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Impact of Anthropogenic Activities on Water Quality: A Comparative Study from Village Sui, Lohaghat, Champawat District (Uttarakhand)

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***Abstract*: Water quality is an important determinant of human health and environmental sustainability. This study compares seasonal variations in the physicochemical parameters of two water bodies in the village Sui located in Lohaghat, Champawat district (Uttarakhand), one situated within a forested area and the other adjacent to a human settlement. Sampling was conducted during the Pre-Monsoon, Monsoon, and Post-Monsoon seasons (2023-25) to evaluate differences in water quality due to natural and anthropogenic factors. Fifteen major parameters Alkalinity (ALK), Calcium (Ca), Chloride (Cl), Color, Dissolved Oxygen (DO), Electrical Conductivity (EC), Fluoride (F), Iron (Fe), Magnesium (Mg), Nitrate (NO_3), pH, Temperature, Total Dissolved Solids (TDS), Total Hardness (TH), and Turbidity (TB) were measured using standard field and laboratory techniques. The results indicate significant seasonal variation, within the forest water body exhibiting an improved water quality, less turbidity, and reduced dissolved impurities compared to the human-influenced site, which recorded elevated TDS, turbidity, and nitrate levels, suggesting contamination risks. The present study emphasizes the need for sustainable water management practices to conserve the conventional water bodies like Naulas and Dharas found in the Kumaun Himalayas, which are under threat from anthropogenic pressures. The present study also provides a baseline for future studies on human activity impacts on mountain water systems and the necessity of preserving traditional water bodies for long-term water security and sustainability.**

***Keywords*: Water Quality, Sustainability, Naula, Dhara, Himalayas, Water Conservation**

I. INTRODUCTION

Water is essential for shaping the Earth's landscape, regulating the climate, and profoundly supporting all forms of life on our planet (Agarwal et al., 2016; Jana et al., 2017; Jeelani et al., 2018). It fosters ecological stability, sustains human life, and drives economic growth (Chhimwal et al., 2022). Although water is naturally abundant, freshwater resources are limited and increasingly threatened by pollution, excessive extraction, and climate change (Barakat et al., 2018; Chhimwal et al., 2022). The urgent need for sustainable management and conservation of water resources is required due to the rising demand for safe and clean water (Aithani et al., 2021).

The Himalayan region serves as a vital source of freshwater for millions, providing water through an intricate network of rivers, lakes, and ground reservoirs (Pant and Rawat, 2015; Basumajumdar, 2016; Seth et al., 2016; Jana et al., 2021; Chhimwal et al., 2022). Among these, the Kumaun Himalaya stands out as a significant region within the Indian Himalayas, rich in natural water bodies that have sustained the local communities (Pant and Rawat, 2015; Basumajumdar 2016; Seth et al., 2016; Jana et al., 2021; Chhimwal et al., 2022). This area is renowned for having unique traditional sources of water like Naulas and Dharas, which have been used over centuries as sources of drinking water and for domestic purposes (Sharma, 2016; Sinha et al., 2021; Bhandari and Kaur, 2023). These ancient systems are not only of historical and cultural importance but also hold practical value today, offering clean and reliable fresh water where modern water supply infrastructure is limited or absent (Maindoli et al., 2018; Sinha et al., 2021).

Naulas are little step wells or percolation wells that are purposefully constructed to collect and store groundwater (Bhandari and Kaur, 2023). They play a vital role in harvesting and conserving water, ensuring year-round access to clean drinking water for villagers, even during periods of drought (Chauhan et al., 2020b; Bhandari and Kaur, 2023). In contrast, Dharas are natural springs that appear along the mountain slopes and usually serve as reliable sources of water in remote villages (Chauhan et al., 2020b; Paliyal et al., 2024). Both Naulas and Dharas have long been integral to sustaining rural communities; however, these traditional water sources are now under severe threat due to rapid urbanisation, widespread deforestation, and increasing contamination (Panwar, 2020; Azam et al., 2022; Chhimwal et al., 2022).

