Chapter 7
Potential Impacts of Climatic Changes and Human Activity on Water Quality

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Abstract The term "climate change" refers to the changes in weather patterns brought on by an increase in the atmospheric concentration of gases that absorb heat. In response to human activity, CO_2 levels in the atmosphere have steadily increased, with the associated "greenhouse" effect possibly altering future climate on both global and regional scales. The greenhouse effect's climatic and hydrological consequences have been studied for some time, but researches on water quality have just lately begun. The quality of water may be influenced in a number of ways. Securing access to high-quality water for its numerous purposes becomes more challenging and pertinent as a result of climate change's impact on long-standing, conventional methods of managing water resources and disruptions to the hydrologic cycle. Higher water temperatures may hasten biological metabolic processes while also affecting stratification, sediment nutrient release, and ice conditions in water bodies. Changes in precipitation volume and distribution will affect runoff conditions. Changes in runoff will affect nutrient loads from non-point sources as well as the residence duration of water system. All of the aforementioned elements may have a substantial impact on the eutrophication of standing waters. Higher CO_2 levels in the atmosphere may have a direct influence on the inorganic carbon system of waters' chemical equilibrium processes. Groundwater is a vital resource, which is used for a range of human activities as well as maintaining natural flows in rivers and other ecosystems. However, a number of human activities are rapidly deteriorating these limited resources, and a variety of natural (geogenic) water quality issues limit its use in some areas.

Keywords Climate change · Water quality · Human activities · Water contamination · Groundwater

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P. Shukla et al. (eds.), *Environmental Processes and Management*, Water Science and Technology Library 120, https://doi.org/10.1007/978-3-031-20208-7_7

7.1 Introduction

Climate change is disrupting ecosystems and daily life. It is described as changes in weather patterns induced by rising gas concentrations in the atmosphere that absorb heat. The devastating effects on water resources, which have recently become increasingly important due to water shortages in many parts of the world, are one of the catastrophes of this event. The impact of the climate change on temperature and precipitation on runoff volume, as well as the transit and dilution of pollutants, might all be affected (Luo et al. 2013; Barrow et al. 1996). A rise in temperature directly affects the rate of chemical processes, which is frequently followed by a decline in water quality and modifications to the aquatic ecosystem. Increasing flow rates may have an impact on the rate of sedimentation, altering the geomorphology and structure of the rivers and jeopardizing the availability of drinking water. According to climate change predictions, droughts will become more severe and floods will be more damaging, leading to unmanageable water inflow coming from various urban areas towards riverine bodies (Rehana and Mujumdar 2011; Whitehead et al. 2009). Low flow rates raise the possibility of a potentially hazardous algal bloom by limiting the amount of oxygen that the algae can get. Increasing water velocity, decreasing water detention time, and lowering dissolved oxygen levels are all variables in rivers and lakes. As a result of the increased soluble organic matter and colour, flows from upstream areas may have an influence on the quality of water resources, particularly rivers. Despite the fact that climate change's implications on water supplies have gotten a lot of attention, current estimates are frequently understated and little knowledge about the repercussions in water quality brought on by climate change (Marzouni et al. 2014).

For the whole ecosystem and human civilization, water is the most significant resource, and its availability must be managed in a fair, stable, and productive manner (Gain et al. 2016). But, presently this natural resource is becoming more and more scarce and contaminated for human civilization worldwide (Mishra et al. 2021). A growing global population and climate change are making the world's water availability worse. More than 1.1 billion people throughout the world are unable to have clean potable water, and almost 2.5 billion are unable to access the basic sanitary facilities (AWDO 2016). A consistent and hygienic supply of drinking water is crucial for the human survival on this planet in order to maintain good health. Areas with less rainfall are highly exposed to severe climatic variation and changes in land-use pattern. Increasing human demand undermines the capacity to supply appropriate water supplies and the functioning of ecosystem services. Water pollution has become a global problem with the enhancement of economical and anthropogenic activities (Chellaney et al. 2011). Groundwater is one of the most extensively distributed and valuable natural resources for municipal, agricultural, industrial, and environmental applications. The impact of groundwater withdrawals on water levels in surrounding wells or wetlands, the migration of pollutants or saltwater towards wells, and the lowering of flow in neighbouring streams must all be considered when studying groundwater systems (Lapwortha et al. 2022). Numerous of these uses place stress on water resources, which is probably made worse by climate change. Climate change is the statistical variation in weather patterns that occurs over an extended period of time. Both natural and man-made processes have been recognized as climate change causative agents. These factors are called climate forcing or forcing mechanisms (Perera 2018). Natural factors leading to climate change are biotic processes, variation in solar radiation received by earth, plate tectonic, and volcanic eruption. The anthropogenic forcing mechanism leading to climate change is caused by human influences. One of the most serious factors contributing to climate change is the increase in atmospheric CO_2 levels owing to emissions from fossil fuel burning and industrial activity (Gornall et al. 2010). Other human factors include land use, faulty agricultural practices, ozone depletion, deforestation, and over-exploitation of available resources. The ecosystem suffers the effects of climate change, including unpredictable weather, altered ecosystems, and risks to human health and civilization. Climate change is also influencing the water quality of both inland and coastal water resources. Water resources are very essential for the normal functioning of the ecosystem. Human survival depends largely on water resources. Climate change influences water resources because of its impact on precipitation quality, variability, timing shape, and intensity. Climate change has its projected effect on the physical and economic status of water reservoirs. Water resources are being impacted by significant climatic changes, including increased evaporation, increased rainfall, less snowfall, higher water temperatures, earlier and shorter runoff seasons, and a reduction in the quality of both inland and coastal water reserves (Hakeem et al. 2020). Quality of water could suffer in areas experiencing increased rainfall. Higher precipitation has a detrimental impact on water infrastructure since sewage systems and water treatment plants are overburden as a result of the increased volume of water.

