

Chapter 6

Chemicals in the Water: A Serious Concern for the Humans and Aquatic Life



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Abstract Water is an essential element for life without which the life cannot sustain on the earth. The earth's major part is covered with water which carry maximum biodiversity. The humans, animals and plants of the terrestrial ecosystem depend on freshwater sources which are less than 3% of the total water available on the earth while marine water sources have saline water available in oceans, seas and saline lakes. Both these sources are suffering from contamination by different chemicals. The majority of chemical contamination in water is due to human activities. Human population growth is directly proportional to the degradation of the environment which means mismanaged human activities are causing different types of environmental problems. Out of all environmental problems, contamination of water and degradation of water quality is a big problem for the water resources. It is evident that water has high levels of harmful chemicals like heavy metals, pesticides and volatile organic compounds. These chemicals are now getting accumulated in the plants, humans and animals. In humans, these chemicals get deposited in the tissues and are responsible for the different types of life-threatening diseases. The studies on different water sources including poles and glaciers have shown the presence of different harmful chemicals, and even at some places these are found in high concentration. The people from different parts of the world are suffering from

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various diseases like arsenic poisoning, fluorosis, itai–itai, mercury poisoning, liver failure, nervous system failure and many more. Some of these chemicals are carcinogenic and mutagenic too which is responsible for the different types of cancer and mutation in the body. Therefore, the proper treatment of waste, awareness of people and following the standard guidelines strictly are only the way to reduce the chance of contamination of different water sources by chemicals.

Keywords Water · Diseases · Pesticides · Heavy metals · Degradation · Environment

6.1 Introduction

Humans are the dominant species among all present on the planet. We are trying to control and rule the nature by modifying the natural ecosystems, overexploiting the natural resources and generating huge amounts of waste of all forms. The economic disparities between the nations as well as in the society are also responsible for environmental degradation. The contamination in the air, water and soil is causing many problems for all types of ecosystems including the extinction of species from the earth. The increasing concentration of carbon dioxide in the air is responsible for global warming and climate change that also results from the melting of ice from the cryosphere. The melting of ice from the poles is causing the emission of different gases trapped in the polar region. All types of water are suffering contamination by chemicals and other types of waste products generated by human activities.

Water contamination can be defined as the changes in the composition of water due to the dumping of waste to an extent which makes it unfit for human uses like drinking/domestic purposes and to support biotic communities, such as fish. The contamination of water also impacts aquatic flora and fauna that survive in the aquatic ecosystem with the effect on individual species or whole populations and biological communities.

The rivers, ponds and lakes are the source of freshwater, facing several problems. The rivers are dying, and lakes are facing the problem of the accelerated rate of eutrophication. Oceans and seas are now acting as dumping grounds for different types of harmful waste especially radioactive waste. The waste from human settlements, agricultural practices, petroleum drilling, landfills, industrial sources, construction sites and mining sites is being dumped into the water bodies which carry different types of hazardous and toxic chemicals to water sources especially rivers, ponds and lakes (Agrawal et al. 2010). Water contaminants are a major threat and cause of global concern which are responsible for detrimental diseases and 14,000 deaths every day (Daniel 2006). Overexploitation of water resources along with other resources and unplanned rapid industrialization is responsible for the fall in the quality of water in most cities with its contamination with many toxicants which are harmful to the health of humans (Jadon et al. 2016).

Excess chemicals in the water bodies reduce the dissolved oxygen in the water which results in the death of the aquatic animals. The major rivers of India like the Ganges and Yamuna are worse polluted with high levels of toxic chemicals in the water. The Yamuna is considered almost a dead river within the Delhi stretch because of DO below 4 ppm. There are reports which show the occurrence of different harmful chemicals like OCPs, VOCs and PAH in the waters of different rivers in India.

Oceans and seas are also facing a similar problem as they are covering a large area of the earth's surface. Most of the world's big cities are situated in the coastal region, and sea routes are also being used to transport goods from one part to the other part of the world. Sometimes, accidents and oil spills also take place which also add harmful chemicals into the marine system. The oceans also receive many harmful chemicals through waste from coastal cities and surface run-off which leads to marine pollution. The oceans are the major sink for CO₂ which is responsible for the acidity of oceans and affects the coral reefs and molluscs. Oil spills are also responsible for the death of many marine animals and birds as it hinders the gaseous exchange in the water.

Groundwater is another source of fresh water on which the majority of the human population is dependent to fulfil their demand. With unplanned construction in the urban areas, overexploitation of groundwater and depletion of recharging points, the groundwater table is depleting rapidly. The quality of groundwater is also diminishing due to landfill sites and open dumping sites of waste which causes the seepage of leachate to the groundwater. The leachate contains different types of toxic chemicals depending on the types of waste on dumping sites. The leachate is highly toxic and contaminates the groundwater badly and causes harmful effects on humans and animals.

6.2 Major Chemicals Toxicants of Water Environment

There are many chemicals' toxicants of the water environment that alter the properties of water as well as get accumulate in humans, animals and plants (Alam et al. 2021). These toxic chemicals disrupt the functioning of important organs of humans and animals as well as disrupt the important process in the plants (Tilwankar et al. 2019a, b). Here, the details of different chemical toxicants of water are given.

