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ENVIRONMENTAL HYGIENE

for Nursing Students

As per the INC Syllabus



WATER

EARTH

AIR

HYGIENE

Adarsh Pal Vig
Sonia Sharma
Sartaj Ahmad Bhat
Namita Khanna

2nd Edition

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Contents

1. Introduction to Environmental Health 1
Environment *1*
Interrelationship between Environmental Components *3*
Environmental Health *3*

2. Water 7
Characteristics of Water *7*
Uses of Water *7*
Water Cycle *9*
Sources of Water *10*
Characteristics of Wholesome and Safe Water *17*
Inorganic Indicator Used for Water Quality *20*
Water Pollution *25*
Waterborne Diseases *28*
Water Purification *28*
Disinfection of Water *34*
Disinfection of Wells *37*
Softening of Water or Removal of Hardness of Water *38*
Rainwater Harvesting *40*
Components of Water Harvesting System *41*
Advantages of Rainwater Harvesting *42*

3. Air 45
Composition of Air *45*
Air Pollution *46*
Consequences of Air Pollution *51*
Air-borne Disease *54*
The Air (Prevention and Control of Pollution) ACT, 1981 *55*
Prevention and Control of Air Pollution *57*

4. Waste 60
Types of Waste *61*
Sources of Solid Waste *61*
Waste Utilization *69*
Sewage Disposal *70*

JAYPEE BROTHERS

Refuse and its Management *72*
Plastic Waste Management Rules in India *74*
Human Excreta and its Management *75*

5. Housing 80
Purpose of Housing *80*
Requirement of Housing *81*
Location of House *81*
Basic Amenities *82*
Housing and Health *84*
Town Planning *85*

6. Ventilation 89
Objectives *89*
Standards of Ventilation *89*
Types of Ventilation *90*

7. Lighting 93
Requirements of Good Lighting *93*
Sources of Light *94*

8. Noise 98
Sources of Noise Pollution *98*
Properties of Noise Pollution *99*
Measurement of Noise *99*
Effects of Noise Pollution *100*
Control of Noise Pollution *100*

9. Arthropods 103
Classification of Arthropods *104*
Transmission of Diseases Caused by Arthropods *105*
Control of Diseases Caused by Arthropods *105*
Control of Arthropods *108*
Rodents *109*

10. Community Organizations to Promote Environmental Health 113
National Pollution Control *114*
Legislations and Acts Regulating the Environmental Hygiene *116*

Index *123*

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CHAPTER

2 Water

LEARNING OBJECTIVES

After completing this chapter, the learner will be able to:

- Describe the basic characteristics and uses of water.
- Explain the water cycle and major sources of water.
- Identify the features of wholesome and safe water.
- Discuss inorganic indicators used to assess water quality.
- Explain the causes and effects of water pollution.
- Describe methods of water purification and disinfection.
- Explain the process of well disinfection and water softening.
- Identify the components of a rainwater harvesting system.

Introduction

Water covers about 70% of earth's surface and is a necessary constituent for life. In fact, it is present as vapor in the air. In the hydrosphere, about 1.4 billion cubic kilometer of water is present. Of this 97% is ocean water and 3% is freshwater. Out of 3% freshwater, 7.2% water is located in glaciers and ice caps, 22.4% occurs in underground soil moisture and 0.36% is available in lakes, streams and rivers.

Characteristics of Water

Water is odorless, colorless, and tasteless liquid compound of hydrogen and oxygen (H_2O). Its boiling point is 100°C (212°F) and freezes at 0°C (32°F). The dense water sinks due to heavy density at 4˚C but light frozen ice floats and insulates the water below it. This helps the aquatic life to survive under the ice in cold weather.

Uses of Water

Human beings use about 54% of fresh water supplies in the world. By 2025, this percentage will increase to 70% and this will become a serious problem for all other kinds of life. **Table 2.1** shows the pattern of water used by human beings in the world.

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Table 2.1: Pattern of water used by humankind.

Sector	*Global use (%)*	*Use in industrialized countries (%)*	*Use in developing countries (%)*	*Use in India (%)*
Agricultural	70	30	82	80
Domestic	8	11	8	5
Industrial	22	59	10	15

(Scheele and Malzs, 2007).

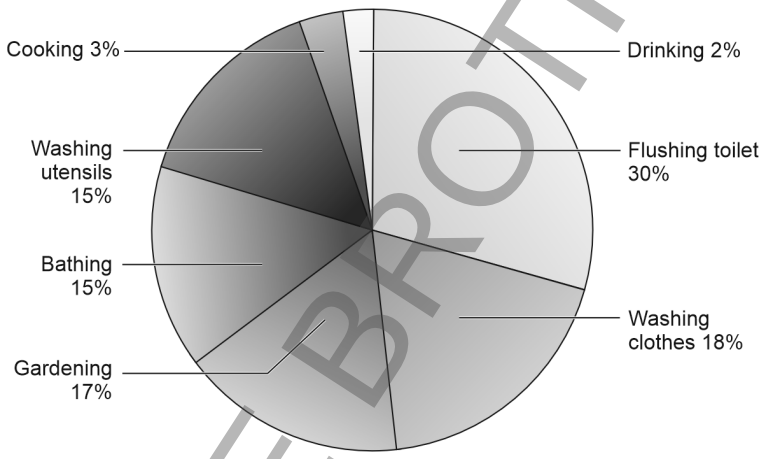


Fig. 2.1: Design of urban water supply system for a consumption of 135 L of water/day/person in India.

