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Research Article

Seasonal variation of temperature dependent physico-chemical parameters of a coastal River Bhadra, Bangladesh

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Abstract

This analysis observed the seasonal variation in the temperature dependent physico-chemical parameters [pH, Transparency, Salinity, Electrical conductivity (EC), Total Dissolved Solid (TDS), Total Alkalinity, Total Acidity, Dissolved Oxygen (DO) and Free Dissolved CO_2] of surface water in a coastal river in Bangladesh. Composite samples from four different sampling points that considered high and low tides were collected and analyzed in three main consecutive seasons: rainy, winter and summer. The study has revealed that most physico-chemical parameters are not a serious problem for Bhadra River eco-system and water quality shows significant seasonal changes. The statistical analysis unveiled a positive correlation of temperature with pH, Transparency, Salinity, EC, TDS, Total Alkalinity, Total Acidity and Free Dissolved CO_2 but only negative correlation with DO.

Keywords: Bhadra River, physico-chemical, water quality and Statistical analysis.

Introduction

Water is undoubtedly the most precious natural resource that exists on the planet. It is the most valuable and vital resource for sustenance of life and also for any development activity (Kumar et al., 2010). Temperature is an important factor to consider when assessing water quality. In addition to its own effects, temperature influences several parameters and can alter the physical and chemical properties of water. These influencing parameters are called temperature correlated parameters (Wilde, 2006). Such as pH, Transparency, Salinity, EC, TDS, Total Alkalinity, Total Acidity, DO and Free Dissolved CO_2. Water temperature can affect the metabolic rates and biological activity of aquatic organisms (Wetzel, 2001). For most fishes, a 10°C increase in water temperature will approximately double the rate of physiological function (Bais et al., 1992). Increased metabolic function can be noticed in respiration rates and in digestive responses in most species.

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Increased respiration rates at higher temperatures lead to increased oxygen consumption, which can be detrimental if rates remain raised for an extended period of time. Furthermore, temperatures above 35°C can begin to denature or breakdown enzymes, reducing metabolic function (Pearson Education, 2011). Temperature fluctuations can affect the behaviour choices of aquatic organisms, such as these moving to warmer or cooler water after feeding, predator-prey responses and resting or migrating routines (Bais et al., 1992). Plants are also affected by water temperature. Temperature can also inhibit plant respiration and photosynthesis. In general, algal photosynthesis will increase with temperature, though different species will have different temperatures for optimum photosynthetic activity (Wetzel, 1975).

Bangladesh is a land of rivers. Around 230 rivers flow in the country including 53 international rivers. Bhadra River is one of the most important rivers of the river system network across the coastal belt of Khulna, Bangladesh. The River Bhadra is a very old river, which flows through Batiaghata upazila and separates "Zolma" union from Batiaghata. It starts from Solmari River and finally flows into the Salta. The river has several tributaries and adjacent villages. This makes the geographical location of this river very significant apart from the ecological perspective. People use land for various purposes. Due to these activities, water characteristics can be influenced through agricultural runoff and other unwanted wastes. Moreover, assessment of water quality in a region is an important aspect of developmental activities, as rivers are used for water supply to domestic, industrial and agricultural purposes (Jackher & Rawat, 2003). Keeping these aspects in mind, the present study was designed to investigate seasonal variation of water quality, which could adversely affect plants and animals, including aquatic habitat in Bhadra River, Khulna.

Methodology

Study area:

Bangladesh has a tropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures, and high humidity. Regional climatic differences in this flat country are minor. Three seasons are generally recognized: a hot, muggy summer from March to June; a hot, humid and rainy season from June to November, about 80 % of Bangladesh's rain falls during the rainy season; and a warm-hot, dry winter from December to February. In general, summer records the highest temperature and while the lowest

temperature is in the winter season (The Washington Post, 2015). The study area, Bhadra River, is located in the Southwest part of Bangladesh and within 22°38'50.3" to 22°45'55.6" North latitude and 89°25'56.6" to 89°28'19.0" East longitude (figure 1). The Southwest coastal region is the most disaster-prone area in Bangladesh and is very vulnerable to the effects of climate change. The region is part of an inactive delta of large Himalayan rivers and is protected from tidal surge by the Sundarban mangrove forest. Cyclones, tidal surges, floods, repeated water-logging and land subsidence are common in this part of Bangladesh.

