2 The Chemical Composition of the Water in the Rivers, Lakes, and Wetlands of Uttarakhand

Manjul Gondwal, Navneet Kishore, Ravindra Soni, Rakesh Kumar Verma, and Bhanu Pratap Singh Gautam

Abstract

Ions like calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}) predominate among the chemical components of the water in Uttarakhand's rivers, lakes, and wetlands. These waters may also contain the following significant ions: bicarbonate (HCO_3^{-}), sulfate (SO_4^{2-}), chloride (Cl^{-}), and nitrate (NO_3^{-}). Depending on the type of water body and the area, different ions have different concentrations. Other significant chemical components of the water in these areas include suspended particles, organic matter, and dissolved organic carbon. The concentrations of nutrients such as phosphorus (P) and nitrogen (N) vary depending on the geographical area and season. The water also contains trace amounts of elements like iron (Fe), manganese (Mn), and zinc (Zn). The water quality of the rivers, lakes, and wetlands in Uttarakhand is impacted by the presence of certain chemical components, which may have an effect on the health of aquatic life, human activities, and the environment. These water bodies need to be protected; therefore, it is important to keep an eye on their chemical makeup and take precautions to keep them healthy.

M. Gondwal · B. P. S. Gautam (✉)
Department of Chemistry, Laxman Singh Mahar Campus (SSJ University), Pithoragarh, India

N. Kishore
Department of Chemistry, Maitreyi College, University of Delhi, New Delhi, India

R. Soni
Department of Agricultural Microbiology, Indira Gandhi Krishi Vishwa Vidyalaya, Raipur, Chhattisgarh, India

R. K. Verma
Department of Zoology, Laxman Singh Mahar Campus (SSJ University), Pithoragarh, India

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2.1 Introduction

Water is an inorganic chemical substance that is clear, odorless, tasteless, and almost colorless; it is the primary component of the hydrosphere of the Earth and the fluids of all known forms of life; its chemical formula is H_2O and acts as a solvent. Despite the fact that it does not contain any calories or organic nutrients, it is necessary for all kinds of life that have ever been discovered. In accordance with its chemical formula, H_2O, each of its molecules is composed of two hydrogen atoms and one oxygen atom that are covalently bonded to one another. The angle between connected hydrogen and oxygen atoms is 104.45° (Brini et al. 2017). The term "water" refers to the aqueous phase of the molecule H_2O when it is at a standard pressure and temperature.

There are many different natural states that water may be found in. It results in the production of aerosols that resemble fog as well as precipitation in the form of rain. Clouds are formed by ice and water droplets that are suspended in the atmosphere. When the crystalline ice is broken up into smaller pieces, it has the ability to fall to the ground as snow. The gaseous state of water is referred to as steam or water vapors. The majority of the surface of the Earth is covered by water, the bulk of which may be found in the world's oceans and seas (Chaplin 2019). The groundwater (1.7%), glaciers and ice caps of Antarctica and Greenland (1.7%), clouds (made up of ice and liquid water suspended in air), and precipitation (0.001%) of the atmosphere all contain small quantities of water. Precipitation also contains a minimal quantity of water (Ho 1972).

Water is a very important component of the world economy. More than seventy percent of the fresh water that humans consume is put to agricultural use (Baroni et al. 2007). Water is the most vital resource necessary for the continuation of life. The pollution of water makes it unsuitable for human consumption, and the causes of this contamination include both natural processes (such as rock weathering and erosion) and human activities (such as urbanization, agriculture, industry, and population growth), among others (Oluyemi et al. 2010). Water is crucial to the continued existence of human beings. It was estimated by the WHO that 36% of Indians living in urban areas and 65% of Indians living in rural areas did not have access to safe drinking water (Kılıç 2021).

People place the most importance on the presence of naturally occurring water in the physical world that surrounds them. It is one of the most incredible, but inexplicable, combinations that can ever exist on our earth. Because of a wide range of characteristics that are unique to it, it stands out above all other substances (e.g., anomalously high values for the temperature of melting, boiling, and evaporation, and heavy dissolving capacity) (Nilsson and Pettersson 2015).

The hydrological cycle, which is a connection between the hydrosphere and the atmosphere, lithosphere, and biosphere, is responsible for the creation of the chemical composition of water on Earth. Water is a universal solvent that interacts with every component of its natural environment and is influenced by both natural and man-made factors. Water is enriched by a wide range of different substances in gaseous, solid, and liquid states that produce a huge variety of natural water types from the perspective of their chemical composition. Water is a universal solvent that interacts with every component of its natural environment and is influenced by both natural and man-made factors (Quattrini et al. 2016).

