E-ISSN: 3048-6041 | Volume- 3, Issue- 6 | June 2026

Hydrogeochemical Assessment of the Asan River, Uttarakhand, India

Dhiraj[1] & Mitasha Kaushik[2*]
[1,2]Department of Applied Science, Ras Bihari Bose Subharti University, Dehradun, Uttarakhand, India
ORCID: https://orcid.org/0009-0000-3067-184X

Abstract

The present study investigates the hydrogeochemical characteristics and water quality status of the Asan River in Dehradun, Uttarakhand, India. Water samples were collected from selected locations along the river and analyzed for major physicochemical parameters, including pH, temperature, turbidity, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), calcium, magnesium, and total hardness. The results revealed that pH values ranged from 7.30 to 7.98, indicating slightly alkaline conditions and compliance with national and international drinking water standards. Water temperature varied between 17.0°C and 22.2°C, reflecting favourable environmental conditions for aquatic ecosystems. Turbidity values ranged from 11 to 29 NTU, exceeding recommended drinking water limits and indicating elevated suspended sediment loads. TDS concentrations varied between 750 and 850 mg/L, suggesting moderate mineralization of river water. Dissolved oxygen levels ranged from 3.8 to 6.2 mg/L, while BOD and COD values varied from 2.8–5.6 mg/L and 3.2–5.4 mg/L, respectively, indicating moderate organic pollution at certain locations. Calcium and magnesium concentrations ranged from 189.5–354.1 mg/L and 108.0–136.6 mg/L, respectively, resulting in total hardness values between 917.8 and 1446.8 mg/L as $CaCO_3$. The elevated hardness indicates strong rock–water interaction and the influence of carbonate weathering processes within the catchment. Comparison with BIS, WHO, and CPCB standards revealed that although the river maintained acceptable pH conditions, elevated turbidity, hardness, calcium, and magnesium concentrations may limit its direct suitability for domestic consumption without treatment. The study highlights the combined influence of natural geogenic processes and anthropogenic activities on river water chemistry and emphasizes the need for regular monitoring and sustainable watershed management for the conservation of the Asan River ecosystem.

Keywords: Asan River; Hydrogeochemistry; Water Quality Assessment; Physicochemical Parameters; Total Hardness; Dissolved Oxygen; Turbidity; Carbonate Weathering; Uttarakhand; River Water Quality.

[*]Corresponding Author Email: mitashahbt@gmail.com
Published: 10 June 2026
DOI: https://doi.org/10.70558/SPIJSH.2026.v3.i6.45782

INTRODUCTION

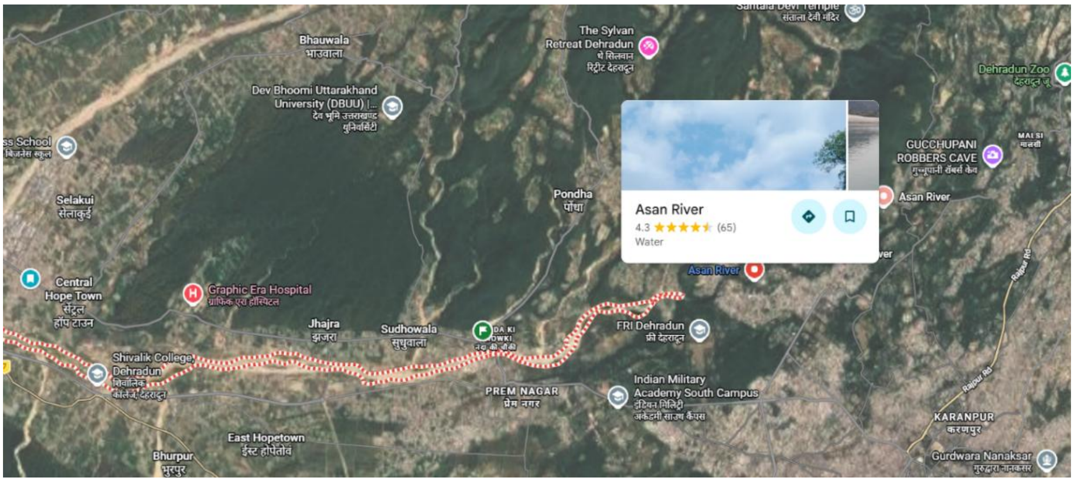
Freshwater resources are fundamental to human well-being, economic development, and ecosystem sustainability. Among these resources, river systems play a critical role in supplying water for domestic consumption, agriculture, industry, and biodiversity conservation. The chemical composition of river water is influenced by a combination of natural processes and anthropogenic activities operating within a watershed. Variations in lithology, climate, topography, weathering processes, and land-use practices can significantly affect the concentration and distribution of dissolved ions and other water quality parameters (Tiwari et al., 2021; Sharma et al., 2023).

