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Spatio-Temporal Variation in Certain Physico-Chemical Parameters of Water from Imphal River, Manipur

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Authors' contributions

This work was carried out in collaboration between all authors. Author AG designed the study, and wrote the first draft of the manuscript. Author DMK managed the literature searches, analyses of the study performed. Author DA managed the analytical study and identified the species of plant. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

The influences of seasonal changes of water properties from Imphal River were investigated in four locations. A range of water quality variables were measured in the river over a period of 12 months. Four selected sites viz, Khonghampat, Heingang, Mahaballi and Kiyamgei were subjected to various anthropogenic activities, as they passed through the heart of the city. Water samples collected from four sites were analysed for pH, temperature, Dissolved Oxygen (DO). Free CO_2, total chlorides, Total Hardness, Total Alkalinity, NO_3–N, PO_4–P and K. The present results revealed that the investigated parameters were within the WHO permissible levels.

Keywords: Imphal River; Anthropogenic; Parameters; Permissible Level.

1. INTRODUCTION

Fresh water plays an important role being the elixir of life. The river water serves for domestic, agriculture, fisheries and industrial purposes and overall development activities.

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However, the water resources have been the most exploited natural system in the recent past. Siltation of sediment water, loss of river basin, soil erosion and flow of nutrients added by chemical fertilizers cause the damage of river ecology.

Many workers in India have studied the physico-chemical parameters of the water. The literature on spatio-temporal variations of physico- chemical parameters and pollution loads of river system comprised of Scientific Investigation in the river Ganges [1]. Ganga River in Kanpur region [2,3] in Kaveri River; [4] in Yamuna river, [5] in Tungabhadra River.The characteristics of the waste effluents from paper mills and electroplating units discharging waste in the river Hindon , the physico-chemical characteristics and quality of Pravara River in Sangammer, Maharastra [6], on Cauvery River stretch in Karnataka [7]. Several workers also worked on the limnological aspects of the River Ganga at various places, [8,9] at Kanpur, in Ganges River [10], in Haridwara District found that some parameters like pH, electric conductivity, Total Dissolved Solids, Turbidity, etc are found in excess than the prescribed limits in some water samples of the study area [11]. On the water quality and pollution status of Kalpi, Gwalior [12], reported organic pollution in River Gomati due to anthropogenic activities. On the Cauvery River [13] reported increase in the pollution load due to the movement of fertilizers, agricultural ashes, industrial effluents and anthropogenic wastes. Seasonal variations in precipitation, surface run off, ground water flow strongly affect river discharge and consequently the concentration of pollution in the river water [14]. Rivers in the watershed with substantial agricultural and urban land use experience increased inputs and varying composition of organic matter [15], in Chambal River [16], the spatio-temporal variation in trace elements in Patuxent River, Maryland [17].

Nambul River is one of the most polluted rivers of Manipur which receives a heavy flux of sewage, domestic and agricultural waste and other effluents which may vary from simple nutrients to toxic and hazardous substances [18]. A few studies have also been made in the limnological aspects of the river systems in Manipur ,on the Kongba River, Manipur [19], Imphal, Iril, and Thoubal, River for only one site each [20], but in this paper we have highlighted selected four sites from the stretch of Imphal River Manipur.

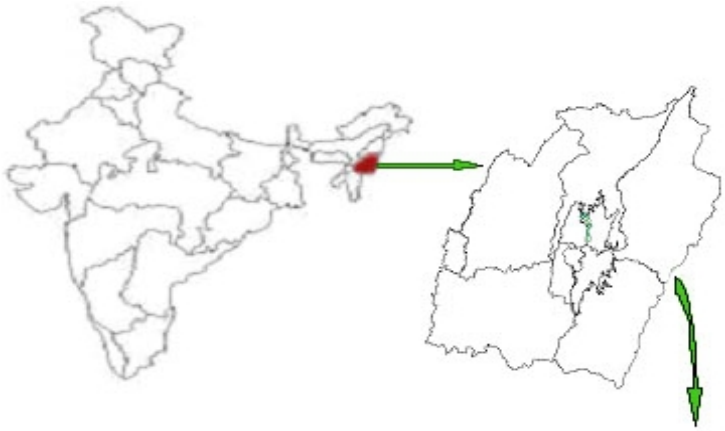
The study viz the spatio-temporal variation in certain physic-chemical parameters were analysed in the Imphal River water and results are shown as follows.

