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Evaluation of the Water Quality of Dhansiri River, North-East India Applying Water Quality Index

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Abstract

The Dhansiri River, situated in north-east India, is a transboundary river running through the states of Assam and Nagaland, and forms an important tributary to the Brahmaputra River. Despite the religious and cultural importance of the river, the anthropogenic waste disposed off at the catchment areas has hampered the potability of the once pristine water source for the communities residing along its banks. In order, to understand the seasonal alteration in the water quality and its applicability for different domestic usage, the study emphasized the application of statistical tools and Water Quality Index to monitor the overall health of the river water. Considering the objectives, from three distinct sites (DS1, DS2, and DS3) water samples were collected during winter, spring, summer and autumn in the year 2021-2022. In total, 16 physicochemical properties were evaluated and the parameters like, water temperature, total dissolve solids, electrical conductivity, turbidity, and total alkalinity exhibited a seasonal significant difference at $p<0.001$. Turbidity and total alkalinity value exceeded the standard permissible limits of Bureau of Indian Standards (2012) and World Health Organisation (2017). The average Water Quality Index was highest in DS3, with the seasonal order: summer (112.61), autumn (90.00), spring (79.88), and winter (69.84). This research suggests that human activities, including urbanization, untreated industrial effluents, agricultural runoff, and improper home waste disposal are key contributors to the degradation of river water. Therefore, it is essential that a robust water resource planning programme be devised by the regional authorities to restore and rejuvenate the deteriorated river.

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Introduction

River water is considered the most dynamic natural resource, supporting the entire ecosystem. If left undisturbed, it has the potential to promote social, cultural, ecological, and overall environmental well-being. As such, water resource management and monitoring have become a global necessity due to the depletion of water resources and contamination

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of freshwater bodies.[1] Factors such as DO, BOD, phosphate, colour, turbidity, iron, manganese, arsenic, aluminium, boron, and barium are the main components impacting surface water, causing water contamination.[2-3] In India, the most significant rivers are affected by the disposal of industrial discharge, tourism, anthropogenic, and religious practices.[4]

Few studies on the physicochemical properties and WQI of several significant rivers in the Northeastern states have been examined, revealing seasonal fluctuations and degradation of water quality due to anthropogenic activities.[5-7] Researchers findings reveal that human disturbance has resulted in reduction in the quality of water, which is a global concern as water resources are severely threatened by natural processes like erosion, weathering, climate change, and atmospheric deposition, as well as anthropogenic influences such as urbanisation, untreated industrial effluents, agricultural runoff, and inappropriate domestic waste disposal, which have made it less suitable for primary and secondary use.[8-9] As reported by UNESCO, approximately 2 million tonnes of waste from factories, chemical compounds, households, and agriculture, including fertilisers, insecticides, and pesticide residues, were found to be discharged into the rivers.[10]

Given the impact of these attributes on aquatic ecosystems, it is imperative to conduct periodic assessments of river water quality to ensure sustainable use of water resources and safeguard the health of people.[11] Evaluation and interpretation of surface water quality pose significant challenges due to the need to monitor multiple samples and physicochemical parameters. In addition to the difficulties of comparing experimentally obtained data with established standards, they need to be improved in their ability to provide a comprehensive understanding of global trends and variations in water quality over various geographical locations and periods.[12] Water Quality Index (WQI) is commonly utilised to estimate surface water grade, providing a holistic and simpler method for comprehending the overall condition of a water source by consolidating multiple water characteristics into a singular numerical number.[13]

The WQI is a computational tool that efficiently assembles comprehensive data on water quality into a single, easily comprehended numerical value.[14] It also helps understand how individual water parameters influence the overall alteration in complete water quality.[15] Additionally, it is a valuable tool for conducting comparisons among various sampling locations and detecting fluctuations in water quality over time.[16] The Weighted Arithmetic Index (WAI) approach,[17] has been widely employed in many studies on river water quality Internationally[12,18,19] and in India.[20,21] In Northeast India, only a few studies on seasonal WQI have been conducted on some major rivers, i.e., Lukha river in Meghalaya,[22] Jatinga and Kolong river in Assam23-24 and Doyang river from Nagaland.[25]

The Dhansiri, previously referred to as Dong-Siri, derives its name from the local term denoting a ravine of peaceful habitation. It originates from the Laisang peak of Peren district in Nagaland, encompassing a vast expanse of untamed terrain with diverse and abundant fauna. The Dhansiri Reserved Forest is on one side, while the Intanki National Park is on the other.[26] Activities like laundry, cleaning utensils, bathing and swimming, providing water for livestock, water supply for agriculture, fishing, ritual practices, sand mining, etc., are observed along the riverside. Furthermore, in 2015, the Central Pollution Control Board (CPCB) identified the Dhansiri River as one of the most contaminated rivers in India.

