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Seasonal and Spatial assessment of Physico-chemical and Microbiological water quality of the Sohiong River, Meghalaya, India

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Abstract

The current study analyzes the Sohiong River's physico-chemical and microbiological quality in the East Khasi Hills District of Meghalaya, as well as its seasonal and geographical variations. Water samples were collected from upstream, midstream, and downstream areas during the rainy and dry seasons. Standard laboratory methods were employed to analyze the parameters of pH, temperature, electrical conductivity, hardness, alkalinity, chloride, sulphate, nitrate, phosphate, biological oxygen demand (BOD), and total coliform. Descriptive statistical analysis, correlation analysis, and Water Quality Index (WQI) were used to interpret the results. The data obtained from the study show that most of the physicochemical parameters were found to be within acceptable limits in both seasons, with relatively stable pH (6.49-7.25), temperature, and conductivity. Descriptive statistics showed that the parameters had low spatial variability for pH, temperature, conductivity, and BOD, but high variability for sulphate, chloride, and total coliform. Pearson correlation analysis showed that there were significant relationships between various parameters, indicating the effect of seasonal hydrological conditions on nutrient and ionic cycles. The river water quality was good to exceptional during both the wet and dry seasons, with somewhat higher values during the dry season, according to the estimated WQI. However, total coliform levels were found to be as high as 1600 MPN/100mL in some places, despite the favorable physicochemical conditions, indicating microbiological contamination. In general, the study proves that although the Sohiong River has good physico-chemical water quality, microbial pollution is still a concern, emphasizing the need of regular monitoring and remediation strategies.

Keywords: Sohiong River, Water quality assessment, Seasonal variation, Physico-chemical parameters, Total coliform, Water Quality Index (WQI).

Introduction

Water makes up 71% of the Earth's surface and is essential to human survival because of its many uses, which include drinking, cooking, cleaning, irrigation, and a variety of industrial processes[1]. Freshwater rivers constitute a vital element of Earth's hydrosphere and are important contributors to life and human civilizations as a source of fresh drinkable water for human consumption, agricultural activities, and other human activities like sanitation and recreation[2]. Unfortunately, river water quality continues to worsen around the globe due to processes like urbanization and industrial activities as well as climate change and agricultural activities[3]. Changes in physico-chemical characteristics, such as pH, dissolved oxygen content, and pollution levels, have a direct effect on river water quality because they affect a river's biological integrity and influence chemical toxicity. These changes are an essential parameter in evaluating river ecosystem integrity based on biological and physio-chemical properties, according to numerous studies conducted worldwide[4]. The physico-chemical and biological properties of river water are important measures of river quality as it reflects both present and long-term changes to an ecosystem due to pollution and other activities[5].

The primary objective of water analysis is to provide a single value corresponding to water quality of the water source by transforming the list of parameters and their concentration found in water into one value, and hence an extensive water is interpreted from the provided single value of water suitably utilized for various activities like consumption, farming, and fishing, etc.[6].

India's rivers face growing pollution from untreated sewage, agricultural runoff, industrial effluents, and solid waste dumping, leading to serious ecological and public health challenges across the country. According to the Central Pollution Control Board's (CPCB) latest 2025 report, there are 296 polluted river stretches (PRS) across 271 rivers in 32 states and union territories, slightly lower than the 311 reported in previous assessments, with monitoring conducted at 4,736 locations including 2,155 river sites[7]. Domestic sewage accounts for 75–80% of surface water pollution, largely due to rapid urbanization and inadequate infrastructure[8]. In addition, agricultural runoff introduces pesticides and fertilizers into water bodies, while industrial effluents contribute heavy metals such as lead, chromium, and mercury, which bio-accumulate in aquatic life and pose risks to both ecosystems and human health[9].

Several studies in India have assessed river water quality by comparing measured parameters with national and international standards. For instance, a water quality assessment of the Bhima River reported that physicochemical parameters such as EC, TDS, hardness, and alkalinity exceeded the permissible limits set by the Bureau of Indian Standards (BIS), reflecting anthropogenic influence and deteriorating water quality[10]. Another investigation of the Vishav stream evaluated measured water quality parameters against BIS and WHO standards to determine suitability for different uses and to understand how the stream’s condition compares with drinking-water criteria[11]. The governmental water quality monitoring programs routinely assess parameters such as pH, dissolved oxygen (DO), biological oxygen demand (BOD), nitrate, and fluoride against BIS criteria (IS 10500:2012) to identify pollution hotspots in rivers across India[12].