1. **Habitat:** Water serves as a habitat for a variety of organisms like protozoans, bacteria, fishes, other animals and plants.
2. **Domestic purpose:** It is required for cooking, drinking, bathing and washing of clothes, utensils, etc. **(Fig. 2.1)**.
3. **Industrial:** Industrial uses consume far more water than do domestic use. They use water for cleaning as a coolant and as part of manufacturing process.
4. **Agriculture:** Majority of water is used for irrigation. About 50 million hectares of land is under irrigation in India.
5. **Aquaculturing:** It is used for raising fishes and other aquatic organisms including animals and plants. In India, about 1.6 million hectares of inland water has a potential for aquaculture.

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6. **Public use:** Water is used for public use in gardens, hospitals, schools, road washing, etc.

Water Cycle

The water cycle is also known as the hydrological or hydrologic cycle, describe continuous movement of water on below and above the earth's surface **(Fig. 2.2)**. Water cycle has two components, long cycle (global) and short cycle (local). Water cycle is energized by solar energy. The various steps involved are as follows:

1. **Evapotranspiration:** This process is the conversion of water into vapor state (gaseous) on absorption of energy. Evaporation occurs from both oceans (84%) and land mass (16%). In plants, transpiration means loss of water from the aerial part of plants mainly through stomata occurs.
2. **Condensation:** In atmosphere, water vapors condense as minute particle. This process leads to the formation of warm moist air called "convection current", which rises upward.
3. **Precipitation:** Moist warm air moves to cold region of the atmosphere or over high mountain. When moist air cools, a level came when atmosphere cannot hold the moisture and condensed water vapors undergo precipitation to take different forms like

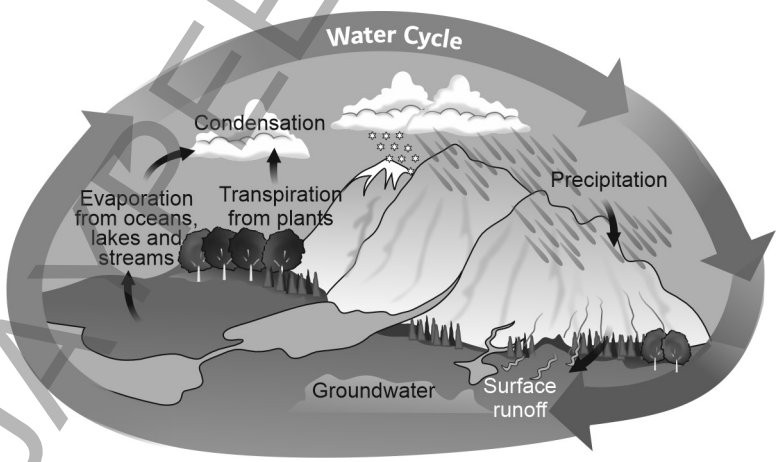


Fig. 2.2: Water cycle.

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rain, fog, snow, mist, etc. Both oceans and lands receive 75% and 25% of total precipitation. Excess precipitation over land is drained down to oceans and seas through flow of rivers. Water also naturally recharges and percolates through ponds, lakes, shallow and open places into the earth and is stored as groundwater for use of the human beings.

Safe and wholesome water: The quality of water for human consumption should be without impurities, safe and wholesome. It should meet the standard set for human consumption as follows:

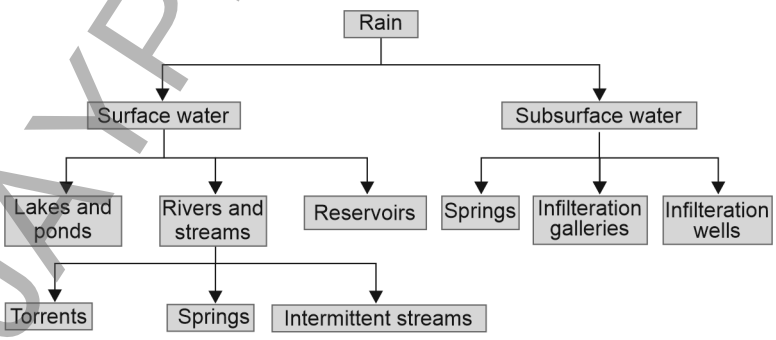
- Free from pathogens
- Free from toxic substances/chemicals
- Free from suspended solids and turbidity
- Moderately soft up to 50–100 ppm or slight hardness up to 100–150 ppm.
- Cool, clean, fresh and without any bad odor or taste having neutral pH.