A comprehensive review of the available scientific literature reveals a notable absence of information and published articles about the water quality of the Dhansiri Rivers, except for the study focused on fish diversity.[26] This scarcity of research highlights the limited attention given to this valuable resource. Following an extensive investigation of the area encompassing the river, a hypothesis has been postulated suggesting that the municipal dumping sites, sand mining, urbanisations, and nutrient deposition from agricultural fields along the river stretch are deteriorating the river water quality. Therefore, the following objectives have been taken up: a) Evaluating the seasonal physicochemical characteristics at various stations of the Dhansiri River. b) Estimating the seasonal WQI of Dhansiri River to assess its potability. The findings will provide significant data input on environmental hazards for the scientific community, create awareness to advocate for the ecological prospects of the river, and facilitate its sustainable rehabilitation.

Materials and Methods

Study Area

Nagaland encompasses a total of 16,579 km^2 theoretically, situated within 25° 06′ N to 27° 04′ N (latitude) and 93° 20′ E to 95° 15′ E (longitude). Myanmar and Arunachal Pradesh geographically border the state to the east, Assam to the north and west, and Manipur to the south. The state exhibits a subtropical monsoonal climate, wherein it experiences annual precipitation ranging from 100 to 300 cm. The peak rainfall is predominantly observed during June, July, and August. The third sampling station is from Karbi Anglong district, with coordinates of 25º33′N to 26º35′N (latitude) and 92º10′E to 92º50′E (longitude) in Central Assam. This district encompasses a total area of 10,434 square kilometers. For this study, a total of 115 km stretch of the river was considered; drainage area map of the three distinct locations (DS1, DS2 and DS3) is shown in Figure 1. The first sampling stations selected for this study are situated upstream (DS1) in Doyapur village (25º45′21.8"N 93º34′39.4"E), which primarily consists of few residences, small-scale agricultural practices, sand mining, and an ongoing railway construction. Additionally, a midstream (DS2) location in Walford colony (25º55′26.1"N 93º44′59.0"E) was chosen due to its proximity to the Dimapur municipal dumping site, which is located near Dhansiri River, where a substantial accumulation of waste materials takes place. The garbage primarily consists of solid and semi-solid substances, including plastic, rubber, domestic waste, building debris, glass, metals, and medical waste, all indiscriminately disposed of at this location. The third sampling station, located downstream (DS3), is picked from Deopani Assam (26º13'06.3"N 93º50'53.9"E). Deopani is also named after the Deopani mandir, located on the river bank and is the site of religious ceremonies along the stretch of the river discharge from commercial areas, agricultural land, brick kilns and cement factories.

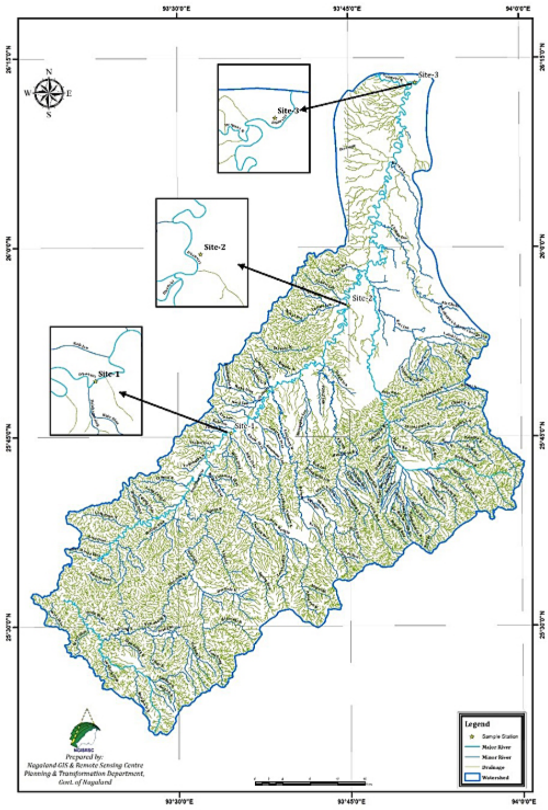

Fig. 1: Drainage area map of the three sampling stations of Dhansiri

Sampling Method and Analysis

Three sampling stations each approximately 30 km apart were monitored for water analysis, with monthly samples collected in triplicate from December 2021 to November 2022. The monthly data was subsequently categorised as March, April, May (spring), June, July, August (summer), September, October, November (autumn), and December, January, February (winter). The sampling procedure were carried out during the early hours, explicitly targeting the surface water at a depth of 1 meter. The collection of water samples was carried out using 1-liter polyethylene terephthalate (PET) bottles that had been pre-cleaned and handled with appropriate precautions. Within 24 hours of collection, the samples were properly labelled, kept in iceboxes from the sampling locations, and subsequently further analysis was examined in the laboratory.

