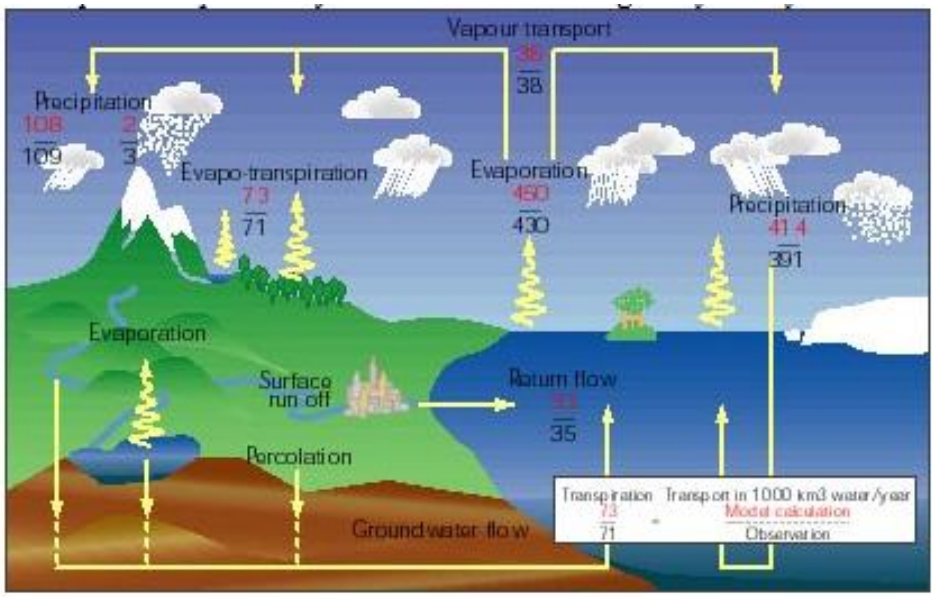
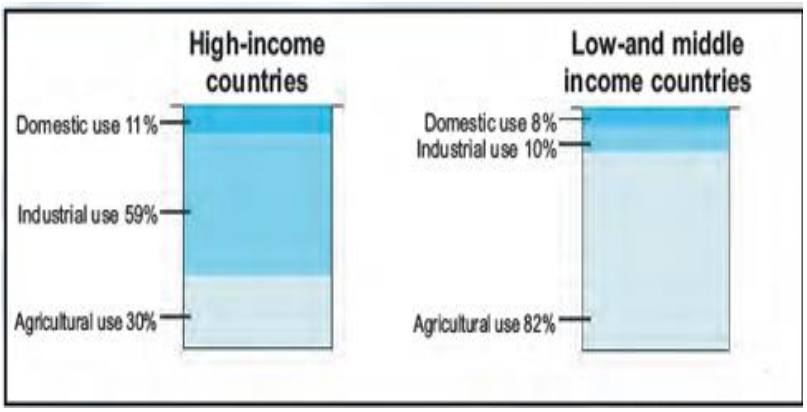
Topic 2: Water Chemistry

Water cycle



Water use in developed and developing countries



Per capacity water requirement

Purpose	Litres/ person/day
Drinking	03
Cooking	04
Bathing	20
Flushing	40
Washing clothes	25
Washing utensils	20
Gardening	23
Total	**135**

Comment form Chemtech

- On comparing an average Indian industry with the best global industry, it is seen that the Indian industry is far more water intensive than its global counterpart. Higher water consumption in Indian industries is due to the sheer(Purna) scale of inefficiency and waste in the industrial system, lack of proper information, dearth(Duskal) of price sensitive and predictive water management information and the lack of a proactive approach.

Specific water consumption for various industries in india

Industry	Unit of Production	Water Requirement in Kilolitres Per Unit
Automobile	Vehicle	40
Distillery	Kilolitre (alcohol)	122–170
Fertiliser	Tonne	80-200
Leather	100 kg (tanned)	4
Paper	Tonne	200–400
Straw board	Tonne	75-100
Petroleum Refinery	Tonne (crude)	1-2
Steel	Tonne	200–250
Sugar	Tonne (cane crushed)	1–2
Textile	100 kg (goods)	8-14
Dairy	1000 litres	6-10

Why to know water?

