

Seasonal Variations in Forested Stream Water Quality of Nagaland, North-East India

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Abstract

This research explores the seasonal variations in the physico-chemical characteristics of the Khichi Ghoki forested stream at Lumami village, Zunheboto district, Nagaland, during winter (January, 2024) and spring (April, 2024). Eleven parameters viz., water temperature, pH, electrical conductivity, total dissolved solids (TDS), dissolved oxygen (DO), total hardness, calcium hardness, magnesium hardness, chloride, total alkalinity and light intensity were analysed and compared with WHO drinking water standards. Temperature, conductivity, and chloride increased in spring while DO, alkalinity and hardness were higher in winter, reflecting natural hydrological and shifts in atmospheric temperature. Mean values of all parameters remained within WHO permissible limits, with TDS (156.11 mg/L), total hardness (87.89 mg/L), DO (6.94 mg/L) and pH (6.54) indicating a clean, soft-water system typical of minimally disturbed forested catchments. Overall, the stream water remained suitable for domestic use in both seasons. Continued monitoring is recommended to detect long-term trends as anthropogenic pressures in the catchment gradually increases.

Keywords: Water quality; Seasonal variation; Physico-chemical parameters; Forested stream; Nagaland.

Introduction

Freshwater ecosystems are essential for ecological functioning, human consumption and agricultural activities, yet they remain highly vulnerable to degradation due to increasing anthropogenic pressures and climatic variability. Surface waters such as streams and rivers show strong spatial and temporal variations in their physico-chemical characteristics, driven by natural factors—including geology, runoff, hydrology, rainfall patterns and organic matter input—as well as human influences such as settlement expansion, land-use change, and agriculture [1, 2]. Seasonal fluctuations are particularly important in hill forest ecosystems where changes in precipitation, temperature and catchment hydrology alter ionic composition, dissolved oxygen, alkalinity, and nutrient dynamics [3]. Monitoring these variations is crucial for maintaining ecosystem stability and determining water suitability for drinking and domestic use, especially in rural communities where streams are primary water sources.

The assessment of physico-chemical parameters such as pH, temperature, dissolved oxygen (DO), hardness, conductivity, alkalinity and total dissolved solids (TDS) provides valuable insight into water quality status and potential contamination risks. Global guidelines such as those of the World Health

Organization (WHO) serve as benchmarks for identifying safe drinking water and detecting emerging threats from pollution or watershed disturbance[4]. With increasing dependence on freshwater systems and rising environmental pressures, regular monitoring of hill streams has become essential for early detection of changes that may compromise human health, agriculture, or aquatic biodiversity[5].

Nagaland, located within the Indo-Myanmar biodiversity hotspot, harbours extensive forest cover, steep terrain, and high rainfall, making its streams sensitive to seasonal hydrological shifts. The Khichi Ghoki stream at Lumami village in Zunheboto district is an important freshwater source for nearby households and agricultural activities. Although largely surrounded by forest, the stream is increasingly influenced by settlement-related activities and catchment disturbances, raising the need for systematic water quality assessment across seasons. Given the ecological fragility of the region and the dependence of local communities on stream water, understanding how water quality varies between winter and spring is essential for both conservation and public health decision-making.

Therefore, the current research investigates the seasonal variations in key physico-chemical parameters of the Khichi Ghoki forested stream and evaluates its suitability for

domestic use by comparing observed values with WHO permissible limits. This work provides baseline information for water quality monitoring in highland villages of Nagaland and offers insights into how natural seasonal processes shape stream chemistry in a forested hill environment.

Materials and Methods

Study Area

The sampling stations were selected along the Khichi Ghoki forested stream located near Lumami village, Zunheboto district, Nagaland, India (Latitude 26.216588°N and Longitude 94.49844°E). The area lies at an elevation of 1874 m above msland is characterized by steep forested slopes typical of the Indo-Myanmar biodiversity hotspot. The region receives an average annual rainfall of about 200 cm, with heavy precipitation occurring between June and September. Winters are cold (often near 10 °C), while spring transitions into warmer temperatures. The stream flows through largely undisturbed forest patches before entering agricultural and settlement zones, where it serves as a primary water source for local communities.