2. MATERIALS AND METHODS

The present study was carried out in Manipur, NE India on Imphal River (latitude 23°13'54"N –24°38'22"N and longitude 93º57'33"E – 93º55' 21" E).The river originates from the Senapati district and is connected with Loktak lake by Khordak and Ungamel channels and finally reaches Myanmar and joins Chindwin river. It is the longest river in the state (129.88 Km) also called Turel Achouba in local language. The total catchment area of the river is 384.8 sq km.

The study was carried out in four sites of the Imphal River – Manipur.

Site I - Khonghampat (Lat.24°52'53"N - Long 93°54'31.3"E),
Site II - Heingang (Lat.24°53'16.4"N - Long 93°56'44.6"E),
Site III - Mahaballi (Lat.24°47'49.7"N - Long 93°56'50.4"E
Site IV - Kiyamgei (Lat.24°44'24.0"N - Long 93°56'58.5"E).



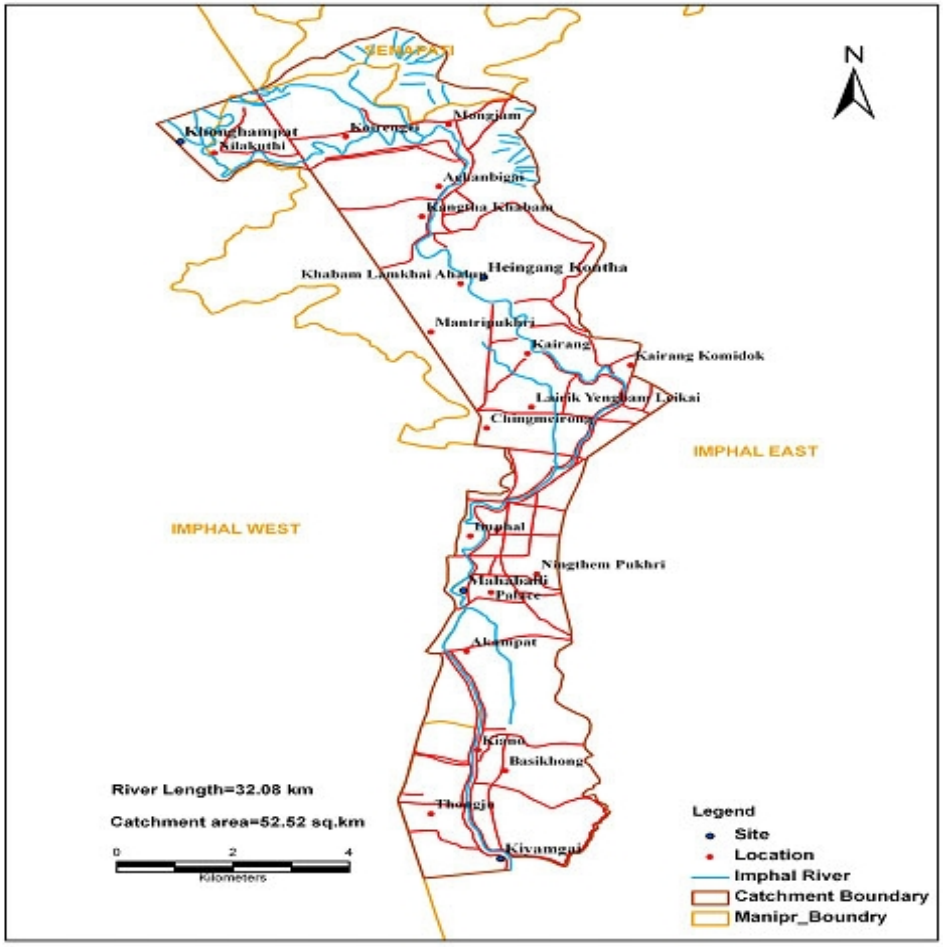


Fig. 1. Map showing Location of Sites and Catchments areas of Imphal River, Manipur.