6.2.1 Heavy Metals

Heavy metals are the elements that have specific density more than 5 g/cm³ (Järup 2003) and are important for the metabolic activities of plants and animals in small quantity. It becomes toxic even in low quantity when goes beyond the threshold limit.

The major sources of heavy metals in water bodies are industries, synthetic pesticides, agro-chemicals, run-off water, industrial and domestic waste water, mining

Table 6.1 Effects of heavy metal on humans

Pollutant	Effects on humans	WHO permissible limit (ppm)
Cadmium	Lung problems like cancer, defects of bone, high B.P., kidney disease, gastrointestinal problems, etc	0.06
Lead (Pb)	Infant encephalopathy, mental problems of children, congenial paralysis, kidney and liver diseases	0.1
Copper (Cu)	Damage of liver and kidney, intestinal irritation	0.1
Chromium (Cr)	Nervous system damage, fatigue and irritability	0.05
Zinc (Zn)	Zn fumes may cause corrosive effect on skin, stomach pain, diarrhoea and nausea	15
Mercury (Hg)	Damage to nervous system, protoplasm poisoning, tremors, acrodynia, gingivitis	0.01
Manganese (Mn)	Damage of CNS, insomnia, memory loss	0.26
Arsenic (As)	Bronchitis, vitamin A deficiency, dermatitis	0.02
Fluoride (F)	Dental and skeletal fluorosis	1.5

and natural process like weathering of rock and magma. The main heavy metals are lead (Pb), Ni (Nickel), Zn (Zinc), As (Arsenic), Cu (Copper), Cr (Chromium) and Hg (Mercury) that have many consequences on humans and other living organisms (Lambert et al. 2000). These chemicals got the entry in the environment through the different routes and persist for longer period of time by the process of bio-accumulation and bio-magnification. These chemicals get accumulated in human body through ingestion, inhalation and through the skin and when the levels of these heavy metals increase inside the body, become toxic and risky for the health of humans (Suruchi et al. 2011). The heavy metals once get high concentration in different components of environment, and they pose threat to humans, animals and vegetation. As these chemicals are having role in different metabolic activities if is in trace amount but metals like Pb, Hg, Cu, Cd, As and Cr are toxic in low concentration and affects metabolism of animals and plants including humans. The accumulation of heavy metals in environment is a matter of great concern as there is a contamination of food we eat, the water we drink and the air we breathe (Tilwankar et al. 2018) (Table 6.1).

6.3 Pesticides

The chemicals used to control the different pests, weeds and other disease-causing agents of agriculture and society are called pesticides. These pesticides are belonged to different category depending on its uses for a particular disease-causing agent

like insecticides, weedicides, herbicides, fungicide, rodenticide, molluscicides and nematicides for insects, weeds, herbs, fungi, rodents, mollusc and nematodes, respectively (USEPA 2014).

The pesticides are developed to kill the insects-pests in general and are designed to kill only target organism avoiding non-target organisms under standard application methodologies. One of the characteristics of these chemicals is susceptibility to certain toxins which mean a chemical toxic to one living being may also cause poisoning to other forms of life. A large dose of these chemicals is required to harm humans than the target organisms but these are toxic to humans. The doses used in a formulation to kill pests are affecting humans by causing disruption of functioning of hormones, disturbance of metabolic activities and effects on reproductive performance (Munkittrick et al. 2005; Cocco 2002; Massad et al. 2002).

The pesticides act as xenohormones (mimicking the action of endogenous hormones) or otherwise interfere with endocrine processes; hence, they have been collectively categorized as endocrine disruptors (Straube et al. 2003). The development of pesticides increased during World War II to increase the production of food and develop potential chemicals as warfare agents (Gupta et al. 2007). The discovery of insecticidal properties of DDT in 1939 marked growth in synthetic pesticides without the concern about its harmful risk and toxicity to the human health, environment and ecosystem (Unsworth 2010). The aquatic life also gets affected due to these chemicals as these tend to accumulate in the different body tissues of the animals and affect their metabolic activities (Table 6.2).

6.4 Radioactive Waste

The radioactive pollutants are the chemical with an unbalanced number of protons and neutrons resulting in unstable atoms that can emit ionizing radiation like caesium, plutonium and uranium. The radioactive waste is generated by nuclear power plants, mining, industrial, medical and scientific processes and has detrimental impacts on all biological forms. The groundwater is more prevalent for radioactive compounds than surface water as radioactive elements are naturally found in the rocks. A good number of radioactive elements like ^3H , ^{14}C , ^{40}K , ^{210}Pb , ^{210}Po , ^{222}Rn , ^{226}Ra , ^{228}Ra , ^{232}Th and 234 , 235 , ^{238}U are found in the surface and sub-surface water. Uranium, thorium, actinium and radium are the radiotoxic elements of the aquatic system.

