WATER

ABSTRACT

Water is one of the necessary components that influence almost all living organisms on the planet earth. It covers about 71% of the Earth's surface and is a key component of various ecosystems. Water-borne illnesses caused by pathogenic microbes that are transmitted through contaminated water. Some of them are: Cholera, Typhoid Fever, Hepatitis A, Dysentery, Giardiasis, Cryptosporidiosis, Leptospirosis. Preventing these diseases involves ensuring access to clean drinking water, practicing good hygiene, and proper sanitation. Boiling water, using water filters, and avoiding consumption of raw or under-cooked food can also help to reduce the risk.

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I. CURRENT SCENARIO

Water is a resource upon which life on Earth depends, not only for the well-being of the organism but also to sustain the health and balance of its ecosystems (Gupta and Biswas, 2021; Suthar *et al*., 2024). Unfortunately, less than half of the world's population has guaranteed access to drinking water that is safely managed-safely managed means at or near the point of use without any contamination. It provides 85% of rural drinking water and 48% in urban areas. However, there is a growing concern that the groundwater resources are depleting. Severe water scarcity has affected all 718 districts in India. Urban areas generally have better access to improved water sources compared to rural areas, but both face challenges related to infrastructure and contamination. Jal Jeevan Mission, one of the initiatives by government of India launched in 2019. This national flagship program aims to provide piped water supply to every household by 2024. As of 2015, India achieved 93% coverage of access to improved water supply in rural areas, but the shift to Sustainable Development Goals (SDGs) has highlighted the need for further improvements. Aging infrastructure and inadequate maintenance can lead to contamination and water loss. Increasing frequency of droughts and floods exacerbates water quality and availability issues. Efforts are ongoing to improve water quality and availability, but significant challenges remain (Suthar and Suthar, 2010; NITI Aayog, 2018; Chen *et al*., 2021; Suthar *et al*., 2012; Suthar *et al*., 2024; RMD-NWM, 2024, World Bank, 2024).

II. PATHOGENIC MICROBES IN WATER

Pathogenic microbes are microorganisms that infect humans through ingestion or direct contact. These microbes include various bacteria, viruses, protozoans and helminthes. They mostly reach water bodies through contamination with human or animal feces, untreated sewage, or polluted environments (Suthar and Suthar, 2013).

Table 1: Pathogenic micro-organisms which can contaminate the drinking water.

Pathogenic Microbe	Disease	Transmission	References
(a) Bacteria			
Escherichia coli (E. coli)	Gastroenteritis, Hemolytic Uremic Syndrome (HUS)	Fecal-oral route, typically through contaminated drinking water or food.	Devane *et al*., 2020; Monsenpour *et al*., 2024

Salmonella species	Salmonellosis	Fecal-oral route, through contaminated water, food, or contact with infected animals	Brown *et al*., 2021
Campylobacter jejuni	Campylobacteriosis	Fecal-oral route, often through drinking contaminated water or undercooked food.	Bintsis, 2017
Vibrio cholerae	Cholera	Fecal-oral route, commonly through drinking contaminated water, especially in areas with poor sanitation.	Crison and Hammer, 2020
Shigella species	Shigellosis	Fecal-oral route, typically through contaminated water or food.	Schnupf and Sansonetti, 2019
Legionella pneumophila	Legionnaires' disease, Pontiac fever	Aerosolized water droplets from contaminated water sources, typically in cooling towers and plumbing systems.	Goncalves *et al*., 2021
(b) Viruses			
Enteric viruses (e.g., Norovirus, Hepatitis A)	Gastroenteritis, Hepatitis A	Fecal-oral route, often through contaminated water or food.	Oteiza *et al*., 2022
Rotavirus	Rotavirus infection	Fecal-oral route, through contaminated water or food, especially in infants and young children.	Chi *et al*., 2024
(C) Protozoa			
Giardia lamblia	Giardiasis	Fecal-oral route, commonly from drinking contaminated water, particularly from lakes and rivers.	Aziz *et al*., 2024
Entamoeba histolytica	Amoebiasis (Amoebic dysentry)	Fecal-oral route, through drinking contaminated water or food.	Mendoza and Knoll, 2020