Hydrogeochemistry is an important scientific approach for understanding the origin, movement, and transformation of chemical constituents in aquatic environments. Analysis of hydrogeochemical characteristics helps identify the dominant mechanisms controlling water chemistry, including rock-water interaction, mineral dissolution, precipitation, evaporation, and anthropogenic inputs. Such investigations are increasingly used to evaluate water quality, trace pollution sources, and support sustainable water resource management (Richards et al., 2022). In recent years, multivariate statistical techniques such as correlation analysis and principal component analysis (PCA) have become valuable tools for interpreting complex hydrochemical datasets and identifying the major factors influencing water quality.

The Himalayan region contains numerous river systems that provide freshwater to a large population in northern India. These rivers are particularly sensitive to environmental changes because of rapid urbanization, agricultural intensification, tourism activities, and increasing developmental pressures within their catchments. Consequently, regular monitoring of river water quality is essential for understanding environmental changes and ensuring the long-term sustainability of water resources (Bhat et al., 2022).

The Asan River, located in the Dehradun district of Uttarakhand, is an important tributary of the Yamuna River. Flowing through diverse geological and land-use settings, the river supports agricultural activities, local communities, and ecologically significant wetland habitats. The catchment area experiences increasing human intervention in the form of settlement expansion, agricultural practices, and tourism-related activities, which may influence the river's hydrochemical characteristics. Despite its ecological and socio-economic importance, comprehensive information regarding the hydrogeochemical behaviour of the Asan River remains limited.

Therefore, a detailed assessment of the hydrochemical characteristics of the Asan River is necessary to understand the factors controlling water quality and to establish baseline information for future monitoring programs. The present study investigates the physicochemical characteristics of river water and applies statistical approaches to evaluate relationships among water quality variables. The study aims to identify the dominant hydrogeochemical processes influencing river water chemistry and to assess the overall status of the Asan River in the context of environmental management and sustainable utilization of freshwater resources.



Asan River - Selaqui to prem Nagar (Source: Google Map)

Study Area and Sampling Locations

Study Area

The Asan River is an important tributary of the Yamuna River located in the Doon Valley of Dehradun district, Uttarakhand, India. The river originates from the southern slopes of the Lesser Himalayas and flows through a diverse landscape comprising forested hills, agricultural lands, rural settlements, and urbanized areas before joining the Yamuna River near Dakpathar. The river basin forms an important component of the Yamuna catchment and contributes significantly to the hydrological and ecological characteristics of the region.

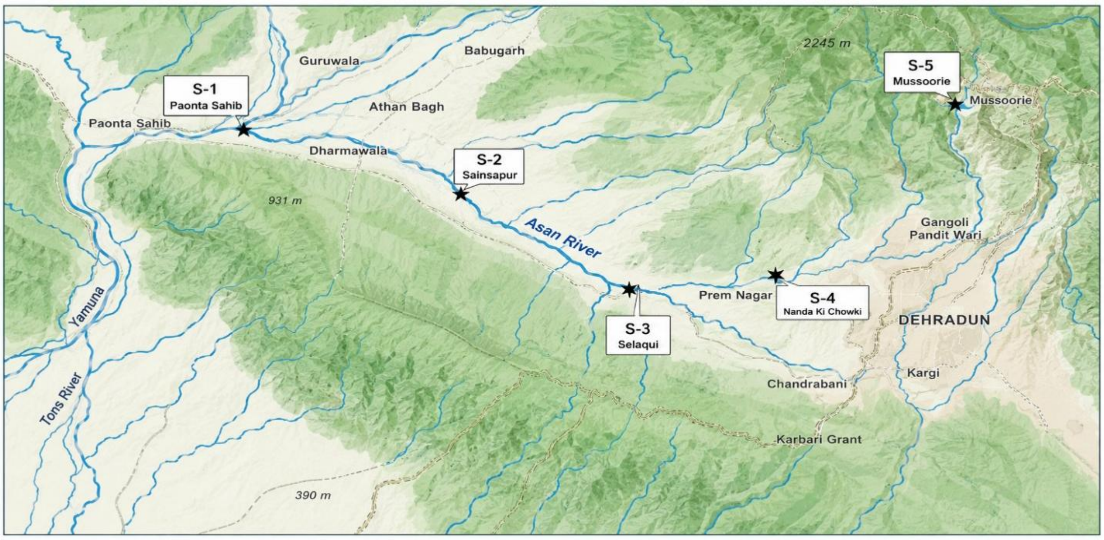
Geographically, the Asan River lies between approximately 30°15′–30°30′ N latitude and 77°40′–78°05′ E longitude. The catchment experiences a subtropical to temperate climate, characterized by three distinct seasons: summer, monsoon, and winter. Annual rainfall is predominantly received during the southwest monsoon season (June–September), which contributes substantially to river discharge and groundwater recharge. The average annual rainfall in the region ranges from 1,800 to 2,200 mm, although interannual variations are common.

