsenic in ground water was reported in sever to very sever in different parts of 10 States of West Bengal, Assam, Bihar, Jharkhand, Uttar Pradesh, Punjab, Haryana, Chhattisgarh, Karnataka & Manipur and excess limit of permissible limit in another additional 11 States in India. The maximum permissible limit in water is 0.01 mg/lit. the arsenic has a very adverse effect cancer, diabetes, liver damages, hyper tension and chronic arsenic toxicities. Hence arsenic removal is necessity to avoid such a worst effect. The main arsenic removal process are

i**) Coagulation and flocculation**.

The coagulation and flocculation method effective remove the soluble arsenic from water. Moreover it remove the other dissolve the notably turbidity, iron, manganese, phosphate and fluoride. This treatment can effectively remove many suspended and dissolved constituents. Significant reductions are also possible in odor, color, and potential for trihalomethane formation. This process improves other water quality parameters, resulting in ancillary health and esthetic parameter. The most commonly used metal salts are aluminum salts such as alum, and ferric salts such as ferric chloride or ferric sulfate. Ferrous sulfate has also been used, but is less effective .Excellent arsenic removal is possible with either ferric or aluminum salts, with laboratories reporting over 99% removal under optimal conditions, and residual arsenic concentrations of less than 1 µg/L Full scale plants typically report a somewhat lower efficiency, from 50% to over 90% removal. During coagulation and filtration, arsenic is removed through three main mechanisms

precipitation: the formation of the insoluble compounds $Al(AsO_4)$ or

$Fe(AsO_4)$

coprecipitation: the incorporation of soluble arsenic species into a

growing metal hydroxide phaseadsorption: the electrostatic binding of soluble arsenic to the external surfaces of the insoluble metal hydroxide.

All three of these mechanisms can independently contribute towards

contaminant removal. In the case of arsenic removal, direct precipitation has not been shown to play an important role. However, coprecipitation and adsorption are both active arsenic removal mechanisms. Numerous studies have shown that filtration is an important step to ensure efficient arsenic removal. After coagulation and simple sedimentation, HAO and

HFO – along with their sorbed arsenic load – can remain suspended in colloidal form.

ii ) Oxidation

a) Oxidation and filtration

b) Photochemical oxidation

c) Photocatalstic oxidation

d)Biological oxidation

e) In situ oxidation

**Oxidation**

Most arsenic removal technologies are most effective at removing the pentavalent form of arsenic (arsenate), since the trivalent form (arsenite) is predominantly non-charged below pH 9.2 Therefore, many treatment systems Oxidation alone does not remove arsenic from solution, and must be coupled with a removal process such as coagulation, adsorption or ion exchange.

Arsenite can be directly oxidized by a number of other chemicals, including gaseous chlorine, hypochlorite, ozone, permanganate, hydrogen peroxide, and Fenton's reagent ($H_2O_2/Fe_2$+). Some solids such as manganese oxides can also oxidize arsenic. Ultraviolet radiation can catalyze the oxidization of arsenite in the presence of other oxidants, such as oxygen. Direct UV oxidation of arsenite is slow, but may be catalyzed by the presence of sulfite ferric iron or citrate. Chlorine is a rapid and effective oxidant, but may lead to reactions with organic matter, producing toxic trihalomethanes as a by-product. Chlorine is widely available globally, though if improperly stored it can lose its potency rapidly. An ozone dose of 2 mg/L, contacted with the water for 1 minute prior to filtration, has been shown to be effective in oxidizing iron and manganese, at the same time removing arsenic and other metals to below detection limits. Permanganate effectively oxidizes arsenite, along with Fe(II) and Mn(II). Itis a poor disinfectant, though it can produce a bacteriostatic effect. Potassiumpermanganate ($KMnO_4$) is widely available in developing countries, where it isused as a topical antibiotic for minor cuts. It is relatively stable with a long shelf life. Residual manganese in treated water should not exceed the WHO guideline of 0.5 mg/L . Hydrogen peroxide may be an effective oxidant if the raw water contains high levels of dissolved iron, which often occur in conjunction with arsenic contamination.

iii) Ion exchange

Synthetic ion exchange resins are widely used in water treatment to remove many undesirable dissolved solids, most commonly hardness, from water. These resins are based on a cross-linked polymer skeleton, called the ‘matrix’. Most commonly, this matrix is composed of polystyrene cross-linked with divinylbenzene. Charged functional groups are attached to the matrix through covalent bonding, and fall into four groups

Strongly acidic (e.g. sulfonate, $–SO_3^-$)

Weakly acidic (e.g. carboxylate, $–COO^-$)

Strongly basic [e.g. quaternary amine, $–N^+(CH_3)_3$]

Weakly basic [e.g. tertiary amine, $–N(CH_3)_2$]

The acidic resins are negatively charged, and can be loaded with cations (e.g.$Na^+$), which are easily displaced by other cations during water treatment. This type of cation exchange is most commonly applied to soften hard waters. Conversely, strongly basic resins can be pretreated with anions, such as $Cl^-$, and used to remove a wide range of negatively charged species.

