

5. Water Pollution: Unraveling the Genesis, Consequences, and Resolutions

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5.1 Introduction:

The sustenance of all life forms relied on the presence of water. Water plays a pivot role not only in household activities, but also remain fundamental for agriculture, industry, fisheries, tourism, and many more activities. However, expanding population, coupled with rapid urbanization and industrialization expansion has pushed the globe towards in a situation of water scarcity and limited water resources.

Additionally, the degrading water quality has been caused by the contamination of water resources with an increasing trend of pollution, which poses possible health risks and negative effects of water contamination. Water pollution has significant effects on numerous Sustainable Development Goals, highlighting how linked environmental, social, and economic issues are. By defending human health, maintaining ecosystems, advancing sustainable development, and creating international alliances, efforts to fight water pollution help fulfill a number of Sustainable Development Goals.

The chapter aims to delve comprehensively into diverse forms, sources, and impacts of water contaminants. Furthermore, detailed discussions encompass the key technologies followed in conjunction with the efforts of regulatory bodies engaged to resolving pressing concerns related with water contamination. The technological advancements are fundamental in enhancing water quality and safeguarding the sustainability of water resources.

5.2 The Basics of Water Pollution:

In accordance with Section 2(e) of the Water Act, “Pollution is defined as any contamination of water, alteration of the physical, chemical, and biological characteristics of water, or disposal of sewage waste in the water that is likely to cause nuisance, renders the water harmful to public health or safety, domestic, industrial, or other legitimate uses, or is harmful to the life and health of the animals and aquatic plants”.

Additionally, it denotes the presence of pollutants in quantities that could cause measurable degradation of the water quality or utility in rivers, lakes, bays, seas, streams, underground water, or oceans. For instance, due to an excessive presence of hazardous chemicals or bacteria, water deviates from its intended suitability, rendering it unfit for its designated purpose.

Most often, the use of water in different processes is subjected to contribute water contamination. Although certain types of water pollution can be brought on by natural phenomena, still majority are connected with anthropogenic activities, as depicted in Figure 5.1

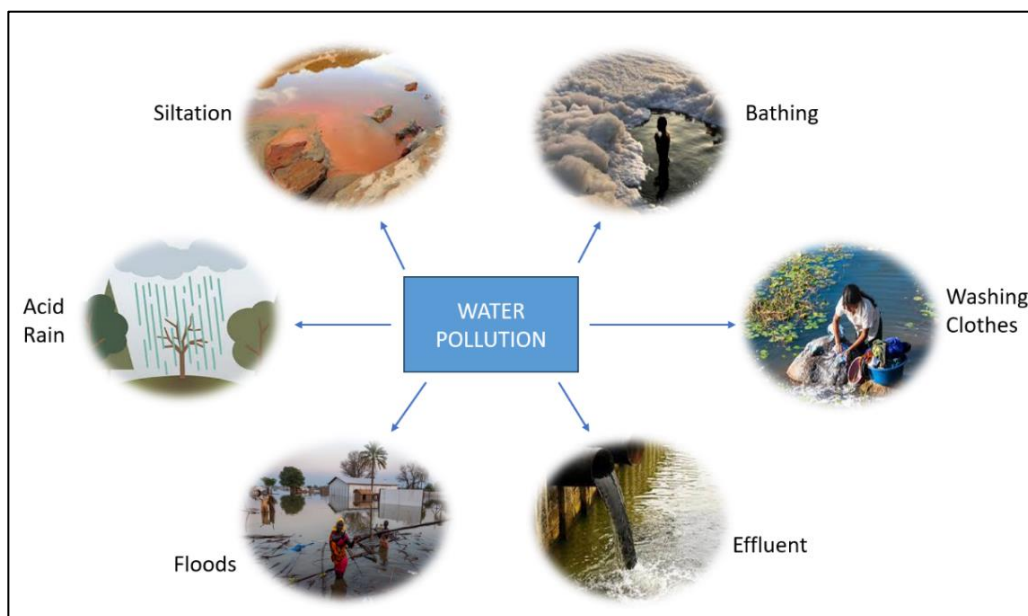


Figure 5.1: Anthropogenic Activities and Water Pollution

When one or more of the factors listed below exceeds a predetermined concentration in water, it is considered to be polluted.

