

Spacio-Temporal Studies of Physico-Chemical and Biological Parameters of Three Urban Traditional Water Reservoirs in Imphal, Manipur, North East India

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Abstract:

Traditional water reservoirs in Manipur have much significance on the fact that they are purely rain water harvest structures, but continued to have water all through the year. Nonetheless, these reservoirs are least cared. The three study sites were selected in the city range because of their presence close to the proximity to human habitation and public places and the local population depend on these reservoirs for various purposes. When monthly data for the three different TWRs were considered, significant variation in some physico-chemical parameter of water samples collected at the three TWRs could be established perhaps since all the TWRs are located under a different land use patterns leading to the significant variations in water properties. Correlation co-efficient and One-way ANOVA for various physico-chemical and biological characteristics amongst the three study sites were evaluated. The present study is an attempt to ensure information concerning the traditional water reservoirs and the likely impact of the different land-use alternatives on the structural and functional values of traditional water reservoirs ecosystem lying in the north eastern region of Manipur.

Key words: Allochthonous, BOD, Coliform, Correlation, D.O, TWRs, lentic, Imphal

Introduction

North-Eastern India harbour's dense forest cover owing to high annual rainfall (Over 1500-2000mm). The rain water drains off the hills and reaches the water bodies in the valley. Nevertheless, the fresh water reservoirs and ponds are the most exploited water bodies in the region and hence are amongst the most threatened habitats on the earth's surface. The increasing human population has dramatically changed the fate of the lentic system for settlements. On the other hand, the human's requirement for portable water increases day-by-day. In this regards, the traditionally followed community ponds ("Leikai pukhri") in Manipur have much significance on the fact that they are purely rain water harvest structures, but continued to have water all through the year. Especially, in the city range, these traditional water reservoirs (TWR) are serving a variety of needs of the humans like drinking water, bathing and washing place. Nonetheless, these reservoirs are least cared. A greater paucity of information on such reservoirs is much concern and warrants immediate need of the water quality assessment and detailed investigation to generate scientific database for improvement and other restoration measures. Hence, the present study in three TWR_s has been undertaken in Imphal city from March 2017 to February 2019 with the specific objectives to study the quality of water (physio-chemical and biological properties) of traditional water reservoirs.

Study sites

The sites were selected because of their presence close to the proximity to human habitation and public places and the local population depend on these reservoirs for various purposes.

Kanglapat (SITE-I):

It is located at the centre of the city and sandwiched by the Imphal and Nambul rivers. Geographically, located between 24° 48' 51.64" N and 93° 56' 21.66" E. The approximate area covered by the site –I is 60,532 m² (IRS-IC LISS III, Dec.2003). The mean depth of this study site is 164 cm. The local population who depends on this water reservoir is approximately 15,000 people.

Bijoy Govinda Thangapat (SITE-II):

This is situated two kilometres south-west of Kanglapat, covering an area of 3,674 m² (IRS-IC LISS III, 2003) and mean depth of 151 cm. It is located between 24° 48' 3.44" N and 93° 55' 11.24" E. Approximately 14,000 people depend on this site.

Wangkhei Thangapat (SITE-III):

It is situated two kilometres of south-east from Kanglapat and located between 24° 47' 38.93" N and 93° 56' 46.10" E. It has an area of 9,923 m² (IRS-IC LISS III, 2003). The mean depth of this site is 130cm and about 8353 people inhabit this area.

Material and Methods

The physico-chemical analyses of TWR were determined at monthly intervals from March, 2017 to February 2019 using standard methods (APHA,1989). A map of study sites was generated using satellite data (IRS-IC LISS III, 2003) and presented in (**fig. 1b**).