Water conservation has become essential due to the rapid depletion of natural water sources (Chauhan et al., 2020a; Prasad et al., 2021; Azam et al., 2022; Chhimwal et al., 2022). Human activities such as deforestation, unregulated construction, and improper waste disposal have reduced the quality and quantity of available water (Chauhan et al., 2020a; Prasad et al., 2021; Bhattacharya et al., 2024). In particular, contamination from sewage, agricultural runoff, and industrial effluent poses a serious threat to human health and ecological balance (Bhattacharya and Bhattacharya, 2020; Kumar et al., 2023; Thakur et al., 2023; Upreti et al., 2024). The water resources of the Kumaun region are especially vulnerable to these challenges, making issues of water quality and accessibility increasingly urgent (Bhattacharya and Bhattacharya, 2020; Kumar et al., 2023; Upreti et al., 2024).

The deterioration in water quality is also witnessed in most water bodies, particularly those located close to human habitations (Bhandari and Kaur, 2023). Increased levels of pollutants, turbidity, and concentrations of toxic chemicals have been noted in such places, highlighting the requirement for effective water management and conservation strategies (Chauhan et al., 2020a; Chhimwal et al., 2022; Bhandari and Kaur, 2023). The maintenance of traditional water bodies like Naulas and Dharas is crucial not only to ensure continued water availability but also ecological balance (Bhattacharya and Bhattacharya, 2020; Kumar et al., 2023; Upreti et al., 2024).

The present study aims to assess the seasonal variation in water quality parameters by comparing a forest-based water body with one located near a human-inhabited area in Village Sui. By analysing key physicochemical parameters during different seasons, the study highlights the impact of human activities on water quality.

Study Area

The study was conducted in Village Sui (Pau), located near the town Lohaghat in district Champawat, Uttarakhand, within the Kumaun Himalayan region. This village has a population of approximately 1573 individuals, out of which 871 are males and 702 are females, having 485 households (https://villageinfo.in). Two traditional water bodies (Naulas) were taken for the study: one situated within a Deodar-dominated Forest on the upper slopes above the village, and the other located in the densely populated central area of the village Fig. 3.

II. Materials and Methods

A total of 18 water samples (triplicate samples from two sites across three seasons i.e. Pre-Monsoon, Monsoon, and Post-Monsoon) were collected for analysis. The physicochemical parameters such as Alkalinity (ALK), Calcium (Ca), Chloride (Cl), Color, Dissolved Oxygen (DO), Electrical Conductivity (EC), Fluoride (F), Iron (Fe), Magnesium (Mg), Nitrate (NO_3), pH, Temperature, Total Dissolved Solids (TDS), Total Hardness (TH), and Turbidity (TB)were analysed to assess seasonal variations and compare water quality between the two selected study sites.

Water samples were carefully collected using pre-cleaned, sterilized polyethene sample bottles at a depth of approximately 30 cm below the surface. The bottles were immediately sealed tightly and tagged with important details such as location, date, and time of sampling. The field samples were brought under controlled conditions to the laboratory for analysis. Parameters like pH, electrical conductivity, and temperature were recorded on-site with portable digital meters. Remaining parameters were analysed following standard procedures prescribed by the APHA (2017).

III. Results and Discussion

The comparative study of water quality between the forest-based and community-based water bodies in Village Sui shows the influence of anthropogenic pressures on natural water sources. The forest water body with minimal human activity exhibited relatively stable and better-quality water throughout all seasons, while the community water body had higher concentrations of pollutants, particularly during the monsoon season (Table 1 and Table 2; Fig. 1 and Fig. 2).

Total Hardness (TH), primarily influenced by calcium and magnesium concentrations, is a critical indicator of water quality. Elevated hardness often arises from mineral leaching, especially in areas with human interference or altered landscapes. In this study, hardness values were consistently higher in the human-inhabited water body (235.49–299.33 mg/L) compared to the forest source (195.83–288.33 mg/L), with monsoon seasons recording the peak levels, likely due to increased surface runoff and erosion. Calcium (Ca) levels were slightly higher in the community site (up to 30.42 mg/L) compared to the forest site (up to 28.42 mg/L) (Table 1 and 2). Magnesium (Mg) values ranged from 13.63 to 23.93 mg/L in community water bodies and 12.63 to 21.93 mg/L in forest water bodies, following a similar pattern to calcium, which suggests possible anthropogenic inputs and soil disturbances. These minerals, while essential in small amounts, in excess can cause scaling and affect water usability (Kumar and Puri, 2012).