Sampling Design and Water Collection

Surface water samples were collected during two distinct seasons: winter (January 2024) and spring (April, 2024) from upstream, midstream and downstream. At each sampling event, water was collected in pre-cleaned 1-L acid-washed polyethylene bottles. Bottles were rinsed on site with stream water prior to collection to prevent contamination. Samples were filled without leaving air space, tightly capped, labelled with date and season and transported to the Ecology Laboratory, Department of Botany, Nagaland University for immediate analysis.

Physico-chemical Parameters Analysed

A total of eleven parameters were assessed viz., Water Temperature (°C), pH, Electrical Conductivity (µS/cm), Total Dissolved Solids (TDS; mg/L), Dissolved Oxygen (DO; mg/L), Total Hardness (mg/L), Calcium Hardness (mg/L), Magnesium Hardness (mg/L), Chloride (mg/L), Total Alkalinity (mg/L) and Light Intensity (Lux; abiotic parameter) as per Trivedy and Goel [6] and APHA [7].

Results and Discussion

Seasonal variation in water quality parameters of the Khichi Ghoki forested stream displayed clear shifts between winter and spring, reflecting the influence of changing temperature, hydrological conditions, and catchment processes. A summary of all parameters is presented in Table 1.

Water Temperature and pH

Water temperature increased from 18.83 °C in winter to 23.11 °C (Fig. 1) in spring, with an overall mean of 20.97 ± 3.02 °C, remaining well within the WHO [8] guideline of 30–35 °C. This seasonal rise is consistent with natural warming during

pre-monsoon periods typical of hill ecosystems, which can influence metabolic activity, solubility of gases and microbial processes in stream water. The pH values (Fig. 2) showed minimal seasonal variation, ranging from 6.61 (winter) to 6.47 (spring), with a mean of 6.54 ± 0.09 , falling within the WHO acceptable range (6.5–8.5). Marginally acidic values are characteristic of forested catchments dominated by organic matter input and limited anthropogenic alkalinity sources. Similar mildly acidic conditions in unpolluted hill streams have been reported by Salmiati et al. [9]. Water temperature was higher at the upstream during spring.