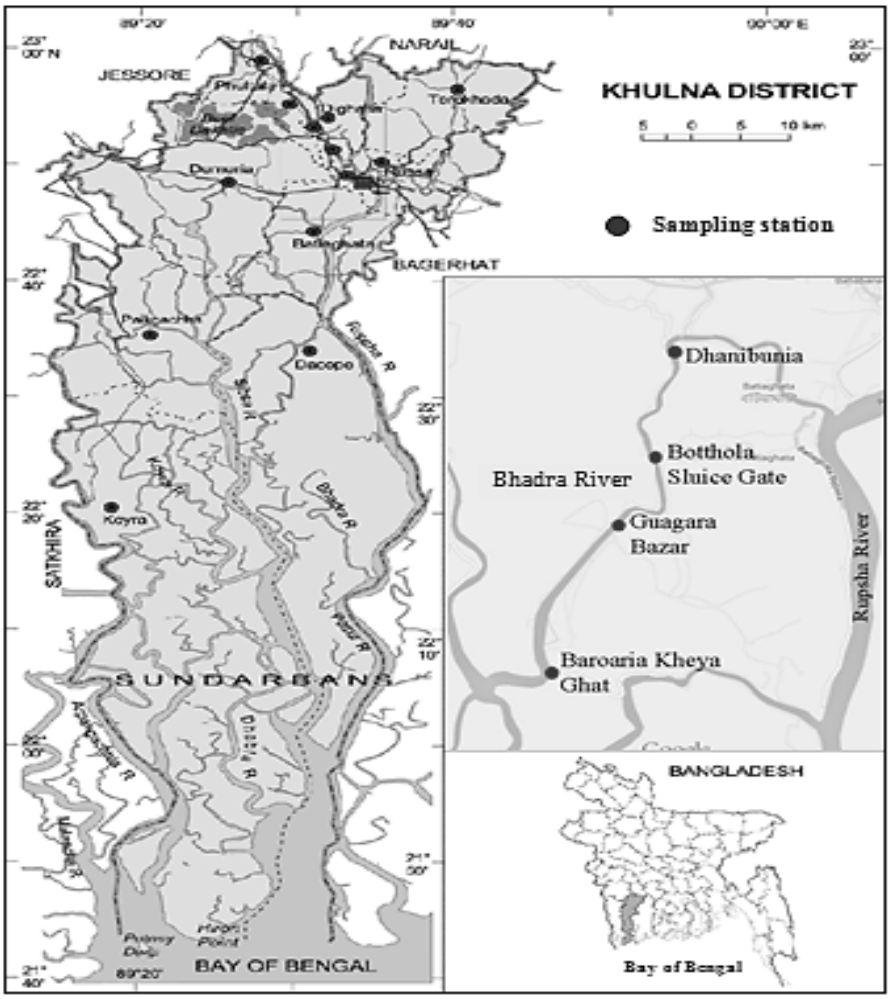

Figure 1. Map of the study area indicating the sampling station (source: Banglapedia)

The average temperature and rainfall in this area is 26.1°C and 1,736 mm respectively. The river Bhadra is about 15.5 km long. Being a coastal river, it faces diurnal tidal fluctuation that sees sea water mixing with fresh water. Water samples were collected from four stations along Bhadra River. The selected sampling sites were Baroaria kheyaghat, Gaugara bazaar, Botthola sluice gate and Dhanibunia. These stations are described in Table 1.

Table 1. Location, Latitude, Longitude and sample ID of the sampling points

Sl. No	Location	Latitude (North)	Longitude (East)	Sample ID
1	Baroaria kheyaghat, Khulna	22°38'50.3"N	89°25'56.6"E	Station-1
2	Gaugara bazaar, Khulna	22°42'06.1"N	89°27'14.5"E	Station-2
3	Botthola sluicegate, Khulna	22°43'37.4"N	89°27'55.8"E	Station-3
4	Dhanibunia, Khulna	22°45'55.6"N	89°28'19.0"E	Station-4

Sample collection and Preservation:

Water samples were collected from four different sites based on characteristics of the location along the Bhadra River; rainy season (July, 2015 to August, 2015), winter season (December, 2015 to February, 2016) and summer season (May, 2016 to June, 2016) with fortnightly variations. The samples were collected from each site both during high tide and low tide from close to about 10 cm depth from the surface of the Bhadra River. For the determination of Dissolved Oxygen, water samples were collected in different BOD bottles and the sample was kept "Fixed" on the spot by some prescribed reagents such as Manganase sulfate $MnSO_4.4H_2O$, concentrated H_2SO_4 and Alkali Iodide Azide (APHA, 1992). In the case of other parameters, one liter capacity clean plastic bottle was used for the collection of samples. To avoid direct sunlight, all the collected samples were placed in a black bag.

