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Keywords

Water Quality Index, Dikhu River, Principal Component Analysis, Minimum Data Set, North-East India

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RESEARCH PAPER

Estimation of Water Quality of Dikhu River of Nagaland Through a Combination of Water Quality Index and Principal Component Analysis Techniques

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Abstract

Monitoring the physico-chemical attributes of water is essential for determining water quality. The present study explores the effect of various anthropogenic factors on the quality of Dikhu River, Nagaland. Water samples from three sampling stations were compared against three standards: Indian Council of Medical Research, Bureau of Indian Standards, and World Health Organization. Although all parameters were within the permissible limits, the Water Quality Index categorized all sites during the rainy season as "poor quality", highlighting anthropogenic impacts. A principal component analysis created a Minimum Data Set (MDS) explaining 100%, 93.27%, and 96.26% of the total variance for the three sites. The MDS creation will enable sustainable, rapid, and cost-effective monitoring of the Dikhu River.

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1. Introduction

The chemical composition of rivers and groundwater heavily influences the balance between economic progress and a country's natural resources [1]. Therefore, although rivers only make up 0.0001% of the total global water supply, they play a vital role in carrying water and nutrients across the globe [2]. However, various physical, chemical, and biological agents alter water quality. Hence, monitoring the physico-chemical attributes of water is critical as they form the baseline data for early indicators of water quality [3]. These parameters include physico-chemical attributes such as pH, dissolved oxygen (DO), electrical conductivity (EC), hardness, alkalinity, chlorides (Cl^-), and nitrates (NO_3^-) [4–6]. The assessment of these parameters enables for evaluation of the condition of the water environment, understanding of the ecosystem dynamics, assessing hydrochemistry, and promoting water quality restoration [5]. Adverse changes in these water parameters can reduce the primary productivity of aquatic ecosystems [7]. Further, contaminants in the water environment hamper the entry of light into bodies of water, resulting in anoxic conditions and the depletion of aquatic flora and fauna [8]. These harm the biotic community, with sensitive populations declining or even disappearing due to changes in water chemistry [9]. Such negative interactions ultimately become a global problem that endangers water resources globally [10].

Therefore, regularly monitoring physico-chemical traits is essential, as natural and anthropogenic sources significantly influence river chemistry [11]. However, with increasing land pressure, anthropogenic factors have been found to contribute to the loading of nutrients into streams, leading to increased water demand and noticeable water quality degradation [12,13]. Contaminants such as

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pesticides, pharmaceuticals, heavy metals, and other toxic domestic products released into the environment can intensify this degradation [14]. Khalil et al. [15] reported that such dangers are more common in developing countries due to inadequate regulation. When combined with uncontrolled and improper waste disposal into water bodies, such practices can cause substantial harm to the water quality [16]. To increase awareness and monitoring, the United Nations (UN) has therefore incorporated improving water quality in the Sustainable Development Goals (SDGs) target 6.3 via monitoring pollution, disposal, and encouraging the reuse and recycling of water [17]. Hence, systematic studies of river pollution and its relation to various anthropogenic activities are essential for developing future conservation strategies [18]. Such water quality assessments are necessary to effectively evaluate water quality, identify pollution sources, and ensure their control [19,20].

One way to assess water quality in the North-Eastern region of India is to use the regional standards set by the Indian Council of Medical Research (ICMR) [21], the Bureau of Indian Standards (BIS) [22], and international standards proposed by World Health Organization (WHO) [23]. These enable for comparison of water quality against both regional and international standards. Water quality is considered harmful and unfit for human consumption and uses when it falls outside the ranges defined by these well-defined standards [5]. Another valuable tool for monitoring and determining the overall water quality is the Water Quality Index (WQI) [24]. WQI provides a numerical expression that defines water quality [25]. Converting large and complex data into simpler data aids in disseminating information to the public and developing various management policies [26]. It is reported to provide factual information on water degradation status and enable efficient monitoring of water [1]. Semy and Singh [6] employed WQI to display the adverse effects of coal mining on the Tsurang River, Nagaland, while Lkr et al. [5] utilized WQI to show that pH, DO, and biological oxygen demand (BOD) significantly affected the quality of Doyang River, Nagaland.

Next, multivariate analysis tools such as Principal Component Analysis (PCA) can also simplify the data collection processes in water monitoring [27]. PCA is a multivariate technique that creates independent components from a set of observed variables. This method reduces workload by removing highly correlated items and enables the creation of key indicators of water quality using only the retained variables in the PCA [28]. Tripathi and Singal [29] note that selecting variables in PCA is more objective and aids in WQI estimation. These tools have enabled the identification of pollution sources in various drainage systems, optimizing water quality and reducing redundancy [10,19]. Such multivariate tools have also allowed researchers to understand the complex relationships between spatio-temporal factors and river water chemistry [5,30].