Meghalaya, one of the eight states in the northeastern region of India, is renowned for its thick network of rivers and streams that sustain regional ecosystems and livelihoods, as well as its remarkably high rainfall[13]. The flow of water in rivers and streams is regulated by forests of the catchment area[14]. Water quality varies from source to source which are largely influenced by natural and human factors[15]. The Sohiong River, located in the East Khasi Hills District of Meghalaya, is an essential freshwater resource for nearby settlements and surrounding ecosystems.

The Sohiong River's water quality seems to be harmed by drainage from mining-impacted areas within the basin, agricultural runoff from cultivated fields, and residential waste discharge from neighbouring habitations. In this study, the water quality of the Sohiong River was assessed using the grab sampling method during both wet and dry seasons to capture seasonal variations. Physical, chemical, and biological parameters were analysed to evaluate the current status of the river water. The results of this study provide baseline data that can support future monitoring programs and contribute to sustainable management and conservation of freshwater resources in the region.

Materials and Methods

Water samples have been collected from the Sohiong River across the wet and dry season to assess the fluctuation in the quality of the water. Three places along the river course in Sohiong town, East Khasi Hills District, State of Meghalaya, India, have been selected as the sampling locations. These sites cover the upstream, middle stream, and downstream conditions of the river (Figure-1). The upstream site is at Mawtap with a latitude of 25°30′22.89″ N and a longitude of 91°42′2.56″ E. The site chosen as the middle stream is at Shilliangdongki with a latitude of 25°29′53.39″ N and a longitude of 91°42′31.11″ E, while the downstream site is at Mawkynthei with a latitude of 25°29′28.40″ N and a longitude of 91°42′0.78″ E.

Figure-1: Location of sampling sites along the Sohiong River.

Sample collection procedure: Water samples were collected by following standard procedures as recommended by the American Public Health Association Society/Public Water Supply/Analysis Committee (reported as APHA) during both wet and dry seasons. Surface river water samples were collected from the river about 20–30 cm below the surface of the river water by using polyethylene bottles for physicochemical analysis and sterile bottles for microbiological analysis. Two to three times rinses with river water were done with the polyethylene bottles prior to sampling for physicochemical analysis. pH values and water temperature were measured directly from the field with portable pH and mercury thermometer. On the other hand, the Biological Oxygen Demand (BOD) analysis for the samples was done shortly after sample collections and water samples for coliform bacteria identification were collected in sterile water bottles and placed straight away in an ice box for transport to the laboratory[16,17]. Various physico-chemical parameters such as electrical conductivity, total hardness, alkalinity, chloride, sulphate, nitrate, and phosphates were determined through conductometry, standard titrimetric and spectrophotometric methods. BOD was determined by using the five-day incubation method, and coliform bacteria were analysed using the Most Probable Number (MPN) method. These tests were conducted before the samples were allowed to hold for the recommended period.

Results and Discussion

During the wet season as shown in Figure-2, pH levels recorded 7.16–7.25 (upstream, middle, and downstream) with temperatures of 21–22°C, while the electrical conductivity levels (171.15-179.43 µS/cm) depicted low to moderately ionic substances characteristic of riverine water during periods of runoff events.

Water hardness recorded higher levels downstream from 28-44 mg/L, while alkalinity also recorded higher levels from 26.6-50 mg/L, representing softness and satisfactory buffering capacity, respectively[18]. The levels of chloride (139-181.1mg/L), sulphate (10.44-85.6mg/L), and nitrate (0.57-1.30mg/L) were low compared to the levels depicted in commonly adopted guideline standards, representing the minimal levels of inorganic contamination of the riverine water bodies during the wet season[19]. The level of Biological Oxygen Demand (BOD) recorded higher levels downstream from 5.13-6.61 mg/L, thus indicating the progressive increase in organic substances. The level of phosphates recorded a slight decline downstream from 2.33-1.78 mg/L, which could be attributed to dilution and subsequent bio-pharmacological assimilation processes along the runoff routes[20].

During the dry season as shown in Figure-3, pH values ranged between 6.49 and 6.70, thus remaining within the typical range of surface waters, while the temperatures were comparatively lower (14–16°C). Electrical conductivity ranged in relatively higher values of 183.87–196.22 µS/cm, which corroborates the increased ionic concentration under low-flow conditions. Hardness values of 14.6–22.6mg/L classified the water of the river as very soft, whereas the alkalinity values of 13.3–23.3 mg/L were indicative of the generally observed reduced buffering capacity during the dry period. Chloride and sulphate were relatively in moderate values in the concentration range of 87.79–143 mg/L and 167.94–216mg/L, respectively; nitrate was very low, in the range 0.07–0.27mg/L, which presupposed the relatively slight enrichment of nitrates[21]. The values of BOD were comparatively higher (6.92–7.89mg/L), showing the increased organic load during the period of reduced flow [22]. Phosphate concentration was high (7.33–7.67mg/L), which indicated nutrient accumulation owing to the restricted dilution.