The collected water samples were tested to determine the values of 16 significant physico-chemical characteristics. These parameters include pH, dissolved oxygen (DO), biological oxygen demand (BOD), water temperature (WT), chloride (Cl-) electrical conductivity (EC), total hardness (TH), total alkalinity (TA), turbidity, magnesium (Mg^{2+}), sulfate (SO_4^{2-}), nitrate (NO^-_3), potassium (K+), calcium (Ca2$^+$) inorganic phosphorus (PO_4^{2-}), and total dissolved solids (TDS). A small digital analyser equipment was used on-site to measure parameters like pH, WT, (HM digital pH- 80 hydrotested) and TDS (Labman, LMCM20). A conductivity meter and a nephelometer were used to determine EC and turbidity, respectively, in the lab. DO samples were fixed on-site and analysed in the laboratory using Winkler's titrimetric method, while for BOD, samples were incubated at 20 °C for 5 days, prior to analysis via the the titration method. Total alkalinity, total hardness, Ca^{2+}, Mg^{2+} were determined titrimetrically using standard 0.05N EDTA and 0.01N. and analysed by the titration method. Cl- was estimated using the standard argentometric method, Brucine method for NO^-_3, K^+ by flame photometer, turbidimetry for sulfate (SO_4^{2-}), inorganic phosphorus (PO_4^{2-}), using double-beam UV–visible spectrophotometer.

The chemical examination was performed in accordance with the procedures described by Trivedy and Goel[27] and the standard procedures described by the APHA.[28] ANOVA (one-way analysis of variance) and Duncan's Multiple Range Test (DMRT) were performed using SPSS version 21 software to statistical analyse the seasonal fluctuations at $p<0.05$.

Water Quality Index (WQI) Calculation

Brown's weight-based approach to the individual parameters were employed to calculate the WQI, aiming to quantify and provide a simple numerical representation of the diverse data collected during the study.[17]

Applying the given mathematical expression.

$WQI = \sum W_n Q_n / \sum W_n$ here, $Q_n =$ ith is the quality rating of water measured out of a total n quality parameter.

W_n = unit weight of nth quality of the water parameter.

Equation on quality grading (Q_n).

$$Q_n = [(V_n - V_o) / (S_n - V_o) \times 100$$

V_n represents the concentration of the nth parameter in the examined sampling.

V_o = ideal value of purified water, that is, $V_o = 0$, with the exception of pH ($V_o = 7.0$) and DO ($V_o = 14.6$mg/l).

The symbol S_n represents criterion allowable for nth variable.

The index is grouped to make the data easier, which includes assigning a "unit weight (W_n)" for calculating the WQI centred on specified physicochemical parameter under investigation. The unit weight (W_n) was determined by employing the given formula.