The water samples were collected at monthly intervals between 6:00 a.m. to 10:00 a.m. from March 2011 to February 2012, from each sampling sites. pH with pen type pH meter model 600 and water temperature was measured with the help of a mercury thermometer in the field because of their unstable nature while the rest Dissolved Oxygen (DO), free CO_2, total chlorides, Total Hardness, Total Alkalinity, NO_3–N, PO_4–P and K were analysed in the laboratory using standard methods [21,22]. SPSS software version 16.0 was used for calculating Pearson's coefficient of correlation.

3. RESULTS AND DISCUSSION

Seasonal physico-chemical water qualities of the four sites of Imphal River are shown in Tables 1, 2, 3, 4 and Tables 5 – 8 reflect correlation matrix among physico-chemical variables of four sites of Imphal River water respectively.

3.1 pH

pH is the negative logarithm of hydrogen ion concentration. It is a valuable parameter which guides not only the status of acid- alkali balance of the water but also serves as an important index for the degree of pollution [23]. It is an important factor which plays a significant role in metabolic activities of aquatic flora and fauna. The pH of water mainly depends upon carbonic acid and interaction between carbonate and bicarbonates [24]. Changes in pH of river water might be attributed due to the climatic and the industrial activities [25]. pH determines the suitability of water for various purposes including toxicity to animals and plants and thus serves as an important index of the degree of pollution. Aquatic organisms are affected by pH because most of their metabolic activities are pH dependent [26]. The factors like photosynthetic activity, respiratory activity, exposure to air, temperature and disposal of sewage etc. bring about the changes in pH [27]. Water analysed could be regarded as neutral and unpolluted [28]. pH value was observed in all sites of three seasons. The recorded pH value was analysed and was found highest at Site-IV (6.82-7.0), followed by Site-III (6.82-6.9),Site-II (6.8-6.97), and Site-I (6.6-6.8) as mean value for three seasons. The values were between the range of 6.50 and 8.50 [29], stipulated for drinking and domestic purposes and also fall within the WHO standard [30]. The mean pH of the water was neutral at all sites during the study period and also found to be negatively correlated with PO_4 and K at Sites-III and IV respectively (see Tables 7 and 8).

3.2 Temperature (ºC)

The surface water temperature is one of the most important physical factors of water body since it is responsible for distribution of plankton and the other organizms [31]. Temperature, the measure of intensity of heat stored in the volume of water is highly correlated with atmospheric temperature and the morphometric features. The increase in temperature of water leads to the speeding of the chemical reaction and may affect the biological and chemical reactions in water. The parameter is of enormous significance, as it regulates various physico-chemical and biological activities [32]. The fluctuation of river water temperature depends on the season, geographic location, sampling time and temperature of effluents entering the stream [33]. The maximum value of temperature was recorded at Site –IV (21.5-29.75), followed by Site-III (21.5-29.5), Site-II (21.5-29.0), and Site-I (21.5-29.0) as obtained in three seasons. The maximum and minimum value of temperature was found in summer and winter respectively. The variation of temperature was found to be significant at Site-I and Site-III with total alkalinity positively correlated ($P>0.05$). And at Site-II,

temperature was significantly correlated with CO_2 and alkalinity positively (P> 0.05). And also at Site-III temperature was found correlated positively with total alkalinity (P > 0.05).