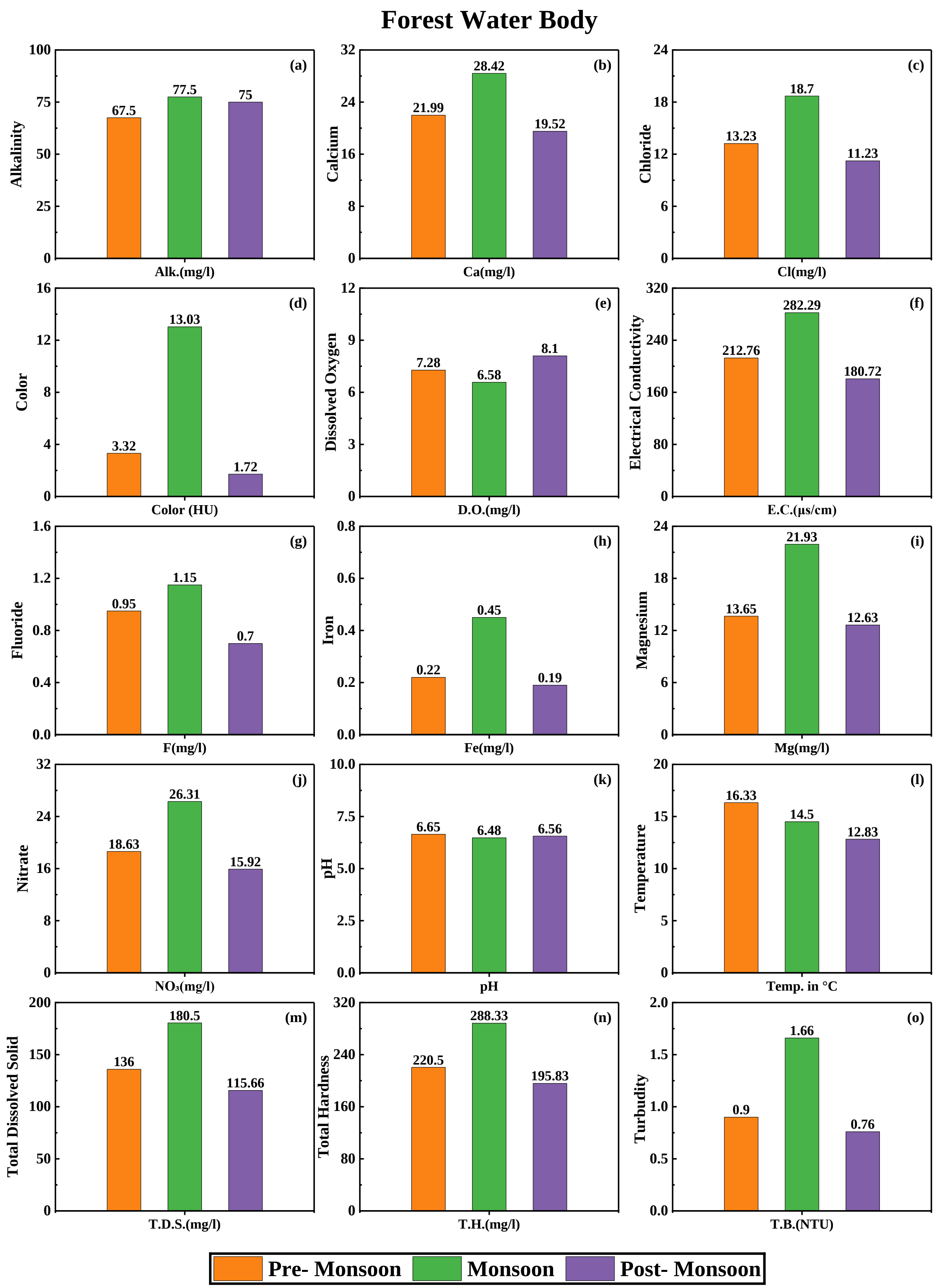

Fig. 1: Water quality parameter variations in different seasons in the forest water body of the village Sui