$$W_n = R/S_n$$

Where R is the proportionality constant calculated using the formula,

$$R = 1/(\sum(1/S_n)$$

Results and Discussion

Physicochemical Variables of the River

The examine results, inclusive of range, mean, standard deviations, and the spatiotemporal variations of the water's physical and chemical properties with one-way ANOVA and DMRT between the seasons listed in Table 1. The pH of water exerts a significant indication of its quality, as it quantifies the presence of hydrogen ions and plays a crucial part in establishing the water's appropriateness for several purposes. Specifically, the pH values exhibited fluctuations of 7.37 ± 0.07 (summer), 7.94 ± 0.07 (winter), 7.72 ± 0.11 (spring), and 7.44 ± 0.23 (autumn). Notably, the lowest and highest pH values were observed during the summer and winter, and the river water was characterised as neutral to slightly alkaline. The variance analysis, at $p<0.05$, revealed a significant variation in pH across the different seasons. A substantial statistical difference at $F=24.207$; $p<0.001$ was found across the seasons, whereas the WT ranged from 23.06 ± 1.56 ºC to 29.94 ± 0.49 ºC. This could be due to the escalation of atmospheric temperature in summer, which has an impact on the exposed surface water, thus enhancing the WT of the river.[29] The EC value reflects its aptitude to conduct liquid phase electric current, which is contingent upon the concentration of ions present in the water. The high conductivity of water indicates a significant level of inorganic pollution.[30] In this study, EC was somewhat elevated in the summer, with a mean value of 185.97 ± 7.21 µS/cm, and diminished in the winter, with a mean value of 138.66 ± 4.08 µS/cm. The concentrations of cations and anions, including calcium, sodium, chloride, and sulphate have greatly affected the electrical conductivity of water. As per the observation on seasonal turbidity, summer and winter were detected to be significantly different at ($p<0.001$). The mean turbidity readings of winter (17.96 ± 0.85 NTU), spring (24.16 ± 2.85), summer (38.76 ± 3.46 NTU), and autumn (29.60 ± 5.04) were all higher than the BIS (2012)/WHO (2017) recommended threshold value. The higher turbidity value during summer may be attributed to various factors such as soil erosion, agricultural runoff, forest runoff, mining runoff, domestic runoff, and the presence of organic and inorganic matters discharged from the watershed.[31] TDS is widely recognised as a fundamental metric in assessing water quality because it directs correlation and susceptibility of TH, TA, EC, and turbidity, which are key parameters analysed in water samples.[32] The average TDS value in winter (75.42 ± 6.19 mg/l), spring (83.58 ± 4.34 mg/l), summer (117.82 ± 7.99 mg/l), and autumn (107.37 ± 9.54 mg/l) was within the BIS (2012)/ WHO (2017) acceptable limit. DMRT indicated significant differences of $p<0.001$ (winter - summer), $p<0.05$ in (autumn - winter), (summer - spring), and (spring - autumn). The elevated concentration of TDS in summer results from the runoff of wastewater into the river during the rainy season, containing colloidal particles, dissolved solids, trace metals, and various chemical salts and ions, which increase the TDS levels. The concentration of Cl- was maximal in summer and minimal in winter, with their seasonal average fluctuating from 11.67 ± 1.09 to 20.94 ± 1.13 mg/l, and these values fall within the acceptable limit set by BIS (2012)/WHO (2017). The concentration of Cl-, was generally low and exhibited seasonal dissimilarity with a significance value of $p<0.05$ and $F=9.199$. The key determinant of chloride levels in river water is the amalgamation of runoff originating from residential, agricultural, and municipal sewage discharge, although other factors may also have influence.[33] Meanwhile, as exhibited by TH, winter presented a significant difference ($p<0.05$) while such outcome was not detected during autumn and spring. The average TH value from the three sampling locations ranged from 56.85 mg/l (summer) to 108.87 mg/l (winter). The escalated value of TH during winter might be attributed to the natural collection of salts and reduced water level resulting from decreased rainfall.[25] The seasonal average TA span from 78.04 to 123.83 mg/l.[34] TA is subjected to the action of inorganic minerals, specifically bicarbonate and carbonate ions. Reasonably, the gradual drop in the water level during dry winter months led to the accumulation of waste disposal from domestic and agricultural runoff in the river. As a result, the highest recorded alkalinity value (123.83 ± 5.48 mg/l) was seen during winter and the rainy months observed lower TA. Ca^{2+} value ranged from 9.8 ± 1.47 to 18.79 ± 2.53 mg/l, while Mg^{2+} value varied from 7.47 ± 2.5 to 14.99±0.95 mg/l. The two cations were within the acceptable limit of BIS (2012)/WHO (2017) throughout the study period. Additionally, a seasonal analysis of variance revealed that Ca^{2+} and Mg^{2+} were significant at $p<0.05$. Ca^{2+} and Mg^{2+} ions are substantially available in natural water due to leaching or mineralisation of organic matter, weathering of rocks, including anthropogenic factors prevalent in the catchment areas like stone crushers, sand mining, and runoff of fertilisers and detergents from adjacent urban areas. DO exhibits crucial component in estimating the quality of different hydro system, and freshwater must have DO levels between 4-6 mg/l, with 14.6 mg/l being the best level for making sure the water is suitable for aquatic organisms.[35] The highest level of DO was recorded in winter (7.85 ± 0.70 mg/l) but a gradual decrease was estimated during the rainy season (5.32 ± 0.61 mg/l). The decrease in dissolved oxygen levels can be ascribed to elevated temperatures and organic materials, alongside diminished photosynthetic activity resulting from increased turbidity.[36] Analysis of variance displayed a statistically difference ($p<0.05$) between summer and winter, while such statistical distinction was not reported for the other seasons. BOD presented a seasonal descending value of 4.71 ± 0.11 mg/l (winter) > 3.69 ± 0.22 mg/l (autumn) > 3.48 ± 0.46 mg/l (spring) > 3.10 ± 0.50 mg/l (summer). During winter, an elevated BOD level suggested substantial biological waste and increased microbial metabolic processes.[22] Analysis of variance for nitrate was notably different at $p<0.05$; seasonally, its mean value ranged between 0.12 ± 0.03 mg/l (winter) to 0.44 ± 0.07 mg/l (summer). The ascend in NO^-_3 levels detected during the summer months could be attributed to precipitation events that result in the runoff of top soil from agricultural areas,[25] transporting the associated nutrients downstream into the river system. In addition, the organic matter mineralization in the river system also contributes to nitrate formation due to microbial processes that convert ammonium into nitrates.[37] The presence of SO_4^{2-} in river water is primarily due to mineral sources such as gypsum. Although small quantities are innocuous, excessive amounts of sulphate in drinking water can induce various bowel disorders.[24] The study determined that the average SO_4^{2-} concentration ranged in between 9.38 ± 0.26 to 13.7 ± 0.76 mg/l, which was within the acceptable threshold set by BIS (2012)/WHO (2017). The highest levels were recorded in summer, exhibiting a difference of $p<0.05$, while such results were not obtained for winter, spring and autumn. Lower SO_4^{2-} concentrations in winter result from sulphate readily precipitating and sinking to the bottom of the river sediment.[38] Through seasonal inspection of K^+ concentration, the ion exhibited slight variations, in autumn (4.18 ± 0.45 mg/l), winter (3.21 ± 0.37 mg/l), spring (4.46 ± 0.75 mg/l), and reaching a maximum value during summer (6.3 ± 0.52 mg/l). Maximum PO_4^{2-} was obtained during autumn (0.22 ± 0.04 mg/l) and minimum was estimated during winter (0.15 ± 0.02 mg/l). The examination of phosphate variance did not exhibit any noticeable seasonal fluctuations; however, its detectable amount could be attributed to the sewage discharge from a nearby point source into the river.[39]