- *Physical parameters:* The physical criteria include appearance, odor, turbidity, flavor, temperature, and electrical conductivity (EC). Color and turbidity are visible symptoms of water pollution, while taste or smell of the water might serve as indicators, potentially representing its unsuitability for consumption.
- *Chemical parameters:* The concentrations of metal ions, carbonates, sulfur compounds, chlorides, fluorides, and nitrates are included in the chemical parameters.
- *Biological parameters:* Aspects like viruses, bacteria, microorganisms, yeast, algae, and fungi are included in the biological parameters. All aquatic forms are significantly impacted by the presence of toxins. Water contamination may lead to decline in population of both lower and higher flora and fauna. Therefore, the biological traits give a less clear view of extent of water contamination.

5.3 Sources of Water Pollution:

Both natural and man-made factors contribute to water contamination adding pollutants into water bodies like rivers, lakes, oceans, and groundwater, imposing potential impacts on aquatic ecosystems and human health. Depending on the contaminants released into water bodies, the sources of water pollution can be divided in four different categories:

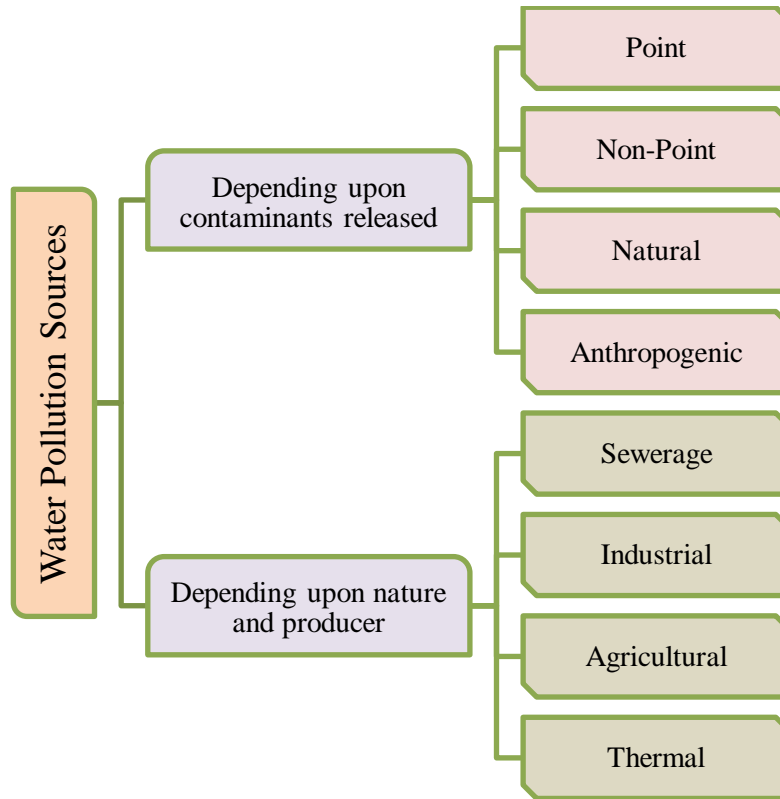


Figure 5.2: Sources of Water Pollution

- *Point Sources (PS)*: These sources originate from a single, well-known source, such as a sewer or industrial outfall pipe. Manufacturing operations are frequently connected with point sources. Discharges from large animal feeding operations and water treatment plant pumps are also considered point sources (Dozier, 2005).
- *Non-Point Sources (NPS)*: These sources originate from a variety of different or diffuse sources rather than from a single, recognizable point. Non-point sources of pollution can be originated from both urban settings like neighborhood yards and agricultural-producing regions like crop fields. These diffuse sources release contaminants into water bodies through runoff, adding pesticides and fertilizers from grounds and agricultural fields (Dozier, 2005).
- *Natural Sources*: A rise in the level of naturally occurring substances is also referred to as pollution. Such an increase is brought on by natural sources. Siltation, which is made up of dirt, sand, and tiny minerals, is one such natural source. A large number of aquatic bodies experience it as a common natural occurrence. Unchecked destruction makes the ground brittle, and floodwaters fill rivers, streams, and lakes with mountainous silt (Owa, 2013).
- *Anthropogenic Sources*: Anthropogenic or man-made sources of water pollution refer to human activities that cause water pollution. Anthropogenic sources include, residential (sewage and wastewater), industrial, and agricultural wastes that enter rivers, lakes, streams, and oceans. This category also includes specific substances that run-off water leaches from the soil and introduces to diverse water bodies (Owa, 2013).