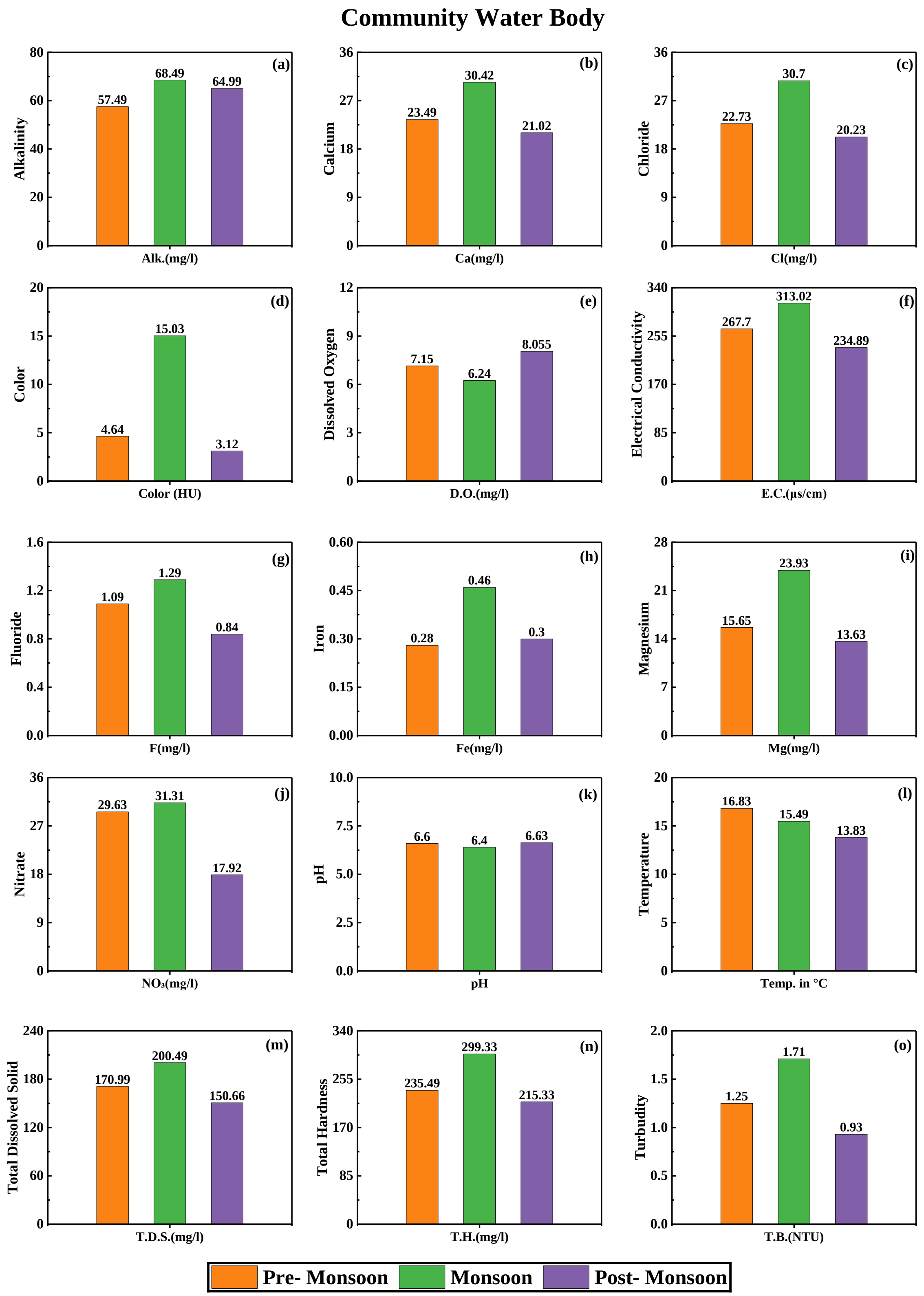

Fig. 2: Water quality parameter variations in different seasons in the community water body of village Sui

Fig. 3: (A) Community Water Body, (B) Horticulture activity near community water body, (C) Water availability in community water body, (D) Collection of water sample from forest water body, (E) Agricultural fields in the village, (F) Forest area of the village