Table 1: Mean seasonal variation in physicochemical characteristics of Dhansiri River from 3 study sites

Water variables	Summer	Autumn	Winter	Spring			
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	*F* values	*p* values	BIS (2012)/ WHO (2017)
pH	$7.37±0.07^a$	$7.44±0.23^a$	7.94±0.07b	$7.72±0.11^{ab}$	10.78	.003	6.5-8.5
WT	$29.94±0.49^c$	$28.36±1.09^{bc}$	$23.06±1.56^a$	$27.07±0.65^b$	24.207	.000	NA
TDS	$117.82±7.99^b$	$107.37±9.54^b$	$75.42±6.19^a$	$83.58±4.34^a$	22.341	.000	600
EC	$185.97±7.21^c$	$164.41±9.44^b$	$138.66±4.08^a$	$151.92±8.30^{ab}$	21.425	.000	NA
Turbidity	$38.76±3.46^c$	$29.60±5.04^b$	$17.96±0.85^a$	$24.16±2.85^{ab}$	20.194	.000	5
Cl-	$20.94±1.13^c$	$13.69±3.33^{ab}$	$11.67±1.09^a$	$17.90±3.01^{bc}$	9.199	.016	250
TH	$56.85±4.66^a$	$72.06±11.29^{ab}$	$108.87±8.36^c$	$81.25±9.11^b$	18.991	.001	200
TA	$78.04±7.65^a$	$85.85±8.70^{ab}$	$123.83±5.48^c$	$102.86±5.84^b$	24.926	.000	120/200
Ca^{2+}	$9.8±1.47^a$	$13.18±2.48^{ab}$	$18.79±2.53^b$	$12.65±3.38^{ab}$	6.494	.015	75
Mg^{2+}	$7.52±0.98^a$	$7.47±2.5^a$	$14.99±0.95^b$	$10.38±3.69^{ab}$	6.922	.013	30/50
DO	$5.32±0.61^a$	$7.78±0.61^b$	$7.85±0.70^b$	$6.75±1.36^{ab}$	5.454	.025	5
BOD	$3.10±0.50^a$	$3.69±0.22^a$	$4.71±0.11^b$	$3.48±0.46^a$	10.824	.003	5
K	6.3±0.52b	$4.18±0.45^a$	$3.21±0.37^a$	$4.46±0.75^a$	17.027	.001	NA
SO_4^{2-}	$13.7±0.76^b$	$11.39±0.80^a$	$9.38±0.26^a$	$10.89±1.11^a$	15.169	.001	200/250
NO^-_3	$0.44±0.07^c$	$0.28±0.07^b$	$0.12±0.03^a$	$0.21±0.03^{ab}$	18.333	.001	45/50
PO_4^{2-}	$0.22±0.05^a$	$0.22±0.04^a$	$0.15±0.02^a$	$0.16±0.01^a$	2.516	.132	NA

WT (ºC), EC (µS/cm) and turbidity (NTU), the remaining parameters measured in mg/l
A $p<0.05$ depicts significant variations between the groups

Table 2: WQI estimation at midstream (DS1)