Depending upon the nature and producers of pollutants, there are four types of water pollution sources:

- *Sewerage/Community wastewater:* Water contamination arises from the discharge of drains and sewers into freshwater ecosystems. Instances encompass substances like soaps, detergents, food wastes, and human and animal excrement. Urban areas are flooded with significant challenges imposed by the mismanagement of community wastewater.
- *Industrial wastes:* It includes waste or effluents produced by several industries in their process section and disposed into the environment after partially or fully treatment. The contamination water through industrial waste, may contain radioactive materials, poisonous compounds, acids, alkalis, metallic salts, phenols, cyanides, ammonia, and many other contaminants. They also contribute to the thermal pollution of the water, which have a greater potential to change the characteristics of water.
- *Agricultural sources:* Agrochemicals such as fertilizers (which contain nitrates and phosphates) and pesticides (which include insecticides, fungicides, and herbicides) also have a greater potential to contaminate the water at different surface water resources through run-off.
- *Thermal pollution or heat:* Thermal and nuclear power facilities, which utilize water as a coolant and generate hot water, are significant sources, contributing thermal pollution. The release of hot water into water bodies may cause the local aquatic life to perish.

5.4 Impacts of Water Pollution on Environment:

The pollutants in the water impose a profound and far-reaching adverse impact on the environment, altering the entire ecosystems on disrupting the ecological balance, specifically in aquatic life. There would be hardly any aspect of the natural world remains untouched by the consequences of contaminated water bodies. Spillage of oil in coastal areas, stagnant water near to the industrial and urbanized area are the common instances of water pollution. Some forms of pollution are simple to spot and recognize. However, other kinds might not even be visually appeared until they start to create serious issues. Water in a lake, creek, or river may appear pure even if it is contaminated. The consequences of many forms of water contamination are intricate and frequently poorly understood. The similar pollutants may have various effects on different organisms, which depends on various factors including shelf life of pollutants, temperature, precipitation, water flow, etc. The impacts of water pollution on the environment are multifaceted and intricate, touching every aspect of aquatic ecosystems and beyond (Goel, 2006, Owa, 2013, Chaudhry and Malik, 2017).

Some of the key impacts of water pollution on the environment are described below:

- *Eutrophication:* The term "eutrophication" refers to an increase in chemical nutrients in the environment, typically in the form of nitrogen- or phosphorus-containing compounds. It could lead to an increase in primary productivity in addition to other negative effects such a lack of oxygen and severe losses in water quality, fish populations, and other animal populations.

- *Loss of Biodiversity:* A loss of biodiversity may come from the degradation of aquatic habitats brought on by water pollution. In addition to upsetting food chains and limiting species variety, polluted water can injure or kill aquatic plants, animals, and microbes.
- *Ocean Acidification:* Various anthropogenic activities caused release carbon dioxide into the atmosphere. The water becomes tainted as a result of dissolution of carbon dioxide in the oceans and seas, which lowers its pH and fastens acidification. The formation of calcium carbonate shells in shellfish and other aquatic life can be decreased due to ocean acidification, along with other physiological problems for marine life.
- *Habitat Destruction:* Water pollution causes sedimentation, siltation, and erosion, which physically modify or destroy aquatic environments. Fish spawning grounds, bird nesting grounds, and other crucial habitats are also harmed as a result of water pollution.

5.5 Effects of Water Pollution:

The water pollution impacted nature in two ways, as it poses harmful effect on living beings as well as the environment (Fig. 3). Insufficient access to clean water causes over 0.2 million deaths annually, according to the 2018 Composite Water Management Index (CWMI) study from NITI Aayog. In a separate report by NITI Aayog, it is projected that by 2030, over 600 million individuals, constituting approximately 40% of India's anticipated population, could potentially experience water scarcity.