The geology of the basin is dominated by sedimentary and metamorphic formations of the Lesser Himalayan sequence, including limestone, sandstone, shale, quartzite, and phyllite. Weathering of these rock formations plays a significant role in determining the hydrochemical composition of river water. Natural processes such as mineral dissolution, surface runoff, and groundwater interactions contribute dissolved ions to the river system, thereby influencing water quality characteristics.

The river supports a variety of ecological habitats and provides water for agricultural, domestic, and recreational purposes. One of the most significant features associated with the river is the Asan Barrage, a freshwater wetland formed at the confluence of the Asan and Yamuna rivers near Dakpathar. This wetland has been recognized as a Ramsar Site because of its ecological importance and serves as a habitat for numerous resident and migratory bird species. The wetland attracts thousands of migratory birds annually and plays a crucial role in maintaining regional biodiversity.

Land-use patterns within the watershed include dense forests in the upper reaches, agricultural fields in the middle reaches, and increasing urban development in downstream areas. Human activities such as agriculture, tourism, domestic wastewater discharge, and infrastructure development have the potential to influence the physicochemical characteristics of river water. Consequently, hydrogeochemical assessment of the Asan River is essential for understanding the processes governing water chemistry and for developing effective management strategies aimed at preserving water quality and ecological integrity.

The present investigation was carried out to evaluate the hydrogeochemical characteristics and pollution status of the Asan River in Dehradun district, Uttarakhand, India. The study area is situated between 77°40′E to 78°00′E longitude and 30°15′N to 30°27′N latitude within the northern part of the Shivalik Himalayan region. The Asan River flows through the Doon Valley, an ecologically significant intermontane basin located between the Himalayan foothills and the Shivalik ranges.



Asan River Satellite View (Source: Satellite View Google)

The Yamuna River is one of the major river systems of northern India, and the Asan River serves as an important tributary of the Yamuna. The river flows across the north-western region of the Doon Valley and supports local agricultural, domestic, and ecological activities. The climatic conditions of the valley vary seasonally. During summer, the temperature generally ranges between 17°C and 36°C, whereas winter temperatures may decline to nearly 6°C. The region receives an average annual rainfall of approximately 2073 mm, with the majority of precipitation occurring during the monsoon season from June to September. Maximum rainfall is usually recorded during July and August.

The Asan River also possesses cultural and religious importance in Hindu mythology. Historical references associated with the Rig Veda mention the river as “Asmavanti.” The origin region near Gautam Kund and Chandrabani Temple, close to Dehradun, is considered spiritually significant.

For the present study, water samples were collected from five selected locations along the course of the Asan River to assess spatial variations in water chemistry and pollution characteristics. The sampling sites were distributed between 29°58′N to 31°02′30″N latitude and 77°34′45″E to 78°18′30″E longitude. The selected locations were designated as Site 1 (Paonta Sahib), Site 2 (Sahaspur), Site 3 (Selaqui), Site 4 [Prem Nagar (Nanda Ki Chowki)], and Site 5 (Mussoorie). These sites were selected to represent different environmental and anthropogenic influences along the river stretch.

3. Materials and Methods

Water Sample Collection

Water samples were collected from selected locations along the Asan River, Dehradun, Uttarakhand, during the study period. Sampling was carried out following standard procedures for river water quality assessment. Grab samples were collected in clean, pre-washed polyethylene bottles from approximately 20–30 cm below the water surface to minimize contamination from surface films and floating debris. Prior to collection, sampling containers were rinsed with river water from the respective site. The collected samples were transported to the laboratory under appropriate storage conditions for subsequent analysis (APHA, 2023).