Cryptosporidium parvum	Cryptosporidiosis	Fecal-oral route, typically from contaminated water sources such as lakes, rivers, and swimming pools.	Jiang *et al*., 2022
(c) Helminths (Worms)			
Schistosoma species	Schistosomiasis	Direct contact with contaminated water (freshwater) containing cercariae, larvae of the parasite.	Gryseels *et al*., 2006. Loverde, 2024
Ascaris lumbricoides	Ascariasis	Fecal-oral route, commonly through contaminated water or soil.	Maurelli *et al*., 2021

(Other Sources are: Various study materials from various books/study reports from World Health Organisation. WHO, 2020; Cisse *et al*., 2019; CWD, 2024).

III. TREATMENT METHODS FOR DRINKING WATER

There are several methods used to treat drinking water to make it drinkable. The most common methods for water treatment are summarized here (Hai *et al*., 2018; Novakova *et al*., 2023; Ihsan *et al*., 2024; Suthar *et al*., 2024).

- **Coagulation:** Chemicals with a positive charge are added to the water to neutralize the negative charge of dirt and other particles. This causes the particles to bind together into larger particles called flocs.
- **Flocculation:** Gentle mixing with water to form larger, heavier flocs that can be easily removes.
- **Sedimentation:** The process includes the heavy floc settles to the bottom, allowing the clear water to be separated.
- **Filtration:**
  - **Sand Filtration:** Water passes through layers of sand, gravel, and charcoal to remove particles.
  - **Membrane Filtration:** Includes microfiltration, ultrafiltration, nanofiltration, and reverse osmosis (RO), which use different pore sizes to remove contaminants.

- **Disinfection**
  - **Chlorination:** Adding chlorine or chlorine compounds to kill bacteria, viruses, and other pathogens.
  - **Ultraviolet (UV) Light:** Using UV light to disinfects water by inactivating microorganisms.
  - **Ozonation:** Using ozone gas to disinfects water.
- **Adsorption:** Activated Carbon is used to remove organic compounds, chlorine, and other contaminants that cause taste and odour issues.
- **Ion Exchange:** Water Softening or removing hardness-causing minerals like calcium and magnesium by exchanging them with sodium or potassium ions.
- **Distillation:** Boiling water to produces steam that condensed back into liquid remaining contaminant.

IV. BIOLOGICAL TREATMENT METHODS

Biological principles to drinking water treatment involve using microorganisms to remove contaminants through natural processes (Chen *et al*., 2021; Thom *et al*., 2022).

D.1 Bio filtration: Water passes through a filter medium (like sand or activated carbon) that supports a biofilm of beneficial microorganisms. These microorganisms break down organic contaminants and nutrients. This method is much effective in removing organic matter, reducing turbidity, and improving taste and odor.

D.2 Constructed Wetlands: These types of systems use plants, soil, and associated microorganisms to treat water. The roots of the plants provide a surface for microbial growth, which helps in dissolving contaminants.

Advantage

- Sustainable and low-cost method
- Effective in removing a wide range of pollutants

D.3 Biological Activated Carbon (BAC): The activated carbon adsorbs organic contaminants, after adsorption they are degraded by the microbes growing on the carbon surface.

Advantages

- Reduce the use of chemical disinfectants.

D.4 Slow Sand Filtration: Water slowly passes through a bed of sand containing microbial biofilm surface. This biofilm trap and degrades contaminants. This is simple and effective method for removing pathogens and organic matter.

D.5 Advanced Bio Filtration: It includes enhancing traditional bio filtration with advanced materials like nanomaterials to improve efficiency and contaminant removal.

D.6 Phytoremediation: This is based on the use of plants to absorb and detoxify contaminants from water. Certain plants can uptake heavy metals and other pollutants. This is Eco-friendly and cost-effective method.