3.3 Dissolved Oxygen (DO)

Dissolved oxygen (DO), is an important parameter for chemical and biological reactions in stream acting in the process of air-water exchanges, photosynthesis, and respiration [34]; and [35]. DO have been extensively used as a parameter delineating water quality and to evaluate the degree of freshness of a river [28]. It is an important limnological parameter indicating level of water quality and organic pollution in the water body [36]. Seasonal variation is related to temperature and biological activities [37]. Low values of DO were usually associated with organic matter [38] and [39]. Lesser photosynthetic activities occur with the lowering of DO and this might serve as limiting factor for the aquatic organisms. Dissolved Oxygen fluctuates with seasonal variation, stream morphology, temperature and biological characters [40]. The minimum value of DO was recorded during rainy season which retarded photosynthetic activities of the aquatic flora which were found more active when the temperature was low. Also lower temperature has greater capacity to hold DO than warm water [41]. Higher DO values were recorded during winter [42];[43] and highest DO value during monsoon season [6]. Higher values of DO recorded in the upstream might be due to the lesser discharge of waste effluents and sewage into the river as the upstream site was less disturbed by human population. This enhances the photosynthetic activities of the phytoplankton. The lower DO recorded downstream might be due to heavy influx of organic waste such as Kitchen waste, municipal waste, domestic effluents etc. The maximum DO value was 12.0 mg/l in the month of May & December and minimal values were recorded in the month of July for all sites. The recorded mean values of Dissolved Oxygen (DO ,mg/l) was found cooperatively higher at Upstream, Site-I (6.55-7.325), Site-II (5.35-7.9), Site-III (4.65-7.25), and Site-IV (4.2-6.675). Seasonal trend was clearly obvious for DO in different sites, with minimum values during rainy season and maximum value in winter season. Low values were associated with organic matter [39] and [44]. All values are well above the WHO permissible limits except at Site-III and -IV in rainy season which reflect the impact of agricultural area and human settlement respectively. As DO is indicator of water quality the lower values adversely affected the water quality and during this period the water are not suitable for use. Our findings are comparable to River Tunga Krishnamurthy as 5.1mg/l – 7.4 mg/l. But lower than in the River Kaveri 8.3 mg/l – 31.1 mg/l [3]. However higher than in Kanhan River 1.5 mg/l – 3.8 mg/l [45]. DO was found to be correlated with PO_4 negatively at Site-III and also with K negatively at Sites-III and Site-IV at (P > 0.01) respectively.

3.4 Free CO_2

The rise in temperature in the river water could be correlated with increase in CO_2 levels [46] when the water level decreased sharply. Free CO_2 is a normal component of all natural water. Biological oxidation of organic matter and dissolved CO_2 from air increases level of CO_2 in water. Thus respiration of aquatic biota, decomposition of organic matters and infiltration through the soil accounts for the presence of CO_2 in water.

High level of CO_2 indicated irregular human disturbance and presence of pollutants and is harmful to aquatic life. Maximum free CO_2 during summer may be due to high rate of decomposition of organic wastes by microbes where they released CO_2 and absorb O_2 during respiration. Downstream position showed higher values because of higher

anthropogenic activities of the riparian zone as well as high microbial respiration due to degradation of organic matter. The recorded Free CO_2 (mg/l) value was analysed and found to be in order Site-I < Site-II < Site-III < Site-IV (see Tables 1-4). The maximum value was recorded as 27.0 mg/l in the summer and the minimum value was recorded as 10.1 mg/l in winter. The higher values of CO_2 were recorded in summer season almost in all sites which are related with the rise of temperature in the river water [47]. However within the range reported at Tungabhadra River (0–54) mg/l [48].

Table 1. Seasonal physico-chemical characteristics of water quality from Imphal River (Site – I, Khonghampat)

Sl no.	Parameters	Summer	Rainy	Winter	Annual average	WHO limits
1	pH	7	6.825	6.875	6.9 ±0.11	6.5-8.5
2	Temperature (ºC)	29	25	21.5	25.2±3.51	30-35
3	DO (mg/l)	8.6	6.55	8.1	7.75±2.2	5.0
4	CO_2 (mg/l)	21	17.775	19.5	19.42±4.2	22
5	Chlorides (mg/l)	22.445	12.725	15.67	16.94±8.7	250
6	Hardness (mg/l)	52.75	38.5	53.25	48.2±19.0	300
7	Alkalinity(mg/l)	53.25	43	41.5	45.9±7.75	120
8	NO_3 –N (mg/l)	0.315	0.55	0.13	0.33±0.21	45
9	PO_4 –P (mg/l)	0.035	0.0675	0.035	0.05±0.020	0.1
10	K (mg/l)	4.26	7.09	4.657	5.3±1.47	50