- India is already an almost water stressed country. Water scarcity (Tanchaie) problem can be mitigated (kami) using an integrated approach, aimed at reducing wastewater generation and recycling the wastewater. Water conservation, rainwater harvesting and water recycling play an important role. These measures can be adopted at the municipality, community as well as at industrial levels. Water is the limiting factor for sustainable development and industrialisation. Water conservation and recycled water is cheaper than fresh water. Hence, water recycling is not a bottleneck but is a good business decision in the long run

Introduction:

- 1Natures most wonderful gift of God to man Because
- Without food, we can survive up to 20 day's But without water, not more than one week
- 2.Earth is blue planet. 4/5 of earth surface is covered by water.
- Out of total water 97.0% present in the sea Out of 3%, 2.7% present in form of glacier & Underground water Only 0.3% water is available for drinking, washing, irrigation, Agriculture & industrialization.

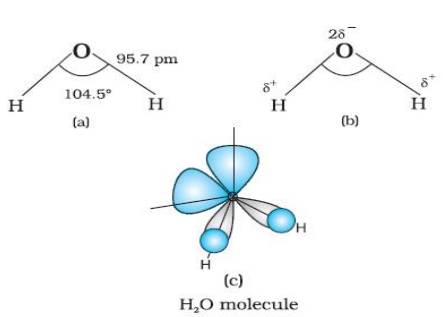
Source	% of Total
Oceans	97.33
Saline lakes and inland seas	0.008
Polar ice and glaciers	2.04
Ground water	0.61
Lakes	0.009
Soil moisture	0.005
Atmospheric water vapour	0.001
Rivers	0.0001

- 3.Properties shown by water is unique one
- On dissociation it gives H^+ & OH^- ions According to Arrhenius, it is acid & base. But it is neutral in nature. When we add water, in acid it becomes acidic & in base it become basic.
- 4. Water is called universal solvent. It is available in large quantity. With low cost. Most of element in periodic tables they are soluble in water.
- 5. On solidification density of water decreases. Therefore ice floats on water.
- The unusual properties of water in the condensed phase (liquid and solid states) are due to the presence of extensive hydrogen bonding between water molecules. This leads to high freezing point, high boiling point, high heat of vaporization and high heat of fusion in comparison to H2S and H2Se. In comparison to other liquids, water has a higher specific heat, thermal conductivity, surface tension, dipole moment and dielectric constant, etc. These properties allow water to play a key role in the biosphere.

Property	H_2O
Molecular mass (g mol^{-1})	18.0151
Melting point/K	273.0
Boiling point/K	373.0
Enthalpy of formation/kJ mol^{-1}	–285.9
Enthalpy of vaporisation (373K)/kJ mol^{-1}	40.66
Enthalpy of fusion/kJ mol^{-1}	6.01
Temp of max. density/K	276.98
Density (298K)/g cm^{-3}	1.0000
Viscosity/centipoise	0.8903
Dielectric constant/$C^2/N.m^2$	78.39
Electrical conductivity (293K/ohm^{-1} cm^{-1})	5.7×10^{-8}

Chemistry of Water

- Name: Water , Chemical formula: H_2O, Atomic Weight: 18, Geometry: Tetragonal, Electro negativity: H: 2.1, O:3.5, Hybridization: SP^3
- **At. No. Of Oxygen: 8, Electronic configuration: $1S^2$ $2S^2$ $2Px^2$ $2Py^1$ $2Pz^1$**



H_2O molecule

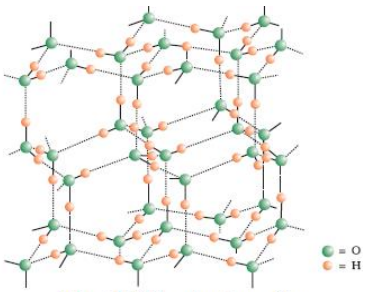


Fig. 9.2 The structure of ice

Sources of water: main source of water is rain water & it is classified in to two types A) Surface water & B) underground water