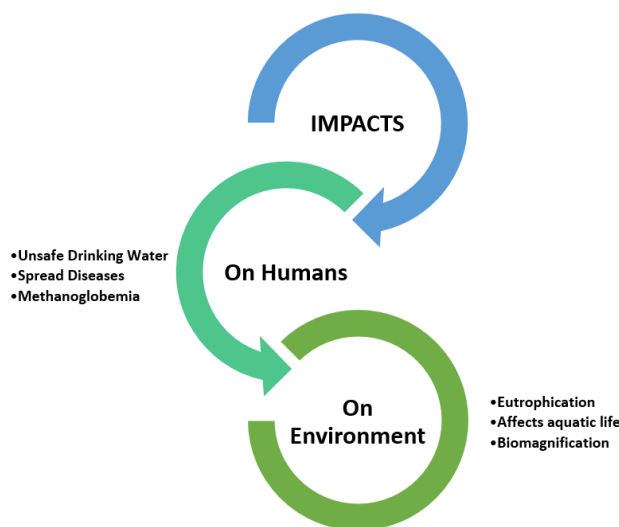


Figure 5.3: Impacts of Water Pollution on human beings and environment

Water contamination exerts detrimental impacts on human well-being. Both surface water and groundwater are contaminated with pathogenic microbes causing compromised water quality, which pose risk to the human health. Additionally, the contaminated water affects nutritional balance of plants and animals and also influence the human health directly or indirectly (Haseena et al., 2017). The excess of nutrients like nitrogen and phosphorus along with other substances promote development of aquatic vegetation causing algal bloom and

quick weed proliferation. Ultimately, the natural equilibrium of water bodies is disrupted with changes in water's smell, taste, and occasionally color.

Furthermore, contaminated water can spread many diseases and cause a variety of health problems. Contamination with various toxic substances like cadmium, arsenic, mercury, nitrates, fluorides, etc. causes a variety of issues in living things (Fazal-ur-Rehman, 2019). Itai-Itai disease, also known as Ouch-ouch disease, is an aching condition of the bones and joints brought on by cadmium contamination. It also causes lung and liver cancer. Black foot disorders with symptoms including diarrhea and peripheral neuritis, as well as skin and lung cancer, can be brought on by arsenic poisoning. Mercury poisoning causes the element to be converted by bacteria into methyl mercury, which then undergoes biomagnification in the food chain and causes the deformity known as Minamata illness, which also causes meningitis, hemolysis, diarrhea, and even death. Blue baby syndrome or methemoglobinemia, both of which are caused by nitrate pollution and which are fatal for infants, reduces oxygen delivery. Fluoride can lead to fluorosis, which can cause dental issues as well as respiratory, neuromuscular, and gastrointestinal system malfunction (Halder and Islam, 2015, Lin et al., 2022).

5.6 Water Pollution Control:

Water pollution control is of paramount importance due to the short- and long-term consequences of water contamination on both the environment and human well-being. Water pollution control involves the implementation of measures and strategies to prevent, mitigate, and manage the contamination of water resources caused by various pollutants. The measures ultimately help to safeguard the environment, human health, and aquatic ecosystems. Moreover, employing a combination of regulatory actions, technological innovations, and community engagement may result in effective control of water pollution. Control and prevention are quicker and less expensive than cleanup, however, it is difficult to regulate pollution due to the vast variety of pollutants and their complexity. Cooperation between scientists, lawmakers, citizens, and industry produces the best methods for reducing pollution (Goel, 2006). A number of control strategies have been proposed to combat water contamination. The following steps are needed to be ensured for effective management of water pollution.

Step 1: Implementing Control measures:

As the initial phase of the process, activities polluting the water should be strictly controlled. The neighborhood ought to curtail practices like dumping sewage, untreated effluent and solid waste in water bodies and avoid using plastic bags. Society can take a variety of actions to put control on water pollution at their premises.