Sources of Water

The fresh water is available in water cycle as rainwater. This is distributed as depicted in **Flowchart. 2.1**.

Rain: In the presence of sun, evaporation of water occurs from sea, ocean and earth surface covered with water. Water is also transpired by plants in sunlight. In the atmosphere, these water vapors condense and cool to form clouds, which give rise to rain.

Flowchart 2.1: Distribution of water.



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Sources of water are mainly divided into two categories:

I **Surface water sources:** When water flows over the surface of earth, it is called surface water. It is further categorized as follows:

a. **Lakes/Ponds:** Lakes and ponds formed when large depressions on earth's surface get filled with rainfall water. The ponds are small in size and formed in plain area whereas lakes are large water body and formed in hilly areas **(Fig. 2.3)**. High altitude lakes have pure water as compared to lakes of plain area, because of sedimentation process.

The quantity of water present in lakes/ponds depends upon the depth of depression and rainfall intensity. The quality of water of ponds/lakes is not so good, due to human defecation, washing of clothes, cattle bathing and aquatic vegetation, etc. This water helps in groundwater recharge.

b. **Rivers and streams:** During rainy season, water flows in streams and combine with springs to form rivers. River flows through the plain area by the contributions of catchment area. River water is available throughout the year whereas streamwater is not available during summers **(Fig. 2.4A)**. In streams, rainwater infiltrates into the soil and joins the groundwater storage. When at any point, water at ground surface, fall below the top surface of groundwater reservoir, then greater hydrostatic pressure exists in the soil mass. Under the pressure, the groundwater finds the way through the soil into the depression forming streams **(Fig. 2.4B)**.



Fig. 2.3: Ponds/lakes.

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Figs. 2.4A and B: Images of (A) rivers and (B) streams.

Streams are further categorized into the following:

- Torrents
- Springs
- Intermittent streams

1. *Torrents:* Torrents carry only surface runoff, where water flows through them only during rainfall and subsequent runoff.
2. *Springs:* These are perennial streams. Water flows through them throughout the year as water table is higher in them as compared to depressed ground level.
3. *Intermittent streams:* Flow of water is only during rainy season because frequent rain raises the water table temporarily. Thus, groundwater level is above the bottom of stream and cause flow of water from soil to ditches.

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River water gets contaminated due to discharge of sewage, agricultural, industrial and cities waste. Ritual activities like disposal of ash of dead bodies and bathing also play an important role in contaminating rivers. These impurities result the change in physicochemical and biological nature of water, make it unfit for drinking. River water has the property of self purification with the help of sunlight, bacteria and sedimentation. Sometimes, it cannot make the water pure as suitable for drinking purpose. So water purification is required before it is made available for drinking.

c. **Impounding reservoirs:** It is a basin constructed in the valley of a stream or river for holding water flow, so that stored water can be used during insufficient supply **(Fig. 2.5)**. They have the following functions:
   1. To generate electric power
   2. To meet the public demand in dry and hot season
   3. To retard floods
   4. To irrigate agricultural land, where there is no rainfall
   5. To impound water for beneficial use.



Fig. 2.5: Image of impounding reservoirs.

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Quality of reservoir water depends upon the distribution of catchment areas and intensity of rainfall. Quality of water in reservoirs is pure because of settling down of impurities, added from the catchment areas. For domestic purposes, reservoir water is needed to be chlorinated and filtered.

II **Subsurface water sources:** The water which is below/beneath the surface of earth as part of water cycle is called subsurface/ underground water. Underground water may return to the surface in groundwater flow from springs, seep or water well or may return to the rivers, streams and oceans **(Fig. 2.6)**.

a. **Springs:** When earth's surface water flows from an aquifer to the surface of earth, springs are formed. Springs are result of Karst topography, where surface water has infiltrated the earth and becomes the part of groundwater **(Fig. 2.7)**. This groundwater then travels through cracks/fissures to large caves. Springs are of three types:

1. *Seepage/filtration spring:* In this type of spring, small flow rates was detected, in which source water has filtered through the permeable earth.