- Rain water: It is purest form of natural water.(It is formed due to condensation of water vapor i.e process similar to distillation) It is called primary source because when it approaches earth's surface it converts/ provides water to other sources called secondary sources like rivers, streams, underground water , seas & oceans.(Water for these sources coming from rain water)
- Presence of impurity in atmosphere it becomes impure
  A) Surface water: Types of surface water is Steady and Flowing water. E.g stream, river, lake & sea
- Water for this sources coming from rain (primary source)
- 1.Flowing water: e.g. Stream, River (Secondary Source)
  In this type water flow over rocks & minerals. During their journey it comes in contact with number of impurities like dissolved, suspended, colloidal & bacterial impurities. This type of water is used for domestic & industrial purpose after sedimentation/ coagulation and sedimentation & purification only. It is applicable to all kind of applications.
  2. Steady water: e.g. Lake, pond
  In this type water collect specific area over earth surface. Distance traveled by water is less compare with flowing water. Therefore amount of dissolved, suspended & colloidal impurities are less, but due to stagnancy of water without any moment, amount of bacterial impurities, organic matters impurities are quit higher than flowing water. When organic matters are more than dissolved oxygen some time un aerobic bacterial decomposition produce foul smell. It is useful for domestic and agricultural applications.
- 3. Sea water: It is most impure water present on earth surface. All rivers terminates at sea, river water carries large amount of salts. Sea water continuously evaporated leaving salt behind thus salinity of sea water continuously increases. It contains on an average 3.5% salts out of that 2.6% NaCl while others are sodium sulphate, bicarbonates of Ca,Mg,K, bromides of K,Mg and other salts.
- It is useful only for water cycle.
- B) Underground water: A part of the rain water, reaches the surface of earth, percolates(natural filtration) into earth, coming out in the form of springs or well water
- Springs or Wells: As compare to flowing water it consist of more amount of dissolved salts, but it is more clear in appearance due to less amount of colloidal & suspended impurities. It is useful for domestic application if pumping is economical then for agricultural purpose.

Comparative chart to source, purity, impurity and significance

Source	Purity	Impurities	Significance
Rain Water	Most pure form of natural water	Dust, Clay dissolved CO_2, O_2	Primary source cannot be used directly
Sea/Ocean	Most impure form	>% of dissolved Salts And minerals	Cannot be used directly Important in water cycle
River/Spring, Streams etc.	Moderately Pure	Floating matter, Clay, Sand, Vegetative waste, Dissolved salts, Mineral Only Dissolved salts	Used for all purposes
Lakes, Ponds	Moderately Pure		
Underground	Moderately Pure		

Effect of water on Rocks & Minerals

- Dissolution: Mineral like NaCl, Gypsum they are easily dissolved in water

- Hydration: Un hydrous substances like Calcium sulphate easily hydrated with water converted into Gypsum
- $CaSO_4 + 2H_2O \rightarrow CaSO_4\ 2H_2O$
- Calcium sulphate Gypsum
- Action of dissolved Oxygen: D.O. in water causes oxidation of minerals
- $2Fe_3O_4 \rightarrow 3Fe_2O_3 \rightarrow Fe_2O_32H_2O$
- Magnetite Hematite Limonite
- Action of dissolved Carbon dioxide : Dissolved Carbon dioxide react with carbonates of Calcium & Magnesium to form Bicarbonates of Calcium & Magnesium
- $CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3)_2$
- $MgCO_3 + CO_2 + H_2O \rightarrow Mg(HCO_3)_2$
-

Impurities in water: Dissolved , Suspended, Colloidal ,Bacterial

- Water from these sources is impure & consist several impurities. These impurities come from soil, vegetation, atmosphere, man made activities etc. The important impurities in natural water are divided as under
- **1. Floating impurities**: They include all types of matter (organic with bigger size & less denser) which floats on surface, such as dried leaves, wood pieces, plastic oil & greases etc. can be separated by simple methods of separation
- **2. Suspended impurities:** These are insoluble impurities held by water. Steady water & underground water is free from such impurities. Suspended matter is of three types
- a) Heavy suspended matter: Silt, Sand, Clay etc.
- b) Fine suspended matter: Fine clay & dust
- c) Colloidal matter: Fine silica & silica gel.
- Besides this harmful pathogens are also considered as biological impurities. e.g ecoli
- These impurities can be removed by keeping water stand still, sedimentation, coagulation, filtration etc
- **3. Dissolved impurities**: It includes all water soluble substances which come to natural water from soil and man made activities. These are classified as
- i) Acidic & Alkaline substances: Bicarbonates, Mineral acids. Providing acidity ,alkalinity to water sample
- ii) Colour salts & Minerals: Transition metal compounds. Providing colour to the water
- iii) Toxic substances: Salts of As,Pb,Hg makes water poisonous
- iv) Dissolved gases: CO_2 &O_2 increases acidity, palatability test, oxygen to aquatic life, increases freshness of water, causes corrosion of material (org, inorganic) if less sufficient cause foul smell to water
- v) Ca & Mg Salts: Causes hardness to the water
- vi) Neutral salts: like NaCl, KCl increases salinity test as well as conductivity of water to increase rate of corrosion.
-