3.2 Physicochemical Analysis

Water temperature was measured in situ using a calibrated digital thermometer. The pH of water samples was determined using a portable digital pH meter calibrated with standard buffer solutions (APHA, 2023). Turbidity was measured by the nephelometric method and expressed as Nephelometric Turbidity Units (NTU).

Total Dissolved Solids (TDS) were determined using a digital TDS meter, whereas Total Suspended Solids (TSS) were estimated gravimetrically after filtration through pre-weighed glass-fiber filters and subsequent drying at standard temperature conditions (APHA, 2023).

Dissolved Oxygen (DO) was analyzed using the Winkler iodometric method. Biological Oxygen Demand (BOD_5) was determined by incubating samples at 20°C for five days and measuring oxygen depletion during the incubation period. Chemical Oxygen Demand (COD) was measured using the closed reflux dichromate method (APHA, 2023).

Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) concentrations were determined through EDTA titrimetric methods. Total Hardness (TH), expressed as mg/L $CaCO_3$, was calculated from calcium and magnesium concentrations using the standard relationship described by Sawyer et al. (2003):

$$TH = (2.497 \times Ca) + (4.118 \times Mg)$$

where calcium and magnesium concentrations are expressed in mg/L.

Biological Oxygen Demand (BOD_5) was determined by measuring the dissolved oxygen content of water samples before and after incubation. The samples were incubated in airtight BOD bottles at 20°C for five days under dark conditions. The difference between the initial and final dissolved oxygen concentrations was used to calculate the BOD value, which represents the amount of oxygen consumed by microorganisms during the decomposition of biodegradable organic matter (APHA, 2023).

Chemical Oxygen Demand (COD) was estimated using the closed reflux dichromate method. A known volume of water sample was digested with potassium dichromate in the presence of concentrated sulfuric acid and a silver sulfate catalyst. After refluxing, the excess dichromate was titrated with standardized ferrous ammonium sulfate solution. COD values were expressed as mg/L O_2 and indicate the oxygen equivalent required to oxidize both biodegradable and non-biodegradable organic matter present in the water sample (APHA, 2023).

Total Hardness (TH), expressed as mg/L $CaCO_3$, was determined by titration with standardized EDTA solution using Eriochrome Black T (EBT) as the indicator at pH 10. The color change from wine red to blue indicated the endpoint of the reaction. Total hardness was also calculated from calcium and magnesium concentrations using the equation:

$$\text{TH (mg/L as } CaCO_3) = (2.497 \times \text{Ca}) + (4.118 \times \text{Mg})$$

where calcium and magnesium concentrations are expressed in mg/L (Sawyer et al., 2003).

All analyses were performed in triplicate, and the average values were used for interpretation. Standard quality assurance and quality control procedures, including instrument calibration, reagent blanks, duplicate analyses, and the use of analytical-grade reagents, were followed throughout the study to ensure accuracy and reliability of the results.

3.3 Quality Assurance and Quality Control

Quality assurance procedures were adopted throughout the study to ensure analytical reliability. All instruments were calibrated prior to analysis using certified standards. Reagent blanks, duplicate samples, and standard solutions were analyzed periodically to verify analytical precision and accuracy. Analytical-grade reagents and deionized water were used for all laboratory determinations. Measurements were performed in triplicate, and mean values were used for subsequent interpretation (APHA, 2023).

3.4 Data Evaluation

The measured physicochemical parameters were compared with drinking water quality standards prescribed by the Bureau of Indian Standards (BIS, 2012), the World Health Organization (WHO, 2022), and the water quality criteria established by the Central Pollution Control Board (CPCB, 2023). This comparison was undertaken to evaluate the suitability of river water for domestic use and to assess the hydrogeochemical characteristics of the Asan River system.

Results and Discussion

pH

The pH values recorded from the Asan River varied between 7.30 and 7.98, indicating slightly alkaline conditions throughout the study area. The narrow range of variation suggests relatively stable acid–base conditions and reflects the buffering capacity of the river water. Such alkaline characteristics are commonly observed in river systems draining carbonate-bearing lithologies, where the dissolution of carbonate minerals contributes bicarbonate ions that regulate pH levels (Tiwari et al., 2021).

