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Quality of Water

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About water: Water is one of the abundantly available substances in nature. Fresh water is available in considerable quantities. But its distribution over the globe is uneven. The per-capita water demand for drinking and other domestic needs in a modern town varies from 100-500 litres a day. Besides, water also consumed in industry and agriculture (irrigation, cattle breeding), and when the total water demand is thus considered, it increases by 10-12 times to per-capita need. Water is to be regarded as universal solvent, because more things can be dissolved in water than in any other liquid.

Management of the quality of water is now the concern of experts in all countries of the world. The decision of WHO's 29th session (May 1976) emphasizes that water delivered to the consumer should meet the high requirements of modern hygiene and should at least be free from pathogenic organisms and toxic substance. The quality of water depends on the location of the source and the state of environmental protection in a given area.

Source of water: In general, water source conform to criteria; (a) the quality of water must be acceptable, (b) the quality must be sufficient to meet the present and further requirements. There are three main sources of water

- Rain water.
- Surface water: Reservoir, Steams, Rivers, Tank ponds, Lakes and Seas.
- Ground water: Shallow wells, Deep wells and springs.

Rain water: Rain water is the purest form of naturally occurring water. The rainwater is associated with dissolved gases such as CO_2, NO_2, SO_2 and NH_3 etc. during the journey through the atmosphere.

Surface water: Surface water includes river water and stagnant water (Reservoirs, Lakes, Ponds, Tanks). It contains soluble impurities as a result of following through the rocks and also insoluble organic materials from human, animal and plant kingdom. Seawater is treated as the most impure from the water as it consists of large quantities of dissolved salts. This is unfit for domestic, industrial and agriculture needs.

Ground water: Most ground water that is free from objectionable mineralization is both safe and potable. However the quality of ground water gets affected due to the entry of pollutants into it, causing physical and or chemical changes.

Physical nature of water: Pure water is colourless (in thin layers) or bluish –green (in thick layers). It is a clear liquid, which has neither odour nor taste. The mass of 1mL of purified river water is assumed to be the unit of mass and is known as a gram. Some physico-chemical properties of water are given in the table-1.

Table 1: Physical properties of water

S.No	Properties	Unit	Value
1	Boling point	◦C	100.00
2	Melting point	◦C	0.00
3	Critical Temperature	◦C	374.20
4	Electrical conductivity at 18◦C	Ohm^{-1} cm^{-1}	$4.3x10^{-8}$
5	Freezing point at 760 mm Hg	◦C	0.00
6	Molar heat of vaporization	K J K Cal	40.67 9.720
7	Molar heat of fusion	K J K Cal	6.020 1.440
8	Molar entropy of vaporization	J deg^{-1} Cal deg^{-1}	109.00 26.10
9	Viscosity at 20◦C	Centipoises	1.005
10	Surface tension at 20◦C	Dynes cm^{-1}	73.00
11	Dielectric constant at 18◦C	-----------	81.0
12	Dipole moment	Debby	1.84
13	Specific heat	Cal g^{-1} C^{-1}	1.00
14	Heat of vaporization	Cal g^{-1}	540.00
15	Thermal conductivity	Cal cm^{-1} Sec^{-1} deg^{-1}	0.00143

Quality criteria of water: Most of ground water is free from suspended impurities and pollution and it is superior to surface water. Certain chemical quality standards have been established for evaluating the suitability of water for drinking, domestic, irrigation and industrial uses.

Drinking purpose: A safe and potable drinking water should conform to the following water quality characteristics. It should be

(a) free from pathogenic organisms
(b) low in concentration of compounds that are acutely toxic or that have serious long term effect, such as lead and arsenic
(c) clear
(d) not saline (salty)
(e) free of compounds that cause an offensive taste, odour and colour
(f) non-corrosive, nor should it cause encrustation of piping or staining of clothes (g)reasonably soft
(h) should not be highly alkaline (pH is about (i)turbidity should be less than 10 ppm
(j) free from objectionable gases likes SO_2,NO_2 etc.

In order to assure that such levels of water quality are maintained, developing countries should establish National standards for water quality, preferable adapted from the new guidelines issued recently in three separated volumes by the World Health Organization (WHO). The standards of drinking water are given table 2.