The Dikhu River originates from Nuroto Hill in the Zunheboto district of Nagaland, North-East India, and flows through the district of Mokokchung. The indigenous inhabitants depend on this river for farming, fishing, agriculture, and other domestic purposes. The river is, therefore, a vital lifeline for the region's residents. As agriculture is the main livelihood in the country, increased fertilizer discharge may lead to pollution in the water bodies [1]. In addition, uncontrolled anthropogenic activities such as fishing with toxic chemicals, improper sewage disposal, and domestic and agricultural runoff are standard practices in the region. Furthermore, surface water is particularly vulnerable to these activities [31] and is significantly affected by physical and biochemical processes in the soil and atmosphere [30,32]. Therefore, it is vital to compare the water quality against the standards such as the ICMR, BIS, and WHO. Further, although other researchers [5,6,33] have generated the WQI for the Tsurang River and Doyang River in Nagaland, India, there is a gap in knowledge regarding the WQI of the Dikhu River, which is essential for the region's inhabitants. Therefore, the novelty of the present study lies in establishing the WQI of the Dikhu River. The study also aims to reduce the Original Data Set (ODS) to a Minimum Data Set (MDS). The MDS's goal is to reduce the time and resources required for water quality monitoring programs in the region while selecting those water quality variables that best represent the river's quality. The utilization of regional and international water quality standards and the WQI enables researchers to determine the water chemistry and status of water pollution [8]. Hence the present study attempts to undertake the following objectives:

- To compare the Dikhu River's water quality against the ICMR, BIS, and WHO standards.
- Calculating the seasonal WQI for the sampling sites along the Dikhu River.
- Implement PCA to reduce the ODS and obtain MDS to aid water monitoring and cost-reduction.

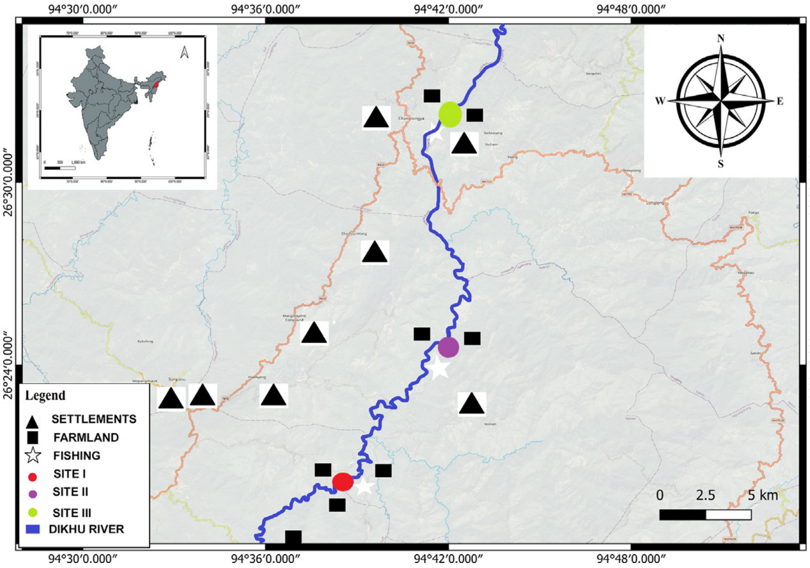

Fig. 1. Sampling sites I-III along Dikhu River, Nagaland, North-East India.

2. Materials and methods

2.1. Study area and sampling stations

Surface water samples were collected from three sampling sites monthly along the stretch of the Dikhu River (Mokokchung district) during 2019−2020 (Fig. 1). Table 1 details the study area, including the significant human activities, land use, population size, and coordinates of the study sites. The region experiences rainfall during summer and autumn (2500 mm), with minimal precipitation during winter and spring [34]. All sampling stations were selected considering the high anthropogenic activities adjacent to the sampling sites (Table 1). Although no quantitative analysis was performed, a preliminary visual survey displayed primary riparian vegetation along the sampling sites consisting of *Aegopodium podagraria, Ageratina adenophora, Ageratina riparia, Ageratum conyzoides, Eupatorium* sp., *Persicaria maculosa, Pneumatopteris pennigera,* and *Solanum americanum*, similar to findings of Krhiel et al. in the region [35].

2.2. Sampling procedure and analysis

The three sampling sites were selected (approximately 16 km apart) based on their utilization and anthropogenic disturbances within the region of the

Table 1. Description of sampling stations along Dikhu River, Nagaland, India.

Sampling stations	Adjacent localities	Population size (2011 census)	Coordinates	Elevation (above msl)	Land use and anthropogenic activities
Site I	Yisemyong, Sungratsu, Mopungchuket	7571	26° 20′ 90″ N 94° 38′ 29″ E	459 m	Fishing practices involving utilization of bleaching powders and explosives, and agricultural run-offs from the adjacent land use area. Influx of waste from upstream municipal area. Located upstream
Site II	Mongsenyimti compound, Chuchuyimlang, Noksen	6883	26° 24′ 38″ N 94° 41′ 59″E	386 m	Fishing utilizing chemicals and agricultural run-offs. Agriculture and influx of waste from upstream municipal area. Located downstream to site I at a distance of 16 km.
Site III	Changtongya, Noksosang, Yachem	11,155	26° 32′ 22″ N 94° 42′ 15″ E	281 m	Fishing, agricultural, animal waste run-offs from adjacent land use. Influx of waste from upstream municipal area. Located downstream to site II at a distance of 16 km.