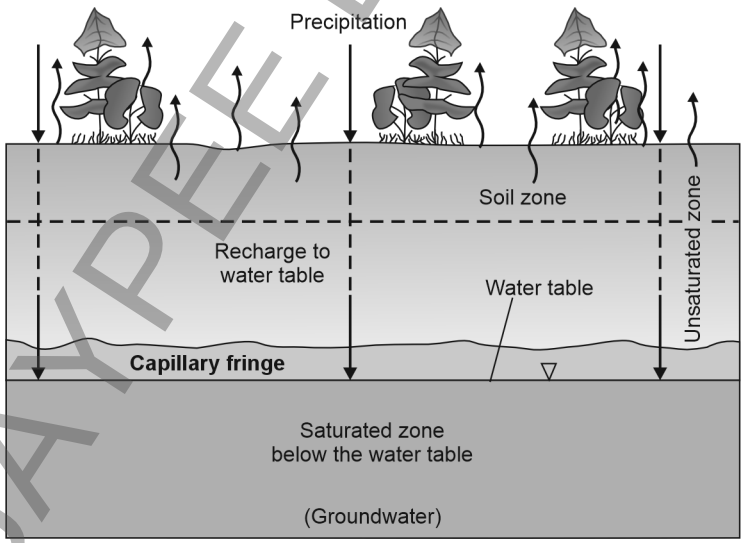


Fig. 2.6: Image of subsurface water (groundwater).

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Fig. 2.7: Springs.

2. *Fracture spring:* When discharge from joints, cuts or faults in the earth get exposed in a valley, fracture/surface springs are formed.
3. *Tubular spring:* In this type, water flows from underground caverns.

   Spring water has a taste, as minerals become dissolved in water as it moves through the rocks. Springs that contain dissolved sodium carbonate are called soda springs. Many resorts have developed around the mineral springs known as spa town. Water of springs is usually clear but for consumption by humans, need purification so as to prevent health hazards. Springs have been used for various human needs like irrigation, navigation, drinking, domestic water supply, mills and electricity generation.

b. **Infiltration gallery:** It includes perforated conduits in gravel to transfer of water to and from the soil aquifer. They are used to collect water from aquifer underlying a river. These galleries have the advantage of bank filtration to reduce the water treatment for a surface withdrawal. Such galleries are a new development urban planning and found in newer housing development.

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c. **Infiltration wells:** They are also called as interception or vertical wells, that allow surface runoff to drain through underground piping. Unlike drainage or inlet well, infiltration wells do not have an inlet at ground level, rather they increase infiltration capacity of ground using installation of porous material. Rocks, straw and wood chips can be used as filtration material. They are usually installed at the lowest depression point. The quality of water is better because organic or suspended impurities are removed in a natural way. Wells are further divided into different categories on the basis of nature of aquifer, flow of condition and way of construction.

On the basis of nature of aquifer, wells are classified into deep and shallow wells.

1. *Deep wells:* These wells tap the water from pervious layer below the first impervious layer. Sometimes, water is hard because of dissolution of salts and percolation removes this hardness. Water quality is good but need chlorination before using for drinking purposes.
2. *Shallow wells:* In shallow wells, water source is the uppermost layer of earth only. These wells are mostly used in villages, isolated buildings and undeveloped towns. Water of these wells cannot be used for domestic purposes because it is contaminated with surface wash and septic tanks. Bleaching powder or chloramines are used to purify the water after every 2–4 weeks.

On the basis of flow of conditions, they are of two types, i.e., gravity wells and artesian wells.

a. **Gravity wells:** In these wells, water enters by gravity and rose to height of saturated material surrounding it. The wells are in previous layer underground and water in these wells is at atmospheric pressure.

b. **Artesian or pressure wells:** When a hole is dug out in a well, the water comes out of it in form of fountain due to high pressure inside than atmospheric pressure. Quality of water of these wells is good and can be used for domestic purpose without any treatment.

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On the basis of method of construction, wells are classified as:

c. **Open wells:** These wells are very common in underdeveloped agricultural areas, may or may not be protected by lining. On the basis of lining, they are further classified into pervious, impervious lines and katcha wells. These wells are constructed in rural areas. Water of these wells is not safe for drinking purpose as being contaminated due to various human activities, such as bathing or washing feet, hand or face, etc.
d. **Tube wells:** In tube wells, pipes are inserted into the ground to tap underground water. In the absence of surface water, tube wells are used to fulfil the demand of people. Water of these wells is good for use but need chlorination before use.
e. **Driven or percussion wells:** In these wells, a casing pipe provided with strainers at lower side is attached to ensure the entry of clear water. The diameter of wells is 20–80 mm approximately. Water of these wells is used for domestic purposes.

Characteristics of Wholesome and Safe Water

Water quality: Quality of water depends upon the use, i.e., consumptive and non-consumptive use. Maximum purity is required for drinking purpose, whereas low quality is acceptable for the purpose of fisheries, live stock, agriculture, etc.