The measured pH values remained within the acceptable limits prescribed by BIS (2012), WHO (2022), and the CPCB criteria for inland surface waters. The absence of extreme pH values indicates that the river is not significantly affected by acidic industrial discharges or other strong anthropogenic inputs. Slight spatial variations may be associated with local runoff, biological activity, and organic matter decomposition occurring within the catchment. Overall, the observed pH conditions indicate a chemically stable aquatic environment capable of supporting diverse biological communities.

Water Temperature

Water temperature exhibited moderate variation, ranging from 17.0°C to 22.2°C across the sampling locations. Temperature is an important parameter influencing physical, chemical, and biological processes within aquatic ecosystems. The observed range is characteristic of Himalayan foothill rivers during the monsoon season, where precipitation, cloud cover, and continuous water movement help moderate thermal fluctuations.

Lower temperatures at certain locations may be attributed to groundwater inflow and shading effects from riparian vegetation, whereas slightly elevated temperatures downstream could result from greater solar exposure and reduced canopy cover. The absence of unusually high temperatures suggests minimal thermal pollution and indicates that the river maintains suitable conditions for aquatic organisms. Similar temperature ranges have been reported for relatively unpolluted river systems in northern India (Sharma et al., 2023).

Turbidity

Turbidity values ranged from 11 NTU to 29 NTU, demonstrating substantial spatial variation along the river course. The increasing trend observed towards downstream locations indicates enhanced sediment transport and accumulation of suspended particles. During the monsoon season, intense rainfall and surface runoff accelerate soil erosion and facilitate the movement of sediments from agricultural fields, exposed slopes, and riverbanks into the river channel.

The recorded turbidity values exceeded the desirable limits recommended by BIS (2012) and WHO (2022), indicating a relatively high suspended sediment load during the sampling period. Elevated turbidity can reduce light penetration, impair photosynthetic activity, and alter aquatic habitat conditions. In addition, suspended particles may act as carriers for nutrients, pathogens, and trace contaminants, thereby influencing overall water quality.

The higher turbidity observed in the present study is likely associated with natural hydrological processes rather than direct chemical contamination. However, persistent high turbidity may affect the suitability of water for domestic purposes and necessitates appropriate treatment before consumption. The findings highlight the influence of seasonal runoff and catchment characteristics on the sediment dynamics of the Asan River.

Overall Water Quality Assessment

Comparison of the observed values with BIS, WHO, and CPCB standards indicates that the pH of the Asan River remained within acceptable limits, reflecting favourable chemical conditions. Water temperature exhibited normal seasonal variability and did not indicate thermal stress. Turbidity, however, exceeded recommended drinking water limits at several locations, suggesting increased sediment influx during the monsoon period. Therefore, while the river exhibits generally stable hydrochemical conditions, turbidity remains an important parameter requiring attention for drinking water applications and watershed management.

Table X. Comparison of Physicochemical Parameters of Asan River Water with BIS, WHO and CPCB Standards

Parameter	Unit	Observed Range	BIS (IS 10500:2012)	WHO (2022)	CPCB Criteria
pH	–	7.30–7.98	6.5–8.5	6.5–8.5	6.5–8.5
Temperature	°C	17.0–22.2	Not specified	Not specified	Not specified
Turbidity	NTU	11–29	1 (Desirable), 5 (Permissible)	<5	Not specified
TDS	mg/L	750–850	500 (Desirable), 2000 (Permissible)	500–1000	Not specified
TSS	mg/L	280–452	Not specified	Not specified	Not specified
DO	mg/L	3.8–6.2	Not specified	Not specified	≥4.0
BOD	mg/L	2.8–5.6	Not specified	Not specified	≤3.0
COD	mg/L	3.2–5.4	Not specified	Not specified	No specific limit
Calcium (Ca^{2+})	mg/L	189.5–354.1	75 (Desirable), 200 (Permissible)	75–200	Not specified
Magnesium (Mg^{2+})	mg/L	108.0–136.6	30 (Desirable), 100 (Permissible)	30–100	Not specified
Total Hardness (as $CaCO_3$)	mg/L	917.8–1446.8	200 (Desirable), 600 (Permissible)	200–500	Not specified

Source: BIS (2012); WHO (2022); CPCB (2023).