Mokokchung district (Table 1) and four seasons, namely winter (December 2019–February 2020), spring (March–May 2020), summer (June–August 2020), and autumn (September–November 2020) were considered [6]. The river flows into the Longleng district of Nagaland beyond sampling station III. Water samples were collected from the first 20 cm of the water column via a bottom-weight polyethylene flask [5,6]. All samples were collected on the same day (afternoon) due to the relatively short distance between sites on the first week of every month. The sample was collected from the middle section of the river from each site to minimize disturbance from factors such as sedimentation or disturbances near the riverbanks [36]. Water pH and total dissolved solids (TDS) were recorded on-site utilizing digital pH (pH system 361) and TDS meter (Model LMCM-20). EC was measured with a digital conductivity meter (Model LMCM-20). In the estimation of DO, water samples were treated with fixatives and estimated via Winkler's method fixatives [37]. BOD was then subsequently recorded following incubation (5 days) in the dark at 20 °C [5]. NO_3^- was estimated utilizing the Brucine method [6] via a double-beam UV–visible spectrophotometer (Elico SL 21-UV VIS). Standard titration methods were utilized for estimating Cl^-, total alkalinity (TA), magnesium (Mg^{2+}), calcium (Ca^{2+}), and total hardness (TH) as per Trivedy and Goel [38] and American Public Health Association [39]. All experiments were performed within 24 h of water collection. To compare the quality of water in the present study, three standards were chosen: ICMR [21], BIS [22], and WHO [23]. All tests are performed in triplicates.

2.3. Data analysis

2.3.1. Statistical analysis

The reduction of ODS to the MDS was performed via PCA [40]. All data were normalized, and factors with eigenvalues >1, explaining at least 5% of the dataset variation, were retained as the MDS at each site [41]. Since each Principal Component (PC) includes information from the observed variables, there is minimal information loss from each sampling site [42]. The obtained PC was then subjected to a varimax rotation with Kaiser Normalization to maximize the loading scores [43]. Loading scores <0.30 were suppressed, and scores >0.75 were retained. The highly correlated items from the correlation matrix were considered redundant and removed [44]. Finally, the representative water quality parameter constituted the MDS for estimating water quality. The present study employs Statistical Package for the Social Sciences (SPSS) version 26.0 to perform all statistical operations [45].

2.3.2. Calculation of water quality index

For the estimation of WQI, the method proposed by Brown et al. [46] was utilized, as shown in equation (1).

$$WQI = \sum Q_s W_s \Big/ \sum W_s \tag{1}$$

Where in, Q_s = quality rating scale for each water parameter. This was calculated by using the expression as shown in equation (2):

$$Q_s = 100[(V_c - V_1) / V_0 - V_1)] \tag{2}$$

Where, V_c = concentration of nth parameter in the water sample, V_1 = ideal value of water, i.e., 0 (the exception being pH whose value is considered as 7.0 and DO considered as 14.6 mg/L), V_0 = recommended standard value of nth water quality parameter.

Unit weight (W_s) is estimated as shown in equation (3):

$$W_s = K / V_0. \tag{3}$$

Where, K = constant of proportionality (Equation (4))

$$K = \left[1 \Big/ \sum 1 \Big/ V_0\right]. \tag{4}$$

Where $\sum 1/V_0$ = $1/V_0$ (pH) + $1/V_0$ (EC) + $1/V_0$ (TDS) + $1/V_0$ (TH) + $1/V_0$ (Ca^{2+}) + $1/V_0$ (Mg^{2+}) + $1/V_0$ (TA) + $1/V_0$ (Cl^-) + $1/V_0$ (NO_3^-) + $1/V_0$ (DO) + $1/V_0$ (BOD).

The BIS/ICMR standards were utilized per Lkr et al. [5] and Semy and Singh [6], presented in Table 2, to generate the water quality standards and unit weights. The Water Quality Status (WQS) is presented in Table 3.

Table 2. BIS/ICMR water quality standards and unit weights.

Parameters	BIS/ICMR standards (V_0)	Unit Weight ($W_s = k/V_0$)
pH	6.5–8.5	0.192
EC	300	0.005
TDS	500	0.003
TH	300	0.005
Ca^{2+}	75	0.022
Mg^{2+}	30	0.054
TA	120	0.014
Cl^-	250	0.007
NO_3^-	45	0.036
DO	5	0.326
BOD	5	0.326
		$\sum W_s = 1.00$

Table 3. WQI range and WQS of the water sample.

WQI range	WQS
0 to 25	Excellent (can be utilized for drinking purposes)
26 to 50	Good (can be utilized for drinking purposes)
51 to 75	Poor (can be utilized only irrigation and industrial purpose)
76 to 100	Very poor (can be utilized for industrial purposes)
100 +	Unsuitable for drinking purpose