Analytical Method set-up and Statistical analysis:

In the experimental work, all of the Physical and Chemical parameters were measured in situ. All physical parameters such as Temperature (Centigrade mercury thermometer), pH (pH-5011, HANNA), Transparency (Secchi disc), Salinity (Refractometer, REF-201 bp), EC and TDS (HI-8733, HANNA) were measured by instrumentally and chemical parameters- Total Alkalinity, Total Acidity, DO and Free Dissolved CO_2 were analyzed by the standard titration method of APHA (APHA, 1992). Replicate analysis of blank, standards and water samples were performed during the study to avoid errors. For statistical

analysis, Q-test and ANOVA (Software SPSS-15) were used to compare the mean values of the tested parameters for different sampling seasons. The coefficient of correlation of temperature along with other physico-chemical parameters was calculated through the Pearson correlations test (Software SPSS-15).

Results and Discussion

The results obtained from some temperature dependent physicochemical parameters of the Bhadra River water samples in various season are presented in Tables 2, 3 and 4. Table 5 exposes the summary of seasonal variation with standard deviation and range of those physicochemical parameters in Bhadra River. Table (5) showed wide variation among seasons through the study period. During the study period, temperature varied from 20^{o}C to 33^{o}C with an average of 27.56±4.52^{0}C at the Bhadra River. Water temperature is generally low, ranging from 5^{0}C-36^{0}C which is standard for fisheries (Boyd & Tucker, 1998). The range of water temperature of Bhadra River was found within the standard range and higher in summer season due to low water level and high air temperature. The present observation is similar to the seasonal fluctuation in temperature studied by Sharma et al. (Sharma et al., 2007). Water temperature has a significant correlation with most of these parameters.

Aquatic organisms are affected by pH because most of their metabolic activities are dependent on it. pH of an aquatic system is an important indicator of water quality and the extent of pollution in watershed areas (Kumar et al., 2010). The mean pH was found to be 7.675 ± 0.74 at the Bhadra River which indicates the river water is slightly alkaline in nature. The alkaline nature of river water values may be due to sewage discharged by surrounding villages and agricultural fields. In the rainy season, the highest average pH is observed (7.68 ± 0.28) because in this season, sewage and agricultural discharges increase. Sewage and agricultural discharges are generally a complex combination of natural organic and inorganic materials and man-made compounds. It usually contains many fertilizers, metals, sediments, pesticides, nutrients, salt, sodium, calcium, potassium, chlorine, phosphate, bicarbonate etc. (Ongley, 2004). Water with pH ranging from 6.0 to 9.0 is generally regard as suitable for growth of organism (Huq, 2002) and results showed that pH values were within the permissible limit.

Table 2. physicochemical parameters in Bhadra River during rainy season

Sampling Site	time	T (^{0}C)	pH	Tra (cm)	Sal (ppt)	EC (mS/cm)	TDS (ppt)	T alka (mg/L)	T acid (mg/L)	DO (mg/L)	F d CO_2 (mg/L)
Station 1	LT	28.50	7.70	10.25	4.38	6.23	3.99	110.0	9.0	6.15	3.63
	HT	29.50	7.83	11.13	4.88	6.75	4.32	115.0	10.15	5.75	4.22
Station 2	LT	28.50	7.68	10.38	2.88	4.52	2.89	98.75	8.83	5.0	4.18
	HT	29.50	7.78	11.25	3.13	4.94	3.16	106.25	9.40	4.60	4.73
Station 3	LT	28.50	7.50	11.0	1.80	2.74	1.75	95.0	6.50	4.60	2.75
	HT	29.50	7.58	11.75	1.93	2.96	1.89	102.50	7.25	4.35	3.19
Station 4	LT	28.50	7.63	10.63	3.13	4.88	3.12	98.75	7.93	5.35	4.033
	HT	29.50	7.73	11.13	3.38	5.23	3.35	105.0	8.83	5.0	4.45