Overall Water Quality Assessment

The physicochemical characteristics of the Asan River indicate varying degrees of water quality alteration across the study area. The pH values ranged from 7.30 to 7.98, demonstrating slightly alkaline conditions throughout the river stretch. These values fall within the acceptable limits prescribed by BIS (2012), WHO (2022), and CPCB guidelines, suggesting a chemically stable aquatic environment. The alkaline nature of the river water may be attributed to the dissolution of carbonate-bearing minerals and weathering of geological formations within the catchment area, which contribute bicarbonate ions and enhance the buffering capacity of the water (Tiwari et al., 2021).

Water temperature varied between 17.0°C and 22.2°C, reflecting moderate seasonal conditions and the influence of monsoonal climate. Such temperatures are generally suitable for aquatic organisms and support biological and ecological processes within the river ecosystem. The absence of extreme temperature values suggests that the river is not significantly affected by thermal pollution or industrial thermal discharges.

Turbidity values ranged from 11 to 29 NTU, exceeding the desirable limits recommended for drinking water. Elevated turbidity levels indicate a high concentration of suspended particles in the river water, which may result from increased soil erosion, surface runoff, sediment transport, and anthropogenic disturbances within the watershed. During the monsoon season, intense rainfall accelerates the movement of sediments from agricultural fields, exposed riverbanks, and nearby settlements into the river channel. High turbidity can reduce light penetration, affect aquatic productivity, and facilitate the transport of microorganisms and pollutants attached to suspended particles.

Total Dissolved Solids (TDS) concentrations ranged from 750 to 850 mg/L. Although these values exceed the desirable limit of 500 mg/L prescribed by BIS, they remain below the maximum permissible limit of 2000 mg/L. Elevated TDS concentrations indicate moderate mineralization of river water and may be associated with natural weathering processes, dissolution of rock minerals, and contributions from agricultural runoff. Similarly, Total Suspended Solids (TSS) ranged between 280 and 452 mg/L, indicating substantial particulate matter within the river system. High TSS values further support the influence of monsoonal runoff and sediment transport processes operating in the catchment.

Dissolved Oxygen (DO) concentrations varied from 3.8 to 6.2 mg/L. While some locations exhibited satisfactory oxygen levels capable of supporting aquatic life, values below the CPCB recommended limit of 4 mg/L at certain sites suggest localized oxygen depletion. Reduced DO concentrations may result from increased microbial decomposition of organic matter, sediment oxygen demand, and restricted reaeration in slower-flowing sections of the river.

The Biological Oxygen Demand (BOD) ranged from 2.8 to 5.6 mg/L. Several sampling locations recorded values exceeding the CPCB criterion of 3 mg/L, indicating the presence of biodegradable organic matter in the river. Elevated BOD levels are often associated with domestic wastewater inputs, agricultural runoff, and decomposition of organic debris. Similarly, Chemical Oxygen Demand (COD) values ranged from 3.2 to 5.4 mg/L, suggesting the presence of both biodegradable and non-biodegradable organic compounds. However, the relatively low COD values indicate that severe organic pollution is absent within the studied stretch.

Calcium concentrations ranged from 189.5 to 354.1 mg/L, while magnesium concentrations varied from 108.0 to 136.6 mg/L. Both ions exceeded the desirable limits recommended for drinking water, indicating substantial mineral enrichment of the river water. These elevated concentrations are likely derived from the weathering and dissolution of carbonate and silicate minerals present within the geological formations of the basin. The abundance of calcium and magnesium significantly influenced the hardness characteristics of the river water.

Total Hardness values ranged from 917.8 to 1446.8 mg/L as $CaCO_3$, greatly exceeding the desirable and permissible limits prescribed by BIS and WHO. According to standard hardness classifications, the river water can be categorized as very hard water. Excessive hardness is primarily attributable to high concentrations of calcium and magnesium ions originating from rock-water interactions and natural geochemical processes. Although hard water is not generally considered a direct health hazard, it can reduce the efficiency of soaps and detergents, promote scale formation in pipes and household appliances, and affect the suitability of water for domestic applications.

Overall, the hydrogeochemical assessment indicates that the Asan River exhibits slightly alkaline conditions with moderate mineralization and substantial hardness. While pH and temperature remain within acceptable limits, elevated turbidity, TSS, hardness, calcium, magnesium, and occasional reductions in dissolved oxygen suggest the influence of natural weathering processes combined with anthropogenic inputs and monsoonal runoff. The findings indicate that the river water may require appropriate treatment prior to domestic use and highlight the need for continuous monitoring and watershed management to maintain water quality and ecological integrity.