In developing National standards, it is necessary to consider a variety of local, geographic, socio-economic, dietary and industrial conditions. This may lead to National Standards that differ appreciably from the guideline values. Table 3 illustrates physico-chemical standards of drinking water as recommended by WHO and adopted in the USA and several developing countries similarly, microbiological water quality standards are presented in table 4.

Table 2. WHO Guidelines for drinking water quality.

S.No	Parameters	Unit	Guideline value
1	Microbiological Quality Faecal coliforms	Number 100 mL^{-1}	Zero
	Coil form organisms	Number 100 mL^{-1}	Zero
2	Inorganic Constituents		
	Arsenic	mg L^{-1}	0.05
	Cadmium	mg L^{-1}	0.005
	Chromium	mg L^{-1}	0.05
	Cyanide	mg L^{-1}	0.1
	Fluoride	mg L^{-1}	1.5
	Lead	mg L^{-1}	0.05
	Mercury	mg L^{-1}	0.001
	Nitrate	mg L^{-1}	10
	Selenium	mg L^{-1}	0.01
3	Aesthetic Quality	mg L^{-1}	
		mg L^{-1}	
	Aluminium	mg L^{-1}	0.2
	Chloride	mg L^{-1}	250
	Color	True color	15
	Copper	mg L^{-1}	1.0
	Hardness	mg L^{-1} (as $CaCO_3$)	500
	Iron	Mg L^{-1}	0.3
	Manganese	mg L^{-1}	0.3
4	pH		6.5to8.5
	Sodium	mg L^{-1}	200
	Solids (total dissolved)	mg L^{-1}	1000
	Sulphate	mg L^{-1}	400
5	Taste and odour		Inoffensive to more consumers
	Turbidity	NTU	5.0
	Zinc	mg L^{-1}	5.0

Table 3. Comparision of chemical and physical drinking water standards recommended by the WHO, the United States and several developing countries.

S.No	Chemical and physical parameters	WHO guideline values	United States (1977)	China (1976)	India (1975)	India recommended (1973)	Korea	Philippines	Qatar	Tanzania Temporary (1974)	Thailand
1	Total hardness (mg L^{-1} $CaCO_3$)	500			600	600	300			600	300
2	Turbidity(NTU)	5	1-5	5			2		5	30	5
3	Color(TCU)	15		15			2		5	30	5
4	Iron,as(mg L^{-1})	0.3	0.3	0.3	1	1	2	1	0.3	1	0.3
5	Manganese as Mn(mg L^{-1})	0.3	0.05	0.1	0.5	0.5	0.3	0.5	0.3	0.5	0.3
6	pH	8.5		6.5	-6.5	-6.5-9.2		6.5-9.2		6.5-9.2	6.5-8.5
7	Nitrate as NO3 (mg L^{-1})	45	45	8.5	9.2 50	45	45	50		100	45

8	Sulphate as SO4 (mg L^{-1})	400			400	400	200	400	250	600	250
9	Fluoride as F (mg L^{-1})	1.5	1.4	-0.5	-2.0	1.5	1.0	1-1.5	1.6	8.0	1-1.5
10	Chloride as Cl(mg L^{-1})	250	250		1000	1000	150	600	250	800	300
11	Arsenic s As(mg L^{-1})	0.05	0.05	0.04	0.2	0.05					
12	Cadmium as Cd(mg L^{-1})	0.005	0.01	0.01		0.01	0.05	0.2 0.01		0.05 0.05	0.05
13	Chromium as Cr (mg L^{-1})	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
14	Cyanide as CN(mg L^{-1})	0.1	0.01	0.05	0.01	0.05		0.01		0.2	0.2
15	Copper as Cu(mg L^{-1})	1.0	1.0	1.0	3.0	1.5	1.0	1.5	.03	3.0	1.0
16	Lead as Pb (mg L^{-1})	0.05	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05
17	Mercury as Hg(mg L^{-1})	0.001	0.002	0.001		0.001					
18	Selenium as Se (mg L^{-1})	0.01	0.1	0.01	0.05	0.01		0.05		0.05	0.01

Table 4: Comparision of Micro biological drinking water standards recommended by the WHO, the United states, and several developing countries