Step 2: Wastewater treatment:

Water treatment is the next stage in reducing the contamination level in water resources. By cutting down on water wastage, water contamination can be reduced. The contaminated water can be treated physically, chemically and biologically to remove impurities. The treatment process involves the following three stages:

- Primary Treatment
- Secondary Treatment
- Tertiary Treatment

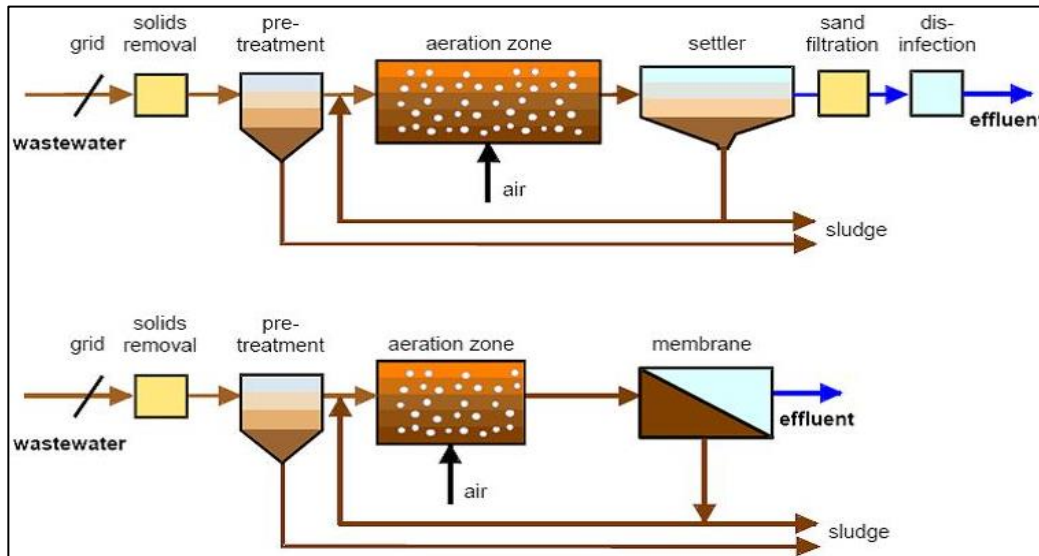


Figure. 4: Different stage of water treatment

Primary Treatment: This stage involves filtration, sedimentation and coagulation are used in the treatment process. The processes involving primary and secondary treatment typically followed to clean wastewater enough to discharge safely into the environment. The treatment must go at advanced level to make water safe for water intents and purposes like drinking water. The basic water treatment involves the following steps:

- Sedimentation:** In the wastewater treatment facility, the sedimentation process is completed in enormous tanks that were created specifically for the task. The contaminated water is allowed to settle, allowing silt, clay, and other debris to fall to the bottom and the water to slowly drain. Fine particles must be eliminated in the following step since they do not settle.
- Coagulation:** Coagulation is the process by which colloidal suspension and fine particles are mixed to form larger particles. Coagulants (also known as flocculants), such as potash alum, are used to complete the process. The large particles are either transferred in the following stage or sink to the bottom.
- Filtration:** By running the water over a bed of sand, coal that has been finely divided, or other fibrous materials, suspended particles, flocculants, bacteria, and other organisms are filtered. Sludge refers to the total contaminants that were gathered in these procedures. It serves as a priceless fertilizer. It emits sludge gas on composting, which can be used in cooking or heating purpose.

Secondary or Biological Treatment: After primary treatment, the water is still unfit for drinking and must undergo additional purification. This is accomplished through a biological or secondary process. One typical technique is to spread contaminated water over

a sizable bed of stones and gravel to foster the growth of various bacteria that require nutrients and oxygen. A swiftly moving food chain develops over time. As an illustration, bacteria eat organic material from contaminated water, while protozoa feed on bacteria. Algae and fungi are examples of living forms that contribute to the cleanup effort. This is referred to as secondary water treatment. It entails the subsequent procedures.

- a. *Softening*: Hard water is treated in this way to get rid of unwanted calcium and magnesium cations. Water is either transported via cation exchangers or treated with lime and soda ash to precipitate Ca^{2+} ions as carbonates to soften the water.
- b. *Aeration*: By pumping air through soft water, oxygen is added to the water throughout in aeration process. This promotes the bacterial breakdown of organic material into safe byproducts like carbon dioxide and water. Oxygen reduces carbon dioxide, sulfur dioxide, etc., however treated water is still unfit for drinking. Therefore, it is necessary to eradicate the harmful germs with advanced treatment methods.