Table 3. physicochemical parameters in Bhadra River during winter season

Sampling Site	time	T (^{0}C)	pH	Tra (cm)	Sal (ppt)	EC (mS/cm)	TDS (ppt)	T alka (mg/L)	T acid (mg/L)	DO (mg/L)	F d CO_2 (mg/L)
Station 1	LT	21.00	7.35	11.70	6.75	12.01	7.68	96.25	19.13	5.77	8.42
	HT	22.00	7.81	11.90	6.88	12.03	7.70	101.25	20.38	5.53	8.96
Station 2	LT	21.00	7.26	10.40	6.75	11.48	7.34	89.38	18.37	5.38	8.08
	HT	22.00	7.36	11.03	6.88	11.75	7.52	95.63	19.13	5.22	8.42
Station 3	LT	21.00	6.92	9.93	6.50	11.09	7.10	85.63	16.63	5.27	7.32
	HT	22.00	6.99	10.45	6.50	11.22	7.18	88.75	17.88	5.19	7.87
Station 4	LT	21.00	7.42	10.91	6.75	11.62	7.43	89.37	18.25	5.44	8.03
	HT	22.00	7.49	11.06	6.75	11.86	7.59	93.13	19.13	5.36	8.42

Table 4. physicochemical parameters in Bhadra River during summer season

Sampling Site	time	T (^{0}C)	pH	Tra (cm)	Sal (ppt)	EC (mS/cm)	TDS (ppt)	T alka (mg/L)	T acid (mg/L)	DO (mg/L)	F d CO_2 (mg/L)
Station 1	LT	32.25	7.02	12.55	17.75	26.4	16.89	112.50	20.25	4.64	9.68
	HT	32.25	7.12	12.51	17.75	26.27	16.81	110.00	22.25	4.28	10.74
Station 2	LT	31.75	7.07	12.47	17.50	25.35	16.22	115.63	19.25	4.59	10.12
	HT	32.00	7.10	12.54	18.75	25.97	16.62	115.63	22.00	4.89	10.12
Station 3	LT	31.75	7.00	12.52	17.50	25.12	16.07	113.13	20.00	3.87	9.79
	HT	32.5	7.12	12.49	18.75	25.52	16.33	111.25	20.50	4.54	9.90
Station 4	LT	32.00	7.10	12.50	17.75	25.25	16.16	114.37	20.75	4.28	9.79
	HT	32.75	7.22	12.53	18.75	26.38	16.88	122.50	23.00	4.18	10.23

NOTES: LT: Low tide; HT: High tide; SD: Standard deviation; T: Temperature; Tra: Transparency; Sal: Salinity; TDS: Total dissolved solid; T alka: Total alkalinity; T acid: Total acidity; F d CO_2: Free dissolved CO_2.

Table 5. Seasonal variation of physicochemical parameters in Bhadra River

Samp. Time	Stat. Para.	T (^{0}C)	pH	Tra (cm)	Sal (ppt)	EC (mS/cm)	TDS (ppt)	T alka (mg/L)	T acid (mg/L)	DO (mg/L)	F d CO_2 (mg/L)
Rainy	Mean	29.00	**7.68**	10.56	3.38	4.77	3.05	103.91	8.31	5.19	3.89
Season	SD	±0.72	±0.28	±1.31	±3.28	±5.19	±3.32	±12.09	±2.42	±1.44	±1.13
	Range	28-30	7.3-8.3	10-13	0.2-10	0.3-16.9	1.85-4.3	80-125	4.7-12.6	2.2-7.2	2.2-5.28
Winter	Mean	21.56	7.32	10.49	6.72	11.63	7.44	92.42	18.61	**5.38**	8.19
Season	SD	±0.84	±0.41	±1.63	±2.23	±2.57	±1.64	±6.07	±2.98	±0.62	±1.31
	Range	20-23	6.7-8.7	9.2-13	3.5-10	7.8-15.9	6.8-8.03	85-110	12-23	4-6.5	5.3-10.2
Summer	Mean	**32.12**	7.09	**12.52**	**18.13**	**25.78**	**16.49**	**114.37**	**21.00**	4.40	**9.85**
Season	SD	±0.79	±0.11	±0.06	±0.91	±0.89	±0.57	±7.24	±1.74	±0.46	±1.18
	Range	31-33	6.9-7.3	12.4-12.6	17-20	24.3-27.3	16-16.7	90-117.5	18-24	3.7-5.4	4.8-11.4
Yearly	**Mean**	27.56	7.675	11.19	3.18	14.06	8.99	103.56	15.97	5.1	3.89
Average	**SD**	±4.52	±0.74	±1.52	±0.74	±9.40	±1.84	±12.57	±6.03	±0.43	±1.13

Samp. time: Sampling time; Stat. para: Statistical parameter; SD: Standard deviation; T: Temperature; Tra: Transparency; Sal: Salinity; T alka: Total alkalinity; T acid: Total acidity; F d CO_2: Free dissolved CO_2.
Bold value: Maximum average value.