Effect of impurity on quality of water

- Colour: Colour of natural water varying from pale straw to yellow to reddish brown.
- Colour of water detected by Tinto meter & unit is silica scale
- Odor & Test: Natural water is odor & test less, Odor & Test due to reaction of chlorine with organic matter, coming as effluent of industry like food, paper & textiles etc. It is removed by passing water on activated charcoal

- Turbidity & sediment: Cause due to presence of suspended impurities in water. It is detected by Turbidimeter

Dissolved impurities in water

- Dissolved impurities in water causes different types of effects on quality of waters
- **1. Hardness**: This type of effect cause due to presence of dissolved salt of Ca & Mg.

e.g. $CaSO_4$, $MgSO_4$, $CaCl_2$, $MgCl_2$, $Fe_2O_32H_2O$, $Ca(HCO_3)_2$ $Mg(HCO_3)_2$, & $CaCO_3$,$MgCO_3$, $Mg(NO_3)_2$ etc

What is hardness of water ?

- **Intoduction**: Pure water is free from dissolved impurities. When this water allow reacting with soap, it form foam with ease i.e. Direct forming foaming agent / without formation of scum or precipitate.
-
- $C_{17}H_{35}COONa + H_2O \rightarrow C_{17}H_{35}COOH + NaOH \rightarrow$ Foam
- Soap (Foaming agent)
- Soft water containing **lower extent** of dissolved salts of Ca & Mg. Interferences of these salts in soap & water reaction is negligible
- (Soap) $+CaCl_2 \rightarrow (C_{17}H_{35}COO)_2Ca \downarrow +2NaCl + C_{17}H_{35}COONa + H_2O \rightarrow C_{17}H_{35}COOH + NaOH \rightarrow$ Foam
- (Form soft water) ppt or scum small amt (Foaming agent)
- Hard water containing **large extent** of dissolved salts of Ca & Mg. Interferences of these salt in soap & water reaction is high. Produces curdy ppt (scum) when most of Ca & Mg converts into scum soap will form lather i.e difficultly
- Thus water contain dissolve salts of Ca & Mg (have tendency to consume soap) is called as Hard water.
- **Definition: <u>Hard water</u> is kind of water which difficultly forms foam or lather with soap**
- **Definition: <u>Soft water</u> is kind of water which easily forms foam or lather with soap.**
- **Definition Hardness**: Hardness of water is tendency of water to resist formation of foam or lather on treatment with soap.
- **Definition Degree of hardness**: Degree of hardness is extent of resistance offered by water towards the formation of foam or lather.
- **Causes of Hardness**: Water becomes hard due to dissolved salt of Calcium & Magnesium from soil. Ca &Mg ions from water interfere during reaction of water with soap as under
- $C_{17}H_{35}COONa + H_2O \rightarrow C_{17}H_{35}COOH + NaOH \rightarrow$ Foam
- Soap (Foaming agent)
- (Sodium Stearate) $+CaCl_2 \rightarrow (C_{17}H_{35}COO)_2Ca \downarrow + 2NaCl$
- (Form hard water) ppt or scum
- Thus hard water produces foam or lather when all Ca &Mg is converted into scum

Types of Hardness & Hard water

- Hardness of water is <u>classified on the basis of boiling</u>. If hardness is due to **bicarbonate of** Ca & Mg then it vanished after boiling because **bicarbonate of** Ca & Mg decomposes into insoluble salts on mere boiling of water, while hardness due to salts **other than bicarbonate** is retained i.e. retain in ionic form and remain soluble even after boiling. Thus two type of hardness are
- **Temporary hardness:** Cause due to bi carbonates of Ca & Mg salts. This type of hardness removed by mere boiling. <u>Kind of water whose hardness removed by mere boiling is called temporary hard water</u>
- $Ca(HCO_3)_2 \rightarrow CaCO_3 \downarrow + CO_2 + H_2O$
- $Mg(HCO_3)_2 \rightarrow Mg(OH)_2 \downarrow + 2H_2O$
- **Permanent hardness:** Causes due to Chlorides, Sulphate, Nitrides of Ca, Mg & Heavy metal ions. They are not removed by mere boiling of water.
- e.g. $CaSO_4$, $MgSO_4$, $CaCl_2$, $MgCl_2$, $Fe_2O_32H_2O$,, $CaCO_3$,$MgCO_3$, $Mg(NO_3)_2$ etc