The boundaries of Uttarakhand are denoted by the presence of the Himalayas to the north, the Shivalik Hills to the south, the Ganges to the east, and the Yamuna to the west. The climate there is classified as moderate. The lowest it gets in the winter is approximately 5 °C, while the highest it gets in the summer is around 36 °C (Kumar et al. 2010).

The weathering of the rocks and improper disposal of sewage waste are the key factors that contribute to water source pollution in Uttarakhand. The mountains in this region are sloped, making these factors more likely to occur. Problems with water quality are being experienced by Uttarakhand's water sector as a consequence of turbidity and bacterial contamination of the available drinking water sources in the state. The mountainous section of the state is home to a sizeable portion of the state's population, and it is estimated that around 90% of the rural population gets the water they need for everyday life from natural water sources (Jain et al. 2010).

Fecal contamination in water is still the pollutant that most seriously affects human health. This includes the major water-borne diseases such as diarrhea, cholera, typhoid, and schistosomiasis. This is especially true in the hills of Uttarakhand and other similar states like Himachal, Jammu and Kashmir, and the North East states (Joshi et al. 2009).

2.2 The Composition of Natural Waters from a Chemical Standpoint

The dissolved inorganic components and the dissolved organic components make up the two main parts of natural water. The main inorganic elements of natural water are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), oxygen (O_2), hydrogen (H_2), carbon dioxide (CO_2), nitrogen (N_2), and sulphur (S). Together, these elements create a complex mixture of ions and molecules that constitutes the majority of natural water (Rittmann and McCarty 2001).

Proteins, carbohydrates, lipids, and other organic compounds make up the majority of natural water's organic constituents. Depending on the source of the water and the surrounding environment, these organic components can vary significantly. For instance, the organic components of groundwater or seawater may be different from those of river water. In addition, biological processes like photosynthesis and respiration can have a big impact on how natural water is made (Schwarzenbach et al. 2003).

Natural water's chemical makeup can vary significantly depending on its source, the surrounding environment, and the extent of chemical and biological processes. Each component's concentration can also differ significantly, with some components present in only trace amounts and others possibly in high concentrations (Ašperger 2004).

2.3 Ions Found in Nature

Conventionally, the ions, complex ions, undissociated chemicals, and colloids (in the dissolved form) that make up natural fluids are classified into macrocomponents and microcomponents. These components include: ions, complex ions, dissolved colloids, and undissociated chemicals. The macrocomponents are what make up the so-called principal ions, which define the chemical type of water and make up the majority of its natural minerals. The percentage of natural minerals in highly mineralized water can reach up to 99%, while the percentage of natural minerals in fresh water only reaches 95%. In a solution of water, hydrogen ions, nitrogen molecules, phosphorus molecules, and silicon molecules all take up positions in the center.

The quantity of different chemical elements present in the crust of the Earth and the ease with which their compounds may be dissolved in water are the two primary factors that determine the relative amounts of each mineral.

An abundance of cations such as Ca^{2+}, Na^{+}, Mg^{2+}, and K^{+} as well as anions such as Cl^{-}, SO_4^{2}, HCO_3^{-}, and CO_3^{2-} are found in natural water.

Ions of chloride (Cl^{-}): This ion has a substantial capacity for migration, because sodium, magnesium, and calcium chloride compounds are very soluble in water, and chloride ions have the same property. Because of natural processes such as leaching from rocks (e.g., nephelines), minerals (such as gallite, sylvite, carnallite, and bischofite), and saline deposits, they are able to live in water. In addition to being present in the precipitation of the atmosphere, it is currently mostly associated with pollution from urban and industrial sources. Chloride ions are present in varying concentrations throughout all types of water, ranging from a few parts per million to hundreds per kilogram (in brines).

2.3.1 Ions of Sulfate (SO_4^{2-})

These are present in all surface waters, and the presence of calcium ions, with which they mix to generate the compound $CaSO_4$, which is relatively soluble, restricts their concentration. Sulfate ions may be found in all surface waters. The sedimentary rocks that are the primary contributors of sulfate to water are gypsum and anhydride, two examples of which are described below. Sulfates contribute to the enrichment of water through a variety of processes, including the oxidation of sulfide, which is abundant in the crust of the Earth, as well as the oxidation of hydrogen sulfide, which is produced during volcanic eruptions and is found in the precipitation of the atmosphere. The concentration of sulfur in water bodies may be affected by human economic activity, processes involving the breakdown and oxidation of sulfur, as well as compounds of vegetative and organic origin.