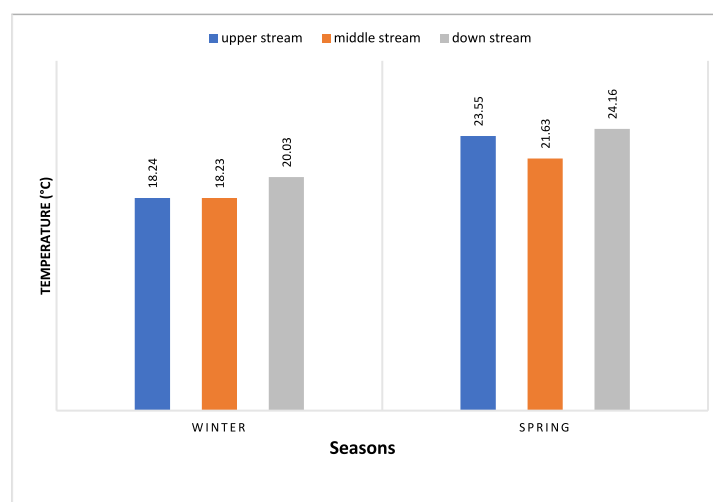


Fig. 1: Seasonal variation in water temperature at the study site

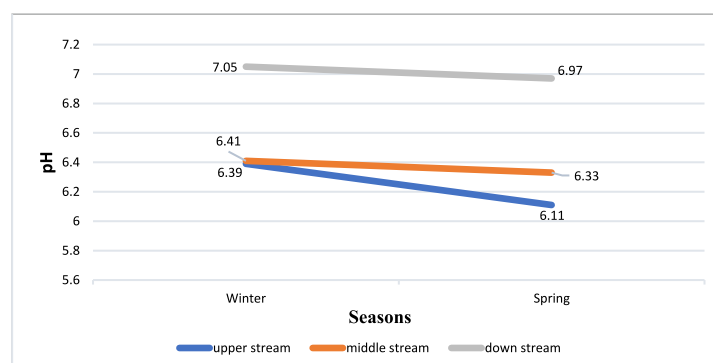


Fig. 2: Seasonal variations in pH at the study site

Conductivity and TDS

Conductivity (Fig. 3) displayed a marked seasonal increase from 172 µS/cm (winter) to 284.1 µS/cm (spring), giving a mean of 228.05 ± 7.26 µS/cm, which is well below the WHO limit of 750 µS/cm. Spring conductivity elevation likely reflects enhanced ionic concentration due to higher temperatures, increased mineral dissolution, and reduced dilution relative to winter flows [10]. Alongside this, TDS (Fig. 4) values remained low and stable (160 mg/L in winter; 152.22 mg/L in spring), with a mean of 156.11 ± 5.50 mg/L, far below the permissible limit (500 mg/L). The overall ionic strength thus indicates a clean, low-mineral stream system typical of forested catchments with limited anthropogenic discharge [11].

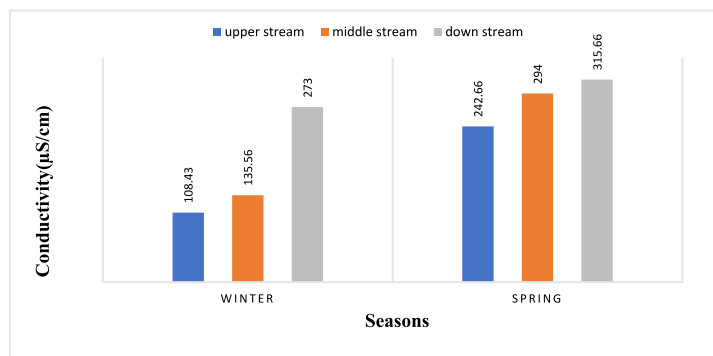


Fig. 3: Seasonal variations in conductivity at the study site

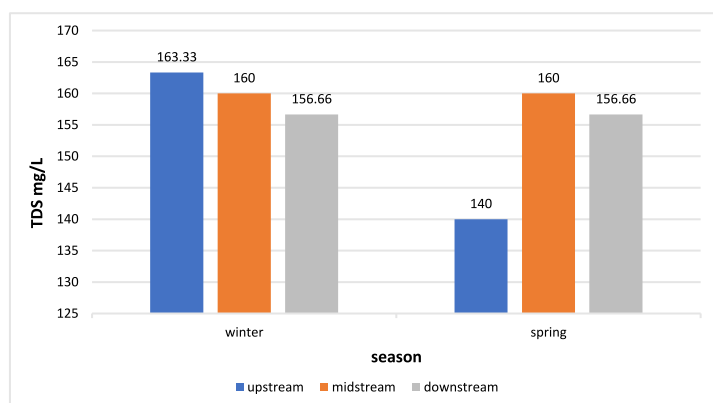


Fig. 4: Seasonal variations in TDS at the study site

Dissolved Oxygen (DO)

DO (Fig.5) ranged from 7.38 mg/L in winter to 6.51 mg/L in spring, averaging 6.94 ± 0.61 mg/L, which fits well within WHO guidelines (5.0–7.0 mg/L). Higher winter DO is expected due to lower temperatures and increased solubility of oxygen, whereas the slight decline in spring can be attributed to warming water, increased microbial respiration and potential organic load from early spring runoff [12, 13]. Nonetheless, DO remain adequate to support aquatic life and indicates good aeration and low organic pollution.