- Kind of water whose hardness retained even after mere boiling is called permanent hard water

Expressing hardness

- Hardness of water is due to different substances having different molecular weights. Simple addition of it to calculate hardness is not considered. Thus universally it decided to convert all soluble impurities amount in to equivalence of $CaCO_3$. In order to express it in single substance it is expressed in terms of equivalence of $CaCO_3$
- Hardness of water is expressed as equivalents of $CaCO_3$
- $$CaCO_3 \text{ equivalent} = \frac{\text{Amount of hardness causing substance} \times 100}{\text{Molecular weight of hardness causing substance}}$$

Units of hardness

- 1.Part Per Millions (ppm): The number of parts of $CaCO_3$ equivalent hardness causing impurities present per million (10^6) parts of water
- 2. Milligrams per liter (mg/l):- It is number of milligram of $CaCO_3$ equivalent hardness causing impurities present in one liter of water.
- 3. Degree Clarks: It is number of parts of $CaCO_3$ equivalent hardness causing impurities present in 70000 parts of water.
- 4. Degree French: It is number of parts of $CaCO_3$ equivalent hardness causing impurities present in 100000 parts of water.
- **1ppm = 1mg/l = 0.07 ^{0}Cl = 0.1 ^{0}Fr**

Calculations of $CaCO_3$ equivalents

Dissolved salts	Molecular weight	Multiple factor for converting into equivalence of $CaCO_3$	Dissolved salts	Molecular weight	Multiple factor for converting into equivalence of $CaCO_3$
$Ca(HCO_3)_2$	162	100/162	$MgCl_2$	95	100/95
$Mg(HCO_3)_2$	146	100/146	$CaCO_3$	100	100/100
$CaSO_4$	136	100/136	$MgCO_3$	84	100/84
$MgSO_4$	120	100/120	CO_2	44	100/44
$CaCl_2$	111	100/111	$Mg(NO_3)_2$	148 Ch. Eq. 74	100/74

Determination of hardness: By soap method.

- First standardize soap solution with standard hard water.
- Known volume of (50ml) of unknown sample is allow to react with standard soap solution till permanent foam is formed for at lest 5 sec.
- EDTA method : First standardize EDTA solution with standard hard water.
- Known volume of (50ml) of unknown sample is allow to react with standard EDTA solution in basic buffer & EBT indicator till colour changes from wine red to sky blue

Examples on hardness

- **1.Find out Temporary, Permanent, Total hardness of water containing following impurities. $Ca(HCO_3)_2$:16.2 mg/l $Mg(HCO_3)_2$:14.6 mg/l, $CaSO_4$:13.6 mg/l, $MgSO_4$:12 mg/l, $CaCl_2$:11.1 mg/l, $MgCl_2$:9.5 mg/l, ,$MgCO_3$:8.4 mg/l, $Mg(NO_3)_2$:7.4 mg/l**

- Calculations of equivalence of $CaCO_3$
- $Ca(HCO_3)_2$:16.2 mg/l = 16.2 X 100/ 162 = 10 mg/l
- $Mg(HCO_3)_2$:14.6 mg/l = 14.6 X 100/146 = 10 mg/l
- $CaSO_4$:13.6 mg/l = 13.6X 100/ 136 = 10 mg/l
- $MgSO_4$:12 mg/l = 12X 100/120 = 10 mg/l
- $CaCl_2$:11.1 mg/l = 11.1 X 100/ 111 = 10 mg/l
- $MgCl_2$:9.5 mg/l, = 9.5 X 100/ 95 = 10 mg/l
- $MgCO_3$:8.4 mg/l = 8.4 X 100 / 84 = 10 mg/l
- Temporary Hardness= Sum of $Ca(HCO_3)_2$ &$Mg(HCO_3)_2$ = 10+10 = 20 ppm
- Permanent Hardness= Sum of $CaSO_4$, $MgSO_4$,$MgCl_2$ & $MgCO_3$ = 10+10+10+10 = 40ppm
- Total Hardness = Temp + Permanent = 20 + 40 = 60 ppm

- **2.Water sample was prepared by dissolving exactly 1.5 gm CaCO3 in minimum quantity of con.HNO3 and diluted to 5 lit Calculate hardness of water before and after boiling of water.**
- 1.5gm means 1500mg in 5Lit
- Hence 1L=300ppm
- CaCO3 converted into Ca(NO3)2 hence before and after boiling hardness = 300ppm