WHO guideline values	1.Water entering distribution system; Chlorinated or otherwise disinfected samples-0/100 mg/L; non-disinfected supplies E.coli 0/100m; coliform 3/100 ml occasionally. 2. Water in distribution system; 95% of samples in year-0/100 ml chloroform; E.coli 0/100ml in all samples; no sample greater than 100 ml of any two successive samples. 3. Individual or small community supplies: Less than 10/100 mL coliform;0/100 E.coli in all samples.
United states	Number of coliform bacteria is determined by membrane filter test shell not exceed one per 100 ml as the arithmetic mean of all samples examined per month. When 10ml fermentation tubes are used , coliform bacteria shell not be present in more than 10% of the portions in any month. When 100 ml tubes are used, coliform shell not be present in any month.
China	Total colony count not more than 100/ml; E.coli not more than 3/ml
India	Coliform=0 to 1.0/100ml permissive; 10 to 100/100 ml excessive but tolerated in absence of alternative, better source; 8 to 10/100ml acceptable only if not in successive samples; 10% of monthly samples can exceed 1/100 ml
India	E.coli =0/100ml
Recommended(1975)	Coliform=10/100 ml in any sample ,but not dectable in 100 ml of any two consecutive samples or more than 50% of samples collected for the year.
Philippines(1963)	Coliform not more than 10% of 10ml portions examined shall be positive in any month. Three or more positive 10ml portions shall not be allowed in two consecutive samples; in more than one sample per month when less than 20 samples examined; or in more than 5% of the samples when 20 are examined per month
Qatar	Coliforms 0/100 ml if present in two successive 100ml samples , give grounds for rejection of supply.
Tanzania(temporary)(1974)	Non chlorinated pipe supplies; 0/100 ml coliform-classified as excellent;1 to 3/100 ml coliform-classified as satisfactory; 4 to 10/100 ml coliform-classifies as suspicious; 10/100 ml Coliform-classified as unsatisfactory.
Thailand	Other supplies;WHO standards to be aimed at. Coliform=2.2/100 ml.E.coil=0/100 ml.

Among the water quality parameters, fluoride is a peculiar constituent since it must be in Drinking water in the limits of 0.5- 1.5 mg L^{-1} (ppm). If it is greater than 1.5 leads in the long run causes disease Fluorosis i.e etching of bones, finally leads to death. This is because bones slowly collapse i.e due to reaction of fluoride with calcium in bones and form Ca F_2 powder in the bone. It slowly decreases the strength of bones and collapses. In the beginning teeth colour also changes to yellow and collapse. It is also called as a slow poison since it is a long run process. If less than 0.5 mg L^{-1} present in water, it is also affect on Children. Teeth cannot come and develop properly since in bone formation fluoride is also important i.e in the Countries where the fluoride is not there, the fluoride containing Tooth paste suggests. But perfect purified water through Reverse Osmosis (R.O) process contains no fluoride in water. One must be careful about this constituent and other constituents. Less content of another constituent calcium leads to the disease Ostero Porosis. Any fresh water contains calcium but deficiency may be due to treatment processes or some other reason. Anyway the water we drink must require some treatment processes which do not affect the health of the living organisms. Every constituent has use within the limits present and above certain limits causes health hazards.

Industrial purpose: Ground water used for industries may be classified into three principal types. They are cooling water, boiler water and process water. Assessment of the incrusting and corrosive properties of water for the industrial purpose is very complicated, as most incrustation and corrosion reactions are very complex. The rate of incrustation and corrosion is even more difficult to predict because of several factors involved. Therefore, the general criteria have been adopted for deciding the incrusting and corrosion properties of the well waters of the present study area as shown in table 5.

Table 5. Water quality parameters lead to incrustation and corrosion

S.No	Parameters	Classification
1	pH<7	Corrosion
2	EC>1500 µ mhos cm^{-1}	Corrosion
3	TDS>1000 mg L^{-1}	Corrosion
4	TH>300 mg L^{-1}	Incrustation
5	HCO3> mg L^{-1}	Incrustation
6	Cl>500 mg L^{-1}	Corrosion
7	SO4>100 mg L^{-1}	Incrustation

Irrigation purpose: The suitability of ground water for irrigation depends upon its mineral constituents. The salts, which are present in the water, besides affecting the growth of the plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. The classifications of irrigation water based on Sodium Absorption Ratio (SAR) and Percent Sodium (PS) are given in the table 6. The quality of water for irrigation was estimated by measuring the electrical conductivity of samples with the U.S. Salinity Laboratory guide groupings of water as shown in the table 7.