Water variables	Summer			Autumn			Winter			Spring		
	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n
pH	7.35	23.33	0.94	7.47	31.55	1.27	8.073	71.56	2.87	7.75	50.22	2.02
WT	30.25	94.52	1.01	28.3	88.44	0.94	23.08	72.14	0.77	27.08	84.63	0.90
TDS	109.11	21.82	0.01	108.62	21.72	0.01	72.78	14.56	0.01	82.78	16.57	0.01
EC	178.47	59.49	0.07	164.65	54.88	0.06	126.77	42.26	0.05	147.89	49.30	0.06
Turbidity	29.54	590.73	40.34	23.85	477	32.57	8.82	176.33	12.04	14.15	283.07	19.33
Cl^-	19.88	7.95	0.01	12.83	5.13	0.01	9.47	3.79	0.01	14.01	5.603	0.01
TH	52.88	17.62	0.02	73.58	24.53	0.03	111.46	37.15	0.04	86.46	28.82	0.03
TA	73.95	61.62	0.175	76.22	63.51	0.18	124.62	103.84	0.30	105.54	87.95	0.25
Ca^{2+}	9.62	12.83	0.06	12.83	17.10	0.08	19.5	26.00	0.12	11.22	14.96	0.07
Mg^{2+}	6.66	22.19	0.25	7.31	24.37	0.28	15.27	50.89	0.58	9.91	33.03	0.37
DO	5.63	93.47	6.38	8.32	65.42	4.47	7.92	69.62	4.75	6.44	84.96	5.80
BOD	3.42	68.47	4.67	3.46	69.2	4.72	4.49	89.87	6.14	3.11	62.13	4.24
K	6.14	51.14	1.45	4.13	34.44	0.98	2.97	24.72	0.70	4	33.33	0.95
SO_4^{2-}	11.24	7.49	0.02	10.11	6.74	0.01	7.94	5.29	0.01	8.7	5.80	0.01
NO_3^-	0.34	0.75	0.005	0.24	0.52	0.003	0.05	0.11	0.0084	0.09	0.19	0.001
PO_4^{3-}	0.19	38	25.95	0.2	40	27.31	0.137	27.33	18.67	0.16	31.33	21.40
	$\sum W_n*Q_n$=81.3710 WQI=81.37			$\sum W_n*Q_n$=72.94 WQI= 72.94			$\sum W_n*Q_n$=47.0564 WQI=47.06			$\sum W_n*Q_n$=55.46 WQI=55.46		

Table 3: WQI estimation at midstream (DS2)

Para-meters	Summer			Autumn			Winter			Spring		
	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n
pH	7.33	22.22	0.89	7.44	29.33	1.18	7.82	54.44	2.19	7.65	43.55	1.75
WT	29.87	93.35	0.10	28.67	89.58	0.95	22.97	71.78	0.76	27.14	84.81	0.90
TDS	119.39	23.88	0.02	96.28	19.26	0.01	71.6	14.32	0.01	83.3	16.66	0.01
EC	193.38	64.46	0.07	167.12	55.71	0.06	124.6	41.53	0.05	143.43	47.81	0.05
Turbidity	42.09	841.8	57.48	31.14	622.8	42.53	22.62	452.4	30.89	28.32	566.4	38.68
Cl-	21.16	8.464	0.01	16.09	6.44	0.01	13.73	5.49	0.01	20.15	8.06	0.01
TH	57	19.00	0.02	65.71	21.90	0.02	106.09	35.36	0.04	74.44	24.81	0.03
TA	77.35	64.46	0.18	89.59	74.65	0.21	114.39	95.32	0.27	84.7	70.59	0.20
Ca^{2+}	10.16	13.55	0.06	13.62	18.16	0.08	19.5	26.00	0.12	13.63	18.17	0.08
Mg^{2+}	7.79	25.98	0.29	7.63	25.43	0.29	14.62	48.72	0.55	10.07	33.57	0.38
DO	5.04	99.62	6.80	7.65	72.43	4.95	8.59	62.57	4.27	6.84	80.80	5.52
BOD	2.82	56.47	3.85	3.71	74.2	5.07	5.3	106	7.24	3.76	75.2	5.13
K^+	6.15	51.22	1.46	4.03	33.61	0.96	3.57	29.75	0.85	4.92	40.97	1.16
$SO4^{2-}$	15.58	10.39	0.02	11.67	7.78	0.02	9.93	6.62	0.01	12.52	8.35	0.02
NO_3-	0.52	1.15	0.01	0.31	0.69	0.005	0.14	0.32	0.002	0.29	0.64	0.005
PO_4^{3-}	0.21	42.67	29.14	0.24	47.33	32.32	0.15	30	20.49	0.17	33.33	22.76
	$\sum W_n*Q_n$=101.3214 WQI=101.32			$\sum W_n*Q_n$=88.6738 WQI= 88.67			$\sum W_n*Q_n$=67.7566 WQI=67.76			$\sum W_n*Q_n$=76.7083 WQI=76.71		

Table 4: WQI estimation at midstream (DS3)