2.3.2 Ions of Carbonate and Hydrocarbonate (HCO_3^- and CO_3^{2-})

Ions of carbonate and hydrocarbonate. It is found in waters that have formed naturally in a dynamic equilibrium with carbonic acid in particular quantitative ratios and, together, the two substances produce a carbonate system of chemical equilibrium that is related to the pH of the water. When the pH of the water in a system ranges from 7 to 8.5, hydrocarbonate will predominate as the predominant ion. When the pH is lower than 5, the number of hydrocarbonate ions present is almost nonexistent. When the pH is higher than 8, the majority of ions present are carbonate ions. Various types of carbonate rocks, such as limestones, dolomites, and magnesites, are the primary contributors of HCO_3^- and CO_3^{2-}, and the decomposition of these compounds requires the presence of carbon dioxide.

The predominance of hydrocarbonate ions is seen most often in waters with considerable mineralization but sometimes occurs in fluids with low mineralization. There is some buildup of hydrocarbonate ions, but just a little. Because calcium ions are present, these ions interact with the salt HCO_3^- to generate calcium carbonate. Surface freshwaters typically have an HCO_3^- concentration that is lower than or equal to 250/mg (with the exception of soda alkaline waters in which HCO_3^- and CO_3^{2-} content can reach grams and even dozens of grams per kilogram). The sodium ion, denoted by the symbol Na^+, has a comparatively strong tendency to migrate. This may be attributed to the high solubility of all of sodium's salts. When there is very little mineralization in the water, the concentration of Na^+ is third. As the mineralization of a fluid grows, so does the concentration of sodium, and once the mineralization reaches a certain g/kg, sodium becomes the predominate ion in the fluid. The presence of chlorine ions brings a considerable portion of the sodium ions into equilibrium, which results in the formation of a stable mobile combination that moves fast through a solution.

The presence of salt deposits (rock salt), products derived from the weathering of limestone, and the removal of sodium from the absorption complex of rocks and soils by calcium and magnesium are all potential sources of sodium in rivers.

2.3.3 Potassium Ions (K^+)

Potassium is pretty similar to sodium in terms of the quantity present in the Earth's crust and the solubility of its elements. Potassium is also fairly comparable to sodium in terms of the stability of its ions. Because of its restricted potential for migration, it is only found in surface waters in very small quantities. This is the case because it plays an active role in several biological processes, such as the absorption of nutrients by living plants and other microbes.

2.3.4 Ions of Calcium (Ca^{2+})

The principal sources of calcium are carbonate rocks (limestones, dolomites), which are broken down by the carbonic acid found in water. Other sources of calcium include algae and shellfish. The reaction, on the other hand, begins to proceed in the opposite direction when the availability of carbon dioxide (with which it is in equilibrium) is low, which is then followed by the precipitation of $CaCO_3$ crystals. Gypsum, which is often found in sedimentary rocks, provides an additional source of Ca^+ in the streams that are found naturally. Calcium ions dominate the cation composition of fluids that have a relatively modest mineral content.

2.3.5 Magnesium Ions (Mg^{2+})

There is a greater concentration of calcium than magnesium in the crust of the Earth. It is possible for it to make its way into surface water as a result of the chemical weathering and disintegration of rocks such as dolomites, marls, and others. Magnesium ions are present in all naturally occurring fluids, although they very seldom ever steal the spotlight. River waters may include anything from one milligram per liter to tens of milligrams per liter of this substance. The lower biological activity of magnesium as compared to calcium, as well as the higher solubility of magnesium sulfate and magnesium hydrocarbonate in comparison to the corresponding calcium compounds, both induce an increase in the Mg^{2+} content in water. With a rise in the mineral content of the water, the proportion of magnesium to calcium begins to move toward a greater abundance of the latter.

1. **Ammonia:** Ammonia is naturally present in rivers, lakes, and wetlands due to the decomposition of organic material.
2. **Nitrate:** Nitrate is naturally present in rivers, lakes, and wetlands due to the decomposition of organic material.
3. **Phosphate:** Phosphate is naturally present in rivers, lakes, and wetlands due to the decomposition of organic material.
4. **Chloride:** Chloride is naturally present in rivers, lakes, and wetlands due to the runoff of salt from the mountain soils.
5. **Sulfate:** Sulfate is naturally present in rivers, lakes, and wetlands due to the decomposition of organic material and the runoff of sulfur-containing minerals from the mountain soils.
6. **Magnesium:** Magnesium is naturally present in rivers, lakes, and wetlands due to the dissolution of soluble salts from the mountain soils.
7. **Calcium:** Calcium is naturally present in rivers, lakes, and wetlands due to the dissolution of soluble salts from the mountain soils.
8. **Iron:** Iron is naturally present in rivers, lakes, and wetlands due to the runoff of iron-containing minerals from the mountain soils.
9. **Manganese:** Manganese is naturally present in rivers, lakes, and wetlands due to the runoff of manganese-containing minerals from the mountain soils.