V. CHEMICAL CONTAINMENTS, THEIR SOURCES AND THEIR HEALTH EFFECTS ON HUMAN WHILE DRINKING CONTAMINATED WATER

Table 2: Chemicals from different sources and their health effects on Human/Mammal.

Sr. No.	Chemical	Sources	Health Effects	References
1	Arsenic (Ar)	Natural deposits in the earth, industrial and agricultural pollution. High levels in Ground Water in many countries, Inorganic form is high toxic.	'Arsenicosis'. It can cause nausea, vomiting, decreased production of red and white blood cells, abnormal heart rhythm, and damage to blood vessels	Farzan *et al*., 2022
2	Lead (Pb)	Lead pipes, brass fixtures, and older submersible pumps. Boat, battery recycling.	Can cause developmental issues in children, kidney and Brain damage, and high blood pressure with reduction in fertility.	Wani *et al*., 2015
3	Nitrate	Fertilizers, septic systems, animal	High levels can decrease the ability of	Picetti *et al*., 2022

		feedlots, and industrial waste.	blood to carry oxygen, particularly dangerous for infants.	
4.	Per- and Polyfluoroalkyl Substances (PFAS)	Fire retardants, non-stick cookware, waterproof clothing, and industrial sites.	Linked to cancer, liver damage, thyroid disease, and developmental issues (Kurwadkar *et al*.,	Kurwadkar *et al*., 2022
5.	Pesticides and Insecticides	Agricultural runoff; Home product (Spray, Powder, Tablets, Food, water, etc)	Can cause a range of health issues, including cancer, reproductive problems, and endocrine disruption.	Tudi *et al*, 2021; Rezende-Teixeira *et al*., 2022; Kaur *et al*., 2024).
6.	Radon (Rd)	Naturally occurring radioactive gas from the decay of uranium, radium, and thorium in the ground.	Increases the risk of lung cancer.	Chen, 2019; Mohammed *et al*., 2023
7.	Disinfection by products (DBPs)	Formed when disinfectants like chlorine react with natural organic matter in water.	Linked to cancer and reproductive issues.	Shrivastava *et al*., 2020; Liberatore *et al*., 2022; Vellingiri *et al*., 2023
8.	Copper (Cu)	Copper pipes, mining, farming, and industrial pollution.	Can cause nausea, vomiting, and diarrhoea Lime.	Pizarro *et al*., 1999; Sicairos-Ruelas *et al*., 2019
9.	Heavy metals [Mercury (Hg), Chromium (Cr), Cadmium (Cd), Nickel (Ni), etc.]	Industrial sources chiefly affluent, Applications of Heavy metal piping - Storage tanks/ salts-products/ metallic Cookware etc.	Can cause to genetic material (DNA), hepatic and reproductive issues.	Rao *et al*., 2001; 2003; Suthar and Suthar, 2013; Emmenuel et al., 2022; Li et al., 2023.
10.	Calcium hardness	Lime-stone, Natural Leaching, High	Calcium (Ca^{+2}) is an important ion which	Suthar *et al*., 2008a; b; c;

	(CH)	amount of dissolve salts of Calcium and Magnesium has higher amount of Total Hardness values. Hence, total hardness value shows higher number of salts of Calcium and Magnesium.	act as a second messenger, synaptic communication and contraction in skeletal muscles. Less amount of calcium leads to altered bone-formation and affect biological endoskeleton of body and cells. Magnesium (Mg^{+2}) is essential component which has important in energy and ribosomal working. Excess concentrations of magnesium can lead to hypotension, urolithiasis, muscular weakness and altered mental functioning	d; Suthar *et al*., 2010; Suthar *et al*., 2017 2017.Suthar *et al*., 2022, 2024).
11.	Magnesium Hardness (MH)			Suthar *et al*., 2008a, b, c, d; Shah *et al*., 2008; Suthar *et al*., 2010; Suthar *et al*., 2015; 2017.Suthar *et al*., 2022, 2024
12.	Total Hardness (CH+MH= TH)			Suthar and Suthar, 2010; Suthar *et al*., 2022; 2024
13	Chlorides (Cl^-) Chlorinity and Salinity	Chlor-alkali Plants, Industries, Chlorination of drinking water in water-supply.	Lower chlorinity amount may be disrupts physiological and osmotic pressure. Higher chloride amount can be affected by Chloride-shift during respiration.	Suthar *et al*., 2017; 2022; 2024; Emmanuel *et al*., 2022: Li *et al*., 2023
14.	Flourine/ Florides(F-)	Drinking water, Toothpastes, Fluoride is used in numerous dental care products, like toothpaste, mouthwashes, and professional treatments such as fluoride varnish.	All of these applications are extremely helpful and quite effective in preventing tooth decay and strengthening the enamel of the teeth. Systemic ingestion of fluoride through water, food, or supplements boosts the development of teeth, especially in children.	Vasisth *et al*., 2024