Tertiary treatment: Water is truly disinfected during the tertiary treatment. The most popular disinfectant for destroying germs is chlorine. However, chlorine also interacts with minute amounts of organic matter in water to create poisonous and potentially cancer-causing chlorinated hydrocarbons. Therefore, it is preferable to limit the amount of organic material in water before introducing chlorine gas. Chlorine treatment is recommended over other disinfection techniques such as ultraviolet radiation, ozone gas treatment, or reverse osmosis, considering the cost of treatment with other techniques.

In a treatment facility, the waste is sent through a number of chambers, screens, and chemical processes to lessen its toxicity and bulk. Most of the suspended particles and inorganic elements in sewage are removed during basic treatment. The secondary stage accelerates biological processes to remove organic material. When water needs to be reused, tertiary treatment is performed.

Here, 99% of the particulates are eliminated, and the water is subjected to a number of chemical procedures to ensure its purity.

Step 3: Purification:

To significantly eliminate pollutants and dangerous components from water, significant water purification activities should also be done. Here are some of the most effective water purification methods:

- *Boiling*: Boiling water for a long time is the simplest way to purify it. High temperatures force the bacteria and virus to vanish, purging the water of any contaminants.
- *Water Purifier*: The type of water filtration most frequently found in modern homes is an electric water purifier. The purest drinking water is produced by a water purifier using a multi-stage process that includes UV and UF filtration, carbon block, and contemporary water filtration technologies.
- *Distillation*: In order to ensure that the water is free of impurities, distillation involves collecting the condensed water after evaporation. This takes longer and removes minerals, thus it is less efficient than a RO filter.

Step 4: Spreading awareness:

After completing the above steps, raising awareness among the general public and disseminating information are essential for boosting participation in the endeavor to prevent water pollution. The concerted efforts of all communities to decrease water pollution can result in long-term improvements or maintenance of water quality.

5.7 Measures Taken by the Government to prevent water pollution:

The Indian government has started a number of programs to preserve and safeguard the nation's rivers and other bodies of water.

- a. **National River Conservation Programme (NRCP):** The National River Conservation Plan (NRCP), created by the Ministry of Environment and Forests (MoEF), aims to preserve rivers from pollution and improve water quality.
- b. **National Lake Conservation Programme:** The Ministry of Environment and Forests is implementing the National Lake Conservation Plan (NLCP) to manage, and conserve contaminated and degraded lakes in urban and semi-urban areas.
- c. **National Green Tribunal:** In compliance with the National Green Tribunal's instructions, the concerned States and Union Territories (UTs) are attempting to implement Action Plans for the restoration of water quality in the identified polluted stretches of rivers.
- d. **Atal Mission for Rejuvenation and Urban Transformation:** It is the goal of the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) to provide every residence with access to a water tap with a dependable water supply and a sewer connection.
- e. **Jal Jeevan Mission:** The Jal Jeevan Mission (JJM), which was launched in August 2019, is being carried out by the Indian government in collaboration with the states with the goal of supplying drinking tap water to every rural home in India by 2024, including those in habitations where the water quality is poor (Singh et al., 2023).

For water pollution control, a comprehensive and well-coordinated strategy involving governmental organizations, businesses, communities, and individuals is required. Through the application of these strategies, community organizations can protect ecosystems, conserve water resources, and ensure that future generations will have access to clean and safe waters.

5.8 Summary:

Water quality is one of the most pressing issues that developed and developing countries are facing today, since it poses a threat to human health, reduces food production, interferes with natural processes, and slows down economic development. Water contamination is now having a severe impact on the whole community and is a global problem. The accidental release of household and agricultural residue, growing populations, overuse of fertilizers and pesticides, and industrialization are the main causes of water pollution. The wellness of people is negatively impacted by the transmission of viral, bacterial, and parasite illnesses through water that has been contaminated.

Adopting adequate trash disposal procedures and treating waste prior dumping in water resources and consuming are vital. Awareness and learning initiatives at community level are also among the established step to maintain the quality of water.

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