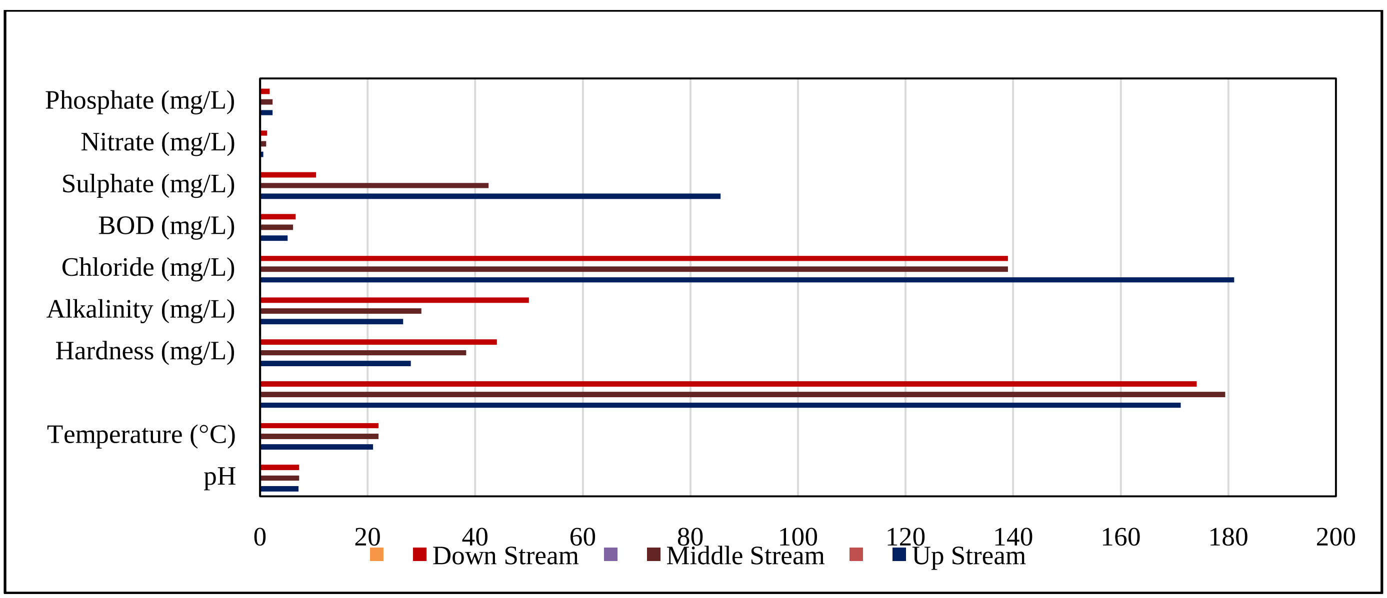

Figure-2: Variation of water quality parameters during the wet season.