3. Results

3.1. Water physico-chemical parameters

Table 4 depicts the result of the physico-chemical parameters of water at the three sampling sites. The pH was highest during winter and lowest during autumn at all study locations. EC values were highest during autumn and summer at all sites. Site III displayed the highest value of EC during the summer (233 ± 14.7 μS/cm), while the lowest value of EC was recorded during the winter at site I (160 ± 9.1 μS/cm). Similarly, TDS values were higher during autumn across all study sites. The highest value of 114 ± 1.3 mg/L was recorded at site II during autumn, while the lowest value of TDS, i.e., 46 ± 1.3 mg/L, was recorded at site I during winter. The TH values were lower during the summer and autumn at all sites, while site II displayed the highest TH value during winter TH (40.2 ± 1.3 mg/L). Ca^{2+} and Mg^{2+} were also highest during winter. The highest Ca^{2+} value was recorded at site III, while the highest Mg^{2+} value was recorded at site II. Similarly, TA values were highest during winter, which decreased with the onset of the rainy season across the sampling sites. The highest TA value was recorded at site II (91.2 ± 1.9 mg/L) during winter, while it was lowest during autumn at site III (36.5 ± 0.7 mg/L). Cl^- was highest during autumn and lowest during winter at all sites, with the highest value recorded at site III. NO_3^- was highest at sites II and III with a value of 0.81 ± 0.005 and 0.81 ± 0.002 mg/L during autumn, respectively. Meanwhile, the lowest value of NO_3^- was recorded at site I (0.63 ± 0.001 mg/L) during summer. The DO values were higher during winter, with the highest value of 10.9 ± 1.3 mg/L at site I. The DO values were lowest during autumn at site III (4.87 ± 0.5 mg/L). BOD was lowest during winter (1.91 ± 0.05 mg/L) and highest during autumn (5.00 ± 0.07 mg/L), respectively.

3.2. Water quality index

Table 5 depicts the WQI of the study sites. At site I, the values of WQI were 48.93 (winter), 55.36

Table 4. Mean values of water quality parameters of the three sampling stations.

Parameters	Winter			Spring			Summer			Autumn			BIS/ICMR	WHO
	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III	Water quality standards	Water quality standards
pH	8.21 ± 0.2	8.15 ± 0.3	8.2 ± 0.1	7.8 ± 0.6	7.69 ± 0.4	7.65 ± 0.1	7.62 ± 0.1	7.65 ± 0.7	7.65 ± 0.1.1	7.5 ± 0.1	7.3 ± 0.5	7.12 ± 0.3	6.5–8.5	6.5–8.5
EC (μS/cm)	160 ± 9.1	170 ± 5.3	172 ± 5.0	175 ± 6.1	180 ± 9.9	181 ± 5.4	220 ± 11.3	232 ± 12.9	233 ± 14.7	194 ± 6.4	190 ± 11.1	210 ± 6.6	300	400
TDS (mg/l)	46 ± 1.3	58 ± 1.5	61 ± 1.9	78 ± 1.1	82 ± 1.9	79 ± 1.2	89 ± 1.6	91 ± 1.4	80 ± 1.8	112 ± 1.5	114 ± 1.3	102 ± 0.5	500	500–1000
TH (mg/l)	38 ± 1.3	40.2 ± 1.3	39.5 ± 1.1	22.75 ± 1.3	23.6 ± 1.9	23.41 ± 1.3	14.01 ± 1.2	13.99 ± 0.9	14.25 ± 1.6	20.12 ± 0.9	18.99 ± 1.6	19.62 ± 1.9	300	500
Ca^{2+} (mg/l)	15 ± 1.6	16.1 ± 0.9	17.2 ± 1.4	14.2 ± 1.4	9.5 ± 1.8	11.2 ± 1.3	9.5 ± 0.7	8.4 ± 1.5	7.6 ± 0.3	11.5 ± 0.7	13.5 ± 1.4	14.02 ± 1.1	75	100
Mg^{2+} (mg/l)	23 ± 1.5	24.1 ± 1.3	22.3 ± 0.7	8.55 ± 1.5	14.1 ± 1.6	12.21 ± 1.7	4.51 ± 1.1	5.59 ± 1.8	6.65 ± 2.3	8.62 ± 1.7	5.49 ± 1.2	5.6 ± 1.2	30	50
TA (mg/l)	89.65 ± 1.3	91.2 ± 1.9	89.56 ± 0.3	77.1 ± 1.8	65.4 ± 1.5	62.3 ± 1.3	50.1 ± 1.5	53 ± 1.8	49.7 ± 1.9	44.7 ± 1.3	39.8 ± 0.8	36.5 ± 0.7	120	NA
Cl^- (mg/l)	24.61 ± 1.5	21 ± 0.9	22 ± 1.2	29 ± 1.1	27 ± 0.7	32 ± 0.3	35 ± 0.9	39 ± 1.3	33 ± 0.7	39 ± 1.1	42 ± 0.5	45 ± 1.1	250	250
NO_3^- (mg/l)	0.72 ± 0.01	0.70 ± 0.001	0.73 ± 0.001	0.70 ± 0.02	0.75 ± 0.01	0.74 ± 0.01	0.63 ± 0.001	0.69 ± 0.02	0.067 ± 0.001	0.68 ± 0.003	0.81 ± 0.005	0.81 ± 0.002	45	50
DO (mg/l)	10.9 ± 1.3	8.9 ± 0.9	8.3 ± 2	8.0 ± 1.4	6.66 ± 0.8	6.9 ± 0.7	5.45 ± 1.3	5.03 ± 1.1	5.08 ± 0.7	5.00 ± 0.5	4.89 ± 0.6	4.87 ± 0.5	5	NA
BOD (mg/l)	1.91 ± 0.05	2.1 ± 0.07	2.2 ± 0.09	2.3 ± 0.07	2.0 ± 0.01	2.1 ± 0.03	3.0 ± 0.10	3.1 ± 0.03	3.1 ± 0.07	3.0 ± 0.05	4.9 ± 0.03	5.0 ± 0.07	5	NA

Mean values (±S.E), NA = Not available.