Quality Standard of Water

Hardness: Less than 100 ppm

Presence of solid: Less than 500 ppm

pH: 6.5–8.0

Dissolved oxygen: 5.0–6.0 ppm

Temperature: 10–15.6°C

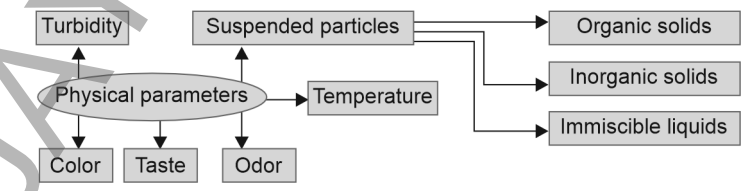
Parameters to assess the quality of water: Earlier people checked the quality of water on the basis of physical sense of smell, taste and sight. Whereas later on, many parameters were used to assess the physical, chemical and biological characters of water. Selection of parameters for water testing, depends upon the purpose of use of water and for what extent we need its purity. Due to the presence

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of very low concentration of metal and pesticide impurities in water, it need highly accurate instruments and trained operator. Following are the different physical, chemical and biological parameters used for monitoring quality of water:

a. **Physical parameters:** This parameter includes the measurement of following factors **(Flowchart 2.2)**:
   1. *Temperature:* In a system, water temperature controls the rate of various chemical reactions for domestic use of water. Temperature should be between 40–60°F and above 80°F temperature is not desirable. Sometimes, temperature of water reaches to harmful level due to heat produced from automobiles, industries and power plants, etc.
   2. *pH:* pH is used to determine the corrosive nature of water as higher the pH value, lower is the corrosive nature. pH is directly related with alkalinity and electrical conductance. Various factors are correlated with pH of water. The higher pH value indicates that carbon dioxide and carbonate bicarbonate equilibrium is more affected due to change in physico-chemical parameters.
   3. *Color:* Water is colorless, but colored water gives the appearance of being unfit for drinking. Colored water also indicates the presence of organic matter, such as algae and humic compound. Reddish and brown/black color of water is due to the presence of iron oxide and magnesium respectively. Likewise yellow-brown color of water is due to the presence of wood, leaves and weed, etc.
   4. *Turbidity:* Turbidity is a measure of light-transmitting property of water and is comprised of light absorbed or scatter by suspended material.

Flowchart 2.2: Physical parameters to check quality of water.



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5. *Taste and odor:* Normally, water is tasteless and odorless. Taste and odor occurs in water due to the presence of salts from soil, minerals, waste water product and biological waste.
6. *Solids:* The total content of suspended solids of water is defined as the residue remaining after the water evaporation and drying the residue at 103°–105°C. The organic fraction is related to the loss of residue weight, remaining after the evaporation of water and after ignition of residue at 500°C temperature. At this temperature, volatile solid will oxidize and driven off as a gas. On the basis of nature of solids, they are classified as settleable solids, suspended and filterable solids. Settleable solids settle under the influence of gravity, whereas suspended and filterable solids are characterized on the basis of particle size and retention time on glass filters.

b. **Chemical parameters:** The chemical parameters of water are a reflection of rocks and soils with which water remains in contact. Many other parameters, such as agricultural, municipal and industrial runoff affect the quality of water. The chemical parameters, such as hardness, metal, alkalinity, total dissolved solids and nutrients are measured to know the quality of water.

Inorganic minerals: Runoff causes weathering and erosion of rocks and soils and this runoff travel to the surface water bodies. Inorganic compounds may dissociate to cations and anions.

1. *Major cations:* Major cations found in water include magnesium, calcium, sodium and potassium. Among these, calcium is the most prevalent cation followed by bicarbonate in surface water. Calcium is the primary constituent of water hardness. Concentration of Ca^{2+} up to 300 mg/L or higher have been reported. However, its common concentration ranges between 40–120 mg/L.

   In steel and iron pipes, calcium precipitate to form $CaCO_3$. A layer of $CaCO_3$ can inhibit corrosion of metal, but its excess accumulation in water heaters, boilers and heat exchanges affect heat transfer and results in plugging of pipes. In natural water, concentration of other constituents like boron, iron, aluminum, phosphate and manganese is 1 mg/L or higher.

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2. *Major anions:* Anions include sulfate, chloride, nitrate, fluoride, carbonate and bicarbonate, etc. Bicarbonate is the common anion found in natural water provides buffer capacity. It is formed on the dissociation of carbonic acid, formed carbon dioxide dissolves in water. Concentration of chloride ions in water determines the quality of water as its concentration increase results in decrease in quality.

pH and alkalinity: It is defined as property of water to neutralize acids added to it. It includes phosphates, carbonate, bicarbonate, ammonia and hydrogen sulfide. Total alkalinity can be calculated by using the following expression:

$$\text{Total alkalinity} = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-] - [H^+]$$

Where $[HCO_3^-]$ is bicarbonate, $[CO_3^{2-}]$ is carbonate and $[OH^-]$ is hydroxide.

When the water mixes with wastewater, its alkalinity perturbed.

Acidity: It is defined as the quantitative capacity of an aqueous media to react with OH^- ions. It indicates the corrosiveness of acidic water in concrete, steel and other materials.

Inorganic Indicator Used for Water Quality

a. **Hardness:** Hardness is correlated with total dissolved solids (TDS) or it means consumption of soap without forming lather. It represents the presence of Ca^{2+}, Mg^{2+}, ions, sulfates, carbonates, bicarbonates, etc., in water (*see* **Table 2.2**). It is expressed as mg/L $CaCO_3$. Water is classified on the basis of hardness as given in **Table 2.2**.