Table 6. The correlation coefficients (r) among the parameters of Bhadra River.

Parameter	Tem.	pH	Trans	Salinity	EC	TDS	T alka	T acid	DO	F d CO_2
Temp	1	-.077	.476**	.498**	.412**	.412**	.723**	-.049	-.36**	.032
pH		1	-.228*	-.522**	-.553**	-.553**	-.030	-.460**	.376**	-.472**
Trans			1	.581**	.550**	.550**	.482**	.396**	-.243*	.416**
Salinity				1	.987**	.987**	.567**	.769**	-.183	.799**
EC					1	1.00**	.516**	.812**	-.178	.842**
TDS						1	.516**	.812**	-.178	.842**
T alka							1	.193	-.027	.225*
T acidity								1	.009	.944**
DO									1	-.029
F d CO_2										1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 7. The ANOVA analysis of temperature dependent parameters of Bhadra River.

Statistical parameters	Tem.	pH	Tra (cm)	Sal (ppt)	EC (mS/cm)	TDS (ppt)	T alka (mg/L)	T acid (mg/L)	DO (mg/L)	F d CO_2 (mg/L)
F	0.467	2.362	4.606	0.881	0.726	0.728	2.322	0.246	0.986	0.647
Sig. figure	0.628	0.10	0.012	0.418	0.486	0.485	0.104	0.782	0.377	0.526

Sig. figure: Significant figure; Tem: Temperature; Tra: Transparency; Sal: Salinity; TDS: Total dissolved solid;
T alka: Total alkalinity; T acid: Total acidity; F d CO_2: Free dissolved CO_2.

Conductivity is a measure of the ability of water to conduct electricity. It is dependent on the ionic concentration and water temperature. The total load of salts in a water body is directly related to its conductivity (Mane et al., 2013; Delince, 1992). The EC value of the study area varied from 2.74 mS/cm to 26.4 mS/cm with mean 14.06 ± 9.40 mS/cm. According to the Federal Environmental Protection Agency (FEPA), the sustainable EC value for aquatic organism is 10.77 mS/cm to 12.30 mS/cm (Aina et al., 1996). Another parameter, Transparency, is determined by the depth that sunlight penetrates in water (Chesapeake Bay Program., 2012). The mean Transparency for Bhadra River was found to be 11.19± 1.52 mS/cm with maximum transparency value 12.6 cm in the summer season. The Transparency of the fresh water is 35 to 45 cm which is suitable for the aquatic environment (Hossain et al., 2011). A higher transparency value was observed during summer due to absence of rain, runoff and flood water as well as gradual settling of suspended particles (Khan & Chowdhury, 1994). The observed EC value is slightly higher and Transparency value is lower than the standard value but Transparency and EC has less effect on aquatic life.

Total Dissolved Solid (TDS) is a measurement of inorganic salts, organic matter and other dissolved materials in water (Phyllis et al., 2007).The values of TDS in the study area ranged from 1.85 to 16.70 ppt and mean TDS value was found to be 8.99 ± 1.84 ppt. Water with total dissolved solids concentration within 0.1 ppt to 20 ppt is considered as suitable for aquatic life (ENVIRO SCI INQUIRY, 2000-2011). The TDS levels recorded in the entire sample points were within the standard guideline for the protection of fisheries and aquatic life. If the TDS levels are high due to dissolved salts, many forms of aquatic life are affected. The salts act to dehydrate the skin of aquatic animal which can be fatal (Johnson et al., 1999). In our study area, the TDS value was high in the summer season because the parameter TDS showed positive correlation with water temperature not exceeding the standard level (Shinde & Deshmukh, 2008). This means the TDS value of river Bhadra is not harmful for aquatic life.
Water Salinity indicates the presence of ionic substances that may come from the reaction of metals and acids present in the water. It is observed that in Bhadra River, the mean valve of Salinity was 3.18± 0.74 ppt. For good aquatic growth and survival, Salinity range should be 0.0 to 25 ppt (Bhatnagar & Devi, 2013). The minimum Salinity value was obtained in the study area during the rainy season. River water salinity decreases in the rainy season due to excessive rainfall and soft water entering the river from the surrounding villages (Furumai et al., 2007).