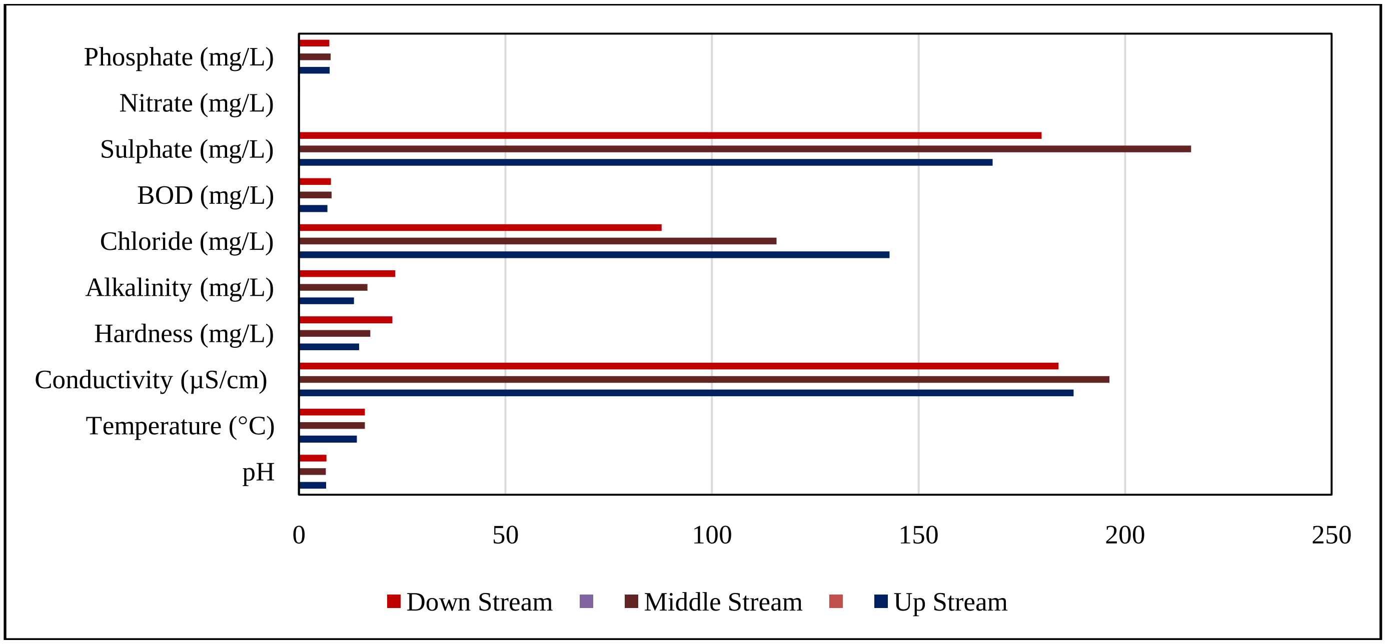

Figure-3: Variation of water quality parameters during the dry season.

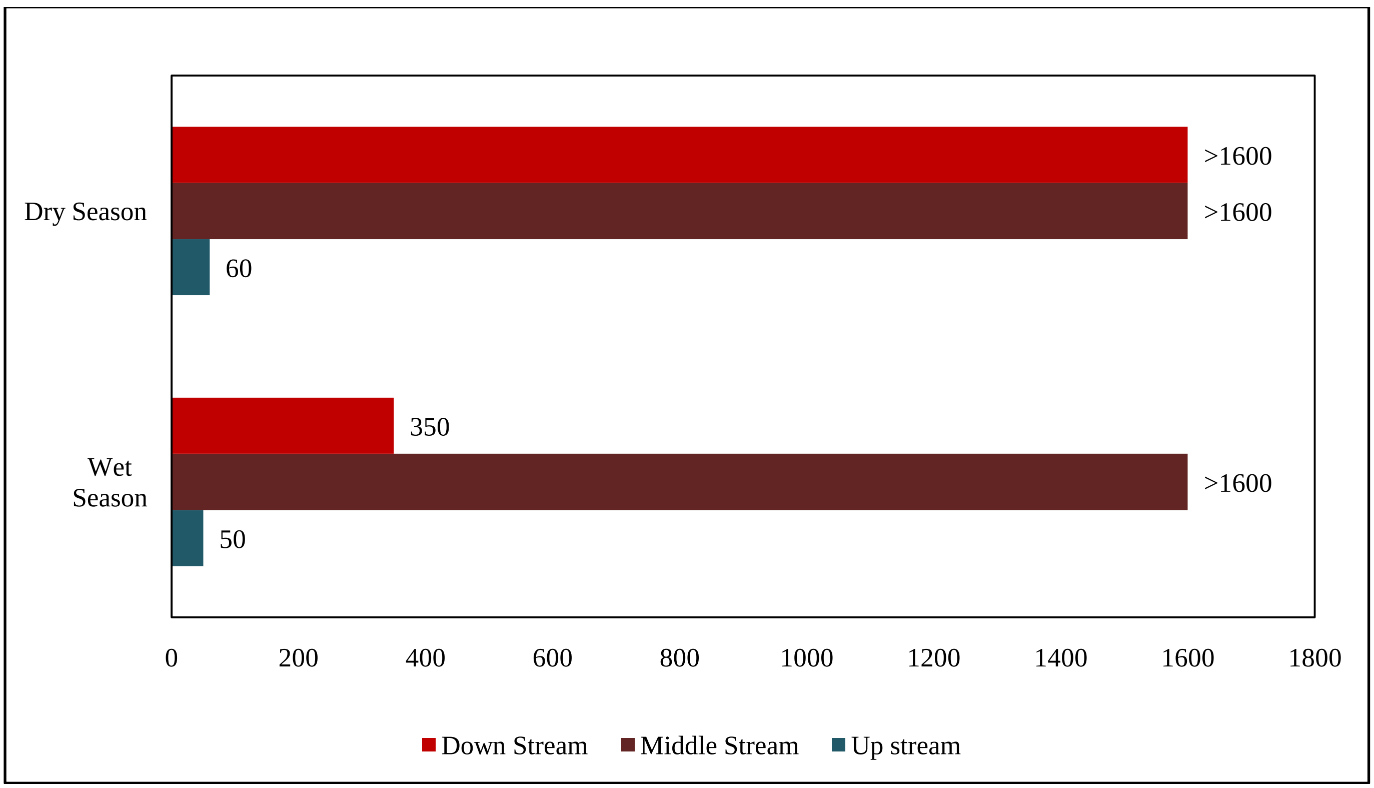

Figure-4: Seasonal variation of total coliform count during wet and dry seasons.