(Summer – March to June; Rainy – July to October; Winter– November to February)

Table 2. Seasonal physico-chemical characteristics of water quality from Imphal River (Site – II, Heingang)

Sl no.	Parameters	Summer	Rainy	Winter	Annual average	WHO limits
1	pH	6.9	6.825	6.85	6.8±0.14	6.5-8.5
2	Temperature (ºC)	29	24.75	21.5	25.1±3.65	30-35
3	DO (mg/l)	7.9	5.35	7.7	6.98±1.8	5.0
4	CO_2 (mg/l)	21.75	19.0	19.0	19.91±2.7	22
5	Chlorides (mg/l)	28.147	10.57	14.51	17.74±12.5	250
6	Hardness (mg/l)	51.5	38.5	49.25	46.4±19.9	300
7	Alkalinity(mg/l)	56.5	42.25	41.25	46.6±11.5	120
8	NO_3 –N (mg/l)	0.28	0.555	0.147	0.32±0.21	45
9	PO_4 –P (mg/l)	0.035	0.0725	0.0425	0.05±0.022	0.1
10	K (mg/l)	4.2675	7.227	4.775	5.4±1.51	50

(Summer – March to June; Rainy – July to October; Winter– November to February)

Table 3. Seasonal physico-chemical characteristics of water quality from Imphal River (Site – III, Mahaballi)

Sl no.	Parameters	Summer	Rainy	Winter	Annual average	WHO limits
1	pH	6.975	6.8	6.8	6.8 ±0.14	6.5-8.5
2	Temperature (ºC)	29.5	24	22.00	25.2±3.68	30-35
3	DO (mg/l)	7.15	4.65	7.25	6.35±1.5	5.0
4	CO_2 (mg/l)	21.00	22.00	25.00	20.75±3.16	22
5	Chlorides (mg/l)	21.957	12.36	15.55	16.62±8.1	250
6	Hardness (mg/l)	61.75	38.5	57.25	52.5±23.7	300
7	Alkalinity(mg/l)	53.25	42.75	41.5	45.8±8.9	120
8	NO_3 –N (mg/l)	0.43	0.582	0.187	0.40±0.22	45
9	PO_4 –P (mg/l)	0.0425	0.0825	0.045	0.06±0.024	0.1
10	K (mg/l)	4.32	7.317	4.725	5.5±1.55	50

(Summer – March to June; Rainy – July to October; Winter– November to February)

Table 4. Seasonal physico-chemical characteristics of water quality from Imphal River (Site – IV, Kiyamgei)

Sl no.	Parameters	Summer	Rainy	Winter	Annual average	WHO limits
1	pH	6.95	6.775	6.9	6.9 ±0.15	6.5-8.5
2	Temperature (ºC)	29.75	24.25	21.5	25.2±3.90	30-35
3	DO (mg/l)	6.45	4.2	6.675	5.78±1.5	5.0
4	CO_2 (mg/l)	23.0	19.0	20.5	20.83±2.75	22
5	Chlorides (mg/l)	23.00	12.74	16.25	17.33±9.9	250
6	Hardness (mg/l)	90.00	50.0	64.25	68.1±32.8	300
7	Alkalinity(mg/l)	59.0	41.25	41.5	47.2±16.56	120
8	NO_3 –N (mg/l)	0.49	0.602	0.252	0.44±0.2	45
9	PO_4 –P (mg/l)	0.045	0.0825	0.055	0.061±0.020	0.1
10	K (mg/l)	4.3775	7.52	4.902	5.60±1.59	50

(Summer – March to June; Rainy – July to October; Winter– November to February).