Table 6. SAR and PS classification for irrigation water

Water Classification	<SAR Value	PS Value
Excellent	<10	<20
Good	10-18	20-40
Permissible(Medium)	18-26	40-60
Doubtful(Bad)	>26	60-80
Unsuitable		80

Table 7: Groups of irrigation water based on EC and TDS

TDS (mg L^{-1})	EC in (µMhos cm^{-1})	Class	Remarks
<200	<250	Excellent	Low salinity Water can be used for irrigation in most soils and for most crops. Some leaching is required, but this occurs under normal irrigation practices except in soils of low permeability.
200-500	250-750	Good	Medium salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most instance without special practice for salinity control.
500-1500	750-2250	Permissible	High salinity water cannot be used on soils with restricted

			drainage. special management for salinity control may be required and plants with good salt tolerance should be selected.
1500-3000	2250-5000	Unsuitable	Water with very high salinity for irrigation under ordinary conditions but may be used occasionally under special circumstances. the soil must be permeable and drainage must be adequate higher amount of water should be used for irrigation and salt-tolerant crops should be selected.

Water pollution: The world pollution is derived from the Latin word POLLUTIONEM meaning defilement. "Any alteration in the physical, chemical and biological properties of water, as well as combination of any foreign substance that leads to a health hazard or decrease in the utility of water" can be termed as water pollution.

Classification of water pollutants: Polluted water adversely affects and causes deleterious effects either due to the toxic nature or reduction of oxygen level due to various pollutants. The major types of water pollutants can be characterized as (a) oxygen demanding wastes(b) infectious agents (c) inorganic pollutants (d) organic pollutants (e) plant nutrients (f) sediments (g) toxic substance (h) thermal pollution (i) biological pollutants (j) farm wastes and fertilizers (k) radioactive pollutants.

Physico-chemical analysis of water samples

Experimental methods: The various water quality parameters are selected and the methods of chemical analysis are listed in the table 8 and 9.

Table 8: Recommended for sampling and preservation of samples according to measurement

S.No	Measurement holding	Volumerequired (mL)	Container	Preservative	Time
1	Physical properties				
	Conductance	100	P,G	Cool,4◦C	24 hours
	Hardness	100	P,G	Cool,4◦C	6 hours
				HNO3 to pH<2	
	pH	25	P,G	Determination	6 hours
	Total solids	100	P,G	Cool,4◦C	7days
	Temperature	1000	P,G	Determination on site	------
	Metals	100	P,G	HNO3 to pH<2	6 months
2	Inorganic and non-metallic				
	Alkalinity	100	P,G	Cool,4◦C	24 hours
	Chloride	50	P,G	-----	7days
	Fluoride	300	P,G	------	7days
	Nitrate	100	P,G	Cool,4◦C	24 hours
	Nitrite	50	P,G	Cool,4◦C	48 days
	Sulphate	50	P,G	Cool,4◦C	7days
	Phosphate	50	P,G	Cool,4◦C	24 hours
	DO winkler	300	G	Determination on site	4-8 hours
3	Organics				
	BOD	1000	P,G	Cool,4◦C	24 hours
	COD	50	P,G	H2SO4,pH<2	7days

P means plastic and G means glass

Table 9: Methods of chemical analysis

S.No	Water quality Parameter	Methods of determination
1	Hydrogen ion Concentration(pH)	pH metry
2	Electrical Conductivity(EC)	Conductometry
3	Total dissolved solids(TDS)	Evaporation method
4	Alkalinity(ALK) as $CaCO_3$	Titrimetry
5	Total hardness(TH) as $CaCO_3$	EDTA- Titrimetry
6	Calcium(Ca)	EDTA- Titrimetry
7	Magnesium(Mg)	EDTA- Titrimetry
8	Sodium(Na)	Flamephotometry
9	Potassium(K)	Flamephotometry
10	Chloride(Cl)(Argentometric method)	Titrimetry
11	Nitrate(NO_3)	Spectrophotometry
12	Nitrite(NO_2)	Spectrophotometry
13	Sulphate(SO_4)	Spectrophotometry
14	Phosphate(PO_4)	Spectrophotometry
15	Fluoride(F)	Spectrophotometry
16	Dissolved oxygen(DO)	Titrimetry
17	Biological oxygen demand(BOD)	Incubation at 20ºC for 5days and titration
18	Chemical oxygen demand(COD)	Titrimetry
19	Trace elements	Atomic absorption Spectrophotometry (AAS)

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