Total coliform counts as shown in Figure-4 varied from 50 MPN/100 mL at the upstream site to >1600 MPN/100 mL at the middle stream, with 350MPN/100 mL recorded at the downstream during the wet season. During the dry season, coliform levels were 60 MPN/100 mL at the upstream station but attained the maximum detectable limits of >1600 MPN/100 mL at both middle and downstream stations. This was far above the recommended limit of 0 MPN/100mL for potable water. Thus, high microbial loads in sections of the middle and downstream could be linked with surface runoff, domestic sewage discharges, livestock, and organic matter accumulation-conditions that are exacerbated by low flow[23,24].

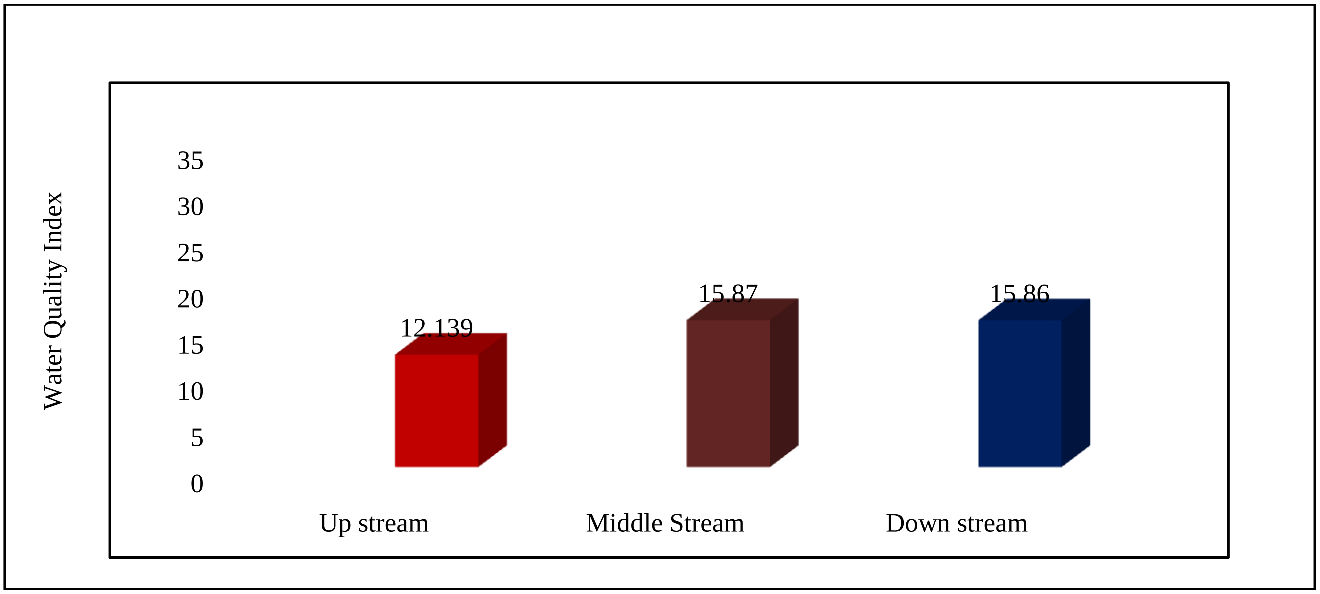

Figure-5: WQI of upstream, middle, and downstream during the wet season.