TABLE 1
Variation in water quality parameters of the forest water body in village Sui across different seasons (2023-25)

Parameters	Seasons		
	Pre-Monsoon	Monsoon	Post-Monsoon
ALK (mg/L)	67.5	77.5	75
Ca (mg/L)	21.99	28.42	19.52
Cl (mg/L)	13.23	18.7	11.23
Color (HU)	3.32	13.03	1.72
DO (mg/L)	7.28	6.58	8.10
EC (µs/cm)	212.76	282.29	180.72
F (mg/L)	0.95	1.15	0.7
Fe (mg/L)	0.22	0.45	0.19
Mg (mg/L)	13.65	21.93	12.63
NO_3 (mg/L)	18.63	26.31	15.92
pH	6.65	6.48	6.56
TB (NTU)	0.9	1.66	0.76
TDS (mg/L)	136	180.5	115.66
Temperature (°C)	16.3	14.5	12.8
TH (mg/L)	220.5	288.33	195.83

Turbidity, a key physical parameter, determines water clarity and quality. It often indicates whether groundwater may be under the influence of surface water sources (Rana et al., 2024). Elevated turbidity levels are usually a sign of suspended particles, which can result from soil erosion, surface runoff, or anthropogenic contamination pathways (Bilotta and Brazier, 2008). In this study, turbidity was found slightly higher in the community water body (1.25–1.71 NTU) than in the forest source (0.76–1.66 NTU), especially during monsoon, likely due to greater human activity and surface influence (Table 1 and 2). Although values remained within WHO (< 5 NTU) permissible limits, the seasonal rise highlights the need for regular monitoring (WHO, 2017).

pH values at both sites remained within a moderately acidic to neutral range, slight acidification was observed in the community water body, particularly during the monsoon season, aligns with previous findings by Bhat et al. (2010), Chauhan et al. (2020a), Kumar et al. (1997), who reported similar acidic compositions in natural springs across Kashmir, Pauri (Uttarakhand), and Almora (Uttarakhand), respectively. This acidity can often be attributed to the leaching of organic acids from surrounding soil and vegetation, as well as the influence of acid rain, especially in forested or mountainous catchments.

Electrical conductivity (EC) and total dissolved solids (TDS) are indicators of the ionic content in water. An increase in dissolved ions directly raises both EC and TDS. (Yilmaz and Koç, 2014). In this study, the forest spring consistently had lower values of EC, ranging from 180.72 to 282.29 µs/cm, and TDS from 115.66 to 180.5 mg/L, compared to the human-inhabited spring, which showed EC values between 234.89 and 313.02 µs/cm and TDS from 150.66 to 200.49 mg/L (Table 1 and 2). The elevated levels in the latter may result from detergents, sewage runoff, road leachates, and fertiliser use, reflecting a clear impact of human activity (Barakat et al., 2016).

TABLE 2
Variation in water quality parameters of community water body in village Sui across different seasons (2023-25)

Parameters	Seasons		
	Pre-Monsoon	Monsoon	Post-Monsoon
ALK (mg/L)	57.49	68.49	64.99
Ca (mg/L)	23.49	30.42	21.02
Cl (mg/L)	22.73	30.7	20.23
Color (HU)	4.64	15.03	3.12
DO (mg/L)	7.15	6.24	8.05
EC (µs/cm)	267.7	313.02	234.89
F (mg/L)	1.09	1.29	0.84
Fe (mg/L)	0.28	0.46	0.3
Mg (mg/L)	15.65	23.93	13.63
NO_3 (mg/L)	29.63	31.31	17.92
pH	6.6	6.4	6.63
TB (NTU)	1.25	1.71	0.93
TDS (mg/L)	170.99	200.49	150.66
Temperature (°C)	16.8	15.5	13.8
TH (mg/L)	235.49	299.33	215.33

TDS levels were observed to be lower in the forest water body, with values of 136 mg/L, 180.5 mg/L, and 115.66 mg/L, compared to higher concentrations of 170.99 mg/L, 200.49 mg/L, and 150.66 mg/L at the human-inhabited site (Table 1 and 2). This variation suggests that human activities may contribute to an increase in dissolved solids in water bodies. However, all recorded TDS values in both sites fall within the "excellent to good" range based on WHO and BIS standards, which classify 50–150 mg/L as excellent and 150–300 mg/L as good for drinking purposes. This indicates that while the human-influenced site has relatively higher TDS levels, the water at both sites remains within safe limits for consumption. Nonetheless, elevated TDS could suggest changes in water quality over time, and continued monitoring is recommended.