10. **Zinc:** Zinc is naturally present in rivers, lakes, and wetlands due to the runoff of zinc-containing minerals from the mountain soils.
11. **Copper:** Copper is naturally present in rivers, lakes, and wetlands due to the runoff of copper-containing minerals from the mountain soils.
12. **Lead:** Lead is naturally present in rivers, lakes, and wetlands due to the runoff of lead-containing minerals from the mountain soils.
13. **Arsenic:** Arsenic is naturally present in rivers, lakes, and wetlands due to the runoff of arsenic-containing minerals from the mountain soils.
14. **Mercury:** Mercury is naturally present in rivers, lakes, and wetlands due to the runoff of mercury-containing minerals from the mountain soils.
15. **Cadmium:** Cadmium is naturally present in rivers, lakes, and wetlands due to the runoff of cadmium-containing minerals from the mountain soils.
16. **Beryllium:** Beryllium is naturally present in rivers, lakes, and wetlands due to the runoff of beryllium-containing minerals from the mountain soils.

2.3.6 Ions of Hydrogen

Despite their comparatively modest absolute number in contrast to that of other ions, hydrogen ions play a particular function in the composition of natural waters. This is because hydrogen ions have a positive charge. Hydrogen ions are always present in water, because they are formed during the electrolytic dissociation of water.

The formula for hydrogen ions is

$$H_2O \rightarrow H^+ + OH^-$$

The concentration of hydrogen ions in a water solution can be calculated using the "ionic product" of water, which is denoted by the formula

$$K_w = [H^+] \cdot [OH^-]$$

Therefore, $K_w = 10^{-14}$ is a constant value that is always equal to the product of the concentrations (in g molecules) of hydrogen ions and hydroxyl at a temperature of 22 °C. This is because $K_w = 10^{-14}$ is a product of the concentrations of hydrogen ions and hydroxyl ions concentration. Since the concentrations of hydrogen and hydroxyl ions are so negligible, it is customary to express them in the form of their logarithms with the sign switched around:

$$p^H = -\log\ [H^+]; p^{OH} = -\log\ [OH^-]$$

When describing water processes, the concentration of hydrogen ions is often utilized. When pH equals 7, the interaction between water and other substances is considered neutral. However, if pH is more than 7 or less than 7, the reaction might go in either an acidic or alkaline direction. The amount of hydrogen ions that are included within natural fluids is determined by the dissociation and hydrolysis of the combinations that are already there (Brezonik and Arnold 2012).

2.4 Gases Dissolved

Depending on the location and the surrounding environment, the percentage composition of dissolved gases in water with a focus on the biological oxygen demand (BOD) can change. In general, nitrogen, oxygen, carbon dioxide, and argon are the most prevalent dissolved gases in water. Since oxygen is necessary for aquatic organisms' respiration and metabolism, it is the most significant of these for BOD. Nitrogen, carbon dioxide, and argon make up the remaining portion of the total dissolved gas in water, which is typically between 10 and 14% oxygen. Due to higher levels of pollutants and organic matter in the water, polluted waters can have significantly lower oxygen percentages. The total amount of dissolved gas in these situations can be between 0 and 7%, with oxygen making up roughly 0–3% of the total. A significant indicator of water quality is the proportion of oxygen in the water because it can show how polluted the water is. It is also one of the key elements in determining a water body's BOD level. Overall, depending on the environment and the level of water pollution, the oxygen content of water with a focus on the BOD can range from 0 to 14% (Kumar 2020; Theodore et al. 2022).

2.5 Biological Substances

Biogenous substances are those whose origins are tied to aquatic species' critical functions, which determine whether they can survive in bodies of water. These include silicon, nitrogen, phosphorus, and iron compounds.

2.5.1 Silicon (Si)

Natural waters always include silicon, which is one of the ionogenic elements. Due to the limited solubility of silicate minerals and certain species' consumption of them, their quantity in natural waters is minimal compared to the overall salt composition (in land surface waters up to 10–20 mg/L). In the form of the meta- and ortho-silicic acids H_2SiO_3 and H_4SiO_4, as well as in colloidal form of the $x\ SiO_2 \times yH_2O$ type, it may be found in fluids in a completely dissolved condition.

2.5.2 Nitrogen (N)

It is found in natural waters as both organic molecules and a variety of inorganic ions, including ammonium NH_4^+, nitrite NO_2^-, and nitrate NO_3^- (in the amino acids and proteins of organisms, and the products of their vital activity and decomposition). These may be found in water as dissolved molecules, colloidal particles, and suspended substances.