- **3. Excess of Na2CO3 was added to 200cc solution of gypsum. The dried ppt of CaCO3 was weighted 0.072gm. Determine molar conc. Of gypsum solution. If same amount of gypsum is present in 400cc solution. What will be its hardness in ppm(Mole wt Na2CO3 106, Gypsum 136, CaCO3: 100)**
- Na2CO3+ CaSO4 Na2SO4 + CaCO3
- Moles of Na2CO3 in 200cc = 0.072/100=0.00072
- M= 0.00072/.2 = 0.0036M
- 400cc solution gives 0.072gm CaCO3
- The. 1000cc solution gives 0.072X2.5=0.18gm = 180ppm
-
- **4.A two lit. of temporary hard water on boiling gives 0.45gm of CaCO3 as ppt Determine its hardness.**
- 0.45gm in 2 lit
- 0.225gm in 1 lit = 225ppm
- **5.15.2 gm of $CaCl_2$ was dissolved in 150 cc distilled water and then solution was diluted to 775 cc. Calculate Normality and hardness of solution. (Molecular Weight of CaCl2: 111)**
- N= (15.2/55.5)/.775 = 0.35338
- Hardness= 15.2 gm in 775 ml solution
- Hence 19.6129 gm in 1 Lit = 19.6129 X 10^3 mg in 1 Lit. CaCO3 equivalence of 19.6129 X 10^3 mg is 17.83 X 10^3 Hardness of water Hence Hardness = 17830 ppm
-
- **Ill effects of hard water Domestic & Industrial**
- Hard water when used in domestic and industrial applications, then it produces several ill effects. The disadvantages of hard water For domestic use are as given
- Wastage of large quantity of soap. It produces curdy white ppt. the scum. Scum damages texture of fabric and also produce skin disorders when chokes skin pores.
- It causes digestive disorders and kindly disorders when regularly consumed as drinking water.
- Damages kitchenware like cookers by scaling and waste more fuel.
- Damages water heating appliances like geysers.
- Causes water line corrosion to metallic store tanks.

The disadvantages in industrial use are as under.

- **Scale and Sludge formation in boilers**- steam generation is common in many industries. Steam is generated by means of water boiler. Boiler is filled with water and the same is taken out as steam. Thus all salt present in water are left in boiler vessel. Some of these salts adhere to boiler walls called as scale and some deposits at bottom called as sludge. Scale and sludge is disadvantageous because
- i) It reduces water carrying capacity of boiler, thus less extent of steam is produced .
- ii) It reduces efficiency of boiler.
- iii) Scale layer is insulating and thus it account for wastage of fuel.
- iv) Water entering through cracks in scale layer causes corrosion and reduces life of boiler.
- v) Sludge may choke various pipes fitting of boiler and increases chance of an accident or explosion.
- vi) Alkaline water causes caustic embrittlement
- Use of hard water causes corrosion of metallic parts, spares, components, equipment, machinery etc.
- Produce disorders in working of heat exchangers using water as coolant.
- **Textile industry**- Hard water causes wastage of soap, damages texture of fabric and dose not give expected shade or colour
- to fabric.
- **Sugar Industry**- Hard water is used cause opacity to crystals, reduces, crystal size. Sugar becomes deliquescent.
- **Food Industry-** Hard water spoils taste of food product.
- **Paper Industry-** Hard water affects paper quality like texture and finish.
- **Chemical and Pharmaceutical Industry**- Hard water when used in such industries then it tends to reduce purity of final product. Also reactors are affected by scale formation, corrosion etc

Alkalinity, **Chloride , Dissolved oxygen, BOD & COD its significance**

Alkalinity:

Alkalinity of water can be defined as tendency of water to neutralize acid. It is caused by increase in extent of OH^-, $CO3^{--}$ or HCO_3^- ions by hydrolysis, dissociation etc. Based on this alkalinity of water is classified in three types.

1. Hydroxil or Hydrate alkalinity: due to OH^- denoted by A_H
2. Carbonate alkalinity: due to $CO3^{--}$ denoted by A_C
3. Bicarbonate alkalinity: due to HCO_3^- denoted by A_B

The alkalinity of all three types will not exist at same time as existence of OH^- & HCO_3^- with each other is ruled out. The total alkalinity A is sum of Hydroxyl, carbonate & bicarbonate alkalinity.