Results and discussion

The physico-chemical and biological properties of water at three TWRs (mean monthly data collected across 2 years) have been presented in figures 2 – 9. It showed that amongst the three study sites, the highest values of water temperature, pH, turbidity, Biochemical oxygen demand (BOD) and lowest values of alkalinity, free carbon-dioxide (CO₂), hardness, sodium (Na) and potassium (K) were found in site –I. The highest values of conductivity, alkalinity, free CO₂, dissolved oxygen (DO), phosphate, nitrate and lowest values of pH, phosphate, total coliform, faecal coliform, were found in site-II. The highest values of hardness, sodium, potassium, total coliform, faecal coliform, and lowest values of conductivity, dissolved oxygen and nitrate were found in site-III. It may be mentioned here that the lowest values of water temperature and biochemical oxygen demand were found at both site-I and site-III. While the lowest values of free CO₂ and potassium were found at both site I and II respectively. In the present investigation, water temperature ranged from 16.2°C to 29.2°C in site-I, from 16.5°C to 27.3°C in site-II and from 16.2°C to 28.3°C in site-III. The water temperature was maximum during the month of June and minimum during the month of November both in site-I and site-II but in site-III, minimum was observed during the month of January (**Fig. 1a**). Monthly variation in water temperature at three sites revealed an increasing trend from March to June and then declined from the month of December to January. When compared seasonally, water temperature at three different TWRs was highest in monsoon and retreating monsoon and lowest values were observed during winter in all the three study sites (**Fig. 2b and c**). The higher water temperature during monsoon and retreating monsoon was because of higher air temperature and greater solar radiation, mixing of urban run-off and waste water from washing activities etc. At all the three study sites, water temperature was lowest during winter and highest during monsoon and retreating monsoon. This was perhaps due to corresponding decrease and increase in air temperature during winter and monsoon respectively. In the present study, water and air temperature were found to go same. This was obviously due to the smaller water body involved in the present investigation. The study also showed that water temperature was found to be positively correlated with turbidity and faecal coliform at $p \leq 0.01$ levels for site –I, II, and III respectively (**Table 1, 2 and 3**). Similar positive relationship with temperature and bacterial densities were also reported by Mc Swain and Swank (1977). All the values of temperature in this investigation were within the permissible limit as prescribed by ISI (40°C) for drinking water quality. Higher values of pH during pre-monsoon and later part of winter in all the three study sites may be attributed to the reduction of photosynthesis and lower values during monsoon may be due to rain water drained into the TWRs resulting in the formation of carbonic acid, which after dissociation of H⁺ and bicarbonate ion gives acidic characters. A positive correlation between pH and DO was during the present study (**Table 1, 2 and 3**). Similar observations were also made by Mruthunjaya and Hosmani (2004) at

Lingambudhi lake in Mysore. pH showed a positive and significant correlation with alkalinity (r values of 0.93, 0.76, 0.87 for sites I, II, and III respectively) (**Table 1, 2 and 3**).

This further adds credence to the fact that an increase in pH is accompanied by an increase in alkalinity value. All the values of pH in the three study sites were within the range of maximum permissible limit as prescribed by WHO for drinking water quality (6.5 to 9.5) during the study period. pH values were found higher than the surface water quality standard as per IS:2296.

Variations in conductivity showed fluctuation between the months and did not show any definite trend both in site-II and site-III. But site-I was found to be less fluctuated between the months (**Fig. 3a**). On seasonal basis, conductivity was found highest during non-rainy months (winter and pre-monsoon) and lowest in monsoon in all the sites except in site I where the maximum was found in retreating monsoon (**Fig. 3b and c**). This could be attributed to increasing concentration of salts and ions during winter and pre-monsoon which were accumulated with organic matter in TWRs during the preceding periods whereas the dilution took place during monsoon led to a decline in conductivity (Dudgeon, 1992). A positive correlation between conductivity and DO was observed in all the sites. Monthly variation in turbidity at three sites revealed that an increasing trend from March to July and then decreasing trend from July to November (**Fig. 3d**). When compared seasonally, maximum turbidity was observed during monsoon and minimum during winter in all the study sites (**Fig. 3e and f**).