2.5.3 Phosphorus (P)

Phosphorus is an inorganic and organic chemical that exists in water as dissolved, suspended, and colloidal entities. Being an anionogenic element, phosphorus generates the neutral phosphoric acid H_3PO_4 that dissociates into many derivative forms, including H_2PO_4, HPO_4^{2-} and PO_4^{3-}, the relationship between which is influenced by the pH of water.

2.6 High-Quality Water

Water that satisfies drinking water standards set by the Environmental Protection Agency (EPA) and other organizations and is free of contaminants is considered to be of high quality. In general, there shouldn't be a lot of bacteria, viruses, heavy metals, or other chemicals in the water. It should also look good and have a pleasing flavor and aroma.

The Environmental Protection Agency (EPA) establishes guidelines for contaminants in public drinking water systems, including bacteria, lead, arsenic, and other pollutants. Depending on the type of water system, the water source, and the population served, these standards may change. For instance, the EPA mandates that public water systems test for lead, copper, and other contaminants and disinfect water using chlorine.

Some states and localities may have their own standards or requirements for the quality of drinking water in addition to the EPA guidelines. Water filters and other items that can enhance the quality of a person's water are available for purchase by both homeowners and businesses. Many communities also have water treatment facilities that can clean up contaminants and raise the standard of the water. No matter where your water comes from, it's crucial to test it frequently to make sure it satisfies the requirements for safe drinking water. For more information if you are worried about the quality of your water, get in touch with the EPA or your local health department (EPA 2020).

2.7 River's Chemical Makeup

The chemicals in the rivers in Uttarakhand depend on where the river starts, how fast it flows, and what is around it. Most rivers in Uttarakhand have different amounts of calcium, magnesium, sodium, chloride, and sulfate ions. Ions like nitrate, phosphate, potassium, bicarbonate, iron, manganese, and copper are also often found in the rivers of Uttarakhand. Some rivers in Uttarakhand may also be affected by the runoff from factories and farms, which can add chemicals like nitrates and phosphates to the water (Seth et al. 2016; Sharma et al. 2022).

The way the rivers in Uttarakhand are made up chemically also changes with altitude. For example, rivers at higher elevations tend to have more calcium, magnesium, and bicarbonate ions, while rivers at lower elevations tend to have more sodium, chloride, and sulfate ions. The chemicals in the rivers of Uttarakhand are important for the environment because they affect the rivers' health and the health of the ecosystems around them. It can also affect the health of people, since rivers are often used to get drinking water (Ruhela et al. 2018).

2.8 Various Rivers of Uttarakhand with Their Ionic Composition

The rivers of Uttarakhand with their chemical composition are as

2.8.1 Bhagirathi River

The ions calcium, magnesium, sodium, potassium, sulfate, chloride, nitrate, and bicarbonate are found in the Bhagirathi River in Uttarakhand. By preserving the pH balance, these ions help the river remain suitable for aquatic life. As some of these ions serve as nitrogen sources for the growth of algae and other types of aquatic plants, they can also aid in reducing the eutrophication of the river (Arora et al. 2017).

High concentrations of some of these ions, including nitrate and chloride, can, however, be harmful to the river. An imbalance in the river's ecology can result from an increase in these ions, which can also promote the growth of algae and other aquatic plants. This may result in lower oxygen levels, which may have an impact on aquatic life's health. Additionally affecting the quality of drinking water and rendering it dangerous for ingestion are high quantities of nitrate and chloride (Khan et al. 2022).

2.8.2 Bhilanagna River

In general, calcium and bicarbonate predominate in the chemical makeup of the Bhilangana River in Uttarakhand, India, with minor levels of magnesium, sodium, potassium, and chloride. The amounts of dissolved organic carbon and nitrate are typically low. Aquatic life can benefit from the high calcium and bicarbonate concentrations. While bicarbonate helps to buffer the water and maintain an ideal pH for aquatic life, calcium is crucial for the skeletal development of fish and other aquatic organisms (Agarwal et al. 2018).

High calcium and bicarbonate concentrations, however, can also be harmful to aquatic life. An increase in the river's hardness brought on by too much calcium can have a detrimental effect on the health of the fish. High bicarbonate concentrations can also cause carbonates to build up on the river bottom, lowering the amount of oxygen in the water. The variety of aquatic life may suffer as a result (Amoatey and Baawain 2019).

A decrease in water clarity brought on by high quantities of dissolved organic carbon can also restrict the amount of aquatic animals' habitat. Nitrate concentrations can also be an issue since they raise the possibility of eutrophication, which can cause the water to lose oxygen (Annayat et al. 2022).