3.5 Chloride

Chloride often serves as a chemical pollution indicator for sewage contamination and it increases the degree of eutrophication [48]. Chloride can be one of the indices of water pollution from sewage and drains in the vicinity of the towns within the drainage basin. High concentration of chloride is considered to be the indicator of pollution of organic wastes of animal or industrial origin as well as human interference. It is found in the form of Na, K, Ca salts and higher concentration of chloride is hazardous for human consumption [49]. Chlorides are troublesome in irrigation water and also harmful to aquatic life [50]. The recorded Chloride (mg/l) values revealed the decreasing order as Site IV- (15.24-26.31), Site -III (13.11-24.45), Site-II (13.072-28.147), and Site-I (12.725-22.445) and found to be within the permissible value of chloride content in potable water given by WHO, [30]. The chloride content shows seasonal trend as R < W < S. However the fluctuation in maximum and minimum values was observed in different months which may be due to reduced flow of water and large amount of sewage being carried in it. Low chloride concentration during rainy season might be due to dilution of river water and rapid flow of water [51,52].

Table 5. Pearson's Correlation among physico-chemical variables of water for Site I, Imphal River

	pH	Temp (ºC)	DO (mg/l)	CO_2 (mg/l)	Chlorides (mg/l)	Hardness (mg/l)	Alkalinity (mg/l)	NO_3 (mg/l)	PO_4-P (mg/l)	K (mg/l)
pH	1.0									
Temp (ºC)	0.527	1.0								
DO (mg/l)	0.225	0.071	1.0							
CO_2 (mg/l)	0.076	0.258	-0.08	1.0						
Chlorides (mg/l)	0.114	0.412	0.45	0.120	1.0					
Hardness (mg/l)	0.459	0.143	0.116	0.036	-0.163	1.0				
Alkalinity (mg/l)	0.314	0.604**	-0.06	-0.07	0.206	0.0808	1.0			
NO_3 (mg/l)	0.162	0.421	-0.35	-0.25	-0.106	-0.117	0.0715	1.0		
PO_4-P (mg/l)	-0.24	-0.04	-0.3	-0.1	-0.165	-0.632	-0.257	0.679	1.0	
K (mg/l)	-0.40	-0.14	-0.5	-0.3	-0.172	-0.623	-0.260	0.70**	0.915*	1.0

** Correlation is significant at the 0.05 level (2-tailed).*

***Correlation is significant at the 0.01 level (2-tailed).*

Table 6. Pearson's Correlation among physico-chemical variables of water for Site II, Imphal River

	pH	Temp (ºC)	DO (mg/l)	CO_2 (mg/l)	Chlorides (mg/l)	Hardnes (mg/l)	Alkalinity (mg/l)	NO_3 (mg/l)	PO_4-P (mg/l)	K (mg/l)
pH	1.0									
Temp (ºC)	-0.073	1.0								
DO (mg/l)	0.071	0.03	1.0							
CO_2 (mg/l)	0.292	0.61**	-0.23	1.0						
Chlorides (mg/l)	0.088	0.49	0.489	0.449	1.0					
Hardness (mg/l)	0.167	0.28	-0.02	0.353	0.0437	1.0				
Alkalinity (mg/l)	0.292	0.59	-0.03	0.626**	0.293	0.474	1.0			
NO_3 (mg/l)	-0.2	0.19	-0.56	-0.14	-0.221	-0.171	-0.2419	1.0		
PO_4-P (mg/l)	-0.411	-0.32	-0.37	-0.51	-0.337	-0.644	-0.403	0.65**	1.0	
K (mg/l)	-0.356	-0.17	-0.65	-0.29	-0.3417	-0.492	-0.379	0.76*	0.884*	1.0