Alkaline water is not suitable for domestic & industrial use. The important disadvantages of alkalinit are

1. Carbonate & bicarbonate alkalinity causes temporary hardness (Ca & Mg bicarbonate)
2. Alkaline water causes digestive disorders when used for drinking.
3. OH^- alkalinity causes caustic embrittlement of metallic components, spares, machines, equipments etc.
4. Alkalinity of water causes damage to constructions made on source of water e.g. Bridges
5. Alkaline water helps scale & sludge formation in boilers.
6. Continuous use of alkaline water for agriculture spoil the soil by change pH.

Chloride content: Chlorides are ionic compounds of chlorine with other elements. Soil consist large extent of solid minerals &salts as chlorides. When rain water comes in direct contact with soil then chlorides from soil dissolve in water. The chlorides present in greater extent are NaCl, KCl, $CaCl_2$, $MgCl_2$, $AlCl_3$, $FeCl_3$ etc.

Chloride extent when exceeds 200 ppm, then it produces several ill effects when used in domestic or industrial applications. Important of them are

1. High % of chlorides imparts saline taste to water i.e. it increases salinity. Such water cannot be used for any direct application e.g. sea water.
2. Ca & Mg Chlorides makes water hard.
3. High chlorides produce large extent of sludge in boiler, while $CaCl_2$ forms scales.
4. Saline water also damages kitchen ware & water heating appliances when used for domestic application.
5. Saline water permanently spoils soil when used in agricultural applications.

Chloride content is not main quality parameter, but we can estimate total dissolved solids (TDS) by knowing extent of chlorine. As 80% of dissolved salts are chlorides

i) BOD and COD – a) **BOD**- BOD is used to designate the term Biological oxygen demand. BOD is very important parameter to determine extent of water pollution. It is defined as 'amount of oxygen consumed by bacteria toward decomposition/ oxidation of organic matter present in known quantity of water at 25^{o}C within 120 hours'. It is expressed in ppm.

Determination – 250 cc water is taken in BOD bottle. Some of sample is analyzed for initial DO content. The bottle is than kept in an incubator at 25oC for 120 hours. Then the final DO level is measured. The difference in initial and final DO level is BOD of water.

BOD is important as 1) High BOD indicates presence of large extent of organic matter and bacteria in water 2) Such water is unsuitable for domestic use is it consist harmful microorganisms and possess offensive odor. 3) Nil BOD indicates absence of organic matter as well as bacteria feeding on it. BOD of natural water increases due to introduction of high amounts of decomposable waste through disposal of domestic and industrial waste water. This organic matter is not completely decomposed due to deficiency of oxygen and this shoots up BOD.

b) COD :- (Chemical oxygen demand) – It is defined as amount of oxygen consumed towards oxidation of ox disable waste present in known quantity of water by adding known excess of strong oxidizing agent. COD is parameter generally associated with effluent. (industrial waste water). COD of water is high if contains non decomposable oxidisable substance. Such constituents can be only oxidezed by providing oxygen.

Determination :- Known volume of water is taken in reflux flask. To this known excess of $K_2Cr_2O_7$ is added as oxidizing agent. The mixture is strongly refluxed for one half hours. The un utilized $K_2Cr_2O_7$ is determined by titrating known volume of refluxed solution with std. solution of ferrous ammonium sulphate. COD is important polluting parameter as 1) High COD indicates presence of high amounts of non decomposable waste which is harmful. 2) High COD reduces DO level 3) If an effluent with high COD is disposed directly to natural source then it affects aquatic life.

BOD	COD
1. It is amount oxygen required for oxidation of decomposable organic matter.	1.It is amount oxygen required for oxidation Non decomposable impurities
2. It is of O_2 consumed toward bio-chemical reaction	2. It is of O_2 consumed toward direct chemical reaction
3. High BOD indicates presence of large Extent organic matter and bacteria in water.	3. High COD indicates presence of large ox disable waste in water.
4. Determination requires period of 120 hours.	4. Determined within 2 hours.
5.BOD is high for domestic waste water (Sewage)	5. High for industrial waste water (Effluent)
6. BOD is reduced by aerobic/anaerobic methods	6. Reduced by aeration.

c) Dissolved Oxygen (DO) – It is amount of dissolved oxygen present in water. Oxygen is sparingly soluble in water and is present up to 14 ppm under normal conditions. This little amount of oxygen is very useful in preserving quality of natural water. Now a days disposal of domestic and industrial waste in nature water sources the DO level is rapidly decreasing. The less DO is harmful as it indicates.