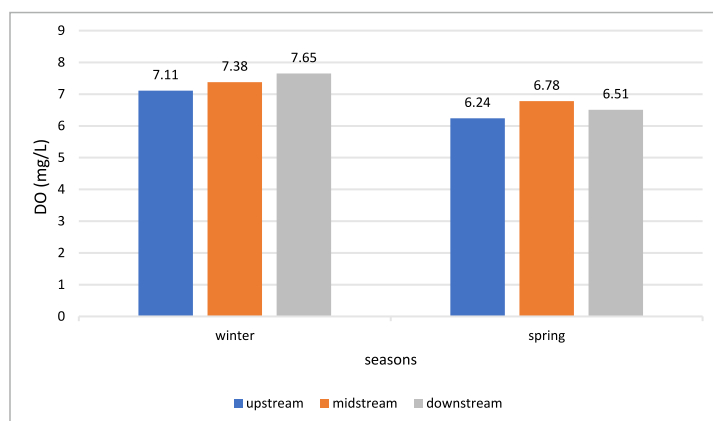


Fig. 5: Seasonal variations in DO at study site

Hardness Parameters

Total hardness (Fig. 6) showed a moderate seasonal decrease (92 mg/L in winter; 83.77 mg/L in spring), averaging 87.89 ± 5.82 mg/L, substantially below the WHO limit of 300 mg/L. Calcium hardness (Fig. 7) also declined from 26.72 mg/L to 19.06 mg/L, with a mean of 22.89 ± 5.41 mg/L, again well within permissible limits. Magnesium hardness (Fig. 8)

followed a similar pattern (9.2 mg/L winter; 6.76 mg/L spring; mean 7.98 ± 1.72 mg/L). These values classify the stream as soft water, typical of high-rainfall forested catchments where weathering rates are low and dilution is high. Seasonal decreases likely reflect spring runoff effects that dilute base cations as temperatures rise and snow/soil moisture inputs increase [14].