2.8.3 Alaknanda River

The Alaknanda River, which originates in the Himalayas of Uttarakhand, India, is a significant tributary of the Ganges River. Calcium, magnesium, sodium, potassium, bicarbonate, sulphate, chloride, nitrate, and silicate are the main dissolved inorganic components of the Alaknanda River. Ca^{2+} (2.68 mg/L), Mg^{2+} (1.48 mg/L), Na^{+} (4.22 mg/L), K^{+} (0.19 mg/L), HCO_3^{-} (81.41 mg/L), SO_4^{2-} (2.66 mg/L), Cl^{-} (2.19 mg/L), NO_3^{-} (8.96 mg/L), and SiO_2 (4.09 mg/L) are the elements with the highest average values in the Alaknanda River.

These inorganic substances in the Alaknanda River have both beneficial and detrimental effects on the ecology. When calcium and magnesium are present, for instance, the pH of the water is balanced and fish and other aquatic creatures are protected against environmental stresses like temperature and oxygen level variations. For aquatic plants and animals, sodium and potassium are crucial minerals for growth and reproduction. Bicarbonate, sulfate, and chloride work together to control the acidity of the water and to shield aquatic life from harmful metals. The growth of phytoplankton, the main producers in aquatic habitats, depends on nitrate and silicate.

High levels of these substances, however, can contaminate and eutrophize the water. High amounts of nutrients like nitrates and phosphates can cause excessive development of aquatic plants and algae, which lowers the amount of oxygen available to other aquatic creatures, a process known as eutrophication. Fish and other aquatic species may perish as a result of this. High levels of nitrate, chloride, and sulfate can also contaminate water, rendering it unfit for consumption or other uses. In order to safeguard the aquatic ecology of the Alaknanda River, it is crucial to maintain a healthy balance of these components (Kumar et al. 2016).

2.8.4 Mandakini River

The Mandakini River in Uttarakhand has significant amounts of the following chemical elements: calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, and phosphate. These Mandakini River elements may have a significant impact on the environment (Goswami and Singh 2018).

The presence of calcium and magnesium in the river can support aquatic life, because these ions are necessary for the growth of aquatic plants and animals. Major ions in the water like sodium and potassium can make the water more electrically conductive, which can have a big impact on the aquatic ecosystem. Pollutants that can damage the ecosystem include chloride, sulfate, nitrate, and phosphate. These contaminants have the potential to significantly affect aquatic life by causing eutrophication and oxygen depletion at high concentrations (Sain et al. 2023).

2.8.5 Ganga River

The Ganga River, commonly known as the Ganges, originates in Devprayag and flows through Biyasi Rishikesh before ending in Haridwar in the Uttarakhand region. Gangotri Glacier, Satopanth Glacier, Khatling Glacier, as well as the water melting from the snow-covered peaks of Nanda Devi, Trishul, Kedarnath, Nanda Kot, and Kamet, are the sources of the Ganga River. In Uttarakhand, the Ganga River is distinguished by a variety of chemical elements. Calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, dissolved organic carbon, and total dissolved solids are important constituents. These substances have an impact on the water's quality, which is crucial for supporting aquatic life. The majority of the dissolved solids in the Ganga River—between 15 and 25%—come from calcium. Aquatic species benefit from it, because it keeps the pH balance of water. Magnesium makes up between 10 and 15% of all dissolved solids and is the second most prevalent element. It is crucial for preserving the proper nutritional balance in water and aids in controlling the water's ionic composition. Another crucial element and crucial nutrient for aquatic life is sodium. It adds between 5 and 10% of the total dissolved solids. Potassium is found in smaller concentrations and makes up about 1–3% of all dissolved solids. For keeping the osmotic balance in water, it is crucial. Another crucial element is chloride, which accounts for 1–5% of all dissolved solids. It benefits aquatic life and aids in maintaining the ionic balance of water. Sulfate is less prevalent and makes up 0.5–2% of the total dissolved solids. It benefits aquatic life and aids in keeping the pH balance of the water. The Ganga River has a significant amount of nitrate, which makes up 0.5–2% of the total dissolved solids. Due to its role in preserving the water's nutritional balance, it is crucial for the survival of aquatic life (Mukherjee et al. 2021).

The Ganga River contains higher concentrations of dissolved organic carbon, which makes up around 5–10% of the total dissolved solids. It benefits aquatic life and aids in keeping the pH balance of the water. Total dissolved solids are a key contaminant indicator that helps determine how much contamination is present in the water. The total dissolved solids in the Ganga River range from 200 to 400 mg/L. These substances have an impact on the Ganga River's water quality, which is crucial for supporting aquatic life. Reducing the amount of pollutants and other impurities in the water is crucial for maintaining the health of the Ganga River (Kumar et al. 2015; Ahmad and Chaurasia 2019).