This can be attributed to the entrance of drained off water containing sewage and other impurities with higher percentage of suspended particles during monsoon. Lower turbidity during winter to monsoon might be due to settling of silt and other suspended particles in all the TWRs studied. A positive and significant correlation between turbidity and free CO₂ were observed in both site-I ($P \leq 0.05$) and site-III at $P \leq 0.01$ (**Table 1 and 3**).

Alkalinity of water is usually due to presence of carbonates, bicarbonates, and hydroxyl ions (APHA, 1995). The higher values of alkalinity during pre-monsoon and winter might be due to increased concentration of carbonates and bicarbonates of calcium and magnesium. While lower values of alkalinity during rainy months might be due to dilution of the water bodies. During rainy season, more of CO₂ in rain that dissolved in water and thus resulted in formation of carbonic acid. It was further observed from the present study that alkalinity of the water body was high during lower CO₂ values. There is a significant negative correlation between alkalinity and free CO₂ at ($P \leq 0.01$) for site-I and site-III respectively (**Table 1 and 3**).

While in site-II, it showed a significant negative correlation at $P \leq 0.05$ level (**Table 2**). When seasonally compared, free CO₂ at three different TWRs was highest in the rainy months of monsoon and retreating monsoon. This might be due to increase influx of free CO₂ through rain water and increase in the decomposition activities in water after addition of urban runoff (**Fig. 4d**). The lowest values of free CO₂ were observed in non-rainy months of pre-monsoon and winter seasons. Higher values of free CO₂ were observed during monsoon which might be attributed to influx of free CO₂ through rain water in the form of carbonic acid. All the values of free CO₂ in the present investigation were found to be higher than the permissible limit for class D for surface water quality

as prescribed by IS:2296 (**Table 3a**). Statistical analysis suggested that there was a significant negative correlation with pH ($r = -0.869$ at $P \leq 0.01$) and DO ($r = -0.508$ at $P \leq 0.05$) at site-I. The relationship between pH and free CO₂ was observed to be negative and significant ($r = -0.72$ at $P \leq 0.01$) at site-II. While the relationship of free CO₂ with pH and DO find to be significant and negative ($r = -0.83$ at $P \leq 0.01$) and ($r = -0.55$ at $P \leq 0.05$) at site-III (**Table 1, 2 and 3**).

In the present investigation, the values of total hardness ranged from 58 mg/L to 128 mg/L in site-I, from 63 mg/L to 135 mg/L in site-II and from 65 mg/L to 148 mg/L in site-III.

The total hardness was found to be maximum during winter (December and January) while the minimum was observed during monsoon (August) in all the three sites (**Fig. 4e and f**).

Monthly variation in DO at three sites revealed a decreasing trend from August to September and then increasing pattern from December to February (**Fig. 5a**).

Dissolved oxygen (DO) is a key indicator of water quality parameters used or assessing the quality of the water for survival of the aquatic life (Divya ghidyal, 2018). When compared seasonally, highest DO value at three different sites was observed in the non-rainy months (pre-monsoon and winter). The lower values of DO were found during monsoon and retreating monsoon except in site-III where lowest value was observed in the pre-monsoon (**Fig. 5b and c**). The higher values of DO during pre-monsoon and winter might be associated with low temperature, more light penetration, more photosynthesis. The lower values of DO in rainy season may be attributed to decreased light penetration due to silt loading inflow of water from surrounding making more turbid and reduced photosynthesis. In addition, presence of more oxygen demanding wastes and high rate of decomposition during summer and rainy months decrease DO value. Further, the presence of more CO₂ in rainwater during the monsoon reduced the amount of DO (Unni, 1996). This is evidenced by a significant negative correlation between DO and CO₂ in all the study sites (**Table 1, 2 and 3**). The similar reason can be attributed to the increasing DO during winter and the decreasing value during monsoon.

But the observed values of DO were not found to meet the minimum tolerance limit (6 mg/L) of surface water, Class A throughout the sampling years except few months as per IS:2996.