Major sources of radioactive waste are nuclear power plants and the research laboratories where research on radioactive substances is being carried out. Cobalt 60, Iridium-192, Caesium-137 and Strontium-90 are the radioisotopes produced by atomic power plants, and ^{40}K and ^7Be are the common radioactive elements occurred in wastewater sludge. ^{40}K also occurs in the marine environment while Uranium is also found naturally in oceans as uranyl carbonate ion. The marine environment contamination of radioactive material is due to accidents of nuclear submarines,

Table 6.2 Summary of the different classes of pesticides, their properties and impacts

Types of Pesticides	Physical and Chemical Properties	Exposition	Toxicokinetics	Toxicodynamics
Organophosphorus pesticides	These chemicals are phosphorus containing organic compounds, soluble in organic solvents. Their properties vary according to size and structure	Lungs, conjunctiva, gastrointestinal system	Fast absorption and metabolized by P450-isozyme in Oxon form. Highly toxic	Makes bond with the serine residue at the acetylcholinesterase active site
Carbamate pesticides	Derivatives of ester Melting point ranges from 50 to 150 °C with low vapour pressure and poor volatility	Skin, lungs and gastrointestinal system	Absorbed by organisms with the exception the blood-brain barrier	Carbamylation at active site of Acetylcholinesterase
Organochlorine compounds	Fat-soluble compounds, persistent in the components of environment, fat soluble and semi-volatile	Fatty tissues of body	Approx. 10% of applied dose absorption by organism but accumulate due to lipid solubility	Disrupt the endocrine system and affect the child growth and also cause cancer
Pyrethrin and pyrethroid	Water insoluble, low Henry law constant, low vapour pressure, have acid moiety, central ester bond, large octanol water coefficient	Gastrointestinal tracts, skin and lungs	Shows hydrolysis/oxidation by P450 isozymes and fast distribution in the target organisms after absorption	Affects sodium channel, muscular system
Triazines	Persistence in soil depends upon the alkyl chain length, melting point ranges from 133 to 177 °C	Respiratory system, gastrointestinal system, eyes and nose	Dealkylation makes conjunction with glutathione	Not reported yet

(continued)

Table 6.2 (continued)

Types of Pesticides	Physical and Chemical Properties	Exposition	Toxicokinetics	Toxicodynamics
Phenoxy derivatives	Aliphatic carboxylic acid found attached to chloride/methyl substituted aromatic ring, absorption coefficient varies from 76 to 315 L kg ⁻¹	Lungs and digestive system	Not stored in target due to fat insolubility, fast dissociation or hydrolyse	Irritation in the respiratory tracts, digestive system, eyes, skin and mucous membrane Damage of cell membrane, uncoupling of phosphorylation
Dipyridyl derivatives	It is a dipyridylum quaternary ammonium, non-volatile with a vapour pressure <0.013 mPa and water soluble	Gastrointestinal system, lungs skin and eyes	Free radicals are produced by biotransformation with liquid peroxidation and cell injury	Due to lipid peroxidation cause tissue damage in liver, lungs and kidney
Glycine derivatives	Sold as iso-propylamine/ammonium salt, have no effect on AChE	Skin and Digestive System	Production of amino-methyl phosphonic acid due to action of glyphosate oxidoreductase	Damage of DNA and uncoupling of electron transport chain
Dithiocarbamates	Zineb and Maneb are identical in structure	Slowly absorb through oral and dermal contact	Formation of ethylene thiourea from dithiocarbamates due to biotransformation	Inhibition of acetaldehyde dehydrogenase, impacts thyroid hormones and thyroid cancer

Ref: Bernardes et al. 2015 (Source: <https://www.intechopen.com/chapters/48406>)

dumping of nuclear waste in the deep ocean and nuclear disasters like Colorado, Fukushima and the Chernobyl nuclear disaster.

The permissible limit for the radioactive substance in drinking water should be 0.1 micro sievert/ year as per the guidelines of World Health Organisation (WHO). The United States Environmental Protection Agency (USEPA) guidelines also called as radionuclides rule are as follows:

- 30 μg /litre for uranium
- 4 millirems/year for gross beta emitters
- 5 picocuries/litre for combined radium
- 15 picocuries/litre for gross alpha emitter

The radioactive chemicals/isotopes have harmful impacts on environment and can cause a risk to human health. These chemicals enter into humans through inhalation, polluted water and foodstuff which leads to harmful diseases. In aquatic systems, these chemicals are equally harmful to humans (Madhav and Ritu 2021).

6.5 Conclusion and Recommendation

The chemical contaminants of water are a matter of concern for the proper functioning of the metabolic activities of living organisms. There are many chemical elements that are required in minor amounts for the proper functioning of the cell but beyond the threshold limit, harmful for the functioning of the body. World water is highly contaminated with different chemical toxicants which are deadly for all forms of life. The apocentric view of humans is also responsible for the deterioration of the water environment. The aquatic animals are under threat due to the dumping of chemical waste and humans get indirect exposure to these elements through drinking water as well as agricultural products. There is a need of the hour to increase awareness among the mass for the conservation of water resources from chemical toxicants. There should be proper execution of prevailing policy and guidelines for the dumping of waste in the water bodies.

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