Interpretation of Average Water Quality

- **pH (7.64)** indicates slightly alkaline water and falls within BIS and WHO permissible limits.
- **Turbidity (20 NTU)** is considerably higher than the recommended drinking water limit, indicating elevated suspended matter.
- **TDS (800 mg/L)** suggests moderate mineralization and exceeds the desirable limit of 500 mg/L.
- **DO (5.0 mg/L)** indicates generally acceptable oxygen availability for aquatic organisms.
- **BOD (4.2 mg/L)** exceeds the CPCB criterion of 3 mg/L, suggesting moderate organic pollution.
- **COD (4.3 mg/L)** indicates the presence of oxidizable organic matter but not severe contamination.

- **Calcium (271.8 mg/L)** and **Magnesium (122.3 mg/L)** are higher than desirable drinking-water limits.
- **Total Hardness (1182.3 mg/L)** classifies the water as **very hard**, primarily due to high calcium and magnesium concentrations resulting from rock-water interaction and mineral weathering.

Overall Assessment

Based on the average values, the Asan River water is slightly alkaline, moderately mineralized, and very hard in nature. While pH and dissolved oxygen are generally satisfactory, elevated turbidity, hardness, calcium, magnesium, and BOD indicate that the water would require treatment before domestic consumption. The hydrochemistry appears to be controlled by both natural geological processes and anthropogenic influences within the watershed.

Water Quality Assessment of the Asan River

Table X. Water Quality Index (WQI) Classification Scheme

WQI Range	Water Quality Status	Suitability for Use
0–25	Excellent	Suitable for drinking without treatment
26–50	Good	Suitable for drinking with minor treatment
51–75	Poor	Suitable for irrigation and industrial use; requires treatment for drinking
76–100	Very Poor	Restricted use; extensive treatment required
>100	Unsuitable for Drinking	Not suitable for direct human consumption

Source: Brown et al. (1970); Tyagi et al. (2013).

Water samples collected from for representative locations(sample) (S-01-S-04) during the monsoon period were analysed to evaluate spatial variation in physico-chemical characteristics. The findings were interpreted in relation to standard drinking water guidelines (WHO and IS:10500) to understand the overall suitability of the river water.

During field observation, the river exhibited noticeable variation in clarity across sampling points. Downstream stretches showed relatively higher suspended load compared to upstream regions. The brownish appearance of water at certain sites can be associated with monsoon-driven surface runoff carrying fine sediments, organic debris, and soil particles into the river channel. Such seasonal influx is typical in foothill river systems where intense rainfall accelerates erosion processes. Although colour and turbidity are primarily aesthetic parameters, persistent high values may indicate increased organic and particulate contamination.

Water Quality Index (WQI)

The Water Quality Index (WQI) was used to assess the overall suitability of Asan River water for domestic purposes. The index integrates multiple physicochemical parameters into a single numerical value representing overall water quality. Parameters such as pH, turbidity, TDS, DO, BOD, calcium, magnesium, and total hardness were considered in the calculation.

The weighted arithmetic index method proposed by Brown et al. (1970) was employed. The quality rating (Qn) for each parameter was calculated using:

$$Qn = [(Vn - Vi) / (Sn - Vi)] \times 100$$

where Vn is the observed value of the parameter, Vi is the ideal value, and Sn is the corresponding standard permissible value.

The unit weight (Wn) for each parameter was calculated as:

$$Wn = K / Sn$$

where K is a proportionality constant and Sn is the standard value of the parameter.

Finally, the overall Water Quality Index was determined using:

$$WQI = \Sigma(QnWn) / \Sigma(Wn)$$

The calculated WQI values were interpreted according to the classification scheme shown in Table X to evaluate the suitability of river water for drinking and other domestic purposes.

Conclusion

The present study assessed the hydrogeochemical characteristics and water quality status of the Asan River, Dehradun, Uttarakhand, through the analysis of key physicochemical parameters including pH, temperature, turbidity, TDS, TSS, DO, BOD, COD, calcium, magnesium, and total hardness. The results revealed that the river water exhibited slightly alkaline conditions, with pH values remaining within the permissible limits prescribed by BIS, WHO, and CPCB standards. Water temperature also remained within the normal range for freshwater ecosystems, indicating favourable environmental conditions for aquatic life.