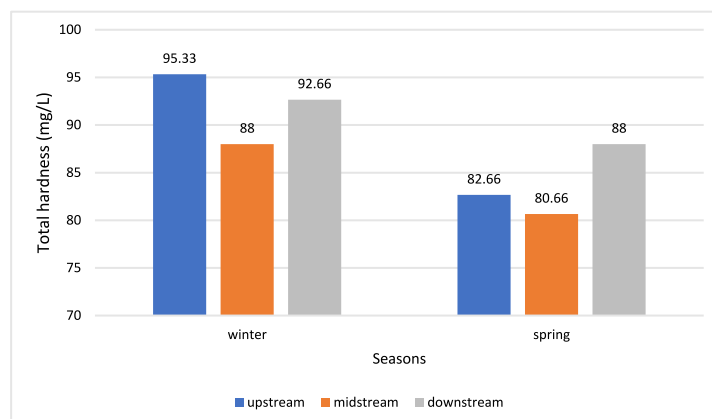


Fig. 6: Seasonal variations in Total hardness at the study site

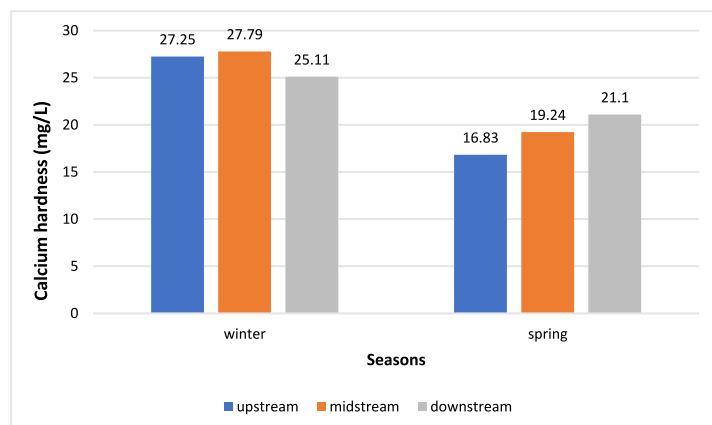


Fig. 7: Seasonal variations in Calcium hardness at the study site

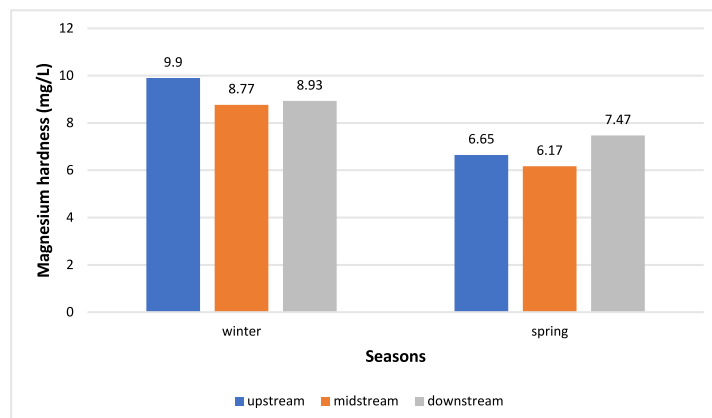


Fig. 8: Seasonal variations in Magnesium hardness

Chloride and Alkalinity

Chloride concentration (Fig. 7) increased from 38.02 mg/L in winter to 52.85 mg/L in spring (mean 45.43 ± 1.48 mg/L), remaining far below the WHO permissible limit (250 mg/L). The spring increase can be attributed to evaporative concentration, catchment leaching and minor anthropogenic inputs from nearby settlements [15]. Total alkalinity (Fig. 8) decreased sharply from 83.33 mg/L in winter to 46.66 mg/L in spring, averaging 64.99 ± 5.93 mg/L, all well within WHO

limits (120 mg/L). Higher winter alkalinity may be due to increased bicarbonate content from slower flow rates and reduced dilution. The substantial spring decline corresponds with enhanced runoff, which dilutes bicarbonates and reduces buffering capacity [16].

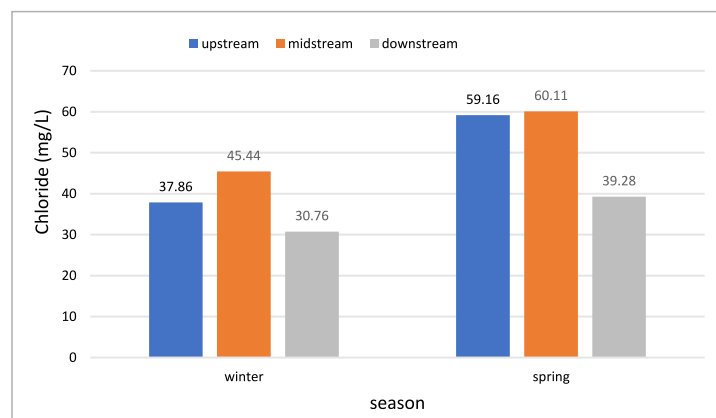


Fig. 7: Seasonal variations in Chloride at study site

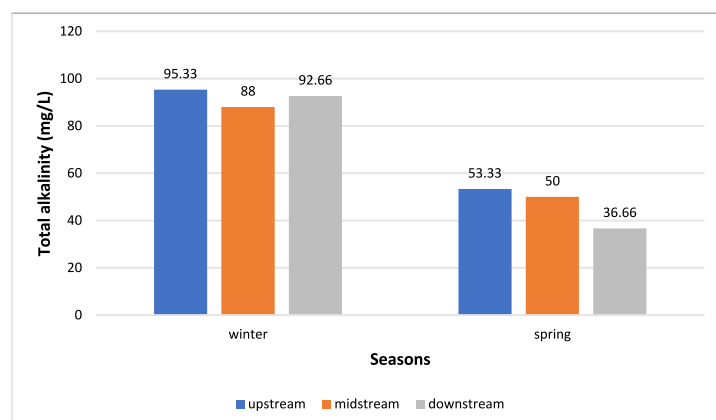


Fig. 8: Seasonal variations in Total alkalinity

Light Intensity (Abiotic Parameter)

Light intensity (Fig. 9) showed clear seasonal variation, increasing from winter to spring in response to changing canopy conditions and solar radiation. Although numerical limits for light intensity are not defined under WHO drinking water guidelines, its seasonal pattern is ecologically relevant. Lower winter light levels correspond to cloudier conditions, reduced day length and higher shading from surrounding forest vegetation. In contrast, increased spring light intensity reflects brighter conditions and reduced canopy obstruction before full leaf-out in many hill species. Changes in light intensity can indirectly influence stream water chemistry by affecting photosynthetic activity, primary production and oxygen dynamics. The slight decline in dissolved oxygen from winter to spring observed in this study aligns with this pattern—higher winter shading and lower temperature favour oxygen solubility, while increased spring light and warming can enhance respiration rates in biofilms and aquatic organisms.