15.	Electrical Conductivity (EC) and Total Dissoled Solids (TDS)	High amount of Calcium and Magnesium salts (Hardness) may have higher electrical conductivity.	Six potential predator families were common in aquatic habitats of *Anopheles funestus* group larvae.	Mehenge *et al*. 2023; Mohsenpour *et al*., 2024
16.	Sodium (Na), Potassium (K) cations (like CO_3^{-2}, SO_4^{-2}, HCO_3^{-1} and Trace Elements	Water, Food, Drugs, Touching /using salts	The probability of cancer and other diseases through long-term exposure via ingestion routes. Functioning of Heart may be altered	Abbas *et al*., 2021

VI. HARDNESS OF WATER

Water hardness is usually defined by, and proportional to, its concentrations of dissolved minerals, which are predominantly calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions within a particular watershed. These are most commonly present in the water, resulting from rock and mineral dissolution of carbonate-containing substances, such as limestone [Calcium carbonate, $Ca(CO)_3$] and dolomite [Magnesium /calcium carbonate], $CaCO_3.MgCO_3$], respectively. Generally, the hardness of natural water is an important consideration in determining its quality both for daily household applications, as well as for wider processing functions (Vogiatzi *et al*., Desye *et al*., 2021).

Types of Hardness

(A) Temporary Hardness: It is primarily due to the presence of dissolved bicarbonates of calcium and magnesium ($Ca(HCO_3)_2$ and $Mg(HCO_3)_2$. This type of hardness can be removed through various methods, the most common being boiling, as well as some chemical treatments.

Methods of Removal

- **Boiling:** Boiling is a simple method to remove temporary hardness. During boiling, calcium and magnesium bicarbonates decompose to form insoluble carbonates ($CaCO_3$ and $MgCO_3$), which precipitate out of the water.

$Ca(HCO_3)_2$ ----^{Boiling}------> $CaCO_3$ (s) + CO_2+ H_2O

$Mg(HCO_3)_2$ ----^{Boiling}--------> $MgCO_3$ (s) + CO_2 +H_2O

- **By Clarks Method:** Calcium hydroxide [$Ca(OH)_2$]is Clark's reagent. It removes the hardness of water by converting bicarbonates into carbonate.

$Ca(OH)_2$ + $Ca(HCO_3)_2$ ----------> $2CaCO_3$ + $2H_2O$

(B) Permanent Hardness: Permanent hardness is caused by the presence of dissolved sulfate (SO_4^{2-}) and chloride (Cl^-) salts of calcium and magnesium ions, such as calcium sulfate ($CaSO_4$) and magnesium sulfate ($MgSO_4$). Permanent hardness cannot be removed by boiling. It requires chemical treatments like ion exchange or the use of water softeners.

Methods of Removal

- **Gan's Permutit Method:** Sodium aluminium ortho silicate (Also known as Permutit or Zeolite) is used to remove the permanent hardness (CH+MH) of the water. Permutit is a synthetic ion-exchange material. The hard water is passed through a bed of Permutit or zeolite. The Permutit material is charged with sodium ions (Na^+), which are exchanged for the calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions present in the water. When hard water passes through the Permutit bed, the calcium and magnesium ions in the water are attracted to the zeolite surface, displacing sodium ions (Na^{+1}) (Santos *et al*., 2022; Schuetz, 2024).