Table 5. *Water Quality Index of study sites.*

Parameters	Winter			Spring			Summer			Autumn		
	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III
	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s	Q_sW_s
pH	15.45412	15.34118	15.43529	14.68235	14.47529	14.4	14.34353	14.4	14.4	15.22824	14.98353	13.40235
EC	0.266667	0.283333	0.286667	0.291667	0.3	0.301667	0.366667	0.386667	0.388333	0.323333	0.316667	0.35
TDS	0.0276	0.0348	0.0366	0.0468	0.0492	0.0474	0.0534	0.0546	0.048	0.0672	0.0684	0.0612
TH	0.063333	0.067	0.065833	0.037917	0.039333	0.039017	0.02335	0.023317	0.02375	0.033533	0.03165	0.0327
Ca^{2+}	0.44	0.472267	0.504533	0.416533	0.278667	0.328533	0.278666667	0.2464	0.222933	0.337333	0.396	0.411253
Mg^{2+}	4.14	4.338	4.014	1.53	2.538	2.1978	0.8118	1.0062	1.197	1.5516	0.9882	1.008
TA	1.045917	1.064	1.044867	0.8995	0.763	0.726833	0.5845	0.618333	0.579833	0.5215	0.464333	0.425833
Cl^-	0.068908	0.0588	0.0616	0.0812	0.0756	0.0896	0.098	0.1092	0.0924	0.1092	0.1176	0.126
NO_3^-	0.0576	0.056	0.0584	0.056	0.06	0.0592	0.0504	0.0552	0.0544	0.064	0.0648	0.0648
DO	14.91308	18.31461	19.63855	20.375	24.69697	23.62319	29.90826	32.40557	32.08661	32.6	33.33333	33.47023
BOD	12.4532	13.692	14.344	16.952	13.04	13.692	19.56	20.212	20.212	19.56	31.948	32.6
$\sum Q_sW_s$	48.9304	53.722	55.49	55.369	56.316	55.505	66.079	69.517	69.305	70.395	82.713	81.952
WQI	48.93	53.72	55.49	55.369	56.31	55.50	66.07	69.51	69.305	70.39	82.71	81.95

(spring), 66.07 (summer), and 70.39 (autumn). During winter, the water quality was categorized as "good" but deteriorated to the "poor" category during the rainy seasons. At site II, the WQI was 53.72 (winter), 56.31 (spring), 69.51 (summer), and 82.71 (autumn), and the water quality was classified as "poor" throughout the study period. Similarly, at site III, the WQI values were 55.49 (winter), 55.50 (spring), 69.30 (summer), and 81.95 (autumn), and the water quality was "poor." Fig. 2 compares the WQI values across the different sampling sites, revealing that the values increased during the rainy season (summer and autumn) across all sites.

3.3. Creation of Minimum Data Set

The results of the PCA and MDS selection are presented in Table 6. At site I, the PCA retained three PC: PC-1 explained 73.31% of the total variance, PC-2 explained 14.73%, and PC-3 explained the remaining 11.95% (Fig. 3). At site II, two PC were retained: PC-1 explained 69.76% of the total variance, and PC-2 explained 23.51% (Fig. 4a). Finally, at site III, PC-1 explained 73.77% of the variance, while PC-2 explained 22.49% (Fig. 4b). The factor loading scores revealed that at site I, TDS (−0.993) and Mg^{2+} (0.780) were retained under PC-1, pH (0.968) and BOD (0.923) under PC-2, and TA (0.999) under PC-3. At site II, TDS (0.949), Cl^- (0.853), BOD (0.968), and NO_3^- (0.827) DO were retained in PC-1, while EC (−0.864) and Ca^{2+} (0.962) were retained under PC-2. Lastly, at site III, TDS (0.930), BOD (0.916), and NO_3^- (0.864) were retained under PC-1, whereas TH (0.902), EC (−0.883), and Ca^{2+} (0.942) were retained in PC-2.

4. Discussion

4.1. Water physico-chemical parameters

The pH range significantly affects the various chemical reactions within the water body [47]. The pH values were mildly basic during the study period at all sampling sites and within the permissible limit of BIS, ICMR, and WHO, i.e., 6.6–8.5. The higher pH values during the winter are because of the calcium carbonates and bicarbonates in the water body due to the area's geology. Elevated pH levels during the rainy season may result from increased rainwater containing enriched minerals dissolved from the hilly upper regions [48]. Similarly, all values of EC and TDS were also below the permissible limit set by the standards. Rajeshwari and Saraswathi [49] attribute the increased TDS and EC levels in the water body to contamination with