Different resins will have differing selectivity sequences, and resins have been developed specifically to optimize removal of sulfate, nitrate, and organic matter. Various strong-base anion exchange resins are commercially available which can effectively remove arsenate from solution, producing effluent with less than 1 µg/L arsenic. Arsenite, being uncharged, is not removed. Analysts have taken advantage of this specificity to develop procedures for analytical differentiation of arsenite and arsenate. Therefore, unless arsenic is present exclusively as arsenate, an oxidation step will be a necessary precursor to arsenic removal. Conventional sulfate-selective resins are particularly suited for arsenate removal. Nitrate-selective resins also remove arsenic, but arsenic break through

occurs earlier. Most commonly, resins are pretreated with hydrochloric acid, to establish chloride ions at the surface, which are easily displaced by arsenic, though the resin can be primed with other anions such as
bromide or acetate. Packed beds are commonly designed to have an Empty Bed Contact Time (EBCT) of 1.5 to 3 minutes.
Arsenate removal is relatively independent of pH and influent concentration. On the other hand, competing anions, especially sulfate, have a strong effect. The number of bed volumes that can be treated before arsenic breakthrough (defined as 10% of the influent concentration) can be roughly estimated with two simple formulas:

iv) Membranetechnology

- a) Microfiltration
- b) Ultrafiltration
- c) Nanofiltration
- d) Reverse osmosis

Synthetic membranes are available which are selectively permeable: the structure of the membrane is such that some molecules can pass through, while others are excluded, or rejected. Membrane filtration has the advantage of removing many contaminants from water, including bacteria, salts, and various heavy metals. Two classes of membrane filtration can be considered: low-pressure membranes, such as microfiltration and ultrafiltration; and high-pressure membranes such as nanofiltration and reverse osmosis. Low-pressure membranes have larger nominal pore sizes, and are operated at pressures of 10-30 psi. The tighter high-pressure membranes are typically operated at pressures from 75 to250 psi, or even higher  it is clear that reverse osmosis (RO) and nanofiltration (NF)membranes have pore sizes appropriate for removal of dissolved arsenic, which is in the 'metal ion' size range. Both RO and NF membranes are most often operated in lateral configurations, in which only a small amount of the raw water(10-15%) passes through the membrane as permeate. In household systems, where only a small amount of treated water is

required for cooking and drinking, this low recovery rate may be acceptable. Municipal systems achieve higher
recovery rates (80 to over 90%) by using multiple membrane units in series. In recent years, a new generation of RO and NF membranes have been developed that are less expensive and operate at lower pressures, yet allow improved flux and are capable of efficient rejection of both arsenate and arsenite. Waypa and others have showed that some of the new membranes, operated at pressures ranging from 40-400 psi, were able to reject from 96-99% of both arsenate and arsenite in spiked natural waters. The authors attribute this rejection of arsenite to the relatively large molecular weight of both arsenate and arsenic, rather than charge repulsion. At these high arsenic rejection rates, membrane filtration can result in extremely low arsenic levels in treated water.

v) Adsorption

a) Activated alumina

b)Iron based sorbents

d) Zero valant Iron

e) Indigenous filters

f) Miscellaneous sorbents

g ) Metal organic frameworks

**Activated Alumina**

Activated alumina is a granulated form of aluminum oxide ($Al_2O_3$) with very high internal surface area, in the range of 200-300 m2/g. This high surface area gives the material a very large number of sites where sorption can occur, and activated alumina has been widely used for removal of fluoride.