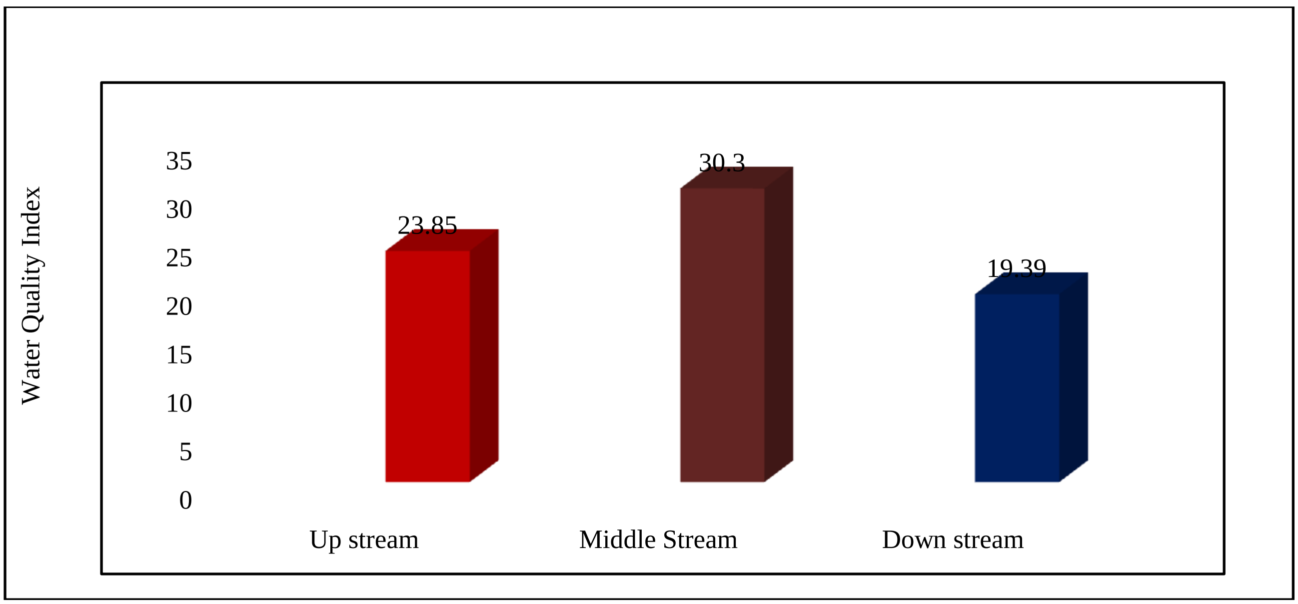

Figure-6: WQI of upstream, middle, and downstream during the dry season.

During the wet season as shown in Figure-5, the WQI varies between 12.14, 15.87, and 15.86 units, indicating that the quality of water remains good or even excellent as well, but there has been a slight increase from one point to another, indicating the influence of streams and rivers that act as receiving sites. In the dry season as shown in Figure-6, a slight increase or relatively higher WQI values were noticed, i.e., 23.85 units, 30.30 units, and 19.39 units, indicating that there has been a slight deterioration in water quality, especially in the middle stream, because of the influence of dry seasons or due to some factors influencing that area. The results of the WQI showed that the overall physicochemical quality of the water is very good with little variation in the various stations and seasons. Microbiological parameters such as the total coliform were not considered in the computation of the WQI but were separately evaluated. The weighted arithmetic index method of computing WQI requires that there should be a fixed and ideal value corresponding to each parameter; both standard and ideal values of coliform are zeros, which are not mathematically possible under WQI. As shown in Figure-4, the results have graphically demonstrated higher concentrations of coliform at the middle and downstream sections than at the upstream section, as observed during both the wet and dry seasons which indicates microbial contamination, despite a general good physicochemical water quality reflected by the WQI[25,26].

Table-1: Pearson correlation among different parameters.