Para-meters	Summer			Autumn			Winter			Spring		
	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n	V_n	Q_n	W_n*Q_n
pH	7.42	27.78	1.11	7.41	27.55	1.17	7.94	62.44	2.51	7.76	50.44	2.03
WT	29.70	92.80	0.99	28.13	87.91	0.94	23.14	72.32	0.77	27.01	84.39	0.90
TDS	124.97	24.99	0.02	117.21	23.44	0.02	81.88	16.37	0.01	84.67	16.93	0.01
EC	186.05	62.02	0.07	161.46	53.82	0.06	164.6	54.87	0.06	164.43	54.81	0.06
Turbidity	44.67	893.4	61.01	33.8	676	46.16	22.43	448.67	30.64	30.02	600.33	40.99
Cl-	21.77	8.71	0.01	12.17	4.87	0.01	11.83	4.73	0.01	19.53	7.81	0.01
TH	60.67	20.22	0.02	76.91	25.63	0.03	109.07	36.35	0.04	82.86	27.62	0.03
TA	82.83	69.02	0.20	91.76	76.47	0.22	132.5	110.42	0.31	118.35	98.63	0.28
Ca^{2+}	9.62	12.83	0.06	13.09	17.46	0.08	17.37	23.15	0.10	13.09	17.46	0.08
Mg^{2+}	8.12	27.06	0.31	7.47	24.89	0.28	15.1	50.34	0.57	11.17	37.22	0.42
DO	5.30	96.84	6.61	7.38	75.17	5.13	7.05	78.68	5.37	6.98	79.41	5.42
BOD	3.06	61.27	4.18	3.89	77.8	5.31	4.34	86.73	5.92	3.57	71.47	4.88
K^+	6.61	55.08	1.57	4.39	36.55	1.04	3.09	25.78	0.73	4.48	37.30	1.06
SO_4^{2-}	14.28	9.52	0.02	12.38	8.25	0.02	10.27	6.85	0.01	11.44	7.63	0.02
NO_3-	0.46	1.02	0.01	0.29	0.64	0.005	0.177	0.39	0.003	0.27	0.6	0.004
PO_4^{3-}	0.27	53.33	36.42	0.22	43.33	29.59	0.167	33.33	22.76	0.17	34.67	23.67
	$\sum W_n*Q_n$=112.6132 WQI=112.61			$\sum W_n*Q_n$=90.0020 WQI= 90.00			$\sum W_n*Q_n$=69.8428 WQI=69.84			$\sum W_n*Q_n$=79.8814 WQI=79.88		

Seasonal WQI of Dhansiri River

The spatiotemporal variation of seasonal WQI for the three sampling stations (DS1, DS2 and DS3) is presented in Table 2, 3, 4.

The weighted WQI was proposed to examine the aptness of water for diverse uses, taking into account the BIS/WHO standard limit of various parameters, as each physicochemical unit forms a holistic approach for estimating the quality status. The unit weight of each parameter significantly influences the calculation. Among the several physicochemical factors under consideration, it was noted that PO_4^{2-} exhibited the highest weightage of 0.683. This was followed by DO, BOD, and turbidity, each assigned a weightage of 0.068 (Table 5). WQI seasonal variation at each sampling stations showcased that maximum values were observed during summer, autumn, spring and winter. Across all examined sites and seasons, it was observed that DS2 and DS3 of summer were the most polluted, with WQI status as "very poor" and "unfit and not potable". Similar findings were also reported from the midstream and downstream stretch of the Sutlej River, which were due to the increased influx of sewage and industrial effluents.[40] This study documented a high WQI score and significant variation between the examined sites, which can reasonably be attributed to the impact of diverse anthropogenic activities, land utilisation patterns, and rainwater carrying surface runoff that then subsequently enters the river, altering its flow.[15] Such results were concurrent in Kolong River Assam affected by man-made pollution.[24] Since the WQI value obtained in the study was >100, as shown in Table 6, it is rated unfit and not potable for drinking during summer, autumn and spring. In contrast, the lowest value was observed during the winter at DS1 (47.06), which is considered good quality as it ranges between 25-50. The decline in water quality from DS1 to DS3 may be attributed to the upstream positioning of Doyapur, which encounters comparatively lower levels of human intervention. However, as the river runs downstream, it accumulates contaminants from point and non-point sources, leading to deterioration in water quality.

The WQI report for each of the three sampling points is listed in Fig. 2 and Table 7, indicating that although the water quality in DS1 is classified as "good," the water quality in DS2 and DS3 is categorised as "poor" and is unfit for residential usage. In spring, in all three stations, DS1, DS2, and DS3, the WQI ranged from 55.46 to 79.88, which was found to be within the range of "poor/very poor" water quality. Summer recorded the highest value compared with the other seasons. The recorded values for DS1, DS2, and DS3 were 81.37, 101.32, and 112.61, respectively. These values were above the threshold of 100, indicating that the water was not potable for human consumption. Likewise, observation was also noted by Das and Semy.[41] During the autumn, DS1 (72.94), DS2 (88.67), and DS3 (90.00), were within the range of 76-100 and were classified as exhibiting very poor water quality according to quantifying water category status.