**SOFTENING**

The reduction or removal of hardness from water is known as water softening. It is not necessary soften the water to domestic supply. Hardness of water are not too high to harm for human health. Main advantage of low hardness is low consumption of soap. This is very vital for some industrial consumption speciallyfor boiler. Hardness are two types temporary or carbonate hardness and permanent or noncarbonated hardness. The temporary or carbonate hardness can be removed by boiling or by addition of lime.The permanent or noncarbonated hardness may be removed by

i ) Lime soda process

ii) Base exchange or Zeolite process

iii) Demineralsation process

## LIME SODA PROCESS

Chemical precipitation is one of the more common methods used to soften water. Chemicals normally used are lime (calcium hydroxide, $Ca(OH)_2$) and soda ash (sodium carbonate, $Na_2CO_3$). Lime is used to remove chemicals that cause carbonate hardness. Soda ash is used to remove chemicals that cause non-carbonate hardness. When lime and soda ash are added, hardness-causing minerals form nearly insoluble precipitates. Calcium hardness is precipitated as calcium carbonate ($CaCO_3$). Magnesium hardness is precipitated as magnesium hydroxide ($Mg(OH)_2$). These precipitates are then removed by conventional processes of coagulation/flocculation, sedimentation, and filtration. Because precipitates are very slightly soluble, some hardness remains in the water--usually about 50 to 85 mg/l (as $CaCO_3$). This hardness level is desirable to prevent corrosion problems associated with water being too soft and having little or no hardness.

LIME ADDITION

<u>Hardness Lime Precipitate</u>

$CO_2$. + $Ca(OH)_2 \rightarrow CaCO_3 + H_2O$

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

$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow CaCO_3 + MgCO_3 + 2H_2O$

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

$CO_2$ does not contribute to the hardness, but it reacts with the lime, and therefore uses up some lime before the lime can start removing the hardness.

**LIME AND SODA ASH ADDITION**

Lime

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

Soda ash Precipitate

$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$

ii) BASE EXCHANGE ( ZEOLITE ) PROCESS

For softening of water by zeolite process, hard water is percolated at a specified rate through a bed of zeolite. Zeolite holds sodium ion loosely and can be represented as $Na_2Z$, where Z represents insoluble radical frame work.

When the water passes through the zeolite the hardness causing ions ($Ca^{+2}$, $Mg^{+2}$ etc.) are retained by the zeolite as CaZ and MgZ respectively, while the outgoing water contains equivalent amount of sodium salts. The block diagram and chemical reactions taking place in zeolite softener are:

$$Ca(HCO_3)_2 + Na_2Z \rightarrow CaZ + 2NaHCO_3$$

$$Mg(HCO_3)_2 + Na_2Z \rightarrow MgZ + 2NaHCO_3$$

$$CaSO_4 + Na_2Z \rightarrow CaZ + Na_2SO_4$$

$$CaCl_2 + Na_2Z \rightarrow CaZ + 2NaCl$$

$$MgSO_4 + Na_2Z \rightarrow MgZ + Na_2SO_4$$

$MgCl_2 + Na_2Z \rightarrow MgZ + 2NaCl$

After some time, when the zeolite is completely changed into calcium and magnesium zeolites, then it gets exhausted (saturated with $Ca^{+2}$ and $Mg^{+2}$ ions) and it ceases to soften water. It can be regenerated and reused by treating it with a 10% brine (sodium chloride) solution.

$$CaZ + 2NaCl \rightarrow Na_2Z + CaCl_2$$

$$MgZ + 2NaCl \rightarrow Na_2Z + MgCl_2$$

iii) DEMINERALATION PROCESS

Demineralized water also known as deionized water, water that has had its mineral ions removed. Mineral ions such as cations of sodium, calcium, iron, copper, etc and anions such as chloride, sulphate, nitrate, etc are common ions present in water. Deionization is a physical process which uses specially-manufactured ion exchange resins which provides ion exchange site for the replacement of the mineral salts in water with water forming H+ and OH- ions.Because the majority of water impurities are dissolved salts, deionization produces a high purity water that is generally similar to distilled water, and this process is quick and without scale buildup. De-mineralization technology is the proven process for treatment of water. A DM water system produces mineral free water by operating on the principles of ion exchange, Degasification, and polishing. Demineralized water system finds wide application in the field of steam, power, process, and cooling.

The principle of the demineralization is raw water is passed via two small polystyrene bead filled (ion exchange resins) beds. While the cations get exchanged with hydrogen ions in first bed, the anions are exchanged with hydroxyl ions, in the second one. In the context of Water purification, ion-exchange is a rapid and reversible process in which impurity ions present in the Water are replaced by ions released by an ion-exchange resin. The impurity ions are taken up by the resin, which must be periodically regenerated to restore it to the original ionic form. (An ion is an atom or group of atoms with an electric charge. Positively-charged ions are called cations and are usually metals; negatively-charged ions are called anions and are usually non-metals).