** Correlation is significant at the 0.05 level (2-tailed).*

***Correlation is significant at the 0.01 level (2-tailed).*

Table 7. Pearson's Correlation among physico-chemical variables of water for Site III, Imphal River

	pH	Temp (ºC)	DO (mg/l)	CO_2 (mg/l)	Chlorides (mg/l)	Hardness (mg/l)	Alkalinity (mg/l)	NO_3 (mg/l)	PO_4-P (mg/l)	K (mg/l)
pH	1.0									
Temp (ºC)	0.526	1.0								
DO (mg/l)	0.413	0.151	1.0							
CO_2 (mg/l)	0.134	0.229	-0.28	1.0						
Chlorides (mg/l)	0.174	0.573	0.482	0.167	1.0					
Hardness (mg/l)	0.434	0.308	0.558	-0.18	0.26	1.0				
Alkalinity (mg/l)	0.415	0.643**	0.354	0.299	0.614**	0.636**	1.0			
NO_3 (mg/l)	0.046	0.323	-0.48	0.448	0.184	0.020	-0.281	1.0		
PO_4-P (mg/l)	-0.65**	-0.32	-0.72	0.126	-0.172	-0.621**	-0.285	0.497	1.0	
K (mg/l)	-0.55	-0.37	-0.81*	0.27	-0.252	-0.669	-0.359	0.57	0.911*	1.0

** Correlation is significant at the 0.05 level (2-tailed).*

***Correlation is significant at the 0.01 level (2-tailed).*

Table 8. Pearson's Correlation among physico-chemical variables of water for Site IV, Imphal River

	pH	Temp (ºC)	DO (mg/l)	CO_2 (mg/l)	Chlorides (mg/l)	Hardness (mg/l)	Alkalinity (mg/l)	NO_3 (mg/l)	PO_4-P (mg/l)	K (mg/l)
pH	1.0									
Temp (ºC)	0.232	1.0								
DO (mg/l)	0.4374	0.026	1.0							
CO_2 (mg/l)	0.437	0.45	0.583**	1.0						
Chlorides (mg/l)	0.248	0.355	0.421	0.224	1.0					
Hardness (mg/l)	0.435	0.482	0.348	0.395	0.2114	1.0				
Alkalinity (mg/l)	0.293	0.474	0.239	-0.02	0.675**	0.237	1.0			
NO_3 (mg/l)	-0.29	0.37	-0.65**	-0.32	0.288	-0.164	0.388	1.0		
PO_4-P (mg/l)	-0.55	-0.37	-0.58**	-0.37	-0.185	-0.715*	-0.345	0.474	1.0	
K (mg/l)	-0.61**	-0.34	-0.73*	-0.52	-0.169	-0.624**	-0.329	0.584**	0.915*	1.0

** Correlation is significant at the 0.05 level (2-tailed).*

***Correlation is significant at the 0.01 level (2-tailed).*

3.6 Total Hardness

Total hardness is the parameter of water quality used to describe the effect of dissolved minerals (mostly Ca and Mg),in determining suitability of water for domestic, industrial and drinking purposes and attributed to presence of bicarbonates, sulphates, chloride and nitrates of calcium and magnesium [53]. It is the most important cation of water and it is the prime cause of hardness in water [54].

The recorded total Hardness (mg/l) value revealed the decreasing order for the site as Site-I (50.0-90.0), Site-II (38.5-61.75), Site-IV (38.5-53.25), and Site-III (38.5-51.5). The hardness of the river stream has reduced from upstream to the downstream. Total hardness was found to be higher in summer (Sites-I,-II,-III) and winter Site-IV. Higher value of hardness during summer and winter can be attributed to low water level and high rate of evaporation. Hardness values declined during rainy season due to dilution of river water [55]. Addition of sewage, detergents and large scale human use might be the cause of elevation of hardness. Total hardness was found to be correlated with PO_4 negatively at Sites-IV at ($P > 0.01$) respectively.