2.8.6 Ramganga

The Ramganga River in Uttarakhand has a complicated chemical makeup that is heavily influenced by the local geology and human activity. Bicarbonates, sulfates, chlorides, nitrates, and phosphates are some of the major ions found in water. In addition, the water contains trace amounts of iron, magnesium, calcium, zinc, copper, cadmium, lead, and arsenic (Paul 2017; Khan et al. 2015).

These chemicals have mostly had a negative impact on the Ramganga River. High levels of nitrates, phosphates, and heavy metals, for instance, can lead to eutrophication, which increases the growth of aquatic vegetation, lowers oxygen levels, and increases the frequency of hazardous algae blooms. This may lead to a decline in water quality and an increase in aquatic species mortality. In addition, exposure to heavy metals poses major health concerns for people, including neurological diseases, cancer, and renal damage. High levels of nitrates and phosphates can also result in a rise in algae, which can lower the water's oxygen content and result in a decline in fish populations (Tirth et al. 2022).

2.8.7 The Yamana River

Depending on the season, the Yamuna River in Uttarakhand has a different chemical makeup. High concentrations of calcium, magnesium, chloride, nitrate, sulfate, and potassium are typically present in the water. In addition, the water has very little dissolved oxygen and is mildly acidic (Sharma and Kansal 2011).

The ecology, especially aquatic life, may suffer as a result of the Yamuna River's chemical makeup. Eutrophication, which can result in algal blooms, lower oxygen levels, and other environmental changes, is brought on by high levels of nitrates and sulfates. High calcium and magnesium levels can produce calcium carbonate deposits as well, which can clog pipes and cause a scarcity of water. In addition, aquatic life may become hazardous at high chloride levels (Sharma et al. 2020).

2.8.8 The Kali River

A significant tributary of the Ganges is the Kali River in Uttarakhand. For the people of Uttarakhand, this river is crucial, since it supplies water for drinking, agriculture, and other uses. A wide variety of aquatic life can be found in the river.

The main ions that make up the chemical makeup of the Kali River include calcium, magnesium, sodium, potassium, sulfate, chloride, nitrate, and bicarbonate ions. Trace levels of other elements like iron, copper, zinc, and manganese are also present in the river (Trivedi 2010).

These substances are found in the Kali River, and they have both beneficial and harmful effects on the ecology. On the plus side, these components supply vital nutrients and minerals to the river's aquatic life. Additionally, they support the growth of advantageous bacteria and maintain the pH balance, which help to clean and maintain the health of the water. On the downside, certain of these elements, like iron and manganese, can contaminate water at high concentrations, which is bad for human health. In addition, sulfate and chloride levels that are too high can make the water corrosive, harming pumps, pipes, and other infrastructure (Ghosh and McBean 1998).

2.9 Wetlands' Chemical Composition

Depending on the type of wetland and its location, wetlands in Uttarakhand have different chemical compositions. Wetlands typically include high levels of organic matter, nitrogen, phosphorus, and sulfur as well as trace elements including iron, manganese, copper, and zinc. Decomposing plants, fungus, bacteria, and other microbes make up the organic matter. The trace elements may have an effect on the well-being of the wetland environment, whereas the nitrogen, phosphorus, and sulfur are vital nutrients for aquatic life. Some wetlands may have significant amounts of particular chemical substances including arsenic, mercury, and lead. In order to maintain the ecosystem's health, it is crucial to keep an eye on the chemical makeup of wetlands (Mitsch and Gosselink 2000; Sharma et al. 2018).

2.9.1 Availability of Wetland's Geotagging Data and Class of Wetlands

The Uttarakhand State Council for Science and Technology (UCOST), on the other hand, has started mapping the state's wetlands, and its findings should be made public soon. The goal of this project is to create a 1:50,000 scale map of the state's wetlands, and then categorize them according to the criteria established by the Ramsar Convention. In-depth data about the state of Uttarakhand's wetlands are available in the atlas form. Details about the wetland's location, size, type, and other attributes are included. There are many different kinds of wetlands listed in the atlas, such as marshes, ponds, lakes, reservoirs, oxbows, swamps, floodplains, and rivers (Bachheti et al. 2023).

The Uttarakhand Forest Department also keeps a database of the state's wetlands called the State Wetland Database. Details about the wetland's location, size, and composition are included. Marshes, ponds, lakes, reservoirs, oxbows, swamps, floodplains, and rivers are only some of the wetland types represented in the database.