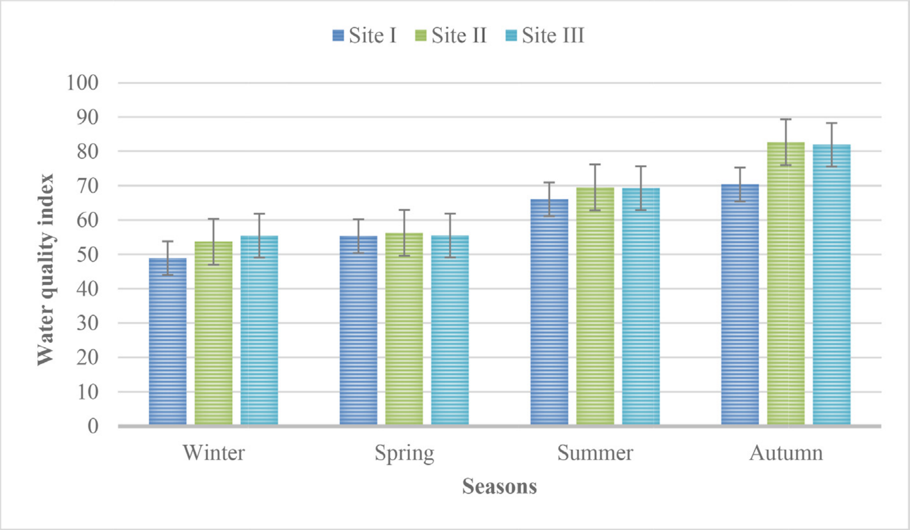

Fig. 2. Seasonal variation of WQI of Dikhu River.

effluents and domestic sewage. This finding confirms our reports of EC and TDS levels rising during the rainy season. This is attributed to increased run-off from the adjacent land use area containing colloidal substances, chemicals, and ions [6,50]. Another reason for the variation in EC levels may be attributed to fishing via blast fishing. Our findings agree with Ali et al. [51], who similarly report on the significant increase in conductivity levels before and after blast fishing. Meanwhile, TH is the accumulation of bicarbonates, sulfates, NO_3^- of Ca^{2+}, and Mg^{2+} in the water bodies [52]. The values of TH were within the permissible limit of the standards, with the uppermost value of TH (40.2 ± 1.3 mg/L) reported at site II during winter. In contrast, site II during summer displayed the minimum TH value (13.99 ± 0.9 mg/L). Similarly, both Ca^{2+} and Mg^{2+} hardness were also within the permissible limits. The uppermost value of Ca^{2+} (17.2 ± 1.4 mg/L) was recorded at site III during the winter season, while it was the lowest during summer at site III (7.6 ± 0.3 mg/L). Likewise, the uppermost value of Mg^{2+}, i.e., 24.1 ± 1.3 mg/L, was observed at site II during winter, while the minimum value of 4.51 ± 1.1 mg/L was reported at site I during summer. A similar variation in the hardness of water was reported by Radhakrishnan et al. [53]. The researchers attribute the variation in hardness to increased run-offs, rock weathering, and sewage deposition during summer, which increases the hardness level of the water. Alkalinity, meanwhile, measures its capacity to neutralize acids [54]. We report higher values of TA during winter and minimal values during autumn. Semy and Singh [6]

Table 6. Principal component analysis of water.

Site	Site I			Site II		Site III	
Principal component	PC-1	PC-2	PC-3	PC-1	PC-2	PC-1	PC-2
Eigen value	8.06	1.62	1.31	7.67	2.58	8.115	2.47
%Variance	73.31	14.73	11.95	69.76	23.51	73.77	22.49
%Cumulative frequency	73.31	88.04	100	69.76	93.27	73.77	96.26
Factor loadings							
TDS	**−.993**			**.949**	−0.302	**.930**	−0.355
Cl^-	−0.963			**.853**	−0.471	0.925	−0.371
DO	0.962			−0.772	0.636	−0.650	0.748
Mg^{2+}	**.780**	0.594		−0.765	0.642	−0.639	0.766
TH	0.775	0.630		−0.598	0.800	−0.409	**.902**
EC	−0.602	−0.725	−0.335		**−.864**		**−.883**
Ca^{2+}	0.624	0.637	0.453		**.962**		**.942**
pH		**.968**			0.943	−0.902	0.403
BOD	0.319	**.923**		**.968**		**.916**	
NO_3^-	−0.664	−0.732		**.827**		**.864**	0.488
TA			**.999**	−0.885	0.461	−0.772	0.634

*Bold indicate the respective data's water parameters in the MDS.