$Na_2Al_2Si_2O_8.xH_2O$ + Ca^{+2} ----------> 2 Na^{+1} + $Ca.Al_2Si_2O_8.xH_20$

- **Calgon's Process:** Sodium-hexa-meta-phosphate [$NaP(O_3)_6$] known as Calgon is used for eliminating Calcium and Magnesium from hard water (Zevdu, 2013).

(C) Measurement of Hardness: Water hardness is conventionally expressed as milligrams per liter (mg/L) or parts per million (ppm) calcium carbonate ($CaCO_3$), which serves as the standard reference for hardness. Hardness can be classified into the following categories based on the concentration of $CaCO_3$ (Suthar and Suthar, 2010; Suthar and Mesariya, 2012; Suthar *et al*., 2011; 2017; 2022; 2024).

Table 3: Hardness level and Classification of water

Hardness Level	**$CaCO_3$ Concentration OR Clacium Hardness (CH) Value**	**Classification**
Soft water	Less than 60 mg/L	Ideal for most uses.
Moderately hard water	60 - 120 mg/L	It is Suitable for most household use.
Hard water	120 - 180 mg/L	It may cause scale formation in pipes and appliances.
Very hard water	More than 180 mg/L	It may cause significant scaling and is harder to treat.

Standards of Water Quality: Water is a major resource which is essential to sustain life on the mother Earth. As per the guidelines, safe drinking water does not have any risk to health over life-long consumption. Ensuring quality of drinking water is crucial to prevent health risks and environmental deterioration. Various national and international organizations such as World Health Organization (WHO, 2020). Bureau of Indian Standards (BIS) etc. have established water quality standards to define safe and acceptable levels of different contaminants in the water. In India, water quality criteria designated by Central Pollution Control Board (CPCB) are given in tabulated form.

Table 4: Classes and Criteria (Standards) of Water quality for various purposes (CPCB, 2024).

Class	**Criteria**	**Uses**
A	• Total Coliforms Organisms (MPN/ 100 ml water) shall be 50 or less. • pH- 6.5 to 8.5 • Biological Oxygen Demand (BOD) 5 days at 293.15K = 2mg/L or less • Dissolved Oxygen (DO)= 6 mg/L. or more	Drinking water source without conventional treatment but after disinfection.
B	• Total Coliforms Organisms (MPN/ 100 ml water) shall be 500 or less. • pH- 6.5 to 8.5 • Biological Oxygen Demand (BOD) 5 days at 293.15K= 3 mg/L or less	Outdoor bathing

	• Dissolved Oxygen (DO)= 5 mg/L. or more	
C	• Total Coliforms Organisms (MPN/ 100 ml water) shall be 5000 or less. • pH- 6 to 9 • Biological Oxygen Demand (BOD) 5 days at 293.15K= 3 mg/L or less • Dissolved Oxygen (DO)= 4 mg/L. or more	Drinking water Source after conventional Treatment and Disinfection.
D	• pH- 6.5 to 8.5 • Free Ammonia (as N) at 293.15 K = 3 mg/L or less • Dissolved Oxygen (DO)= 4 mg/L. or more	Propagation of Wildlife and Fisheries
E	• pH- 6.0 to 8.5 • Electrical Conductivity (EC) at 293.15 K- Maximum 2250 micro mhos/cm. • Sodium Absorbance Ratio= Max. 26 • Boron= Max. 2 mg/L	Irrigation, Industrial Cooling, Controlled Waste Disposal

VII. CONCLUSION

Water is essential for the sustenance of life. From unicellular microscopic organisms such as Entamoeba, to most advanced multi-cellular mammals, all living organisms depends on water for survival. Chemically, water is universal solvent and accounts for 70 % human body. Water is a primary component of cells and provide an ideal medium for metabolic reaction essential for life. Thus, maintaining high quality standards is necessary for health, environmental sustainability and economic stability (Suthar and Suthar, 2013; Rathi and Mishra, 2021; Suthar *et al*., 2024).

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