Table 5: Unit weight (Wi) of water characteristics and standard limits

Water characteristics	BIS/WHO limits (S_n)	$W_i = R/S_n$
pH	6.5-8.5	0.04016922
WT	32	0.01066995
TDS	500	0.00068288
EC	300	0.00113813
Turbidity	5	0.06828768
Cl-	250	0.00136575
TH	300	0.00113813
TA	120	0.00284532
Ca^{2+}	75	0.00455251
Mg^{2+}	30	0.01138128
DO	5	0.06828768
BOD	5	0.06828768
K^+	12	0.0284532
SO_4^{2-}	150	0.00227626
NO^-_3	45	0.00758752
PO_4^{2-}	0.5	0.68287681
		∑Wi= 1.00

The study identified a distinct seasonal pattern in water quality, wherein alterations in water suitability were significantly influenced by ongoing developmental works (building of bridges and railway tracks), municipal dumping sites, fertilizers and pesticides, the inflow of sewage from residential and commercial areas, cement factories, brick kilns, immersions of idols, bathing and washing of clothes or utensils, oil leaks from vehicles, and connections of nallahs directly into the river body. These findings coherently imply the effect of man-made actions polluting the natural water source of Dhansiri River at various catchment areas. Hence, applying accurate approaches such as microfiltration, precipitation reaction method, cation exchange, leaching process, and reverse osmosis to treat the impurities in the water will prove advantageous in treating the contaminants.[29]

Table 6: Grading of WQI according to Brown *et al.* (1970)

Range of WQI	Quantifying water category status (QWCS)
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit and not potable

Table 7: Overview of water quality grade and WQI of Dhansiri River

Sites	Summer		Autumn		Winter		Spring	
	WQI	QWCS	WQI	QWCS	WQI	QWCS	WQI	QWCS
Site 1	81.37	Very poor	72.94	Poor	47.06	Good	55.46	Poor
Site 2	101.32	Unfit and not potable	88.67	Very poor	67.76	Poor	76.71	Very poor
Site 3	112.61	Unfit and not potable	90	Very poor	69.84	Poor	79.88	Very poor

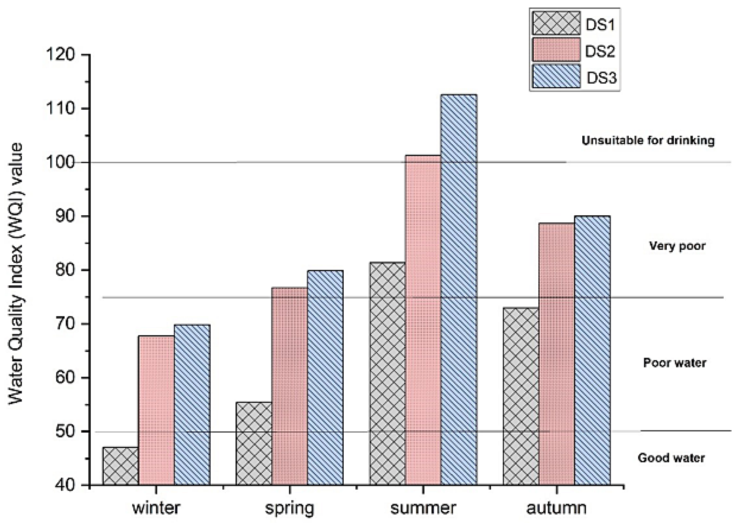

Fig. 2: Seasonal WQI rating of Dhansiri River

Conclusion

The current survey aims to elucidate the influence of environmental and anthropogenic factors on river water by examining the coherent impacts of seasonal variations in water quality indices across all seasons at three sampling points along the Dhansiri River. The finding of this study reveals that turbidity was higher than the BIS/WHO permissible level across all four seasons, while TA exceeded the given desirable limit during winter. In sampling point DS1, the river water quality was graded as good during the winter, but poor throughout the remaining seasons. While in DS2 and DS3, in all the seasons, the water quality was found to be deplorable and deemed unsuitable for domestic and human consumption. The degradation in water quality at the three monitoring stations can be attributed to significant anthropogenic practices such as the unauthorised release of effluent, entry of waste from municipal dumping sites, washing and cleaning practices, religious activities, farm runoffs containing chemical compounds, and drainage from cities, are accountable for the decline and depletion of the water quality. The outcome of this study offers substantiation for our hypothesis that the water of Dhansiri River is contaminated due to the proximity of municipal dumping and direct discharge of agricultural, domestic, and commercial effluents into the river, and the utilisation of this water by the indigenous community may lead to an increased susceptibility to waterborne illnesses. Thus, to reduce the river's further exploitation and ensure that its health is restored, it is recommended to implement an effective drainage system and enforce measures to avoid the introduction of residential sewage and agricultural runoff into the river. At the same time, the area where municipal solid waste is dumped should be relocated to obstruct the infiltration of waste into the river.

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The data collected is a part of the research work and is provided with the best if its experiments.

Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Author Contributions

- **Wati Lemla:** Fieldwork, experiments and construction of manuscript.
- **MR Singh:** Supervision of the work and manuscript.
- **Khikeya Semy:** Experimental reviews and manuscript proof-reading.

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