Water temperature plays a key role in regulating other physico-chemical parameters such as dissolved oxygen and microbial activity (Delpla et al., 2009). In this study, the forest water body recorded slightly lower temperatures, i.e., 16.3°C (Pre-Monsoon), 14.5°C (Monsoon), and 12.8°C (Post-Monsoon), compared to the human-inhabited source, which showed slightly higher values of 16.8°C, 15.5°C, and 13.8°C (Table 1 and 2). These differences, though minimal, can be linked to reduced vegetation cover and greater exposure in inhabited areas. All recorded temperatures fell within the normal range, posing no direct threat to water quality but reflecting subtle impacts of human activity (Bhat et al., 2010; Chauhan et al., 2020b).

Alkalinity (ALK) reflects the buffering capacity of water against pH changes. The forest water body consistently showed higher alkalinity (67.5–77.5 mg/L) compared to the human-influenced site (57.49–68.49 mg/L) (Table 1 and 2), suggesting a more stable and natural mineral balance in undisturbed ecosystems (APHA, 2017).

Chloride (Cl) concentrations were significantly higher in the human-inhabited area (22.73–30.7 mg/L) compared to the forest site (11.23–18.7 mg/L) (Table 1 and 2). This elevation can be attributed to a combination of anthropogenic sources such as domestic effluents, agricultural fertilizers, and septic system leakage, as well as natural inputs including rainfall, dissolution of Cl^- bearing minerals, and fluid inclusions (Ritzi et al., 1993; Jeong, 2001; Barakat et al., 2018). Although chlorides are generally not harmful to the human body, when present as sodium salts, they can potentially affect heart and kidney function (Kumar and Puri, 2012).

Nitrate (NO_3) levels showed a similar pattern, with significantly elevated concentrations in the community site (up to 31.31 mg/L) compared to the forest source (up to 26.31 mg/L), particularly during the monsoon. This spike could be attributed to surface leaching from fertilizers, domestic effluent, atmospheric precipitation and organic waste (Makhijani and Manoharan, 1999).

Iron (Fe) levels, while within permissible limits, were slightly higher in human-influenced water (up to 0.46 mg/L) (Table 1 and 2), likely due to metal corrosion and soil leaching in disturbed environments (BIS, 2012).

Fluoride (F) level was higher in the human-inhabited site (up to 1.29 mg/L), compared to the forest (up to 1.15 mg/L) (Table 1 and 2), though all values remained within safe limits. Elevated fluoride may result from geogenic sources as well as human activities.

Electrical Conductivity (EC) and Total Dissolved Solids (TDS) showed a clear correlation, with higher values in the community site, indicating a greater concentration of dissolved ions due to runoff and anthropogenic contamination (Yilmaz and Koç, 2014). Colour (HU) was noticeably more intense in the human-influenced water body, especially during the monsoon (up to 15.03 HU), which may be due to increased organic and inorganic particulate matter. Dissolved Oxygen (DO) was found to be consistently higher in the forest water body (6.58–8.10 mg/L) (Table 1 and 2), which reflects better aeration, lower organic load, and overall ecological health, in contrast to reduced levels in human-impacted areas.

IV. Conclusion

The present study highlights the significant impact of human activities on the quality of traditional water sources in Village Sui (Pau), situated in the Lohaghat of the Kumaun Himalayan region. By comparing the seasonal variation in physicochemical parameters between a forest water bodies and a community water bodies, it is concluded that areas with minimal human interference, such as forest zones tend to maintain better water quality because of natural filtration, less human intervention, and more dissolved oxygen. In contrast, water sources located near human settlements show higher levels of contamination, likely due to factors such as domestic waste discharge, agricultural runoff, soil erosion and poor sanitation practices. Thus, the present study focuses on the urgent need to conserve and revive traditional water sources to ensure safe drinking water, long-term water security and ecological sustainability.

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