Table 2.2: Classification of water on the basis of hardness.

Hardness (mg/L $CaCO^3$)	*Type*
0–60	Soft
61–120	Moderately hard
121–180	Hard
>180	Very hard

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Hardness of rivers and stream water, throughout the world ranges between 1–1,000 mg/L $CaCO_3$.

b. **Total dissolved solids (TDS):** It is a measure of salt dissolved in water sample after removal of solids. TDS is a residue remaining after evaporation of water and this load carried in streams.
c. **Conductivity:** It measures the capacity of water to transmit electrical current. Conductivity of a sample measures with the concentration of TDS. Both TDS and conductivity affect the water sample and solubility of solid and gases in water.
d. **Sodium Adsorption Ratio (SAR):** It is used to examine the hazard caused by sodium in irrigation water. SAR correlates the concentration of sodium ions to the magnesium ions and calcium ions.

$$\textbf{SAR} = \frac{Na^{+}\ mg/L}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

The proper ratio of SAR in irrigation soil results in granular and permeable texture, while increasing concentration of sodium in this ratio results in increase SAR and soil becomes less permeable and difficult to work.

Organic material: Organic compounds made up of carbon, hydrogen, oxygen are derived from industrial sources and living organisms. Organic compounds also contain phosphorus, fluorine, sulfur, bromide, chlorine and iodine. Presence of organic material in water, affect the quality of water by causing disagreeable odors and tastes. Benzene, vinyl chloride, chloroform and other organic contaminants are well known carcinogenic agents. Organic material is further classified into natural and man-made agencies.

a. **Natural organic compounds:** Organic matter is formed in water as a result of wide range of methods, together with surface water and precipitation. Organic materials in soils came from animals and plants degradation products. These products further condense and polymerize into humic and fulvic acids. This acids further convert to kerogen and finally to coal. Microbial and chemical processes produce transformation by attacking aliphatic side chains and functional groups. Reactive groups

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Table 2.3: Different analytical water quality parameters with their techniques and guidelines according to WHO and Indian standard.

S. No.	*Parameter*	*Technique used*	*Value*	*WHO standard*	*Indian standard*
1.	Temperature	Thermometer	40–60°C	—	—
2.	Color	Color kit	15TCV	—	5 Hazen units
3.	Odor	Physiological sense	0–4p value	Acceptable	Acceptable
4.	Turbidity	Kit	5NTV	—	—
5.	Electrical conductivity	Water analysis kit	—	—	—
6.	pH	pH meter	6.5–8	65–9.5	6.5–9.5
7.	Dissolved oxygen	Redox titration	5–6 ppm	—	—
8.	Total hardness	Complexometric titration	Less than 100 ppm	200 ppm	300 ppm
9.	Alkalinity	Acid-base titration	—	—	200 ppm
10.	Acidity	Acid-base titration	—	—	—
11.	Ammonia	UV-visible spectrophotometer	0.1–0.7 ppm	0.3 ppm	0.5 ppm
12.	BOD	Titration	5–32	6	30
13.	Chloride	Argentometric titration	Less than 250 ppm	250 ppm	250 ppm
14.	Magnesium	Complexometric titration	0.05 ppm	150 ppm	30 ppm
15.	Nitrate	UV-visible spectrophotometer	40 ppm	45 ppm	45 ppm
16.	Nitrite	UV-visible spectrophotometer	45 ppm	3 ppm	45 ppm
17.	Sodium	Flame photometer	200 ppm	200 ppm	180 ppm
18.	Sulfate	Nephelometer	250 ppm	250 ppm	200 ppm

(Guidelines for Water Quality Monitoring Central Pollution Control Board, Central Pollution Control Board, New Delhi)

undergo condensation and polymerization, results in production of large aromatic molecules humin **(Table 2.3)**.

b. **Man-made organics:** Synthetic organic compounds include aromatic and aliphatic compounds. Manufactured compounds

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may be found at very low concentration in water. Isolation, identification and detection of health effects of manmade synthetic compounds at very low concentration are lacking.

Biological oxygen demand (BOD): It is the most widely common parameter used to measure the amount of oxygen consumed by microbial population in water in response to the presence of degradable organic matter. This parameter depends upon the different characteristics of water, such as dilution, essential nutrients and bacteria. The BOD_5 (5-day BOD) of water is related to the concentration of dissolved oxygen, measured at 0 time and after 5 days of incubation at 20°C temperature. The difference indicates the dissolved oxygen used by microorganisms during the oxidation process. So,

$$BOD_5 = D_0 - D_1$$

Where D_0 and D_1 are dissolved oxygen concentration (mg/L) at time 0 and 5 days respectively. For streams and rivers, concentration of BOD_5 throughout the world ranges between <2 to 15 mg/L and observed range is between <2 to 65 mg/L.