The following ions are widely found in raw water

There are two basic types of resin - cation-exchange and anion-exchange resins. Cation exchange resins will release Hydrogen (H+) ions or other positively charged ions in exchange for impurity cations present in the Water. Anion exchange resins will release hydroxyl (OH-) ions or other negatively charged ions in exchange for impurity anions present in the Water.

First, cation-exchange resins alone can be employed to soften Water by base exchange; secondly, anion-exchange resins alone can be used for organic scavenging or nitrate removal; and thirdly, combinations of cation-exchange and anion-exchange resins can be used to remove virtually all the ionic impurities present in the feed water, a process known as deionization. Water deionizers purification process results in water of exceptionally high quality. For many laboratory and industrial applications, high-purity Water which is essentially free from ionic contaminants is required. Water of this quality can be produced by deionization.The two most common types of deionizationare :

a)Two-bed deionization

b)Mixed-bed deionization

Two-bed deionization

The two-bed deionizer consists of two vessels - one containing a cation-exchange resin in the hydrogen (H+) form and the other containing an anion resin in the hydroxyl (OH-) form. Water flows through the cation column, whereupon all the cations are exchanged for hydrogen ions. To keep the Water electrically balanced, for every monovalent cation, e.g. Na+, one hydrogen ion is exchanged and for every divalent cation, e.g. $Ca_2$+, or Mg2+, two hydrogen ions are exchanged. The same principle applies when considering anion-exchange. The decationised Water then flows through the anion column. This time, all the negatively charged ions are exchanged for hydroxide ions which then combine with the hydrogen ions to form Water( $H_2O$)

## MIXED-BEDDEIONIZATION

In mixed-bed deionizers the cation-exchange and anion-exchange resins are intimately mixed and contained in a single pressure vessel. The thorough mixture of cation-exchangers and anion-exchangers in a single column makes a mixed-bed deionizer equivalent to a lengthy series of two-bed plants. As a result, the water quality obtained from a mixed-bed deionizer is appreciably higher than that produced by a two-bed plant. Although more efficient in purifying the incoming feed water, mixed-bed plants are more sensitive to impurities in the water supply and involve a more complicated regeneration process. Mixed-bed deionizers are normally

used to ‘polish' the water to higher levels of purity after it has been initially treated by either a two-bed deionizer or a reverse osmosis unit.

## DESALINATION

Desalination is the processes to separate dissolved salts and other minerals from water. The raw water from sea water, surface water, waste water and industrial water or brackish water contain salts and minerals. Membrane separation requires driving forces including pressure (applied and vapor), electric potential, and concentration to overcome natural osmotic pressures and effectively force water through membrane processes. At costal zone enough sea water convert into potable water. Reverse osmosis (RO) and Nanofiltration (NF) are the leading pressure driven membrane processes. Membrane configurations include spiral wound, hollow fiber, and sheet with spiral being the most widely used. Direct current (DC) processes Electrodialysis (ED) and Electrodialysis Reversal (EDR) processes are driven forces by direct current (DC) sources through ion selective membranes to electrodes of opposite charge to separate the ions.. In EDR systems, the polarity of the electrodes is reversed periodically. Ion-transfer (perm-selective) anion and cation membranes separate the ions in the feed water. These systems are used primarily in waters with low total dissolved solids (TDS). Forward osmosis (FO) is a relatively new commercial desalting process in which a salt concentration gradient (osmotic pressure) is the driving force through a synthetic membrane. The raw water is on one side of the semi permeable membrane and a higher osmotic pressure "draw" solution is on the other side. The water from the feed solution will migrate through the membrane to the draw solution without applying any external pressure. The diluted solution is then processed to separate the product from the reusable draw solution.

Membrane Distillation (MD) is a water desalination membrane process currently in limited commercial use. MD is a hybrid process of RO and distillation in which a hydrophobic synthetic membrane is used to permit the flow of water vapor through the membrane pores, but not the solution itself. The driving force for MD is the difference in vapor pressure of the liquid across the membrane.

## CHAPTER -9

# Conclusion

There are so many process and method in water treatment technology. Every process have some merit and demerits. In this chapter compendium of water treatment technology main processes are discussed briefly. So to keep the optimum cost for that purpose for which it is chosen a brief knowledge is necessary every designer. In It will be certainly helpful to chosen the right process.

# CHAPTER – 10
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