Correlations		Season	Flow	SO_4	NO_4	PO_4	Cl	Coliform	Temperature	pH	Conductivity	Hardness	Alkalinity	BOD
Season	Pearson Correlation	1	0	-.938**	.876*	-.997**	0.663	0.454	.973**	.973**	-.852*	.871*	0.749	-.826*
	Sig. (2-tailed)		1	0.006	0.022	0	0.152	0.365	0.001	0.001	0.031	0.024	0.087	0.043
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
Flow	Pearson Correlation	0	1	-0.171	0.205	0.018	-0.5	-0.18	0.188	0	0.413	0.249	0.115	0.431
	Sig. (2-tailed)	1		0.746	0.696	0.974	0.312	0.733	0.721	1	0.416	0.634	0.828	0.394
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
SO_4	Pearson Correlation	-.938**	-0.171	1	-.914*	.933**	-0.596	-0.435	-.913*	-.921**	0.673	-.864*	-0.694	0.713
	Sig. (2-tailed)	0.006	0.746		0.011	0.007	0.212	0.388	0.011	0.009	0.143	0.026	0.126	0.112
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
NO_4	Pearson Correlation	.876*	0.205	-.914*	1	-.899*	0.32	0.624	.900*	.934**	-0.713	.983**	.892*	-0.514
	Sig. (2-tailed)	0.022	0.696	0.011		0.015	0.536	0.185	0.015	0.006	0.112	0	0.017	0.297
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
PO_4	Pearson Correlation	-.997**	0.018	.933**	-.899*	1	-0.637	-0.514	-.972**	-.981**	.869*	-.896*	-0.793	0.804
	Sig. (2-tailed)	0	0.974	0.007	0.015		0.174	0.297	0.001	0.001	0.025	0.016	0.06	0.054
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
Cl	Pearson Correlation	0.663	-0.5	-0.596	0.32	-0.637	1	0.214	0.495	0.534	-0.603	0.252	0.174	-.908*
	Sig. (2-tailed)	0.152	0.312	0.212	0.536	0.174		0.684	0.318	0.275	0.205	0.629	0.742	0.012
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
Coliform	Pearson Correlation	0.454	-0.18	-0.435	0.624	-0.514	0.214	1	0.444	0.487	-0.477	0.631	.830*	-0.164
	Sig. (2-tailed)	0.365	0.733	0.388	0.185	0.297	0.684		0.378	0.327	0.338	0.18	0.041	0.756
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
Temperature	Pearson Correlation	.973**	0.188	-.913*	.900*	-.972**	0.495	0.444	1	.957**	-0.786	.924**	0.806	-0.693
	Sig. (2-tailed)	0.001	0.721	0.011	0.015	0.001	0.318	0.378		0.003	0.064	0.008	0.053	0.127
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
pH	Pearson Correlation	.973**	0	-.921**	.934**	-.981**	0.534	0.487	.957**	1	-.884*	.925**	0.805	-0.76
	Sig. (2-tailed)	0.001	1	0.009	0.006	0.001	0.275	0.327	0.003		0.019	0.008	0.053	0.079
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
Conductivity	Pearson Correlation	-.852*	0.413	0.673	-0.713	.869*	-0.603	-0.477	-0.786	-.884*	1	-0.723	-0.694	.826*

	Sig. (2-tailed)	0.031	0.416	0.143	0.112	0.025	0.205	0.338	0.064	0.019		0.104	0.126	0.043
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
Hardness	Pearson Correlation	.871*	0.249	-.864*	.983**	-.896*	0.252	0.631	.924**	.925**	-0.723	1	.936**	-0.469
	Sig. (2-tailed)	0.024	0.634	0.026	0	0.016	0.629	0.18	0.008	0.008	0.104		0.006	0.348
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
Alkalinity	Pearson Correlation	0.749	0.115	-0.694	.892*	-0.793	0.174	.830*	0.806	0.805	-0.694	.936**	1	-0.331
	Sig. (2-tailed)	0.087	0.828	0.126	0.017	0.06	0.742	0.041	0.053	0.053	0.126	0.006		0.521
	N	6	6	6	6	6	6	6	6	6	6	6	6	6
BOD	Pearson Correlation	-.826*	0.431	0.713	-0.514	0.804	-.908*	-0.164	-0.693	-0.76	.826*	-0.469	-0.331	1
	Sig. (2-tailed)	0.043	0.394	0.112	0.297	0.054	0.012	0.756	0.127	0.079	0.043	0.348	0.521	
	N	6	6	6	6	6	6	6	6	6	6	6	6	6

The Pearson correlation as shown in Table-1, showed that seasonality is the dominating parameter regulating the variation of water quality in the study area. There was a strong negative relationship between seasonality and sulphate ($r = -0.938$, $p = 0.006$), phosphate ($r = -0.997$, $p = 0.01$), conductivity ($r = -0.852$, $p = 0.031$), and BOD ($r = -0.826$, $p = 0.043$), which suggested dilution of these constituents in the wet or high-flow seasons. However, there was a strong positive relationship between seasonality and nitrate ($r = 0.876$, $p = 0.022$), temperature ($r = 0.973$, $p = 0.001$), pH ($r = 0.933$, $p = 0.001$), and hardness ($r = 0.871$, $p = 0.024$), which suggested the leaching of mineral salts, accumulation of nitrate, and high pH in the warm and dry season[2728].

Flow showed no relationship with any of the measured variables ($p > 0.05$). Nutrient interaction analysis showed the presence of strong positive relationship between sulphate and phosphate ($r = 0.933$, $p = 0.007$), indicating possible common point sources, and the two variables had strong inverse relationship with nitrate (SO_4-NO_4) ($r = -0.914$, $p = 0.011$) and (NO_4-PO_4) ($r = -0.899$, $p = 0.015$). There were also very strong positive relationships between temperature and pH ($r = 0.957$, $p = 0.003$) and hardness ($r = 0.924$, $p = 0.008$), while marginal positive associations of temperature were observed with alkalinity ($r = 0.806$, $p=0.053$), again supporting the role of carbonate equilibrium and rock-water interaction. Conductivity was significantly positively correlated with phosphate ($r = 0.869$, $p = 0.025$) and BOD ($r = 0.826$, $p = 0.043$), which suggests that nutrient enrichment and organic pollution increase dissolved ionic content.
Also, the strong positive correlation between coliform and alkalinity ($r = 0.830$, $p = 0.041$) indicates that organic or domestic pollution and microbial activity contribute to high alkalinity instead of a direct cause-effect relationship[29].