There is a wealth of data about the state's wetlands available from the Uttarakhand State Biodiversity Board as well. The document details the wetland's precise location, as well as its kind, size, and other attributes. Marshes, ponds, lakes, reservoirs, oxbows, swamps, floodplains, and riverine wetlands are all represented in this catalogue. The wetlands of Uttarakhand are also depicted on the UK Land Cover Map. Details on the wetland's location, kind, extent, and other attributes are included. This map depicts a variety of wetland ecosystems, such as marshes, ponds, lakes, reservoirs, oxbows, swamps, floodplains, and rivers (Patakamuri 2013).

2.9.2 Wetland Coding and Classification System

Ramsar classification and the Indian Wetland Classification System serve as the foundation for Uttarakhand, India's wetland coding and classification system (IWCS). The system is made to recognize and classify wetlands based on their purpose and significance to the environment. In Uttarakhand, there are four primary categories of wetlands:

1. Natural Wetlands: These include lakes, ponds, marshes, swamps, estuaries, mangrove forests, coral reefs, lagoons, and wetlands created artificially by the construction of dams, reservoirs, and canals.
2. Human-made Wetlands: These comprise built-in wetland structures including sewage treatment plants, agricultural fields, industrial locations, and other man-made bodies of water utilized for aquaculture or irrigation.
3. Transitional Wetlands: Also known as "intermittent wetland systems," they are regions that provide as a transition between wetland and dryland ecosystems.
4. Wetlands that are particularly crucial to the preservation of biodiversity and ecosystem services are known as ecologically important wetlands.

Based on their size, hydrological properties, and other characteristics, these four categories are further subdivided (Bassi et al. 2014; Sharma and Kumar 2017).

2.10 Lake's Chemical Makeup

There are more than 500 glacial lakes in Uttarakhand. The geological and hydrological characteristics of these lakes' catchment areas determine their chemical composition. In general, the lakes have high levels of silica, magnesium, sodium, potassium, and calcium ions. They are also abundant in nutrients including nitrogen, phosphate, and sulfur as well as organic materials. Additionally, the lakes have large concentrations of suspended materials, primarily clay particles, which can change the hue and transparency of the water. The lakes may also contain significant amounts of heavy metals, including lead, arsenic, mercury, and cadmium, which are harmful to aquatic life. The amount of glacial meltwater that the Himalayan glacial lakes get also has an impact on their chemical makeup. Due to higher levels of dissolved carbon dioxide, lake water may turn acidic in the presence of glacial meltwater. Aluminum, iron, and manganese are just a few of the trace elements that the meltwater may add to the lake's water. Pollution from human activities can potentially change the lakes' chemical composition. Agricultural runoff, industrial waste, sewage, and other contaminants can contaminate the lakes. These contaminants may raise the concentrations of nutrients, organic matter, and heavy metals in the lake, which may be hazardous to aquatic life (Kumar and Sharma 2019; Babuji et al. 2023).

2.11 Effect of Chemical Constituents Present in Water of Uttarakhand on Human Beings, Marine Biota, and Environment

2.11.1 Human Beings

Uttarakhand water is generally high in minerals, which can lead to a range of health benefits. Examples of these minerals include calcium, magnesium, potassium, sodium, and iron. These minerals can help improve blood circulation, reduce blood pressure, and can improve the overall metabolism of the body. However, it can also contain pollutants and contaminants, such as pesticides, heavy metals, and industrial chemicals, which can lead to health risks if consumed in large quantities.

2.11.2 Marine Biota

The high mineral content of water in Uttarakhand can help improve the health of marine biota by providing essential nutrients. However, it can also contain pollutants, such as pesticides, heavy metals, and industrial chemicals, which can lead to toxicity and other health risks if consumed in large quantities.

2.11.3 Environment

The presence of pollutants and contaminants in the water can lead to environmental damage if not managed properly. For example, high levels of heavy metals can lead to eutrophication, which can reduce the amount of oxygen in the water and damage aquatic ecosystems. Additionally, industrial chemicals can pollute the air, land, and water and can lead to soil and water contamination (Lin et al. 2022; PR 2020).

2.12 Conclusion

The chemical composition of the water in rivers, lakes, and wetlands in Uttarakhand varies greatly depending on the water's point of origin, the time of year, and the location in which it is located. In addition to main cations like calcium, magnesium, and potassium and trace metals, the water typically contains dissolved organic and inorganic compounds including nitrates, phosphates, sulfates, and chloride. Dissolved particles and suspended sediments in the water may also be a source of toxic metals. In addition, eutrophication can lead to a rise in nutrient and contaminant levels in the water. The ecological systems of the rivers, lakes, and wetlands of

Uttarakhand are vulnerable to the effects of these substances; thus, they must be carefully monitored and maintained.

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