7.2 Water Contamination

Whenever rainfall is heavy, the runoff into lakes, rivers, streams increases with a high amount of trash, nutrients, animal faeces, and other types of contaminations and pollutants. This turns water supplies harmful and unusable, and a proper remedial process of water treatment is required (Cui et al. 2020). In many areas, high losses of water like evaporation create water scarcity. In the summer season as the temperature rises, this water scarcity occurs which leads to lower water content in the soil which ultimately results in severe conditions of drought. As a result of climate change, droughts will become more frequent and severe, providing significant management problems for water resource users (Delpla et al. 2009). Especially in India where most of its development depends on agriculture is particularly vulnerable to this situation because here the agricultural sector is largely dependent on natural water precipitation. Freshwater resources near beaches are threatened by the rising sea levels. As the water level rises in the sea, the chances of moving salt into freshwater also rise (Li et al. 2020). This situation creates a problem with the supply of drinking water, and the managers either need to find other sources of freshwater or desalination, i.e. removal of salt from the water is required on a high scale. The use of freshwater from river streams for household or industrial purposes will lead to saltwater moving further upstream (Cosgrove and Louck 2015). Droughts can deplete freshwater supplies in the river, making coastal water resources more saline. Even the water infrastructure built in coastal cities like sewer systems, water supply systems, water treatment facilities are at risk with the rise of sea levels and the surges that may create in storm conditions may damage them (Xia et al. 2014). The high water temperatures also decrease dissolved oxygen (DO), increase the pH of increasing, resulting in more acidic water. Decreased DO solubility is associated with increased assimilation of DO in the biodegradation of organic matter by microorganisms. The principal sources of organic matter in the water bodies are dead and decaying organic matter, runoff water from the agricultural lands, and soil leaching. Degrading and dissolved organic matter affects the water quality and aquatic ecosystem through its influence on acidity, trace metal transport, light absorbance, photochemistry, energy, and nutrient supply. Water quality and the aquatic environment are impacted by degrading and dissolved organic matter due to their effects on pH, photochemistry, energy, and nutrition availability. Many potential factors like air, temperature, and increase in rainfall intensity, atmospheric CO_2 increase, and decline in acid deposition change the amount of dissolved organic matter available in water bodies. Significant hydrological changes, an increase in water temperature, and an increase in pollution load may all be consequences of climate change either chemical or microbiological. Weather seasonality affects the quality of water bodies, which has a substantial impact on their nutrient patterns (Mujere and Moyce 2017). Even the temperature rises of the environment results in degradation of water quality of ponds and rivers with increased thermal stability and changed mixing patterns, which results in a reduction of oxygen concentration and the phosphorus release is increased from the sediments. A warmer temperature will have indirect consequences on water bodies, such as increasing the amount of nutrients in groundwater and surface water, which will negate the effects of measures that reduce external nutrient loading. The release of nitrogen, phosphorus, and carbon as well as the mineralization of soil organic matter will all be accelerated by rising temperatures (Prathumratana et al. 2008). Additionally, higher runoff and erosion due to increased precipitation intensity accelerate the transmission of pollutants, especially during a drought period. Higher ammonium concentrations may be detected in rivers that have less diluting capability as a result of droughts. Due to the decreasing oxygen levels in the bottom waters, it is anticipated that the release of phosphorus from bottom sediments in stratified lakes will rise. These habitats are affected by climate change in a variety of ways: temperature, ice, wind, and precipitation changes (Kiedrzynska et al. 2015). The amount of phosphorus loading in the water bodies is determined by the discharge carried by heavy rainfalls. Climate change will likely lead to a rise in phosphorus loading exports, which is controlled by discharges following significant rainfall, which will have an effect on lakes. In the limnetic zone, phosphorus loading increases due to the death and decomposition of organisms by microbes. But nitrogen content in water bodies is not dependent upon stream flow. It is anticipated that the nitrogen concentration would change as the temperature increased. Higher denitrification as a result of temperature change leads to increased nitrogen losses in soil and surface water upstream.