3.7 Total Alkalinity

Total alkalinity of water is due to the presence of mineral salt present in water. Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them [56]. It is primarily caused by the carbonate and bicarbonate ions. The alkalinity makes water tasteful and helps in coagulation [57]. Total alkalinity of the water is its capacity to neutralize a strong acid and is characterised by the presence of all hydroxyl ions capable of combining with the hydrogen ion. It is the capacity of neutralising acidic nature and is characterised by the presence of hydroxyl ions [58]. Minimum alkalinity value in winter and maximum in summer in the river system of Manipur and Ganga River was obtained. During study period the highest value was recorded in summer (April) in all four sites. The recorded Alkalinity (mg/l) values reflected the ranges as Site-II (41.25-56.5), Site-III (41.5-53.25), Site-IV (41.25-51.5) and Site-I (41.5-53.25). It might be due to increased rate of decomposition, when water temperature was high and the water level was low [59].

3.8 Nitrate (NO_3 –N)

The presence of nitrates in a lotic system depends mostly upon the activity of nitrifying bacteria, stream currents, and catchment characteristics. Nitrate in surface water is an important factor for water quality assessment [60]. The recorded Nitrate NO_3 – N (mg/l) values reflected the ranges with values as in decreasing order as Site-IV (0.252-0.602), Site-III (0.187-0.582), Site-II (0.147-0.555), and Site-I (0.13-0.55). High NO_3 –N (mg/l) was obtained in rainy season and low nitrates were obtained in the winter season. It was maximum during rainy in all sites which was attributed mainly to anthropogenic activities such as runoff water from agricultural lands, discharge of household and municipal sewage from the market place and other effluents containing nitrogen species. Similar observations were also reported [61]. Nitrate was found correlated with K positively at Sites-IV at ($P > 0.01$).

3.9 Phosphate (PO_4 –P)

Agricultural runoff containing phosphate fertilizers as well as the waste water containing the detergents etc. tends to increase PO_4 –P pollution in water. Phosphorous is the first limiting nutrient for plant in fresh water which regulates the phytoplankton production in presence of nitrogen [62]. It is available in the form of phosphate (PO_4 –P) in natural waters and generally occurs in low to moderate concentration. PO_4 in water could be due to washing of clothes, utensils and bathing using soaps and detergents directly with river water, higher phosphate values at Kasipalatan in Nayyan River were observed [63]. High level of both phosphate and nitrate can lead to eutrophication, which increases algal growth and ultimately reduces dissolved oxygen levels in the water [64]. The recorded Phosphate PO_4 – P (mg/l) values ranges as Site-I (0.035-0.0675), Site-II (0.035-0.0752), Site-III (0.0425-0.0825), and Site-IV (0.045-0.08).The maximum value was obtained in rainy season and minimum value in summer season which found to be within the WHO permissible limits. Our observation is inconformity with the work of [65]. PO_4 was found to be correlated with K positively at four Sites at ($P > 0.01$) respectively.

3.10 Potassium (K)

The sources of K in water are through weathering of rocks, effluents and waste water discharges [66]. Potassium is required for all cells principally as an enzyme activator and stored in the plant tissues than in surrounding medium [67]. The recorded Potassium K (mg/l) values were recorded as Site-I (4.26-7.09), Site-II (4.265-7.227), Site-III (4.32-7.317), and Site-IV (4.377-7.52).The maximum value were in rainy season and minimum in summer season which were within the WHO permissible limit**.** Potassium was found maximum in rainy seasons in all sites, similar observation were also reported by [68].

4. CONCLUSION

The spatio - temporal scopes of human impact may therefore affect different parts of a river differently. Restoration efforts should consider and reflect the dynamic nature of these systems. The reliability of water required to maintain ecological functions which people demand shall be reserved so that the human use of water does not individually or cumulatively compromise the long–term sustainability of aquatic and associated ecosystems [69]. More flexible approach could be to follow restoration trajectories based on best available knowledge about the system, to evaluate if a system is moving towards a desired state.

Thus, various analyses revealed that the spatio-temporal variation in physico- chemical properties of water occur in Imphal River, it might be attributed to the different land use pattern around the river. The levels are within the acceptable limits of WHO and therefore, may be suitable for domestic purposes. However, there is need to properly manage waste in the city in order to ensure that such activities have minimal negative effects on the city's streams.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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