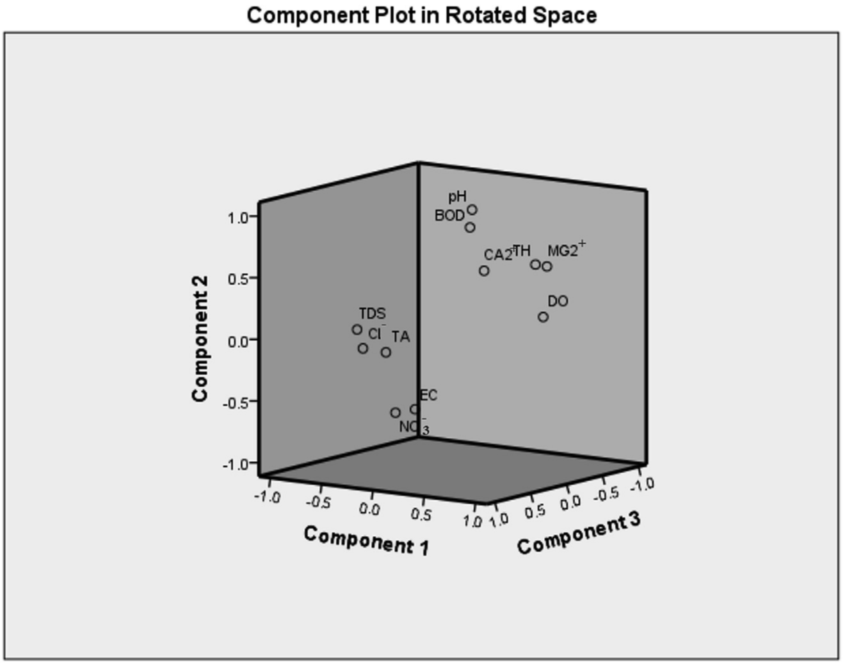

Fig. 3. PCA bi-plot of site I displaying three principal components.

similarly report on the increased TA levels during winter (175–230 mg/L) and lowered TA levels during autumn (158.88–136.66 mg/L) at coal-mining affected Tsurang River, Nagaland. The increased levels of Cl⁻ during the rainy season are attributed to several factors: an increase in the water temperature, the subsequent evapotranspiration, and higher microbial activity [55]. A similar observation of increased Cl⁻ with the onset of the rainy season is reported [5,56]. Increased NO_3^- is attributed to the death of organisms in the water body [57]. The NO_3^- values were lowest during summer, with a value of 0.70 ± 0.001 mg/L (site II) and 0.70 ± 0.02 mg/L (site I). Similar variations and levels of NO_3^- have been reported by Lkr et al. [5], with values ranging from 0.49 to 0.84 mg/L in Doyang River, Nagaland. The increased influx of nitrogen-rich wastewater and run-offs during the rainy season elevates the NO_3^- levels [6]. Unpolluted surface waters have a high amount of DO, while polluted water possesses lower values due to microbes that demand high oxygen [58]. The DO values were lowest during autumn at site III (4.87 ± 0.5 mg/L) and highest during winter at site I (10.9 ± 1.3 mg/L. This DO depletion is attributed to increased temperature and nutrient loading during the rainy season compared to the colder seasons [59]. Meanwhile, the elevated BOD levels during the rainy season represent the

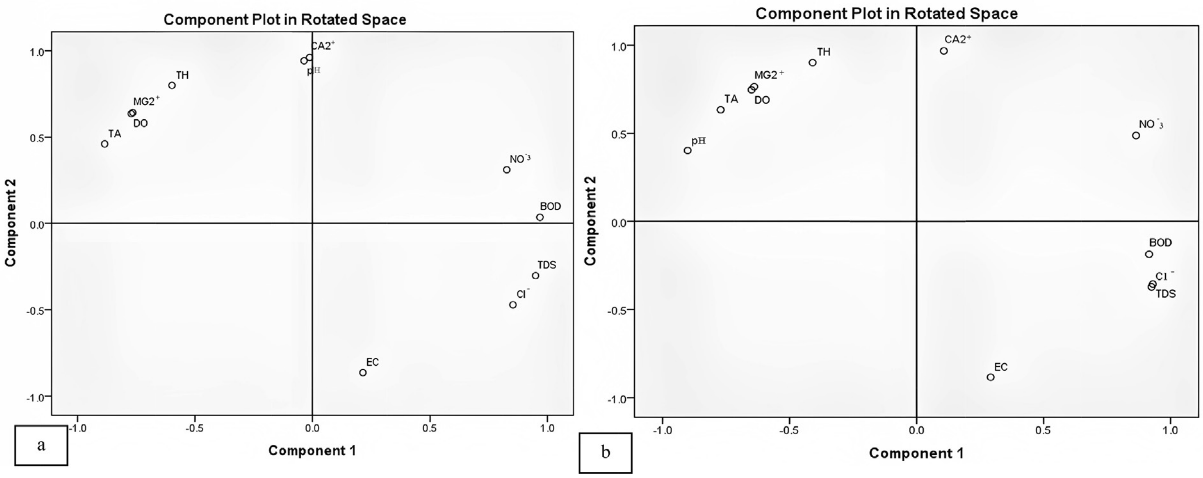

Fig. 4. PCA bi-plot of site II (a) and site III (b) displaying two principal components each.

high organic matter content in the river to be oxidized by the microbes [5]. On inspection of all water parameters, it is observed that the respective values are within the permissible limits set by the three standards. Despite the increased anthropogenic disturbances, riparian vegetation along the stretch of the water body may be one factor preserving the river's water quality. The water body flowing downstream undergoes a process of natural filtration as it passes through riparian vegetation [35]. Lkr et al. [5] similarly report on the remedial role of riparian vegetation in restoring water quality in the region. The generation of such data allows for monitoring the water quality and also acts as baseline data for future comparison of water bodies in the area [10].