Water Alkalinity is a measure of its capacity to neutralize acids. Water with high alkalinity is undesirable. The obtained alkalinity ranged from 80.0-125.0 mg/L with a mean of 103.56±12.57 mg/L. The standard value of alkalinity for river water is (100-200) mg/L for fisheries activities (Boyd & Tucker, 1998). On the other hand, Acidity is a measure of the capacity of water to neutralize bases. The average Total Acidity content varied from 8.0 mg/L to 24.15 mg/L. The mean Total Acidity content of the river was 15.97 ± 6.03 mg/L. The standard value of acidity for river water is less than 19 mg/L (Yisa & Jimoh, 2010). The maximum Total Alkalinity and Total Acidity value were obtained during the summer season and minimum value during the winter and rainy seasons, respectively. During the summer season the water temperature was high and the parameter of Total Acidity and Total Alkalinity show positive correlation with water temperature. For this reason, Total Alkalinity and Total Acidity values were maximum in the summer season (Tripathi et al., 2014; Shashi et al., 2009). The values obtained for alkalinity and acidity were within the standard range and these make the river suitable for aquatic life.

Dissolved Oxygen (DO) and Free Dissolved CO_2 are present in water in the form of a dissolved gas. Dissolved Oxygen is one of the most vital parameters in water quality assessment and reflects the physical and biological processes prevailing in the water (Trivedi & Goel, 1984). The mean DO was found to be 5.1 ± 0.43 mg/L during the study period. The level of DO was lower in the summer season, compared to the rainy and winter seasons. During our research, high oxygen was dissolved in winter due to low temperature, high wind speed and high brightness (Shinde & Deshmukh, 2008). At the same time the DO level is higher in LT than HT because at low temperature and low salt level the amount of Dissolved Oxygen is higher (Wetzel, 2001). The optimum DO level should be 5.0 mg/L or more for fish and various aquatic lives (Bhatnagar & Singh, 2010). The lower values of Dissolved Oxygen in summer season occurs due to higher rate of decomposition of organic matter and limited flow of water in a low holding environment can be noticed due to high temperature (Rani et al., 2004). The mean Free Dissolved CO_2 was found to be 3.89±1.13 mg/L. The maximum Free Dissolved CO_2 value was observed during the summer season (Chatap et al., 2016). The optimum level of free carbon dioxide level for the survival of organisms is less than 5 mg/L (Huq, 2002). When the water is polluted with large amounts of organic matter, a lot of dissolved oxygen will be rapidly consumed. And Free Dissolved CO_2 in the biological aerobic decay will affect the water quality and aquatic life (Dara, 2007). From the data and above discussion it is clear that the various physical and chemical parameter ranges of Bhadra River fall within standard range and

are able to maintain the productivity of water and normal physiology of aquatic life.

The study shows that the temperature dependent parameters are linearly correlated to a large extent. Table 6 shows the correlation matrix of water sample, which describes significantly positive correlation between water temperature with Transparency (r = 0.476), Salinity (r = 0.498), EC (r = 0.412), TDS (r = 0.412), Total Alkalinity (r = 0.723), Free Dissolved CO_2 (r = 0.032) and significantly negative correlation with DO (r = -0.366). pH (r = -0.077) and Total Acidity (r = -0.049) show negative correlations with temperature but not significantly. Another statistical one-way ANOVA analysis shows a significant seasonal change of Transparency, at the 0.01 level of significance but other proposed parameters are not significant at this level of significance (Table 7).

Q-test is used for identification and rejection of outliers. From the calculated Q values, we can see that more than 50 % values of Q are greater than the standard value of the Q_{table}. So, there is an outlier among the values and the test shows (90 % sure) that 50 % of the values of temperature dependent parameters are not the same. From statistical analysis ANOVA-test, Q-test and standard deviation, it is concluded that there are changes in almost all the parameters but changes in one parameter Transparency were significant with seasonal variation and in other parameters changes are insignificant.

Conclusion

From the water quality analysis, it can be observed that there is seasonal variation in water quality with respect to temperature dependent physico-chemical parameters. The statistical analysis Pearson correlation exposed that Transparency, Salinity, EC, TDS, Total Alkalinity, Total Acidity and Free Dissolved CO_2 increase with temperature but DO decreases with a rise in water temperature. The water quality parameters of the Bhadra River found most of the parameter values (except EC and Transparency) between the standard ranges of river water for aquatic life. However, it is not easy to characterize the water quality fully by measuring these certain temperature dependent parameters. However, the findings of the present study would be helpful as baseline information for developing monitoring, management and conservation of the Bhadra River ecosystem in future.

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