As water temperature changes, precipitation intensity increases, and extended periods of low flows occur, several types of water pollution, such as increased flow of sediments, nutrients, dissolved organic matter, pathogens, pesticides, salt, and thermal pollution, are likely to rise. The increased flow of sediment and dissolved organic matter and nutrients will assist algal blooms, bacterial biomass, fungus, and plant materials. Eutrophication is defined as excessive plant and algal development and is brought on by an increase in the availability of one or more factors that limit growth, such as nutrients, sunshine, and carbon dioxide (Alexandra et al. 2020). By releasing nutrient-limiting substances from both point and non-point sources, like nitrogen and phosphorus, man-made activities have accelerated eutrophication's rate and range. These types of point and non-point discharge caused due to runoffs from agricultural fields are mixed with several pollutants like chemical fertilizers and pesticides, industrial and sewage disposal (Xia et al. 2020). Freshwater resources, aquaculture, and water amusement parks, all suffer as a result of eutrophication. This affects the quality of drinking water like foul-smelling, increase in phytoplankton and blooms of noxiousness, and reduction of water clarity. The growth and development of organisms in the littoral zones are hampered by the algal blooms, which reduce light penetration in water bodies. Additionally, during the day time, high rates of photosynthesis brought on by eutrophication can deplete dissolved inorganic carbon and increase pH to dangerous levels. By diminishing chemosensory abilities, increased pH can render blind species that depend on detecting dissolved chemicals for survival. When dense algal blooms die, microbial decomposition reduces the amount of dissolved oxygen, creating a hypoxic or anoxic "dead zone" where the majority of species cannot survive. Hypoxia and anoxia caused by eutrophication continue to be a threat to commercial and recreational fisheries all over the world. Some algal blooms also act as potential harmful agents because they produce toxic substances like microcystin and anatoxin-a. Toxic cyanobacteria like *Microcystis, Anabaena, Oscillatoria,* and *Cylindrospermopsis* with their inherent superior efficiency they tend to dominate freshwater systems enriched with nutrients under certain physico-chemical conditions (Miruka et al. 2021). Toxic cyanobacterial blooms have poisoned wildlife, farm animals, and even people. This bacterium is also responsible for many off-flavoured compounds like methylisoborneol and geosmin that are found in drinking water systems. They are also affecting the aquaculture-raised fishes, due to which state and regional economies face large financial loss. Modern-day agricultural system relies on the use of excessive chemical fertilizers and pesticides for increasing crop productivity and resistance to insect pests. The runoff from agricultural fields and eroding soils can carry pesticides into aquatic environments. The residues of pesticides have been detected in rain, river, ground, and drinking water; also among these, the surface water resources act as significant receptors of pollution created by various pesticides. The fate of pesticides in water bodies is influenced by climate drivers like change in rainfall seasonality, intensity, and increased air temperature. The physico-chemical interactions between aquatic organisms and pesticides depend upon the climatic condition and quality of water bodies. Variations in soil water content have been found to alter the structure of the soil's organic matter, which interferes with the pesticides' ability to diffuse and become trapped in the soil. With the increase in industrialization, the discharge of industrial waste containing metals has also increased during the past few decades. Seasonal variations influence the concentration of these metals in river bodies. Metals are known to interact with the suspended particulate matter of the water and get adsorbed on them. The mobilization of trace elements in soils and water can benefit greatly from these organic and inorganic collisions (Kaur and Sinha 2019).