Table-2: Descriptive statistics of wet season water quality parameters.

Parameter	Mean	SD	Min-Max
pH	7.22	± 0.05	7.16-7.25
Temperature (^{0}C)	21.67	± 0.58	21-22
Conductivity (µS/cm)	174.89	± 4.20	171.15-179.43
Hardness (mg/L)	36.78	± 8.11	28-44
Alkalinity (mg/L)	35.53	± 12.64	26.6-50
Chloride (mg/L)	153.03	± 24.31	139-181.1
BOD (mg/L)	5.96	± 0.76	5.13-6.61
Sulphate (mg/L)	46.18	± 37.71	10.44-85.60
Nitrate (mg/L)	1.01	± 0.39	0.57-1.30
Phosphate (mg/L)	2.15	± 0.32	1.78-2.33
Total Coliform (MPN/100 ml)	666.67	± 838.15	50- >1600

During the wet season as shown in the Table-2, pH values showed very low variability with an average of 7.22 ± 0.05 (7.16-7.25), and temperature values had minimal variability (21.67±0.58°C). Conductivity values were relatively stable (174.89±4.20µS/cm), while BOD values recorded low variability (5.96 ±0.76mg/L). Moderate variability was recorded for hardness (36.78 ± 8.11 mg/L) and alkalinity (35.53 ± 12.64 mg/L). Nitrate level showed moderate variability (1.01 ± 0.39 mg/L), while phosphate level was relatively stable (2.15 ± 0.32 mg/L). However, the higher standard deviation of sulphate (46.18 ± 37.71 mg/L), chloride (153.03 ± 24.31 mg/L), and total coliform (666.67 ± 838.15 MPN/100 mL) values indicates high variability in their distribution in the river during the wet season.

Table-3: Descriptive statistics of dry season water quality parameters

`	Mean	SD	Min-Max
pH	6.60	± 0.11	6.49-6.70
Temperature (^{0}C)	15.33	± 1.15	14-16
Conductivity (µS/cm)	189.21	± 6.34	183.87-196.22
Hardness (mg/L)	18.17	± 4.07	14.6-22.6
Alkalinity (mg/L)	17.73	± 5.10	13.3-23.33
Chloride (mg/L)	115.46	± 27.61	87.79-143
BOD (mg/L)	7.52	± 0.52	6.92-7.89
Sulphate (mg/L)	187.91	± 25.04	167.94-216
Nitrate (mg/L)	0.17	± 0.10	0.07-0.27
Phosphate (mg/L)	7.48	± 0.17	7.33-7.67
Total Coliform (MPN/100 ml)	1086.67	± 888.19	60- >1600

During the dry season as shown in the Table-3, pH measurements showed lower variability (6.60 ± 0.11), while temperature variability was slightly higher but limited (15.33 ± 1.15°C). Conductivity was relatively uniform at sampling points (189.21 ± 6.34 µS/cm), while BOD variability was low (7.52 ± 0.52 mg/L). Hardness (18.17 ± 4.07mg/L) and alkalinity (17.73 ± 5.10 mg/L) presented moderate variability. Nitrate variability was low to moderate (0.17 ±0.10mg/L), while phosphate variability was very low (7.48 ± 0.17mg/L). The relatively higher standard deviation of sulphate (187.91 ± 25.04 mg/L), chloride (115.46 ± 27.61 mg/L), and total coliform (1086.67 ± 888.19 MPN/100 mL) indicates higher variability in water quality spatial distribution during the dry season.

Conclusion

The WQI scores, which varied from good to excellent categories, suggest that the Sohiong River has good physico-chemical water quality during both the rainy and dry seasons. Variations in water quality were observed to be seasonal and spatial, with lower dilution capacity in the dry season, which resulted in relatively higher values and variability of some parameters. Descriptive statistical analysis revealed low variability of pH, temperature, conductivity, and BOD, which indicated homogeneity, while higher variability of sulphate, chloride, and total coliform indicated heterogeneity of the spatial distribution of water quality along the river course. Correlation analysis further supported the effect of seasonal changes on water quality dynamics. While the physicochemical parameters generally met the recommended standards, the high total coliform values, particularly in the middle and downstream sections of the Sohiong River, indicate potential microbiological hazards. These results underscore the importance of not solely relying on the use of physicochemical parameters like WQI in underestimating health-related issues.

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