Chemical oxygen demand (COD): This test yields the oxygen equivalent of organic matter that can be oxidized in an acidic medium. Potassium permanganate is used as an oxidizing chemical and silver sulfate is added in a reaction as a catalyst.

Organic matter

$$(C_aH_bO_c) + Cr_2O_7^{2-} + H^- \rightarrow 2C_r^{3+} + CO_2 + H_2O$$

The chemical oxygen demand observed in rivers and streams is <2 mg/L to 100 mg/L.

Dissolved gases: Gas transfer is used to strip hydrogen sulfide, ammonia and other volatile compounds from natural water. In this process, gases are transferred from one phase to another across a gas-liquid interface. Example: Oxygen is transferred from gaseous phase into liquid phase (water). At equilibrium concentration of gases/volatile organic compounds dissolved in natural water depends on the type of volatile compounds, temperature and partial pressure of gas. Henry's law is used to calculate relationship between partial pressure of gas above the water and concentration of gas dissolved in water.

$$X_g = HP_g$$

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Where P_g: Partial pressure of gas (atm); H = Henry's law constant; X_g: Equilibrium mole fraction of dissolved gas (mol/dm^3).

III Microbial characteristics: The principal group of microorganisms in water include parasites, animals and plants. Physical and biological characteristics of organism's effect quality of water are present in **Table 2.4**.

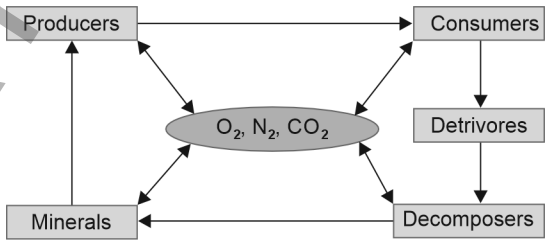
Many of these microorganisms are responsible for various virulent diseases transmitted to living/humans through food and water.

Biological characteristics: In an aquatic system, animals and plant material are composed of carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur. These elements are used as building blocks for lipids, carbohydrates, proteins, nucleic acid and phosphorus. The cycling of these nutrients and gases among producers, consumers, detritivores, decomposers, and minerals is shown in **(Flowchart 2.3)**.

Table 2.4: Classification of microorganisms in water.

Kingdom	*Members*	*Size*	*Shape*	*Resistant stage*
Animal	Crustaceans	—	—	—
	Worms	—	—	—
	Rotifers	—	—	—
Protists	Protozoa	10^0–10^2	variable	Cysts
	Algae	—	—	—
	Fungi	10^0–10^2	Filamentous/ coccoid	Spores
	Blue-green algae	10^0	Coccoid/ filamentous	Cysts
	Bacteria	10^{-1}–10^4	Rod/coccoid/spiral	Cyst like

Flowchart 2.3: Cycling of nutrients and gases in an ecosystem.



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WHO (1993–96) recommended the guidelines for the quality of drinking water that includes microbiological, radiological and chemical aspects, which if not maintained can be dangerous to health.

Water Pollution

Water pollution is defined as the addition of organic, inorganic, biological and radiological substances, etc., which degrade the quality of water and make it either health hazard or unfit for use. Water pollution is very serious problem in India as it is estimated that 50–60% of Indian population suffers from different diseases. Pollutants in water produce the following effects:

- Addition of suspended particles
- Water deoxygenation
- Addition of non-toxic salts
- Excess heating
- Addition of poisonous substances.

The impurities are broadly categorized by their origin into natural and acquired sources.

Natural Impurities

Natural impurities enter water from the environment and may affect its quality. These include:

- **Dust and soluble gases:** Gases, such as carbon dioxide, hydrogen sulfide, nitrogen and ammonia may dissolve in water.
- **Dissolved minerals:** Minerals like calcium, magnesium and sodium, along with salts of iron, lead and manganese, may be present naturally.
- **Vegetable impurities:** Plant materials, such as algae, microplants and dried leaves may contaminate water.
- **Pathogenic agents:** Disease-causing organisms, such as bacteria, viruses, ova, worms and cysts may be found in polluted water.
- **Inorganic impurities:** Sand, soil, sludge and sediment particles may enter water from natural sources.

Acquired Impurities

Acquired impurities are mainly introduced into water through human activities. With rapid industrial growth and urban development,

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these impurities have increased considerably. The major acquired sources of water pollution are:

- **Sewage:** Sewage discharge is one of the common causes of river pollution. It contains organic matter that reduces the oxygen content of water, harms aquatic life and produces an unpleasant odor. It may also carry disease-producing organisms, leading to waterborne illnesses.
- **Industrial waste:** Effluents from industries, such as paper, textile, alcohol, iron, sugar, steel, tanneries, oil refineries, paint and fertilizer units can severely contaminate water bodies. These wastes alter the quality and potability of water. Toxic chemicals present in industrial discharge may pose serious health hazards, making water near industrial areas unsafe for drinking.
- **Agricultural pollutants:** Excessive use of chemical fertilizers and pesticides in farming can pollute water sources. These chemicals may run off from fields into nearby water bodies and dissolve in water. Agricultural waste, weeds and plant residues dumped into water also contribute to pollution.
- **Physical pollutants:** Radioactive materials, acid rain and thermal pollution are examples of physical pollutants that can adversely affect water quality.
- **Inappropriate social practices:** Disposal of human or animal remains and immersion of worship materials into rivers, ponds and other water bodies can further increase water pollution.