1. Presence of oily and greasy impurities which avoid air water contact

2. Presence of large extent of organic matter. (DO consumed for decomposition) This matter is not completely decomposed and water produce offensive odor. Partially decomposed matter accelerate bacterial growth. Such water is non hygienic. This increases BOD of water.

3. Water may contain ox disable waste in high amounts.

4. If DO of water is maximum i. e. up to 13-14 ppm then water is fresh, free from offence odor, organic matter, pathogens, oil and gresse etc. and also suitable for aquatic life. Bear low BOD values.

DO (Dissolved Oxygen)

Dissolved Oxygen in water (DO) play very important role in deciding water quality for domestic & industrial use. Water when comes in direct contact with air then it dissolves oxygen from air. Oxygen is sparingly soluble & water can dissolves maximum 10-15 ppm of oxygen.

Maximum extent of DO in natural water ensure freshness. If DO is very less than this water is not fresh & not safe for drinking & other uses. Decreases in DO is due to any or all following reasons.

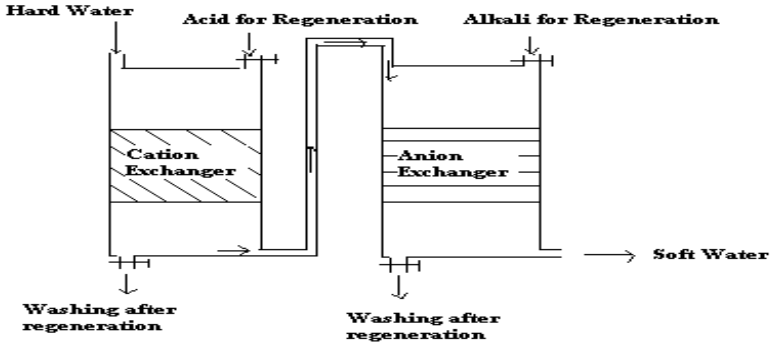
1. Direct contact of air & water is not possible: This is due to presence of great extent of floating matter or presence of oil & greasy impurities which spreads on surface of water.
2. Contamination of water by Organic matter: If water consist large extent of organic matter then it consumes DO towards its decomposition. The residual DO level will then leave organic matter partially decomposed, which produces foul odor & accelerates growth of pathogens.
3. Presence of oxidisable matter: If water contain greater extent of oxidisable waste then it consume DO & reduces DO level in water.

Thus, water with less DO is not suitable for domestic use & DO level must be maximum.

In industrial use water is used after deoxigenation when it is used for boiler & in contact with metals at high temperature. This is because if DO is maximum, at high temperature it is removed & causes corrosion.

Softening of water by Ion exchange method

- Principle: Ion exchange method removes hardness by exchanging impurity cations & anions for H^+ & OH^- ions from exchange resins.
- Definition of resin: Ion exchange resins are organic polymers with ability to exchange ions.
- The resin with functional group like SO_3H will exchange H+ with Ca & Mg from water & are called as cation exchange resin.
- The resins with $Me_2(OH)$ functional group will exchange anions for OH^- and are called Anion exchange resin.
- Diagram:



Ion Exchanger for Demineralisation of water

- Construction: It consist of two tubular columns, every column have lower and upper support in between them resins are filled. First column was filled with cation exchange resin called cation exchanger, while second was filled with anion exchange resin called anion exchanger. At the top of cation exchanger, there is entry for hard water which is free from suspended impurities and this exchanger connected to anion exchanger from bottom to top. Every exchanger have their own regeneration inlet and outlets.
- Procedure: The water to be softened is simply passed through cation exchange containing cation exchange resin and then through anion exchange containing anion exchange resin as shown in diagram
- Reactions are as follows
- $2RH + Ca^{++} \rightarrow R_2Ca + 2H^+$
- Cation Ex Resin. Exhausted Resin
- $2ROH + 2Cl^- \rightarrow 2RCl + 2OH^-$
- Anion ExResin

Regeneration:

When all H^+ and OH^- from resin are exchanged .Then these are regenerated with dilute acid and base solution and washing are rejected.

Regeneration: $R_2Ca + 2HCl \rightarrow 2RH + CaCl_2$

(Washing)

$2RCl + 2NaOH \rightarrow 2ROH + 2NaCl$

Advantages--- 1) Very low residual hardness O-2 ppm 2) Compact and portable equipment 3) No sludge formation 4) No need of skilled labor 5) Resin are used for longer time 6) Relatively speedy method. 7) No need of special training as such.

Disadvantage---- 1) Resin are costly 2) Water must be free from suspended matter.