The heavy flow of sediments and nutrients caused by the events of heavy rainfall will also be an additional overload to the sewer systems and wastewater treatment plants. Areas such as semi-arid areas facing drought situations will have a problem of low flows in streams of water. As low flows become more typical, contaminant diluting capabilities will be reduced, resulting in higher pollutant concentrations, including illness. Areas with overall decreased runoff lead to increasing evapotranspiration which ultimately increases the salination of the groundwater. This increase in salination may also be a cause of lower levels of water in streams which increases estuaries. More evapotranspiration also leads to lower infiltration and reduction of groundwater recharge. This will minimize subsurface salt mobilization, perhaps counteracting the effect of lower salt dilution in estuaries. Storm water drainage and sewage disposal are also some of the negative effects of rising sea levels in coastal areas. While in the aquifers present in coastal areas, saline water intrusion into fresh groundwater will become more widespread, posing a hazard to groundwater resources. An increase in the rate of precipitation and its intensity leads to lower water quality because high runoff will result in soil erosion and transport high number of pathogens and other dissolved pollutants like chemical fertilizers and pesticides to the surface water and groundwater; this, in turn, leads to mobilization of adsorbed pollutants such as heavy metals and phosphorus. Another reason for highly intensive precipitation leading to more pollutants could be because of suspended solids whose presence will increase in lakes and reservoirs due to soil fluvial erosion (Alam et al. 2021). This change in quality and increase of microorganisms can deteriorate human health and also the ecosystem.

In recent time, one of the highly contentious issues pertaining to river water quality has been Ganga River's contamination. The river has grown significantly contaminated as a result of unchecked household sewage discharge without treatment, excessive industrial pollution discharge, agricultural runoff, and other issues. The Ganga Action Plan (GAP) was created in 1986 with the objective of improving the water quality to that of a "Bathing Class". Individual companies are required to employ centralized monitoring systems and several sewage treatments plants, as well as common effluent treatment plants in places with enterprises are created under GAP. The pulp and paper industries, as well as the tannery, sugar, and distillery sectors, are the biggest polluters of the Ganga River. The primary pollutants produced by these industries include solids, total nitrogen (TN), chromium, sulphide, sulphate, and chloride, as well as biochemical oxygen demand (BOD), chemical oxygen demand (COD), and sulphate and chloride. Furthermore, because agricultural land makes up a large amount of the river's catchment area, nutrient contamination (nitrogen N and phosphorus P) becomes an issue (Santy et al. 2020).

7.3 Conclusion and Perspective

Climate change is a challenging phenomenon nowadays worldwide leading to irrational weather changes. Water quality is being impacted by the climate change phenomena, and the deterioration of drinking water quality is increasing the danger of extreme climatic events having a negative impact on health. Due to rising temperature (in the water, air, and soil), as well as heavy precipitation, certain water quality metrics, such as dissolved organic matter, micro-pollutants, and pathogens, are prone to concentration increases.

The waste arising from industries, emissions from the transport sector (surface, air, water) municipal sewage sludge, and agriculture runoff needs to be reduced and managed in such a way as to minimize global warming phenomena. Changing the scenario of climate leading to a drastic change in weather cycles demands the urgent attention of the planners, technologists, and social workers for the benefit and welfare the humanity. In order to identify health concerns, take corrective and ameliorative measures; we needed tools for water quality monitoring, predicting models, and decision support system immediately. These alarming situations require and force society to adopt sustainable development practices in the different field of industry, agriculture, and transport sector to control future global warming and climatic challenges and to compensate for the damages caused until now.

Global change has a direct impact on the chemical processes occurring in sediment and the water column, and because higher temperatures hasten biological processes, climate warming is a direct result of this impact. Nitrification and denitrification, for example, are biological reactions that are intimately tied to temperature. Climate change-related changes in hydrology have an indirect impact on physico-chemical water quality. Increased and more intense precipitation is projected to enhance nutrient runoff from agricultural fields into surface waterways.

Several aspects of climate change affect the distribution and mobility of hazardous chemicals in freshwater systems (e.g. temperature increases, fluctuations in rainfall and runoff).

Hazardous substance loading may increase as a result of sewage overflows, as well as increased pesticide use and runoff as a result of heavy rains, while higher temperatures accelerate the degradation of some pesticides and organic pollutants, potentially lowering their concentrations in rivers and lakes. As a result, the overall impact of climate change on dangerous compounds remains unknown.

According to widely recognized climate change projections, the summer will witness an increase in droughts and flash floods, which will result in unchecked outflow from metropolitan areas into receiving water courses and estuaries. In rivers and lakes, reduced flow and lower velocities lead to prolonged water residence times, which increase the danger of harmful algal blooms, and lowers dissolved oxygen levels. In order to prevent dangerous by-products from entering public water sources, water treatment facilities may need to intervene when dissolved organic carbon and colour levels in upland streams increase. Drought periods will cease when storms wash minerals out of the urban and rural areas and cause acid pulses in acidified highland catchments. Freshwater quality will be significantly impacted by policy responses to climate change, such as the adoption of biofuels or emission restrictions.

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