4.2. Water quality index

WQI is a tool that enables the creation of a simple expression like a grade that ultimately reflects water quality based on several complex selected variables [60]. The present study reports that at all sampling sites (I-III), the WQI degrades with the onset of the rainy season. All sites were in the poor category during the sampling period except for site I, which was in the "good" category during winter. This "good" quality indicates that the water body is safe and suitable for domestic and industrial purposes [5,6]. One factor for the water retaining its "good quality" may be the presence of the adjacent riparian vegetation [5], as discussed. This riparian vegetation enables a unique ecosystem by forming a buffer between the stream and adjacent land use. This is accomplished by processing nutrients and sediment inflow from the adjacent land use areas and functioning as a sink for the nutrients [61]. We also observe that with the onset of the rainy seasons, all sampling sites displayed higher values of WQI. As a result, WQI lies in the lower spectrum of the "poor" status, with a maximum value of 82.71 at site II and 81.95 at site III during the autumn season, respectively (Table 5). The poor quality indicates that the water may be utilized only for irrigation and industrial purposes (Table 3). Lkr et al. [5] and Singh et al. [62] similarly reported water quality degradation with the onset of monsoon. Further, factors such as increased settlements in the catchment area, fishing, and adjacent agricultural land use may significantly alter the nutrient content, resulting in variation of the WQI. Shah and Joshi [63] report that activities such as run-off and sewage disposals are the main causative agents that lower water quality leading to its eventual deterioration. The present findings also report an increase in WQI in sites II and III compared to site I (Fig. 2). The location of site I, which was upstream of sites II and III, may explain the lower values of WQI. Our work is supported by similar observations that have been reported on the decline of water quality downstream due to increased upstream anthropogenic activities [5,6,64,65]. Another factor may be the increased human settlement adjacent to site III (Table 1), which inadvertently creates more anthropogenic disturbances via run-offs and domestic waste [5]. The implementation of the WQI also highlights that, although the water parameters were within the permissible limits of the standards, the water was not suitable for consumption during the study period. Semy and Singh [6] similarly reported that although the water parameters were within the permissible limit, the WQI peaked in the "poor" category (63.77). The present study thus highlights the effectiveness of utilizing WQI to monitor the Dikhu River. Hence, these techniques may be implemented in future water quality monitoring programs [1,5,6,30].

4.3. Creation of Minimum Data Set

The study creates unique MDS for each sampling site from the factor loading scores and redundancy reduction result (Table 6). The selected parameters in MDS do not represent the most critical or essential values but instead, choose the best representative parameters for each of the sampling sites [66]. Therefore, in the present study, five MDS, i.e., TDS, Mg^{2+}, pH, BOD, and TA, best represent site I. Six MDS, i.e., TDS, Cl^{-}, BOD, NO_3^{-}, DO, EC, and Ca^{2+}, best represent site II. Lastly, site III consists of six MDS, i.e., TDS, BOD, NO_3^{-}, TH, EC, and, Ca^{2+}. Yang et al. [20] similarly utilized PCA to extract three components from the original eighteen ODS representing anthropogenic activity, heavy metals, and pH, respectively. In the present study, we observe that TDS and BOD are highly loaded variables in the PC and retained in the MDS at all sites (Table 6). This displays the negative effect of anthropogenic activities such as sewage and run-offs altering the BOD levels and simultaneously increasing the TDS content. Therefore, the selected variables in each PC represent those physicochemical properties of water that significantly determine water quality [33]. Our results confirm similar findings on the utilization of PCA to explain the total variance in aquatic water bodies by Lkr et al. [33], Mir and Gani [67], and Rezaali et al. [68]. The creation of such MDS by implementing PCA enables local researchers to tailor their work based on the unique aspect of the region. This will ultimately allow for the dissimilation of information to the stakeholders faster.

5. Conclusion

The physico-chemical attributes of the Dikhu River were within the permissible limit set by ICMR, BIS, and WHO during the study period. The study's findings also highlight the successful utilization of WQI for monitoring the Dikhu River. Upon closer inspection of the water quality by utilizing WQI, it is apparent that during the rainy season, all sampling stations deteriorate to the "poor quality" status owing to the increased anthropogenic pressure upstream and adjacent land uses. Practices such as rampant sewage disposals, run-offs, and fishing utilizing chemicals, must be routinely checked and monitored to ensure sustainable utilization of the water body. Such activities also significantly aid the SDGs goals of monitoring water quality. Further, the application of PCA in the present study enables the creation of a unique MDS for the river. The creation of the MDS at site I (TDS, Mg^{2+}, pH, BOD, TA), site II (TDS, Cl^-, BOD, and NO_3^-, DO, EC, Ca^{2+}), and site III (TDS, BOD, NO_3^-, TH, EC, Ca^{2+}) allows for the selection of variables that best represent water quality at each site. The MDS will aid in rapid water monitoring of the Dikhu River while reducing the researchers' workload. The reduction of time and resources in water monitoring ultimately increases monitoring efficiencies. Future work on riparian vegetation and its role in pollution mitigation, identification of household contaminants, industrial effluences, and microbial contamination will enable stakeholders to efficiently manage the water body. Studies on Organic Pollution Index (OPI), Nutrient Pollution Index (NPI), Heavy metals, etc., will also aid in efficient regional monitoring. The present findings provide baseline data underlining the immediate need for conservation strategies and improved management practices to protect the natural capital of the Dikhu River and ensure the well-being of the local communities depending on it.

Conflict of interest

The authors declare no conflict of interest.

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