However, several parameters indicated deterioration in water quality. Turbidity and TSS values were relatively high, reflecting increased sediment transport and surface runoff during the monsoon period. TDS concentrations suggested moderate mineralization of the river water, primarily influenced by natural weathering processes and dissolution of geological materials within the catchment. Dissolved oxygen levels were generally adequate, although values below the recommended threshold at certain locations indicated localized oxygen stress. Elevated BOD values at several sampling sites further suggested the presence of biodegradable organic matter, likely originating from domestic activities, agricultural runoff, and natural decomposition processes.

The concentrations of calcium and magnesium were considerably high, resulting in exceptionally elevated total hardness values ranging from 917.8 to 1446.8 mg/L as $CaCO_3$. These findings indicate strong rock–water interactions and the dominance of carbonate weathering processes within the basin. Based on standard hardness classifications, the river water can be categorized as very hard water. Although hardness does not pose a direct health risk, it may affect domestic usability through scale formation and reduced efficiency of soaps and detergents.

Overall, the hydrogeochemical characteristics of the Asan River reflect the combined influence of natural geogenic processes and anthropogenic activities within the watershed. While the river maintains acceptable pH conditions and moderate organic pollution levels, elevated turbidity, suspended solids, hardness, calcium, and magnesium concentrations indicate concerns regarding water quality for direct domestic consumption. Therefore, appropriate treatment measures are recommended before potable use. Continuous monitoring, effective watershed management, and control of anthropogenic inputs are essential for preserving the ecological health and long-term sustainability of the Asan River system.

Reference

APHA (American Public Health Association). (2023). *Standard Methods for the Examination of Water and Wastewater* (24th ed.). Washington, DC: American Public Health Association.

Bhat, S. U., Dar, S. A., & Hamid, A. (2022). Freshwater resource assessment and hydrogeochemical studies in Himalayan environments. *Scientific Reports, 12*, 5817.

BIS (Bureau of Indian Standards). (2012). *IS 10500: Drinking Water Specification*. New Delhi, India: Bureau of Indian Standards.

Brown, R. M., McClelland, N. I., Deininger, R. A., & Tozer, R. G. (1970). A water quality index—Do we dare? *Water and Sewage Works, 117*(10), 339–343.

Central Pollution Control Board. (2023). *Water Quality Criteria and Classification of Inland Surface Waters*. Ministry of Environment, Forest and Climate Change, Government of India.

Government of India. (2023). *Ramsar Information Sheet: Asan Conservation Reserve*. Ministry of Environment, Forest and Climate Change, New Delhi.

Rawat, J. S., & Rawat, M. S. (2021). Geology and geomorphology of the Doon Valley, Uttarakhand, India. *Journal of Himalayan Earth Sciences, 54*(2), 45–58.

Richards, L. A., Mukherjee, A., & others. (2022). Hydrogeochemical dynamics in river systems and implications for water quality assessment. *Water Research, 211*, 118054.

Sawyer, C. N., McCarty, P. L., & Parkin, G. F. (2003). *Chemistry for Environmental Engineering and Science* (5th ed.). New York: McGraw-Hill.

Sharma, A., Kumar, D., & Singh, R. (2023). Hydrogeochemical processes controlling river water chemistry in Himalayan watersheds. *Environmental Monitoring and Assessment, 195*, 1245.

Sharma, N., Liang, M. C., Laskar, A. H., et al. (2023). Basin-scale geochemical assessment of river water quality. *Water, 15*(11), 2026.

Tiwari, A. K., Singh, A. K., Phartiyal, B., & Sharma, A. (2021). Hydrogeochemical characteristics and water quality assessment in Indian river systems. *Chemistry and Ecology, 37*(9–10), 780–808.

Tyagi, S., Sharma, B., Singh, P., & Dobhal, R. (2013). Water quality assessment in terms of Water Quality Index. *American Journal of Water Resources, 1*(3), 34–38.

Uttarakhand State Wetland Authority. (2022). *Management Plan of Asan Conservation Reserve and Ramsar Site*. Dehradun, Uttarakhand.

Wetzel, R. G. (2001). *Limnology: Lake and River Ecosystems* (3rd ed.). San Diego: Academic Press.

World Health Organization. (2022). *Guidelines for Drinking-water Quality* (4th ed., updated). Geneva: World Health Organization.