Water pollutants are known to cause following effects on the basis of water sources:

a. **Surface water pollution:** Sources of surface water, such as ponds, tanks, lakes, rivers and streams, etc., are mainly polluted due to the following pollutants:
   i. *Sewage and domestic waste:* Untreated sewage of municipalities is poured into water bodies. Organic wastes are added into tanneries, canning industries and slaughterhouses, etc. Village pond water get contaminated with pathogens of cholera, dysentery, typhoid, jaundice and skin diseases.
   ii. *Surface run-off:* This water brings fertilizers such as potassium, phosphorus, urea and nitrates, etc., insecticides like BHC, aldrin, DDT, copper sulfate, etc., fungicides, rodenticides, nematicides and fumigants.

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iii. *Industrial waste:* It contains heavy metals like lead, copper, zinc, cadmium and nickel, etc. Inorganic and organic pollutants, such as acids, cyanides, oil, phenol, sugar, wood, cellulose, fiber etc.
iv. *Oil:* Refineries discharge a lot of oil in the rivers and leads to the destruction of aquatic life.
v. *Solid particles:* Excess and wrong agricultural and forestry products leads to soil erosion during rainy season. This make the water muddy, that may choke water courses, cause turbidity and effect organisms living in the bottom.
vi. *Thermal pollution:* This pollution is caused by adding hot effluents into water bodies from refineries or thermal power plants, etc.

b. **Underground water pollution:** The common sources of underground water pollution are as follows:
i. Excessive fertilizers and pesticides sprayed in agricultural field.
ii. Untreated sewage and industrial effluents.
iii. Waste dumps, seepage pits, septic tanks and mining activities, etc.

c. **Marine water pollution:** The main sources of marine water pollution are:
i. Oil, petroleum products, sewage, grease, garbage and detergents from ships.
ii. Discharge of fertilizers and pesticides.
iii. Dumping of industrial wastes.
iv. Accidents during extraction and transportation spread oil in many hundred kilometers.
v. Discharge of sewage of coastal cities through rivers.

Consequences of water pollution:
i. *Deoxygenation:* Microorganisms take up most of dissolved oxygen present in water, during decomposition of sewage waste.
ii. *Anaerobiosis:* This process is also known as deoxygenation, that results in production of various secondary pollutants.
iii. *Eutrophication/blooming:* Sewage and soap/detergents stimulate growth of algae in water that results in oxygen depletion.

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Adarsh Pal Vig MSc PhD is a Professor in Amritsar Group of Colleges (UGC-Autonomous), Amritsar, Punjab, India. He is a former professor in the Department of Botanical and Environmental Sciences, Guru Nanak Dev University (GNDU), Amritsar, Punjab, India. He also served as Former Chairman of Punjab Pollution Control Board (PPCB). He has more than 32 years of teaching and research experience. He has published more than 142 research papers, 26 book chapters, 4 patents, and 5 books. He has supervised 1 Postdoctoral Fellow, 19 PhD, and 11 MPhil students. His area of research is vermitechnology, earthworm ecology, solid waste management, bioactivities of glucosinolates, and pollution control regulations.

Sonia Sharma MSc MPhil PhD (Botany) is an Assistant Professor, Khalsa College, Amritsar, Punjab, India. She has teaching experience of 9 years of undergraduate and postgraduate classes. Till date, she has published 17 research papers. She is an active reviewer of various reputed research journals. She has also published three books for science students. Her area of specialization includes natural plant products, genotoxicity, and anticancer.

Sartaj Ahmad Bhat MSc MPhil PhD (Environmental Sciences) is an Assistant Professor at IIMT University, Meerut, Uttar Pradesh, India. He has served as a JSPS Postdoctoral Researcher at the River Basin Research Center, Gifu University, Japan and earned his PhD in Environmental Sciences from Guru Nanak Dev University, India. He has published more than 70 research articles and coedited 20 books. His area of research is sustainable treatment of organic waste and wastewater, waste valorization, and earthworm-based biotechnologies for environment remediation.

Namita Khanna MBBS MD (Physiology) is a Professor in the Department of Physiology, GGS Medical College, Baba Farid University of Health Sciences (BFUHS), Faridkot, Punjab, India. In her MD, she worked on "effect of antihypertensive drugs on autonomic nervous system activity." She held various positions like medical officer and registrar. She has published 11 research papers and two chapters of book in national and international journals. Her area of specialization is physiology.

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