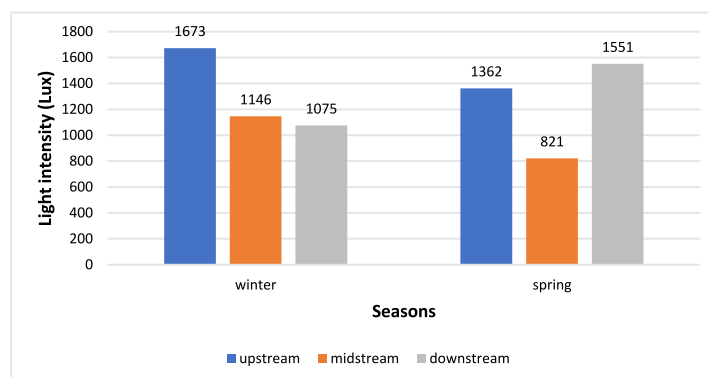


Fig. 9: Seasonal variations in Light intensity

Overall Water Quality

Comparison with WHO drinking water standards indicates that all measured parameters fall within safe limits in both winter and spring. Variations observed across seasons correspond primarily to natural hydrological and temperature-driven processes rather than pollution signatures. The stream's low TDS, soft water character and adequate DO content collectively indicate a clean, minimally impacted freshwater system. Seasonal fluctuations such as increased conductivity and chloride in spring, and reduced alkalinity, likely reflect pre-monsoon concentration effects and hydrological transitions rather than contamination. Such patterns match observations in other upland streams where temperature, catchment runoff and organic matter inputs govern short-term chemical dynamics [17, 18]. Overall, the Khichi Ghoki forested stream retains good water quality across seasons and remains suitable for domestic use. Continued monitoring, however, remains essential due to increasing anthropogenic pressures in the catchment.

Table 1: Water parameters from two seasons and WHO standard limits

Parameters	Seasons		Mean $\pm$ S.D	WHO permissible Limits
	Winter	Spring		
Water Temperature($^{\circ}$ C)	18.83	23.11	20.97 $\pm$ 3.02	30-35
pH	6.61	6.47	6.54 $\pm$ 0.09	6.5-8.5
TDS (mg/L)	160	152.22	156.11 $\pm$ 5.50	500
DO (mg/L)	7.38	6.51	6.94 $\pm$ 0.61	5.0-7.00
Total Hardness (mg/L)	92	83.77	87.885 $\pm$ 5.81	300
Calcium hardness(mg/L)	26.72	19.06	22.89 $\pm$ 5.41	100
Magnesiumhardness(mg/L)	9.2	6.76	7.98 $\pm$ 1.72	150
Conductivity (μ S/Cm)	172	284.1	228.05 $\pm$ 7.26	750
Chloride(mg/L)	38.02	52.85	45.43 $\pm$ 1.48	250
Total Alkalinity (mg/L)	83.33	46.66	64.995 $\pm$ 5.92	120

Conclusion

The present study assessed seasonal variations in the physico-chemical characteristics of the Khichi Ghoki forested stream at Lumami village, Zunheboto district, Nagaland.

All measured parameters, including pH, temperature, dissolved oxygen, hardness, conductivity, alkalinity and TDS, remained within WHO permissible limits during both winter and spring seasons. Although natural seasonal shifts were evident, such as increased conductivity and chloride concentration in spring and higher alkalinity and DO in winter, none indicated pollution or degradation of water quality. Overall, the stream exhibited the characteristics of a clean, soft-water system typical of minimally impacted forested catchments. The observed patterns primarily reflect natural hydrological and temperature-driven processes rather than anthropogenic disturbances. Given that the stream serves as a water source for nearby communities, these results provide reassurance regarding its present suitability for domestic use. However, considering growing settlement pressures and land-use changes in the surrounding catchment, regular monitoring of stream water quality is recommended. Establishing long-term data sets will also help detect emerging trends and support effective management of freshwater resources in the ecologically fragile upland landscapes of Nagaland.

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