Monthly variation in BOD at the three study sites revealed that the BOD fluctuates between months depending on the rainy and intervening rainless hot spells. However, there is decreasing trend from October to December and increasing pattern from January to March (**Fig. 5d**). When compared seasonally, in all the three study sites, BOD was lowest during winter and highest during monsoon (**Fig. 5e and f**). The higher value of BOD during monsoon was probably since increased organic matter into the TWRs through run-off increased bacterial population that continuously used the DO in the water for their growth and reproduction, thus leading to a decreased in DO value in TWRs. Monthly variation in phosphate at the three study sites revealed that there is an increasing trend from March to May and then declined from August to September (**Fig. 6a**). When compared seasonally, highest values of phosphate were found in the monsoon except in site-I where it was recorded in pre-monsoon. While the lowest

values of phosphate were found in the winter season except in site-I where the lowest value was recorded in retreating monsoon (**Fig. 6b and c**). High values of phosphate during monsoon may be attributed to allochthonous sources, erosion of soil by rain and deposition of nutrients from surrounding including faecal matters. Lower values of phosphate during winter season might be since less allochthonous input and perhaps increase consumption of phosphate by phytoplankton, periphytons and macrophytes (Antwi and Ofori-Danson, 1993). It was further observed that phosphate was negatively correlated with pH and hardness in site-III significantly (**Table 1, 2 and 3**).

The higher values of potassium were observed during the months of September, October and November and lower values were observed during January, March, and April (**Fig. 7a**).

When compared seasonally, the value of potassium was highest during retreating monsoon whereas lowest values were observed during winter and pre-monsoon (**Fig. 7b and c**).

The lower values of potassium during winter and pre-monsoon were perhaps due to less input of run-off and more absorption by soil colloids. It was observed that the potassium was positively correlated with sodium significantly ($r = 0.52$ at $p \leq 0.05$; and 0.62 at $p \leq 0.01$ for site-I and site-II respectively). It was further observed that potassium was found to be correlated negatively with DO in site-I significantly ($r = 0.48$ at $p \leq 0.05$) (**Table 1, 2 and 3**). This was probably due to regular input of waste discharge in this site from the surrounding activities like washing of cloths and vehicles etc.

The value of nitrate was found to be highest during winter (January and February) in almost all the study sites except in some few cases where highest was recorded during the month of October. The lowest values of nitrate were observed mostly during the month of November (Retreating monsoon) but in some case it was observed during the month of June (Monsoon) (**Fig. 6d**). When seasonally compared, the high values of nitrate were observed during winter and retreating monsoon. While the low values of nitrate were observed during the summer months i.e., pre-monsoon and monsoon (**Fig. 6e and f**). The high value of nitrate during winter and retreating monsoon might be perhaps due to less availability of Cyanophyceae members.

It was observed from the present study that the nitrate was positively correlated with pH, alkalinity and DO at site-III significantly. And, negatively significant correlation was observed with free CO₂ and total coliform for site-III and site-II respectively (**Table 1, 2 and 3**).

In the present study, the values of sodium were found to be maximum in the month of September and minimum during the months of February to April. Monthly variation in the concentration of sodium revealed an increasing trend from July to September and then decline from September to January (**Fig. 7d**). When compared seasonally, maximum values were observed during retreating monsoon and minimum during winter season (**Fig. 7e and f**). High values of sodium during rainy seasons may be attributed to the addition of urban-runoff and other sodium bearing minerals in the TWRs.

Total coliform and Faecal Coliform count: When compared seasonally, the highest values of total coliform were observed in the monsoon season while the lowest values were observed during winter and pre-monsoon season (**Fig. 8b and c**). The maximum

total coliform population in the rainy seasons may be correlated with rainfall. During this period domestic wastes run-off from the surrounding areas might be high. The total coliform population were found to be above the tolerance limit for surface waters, class A but were found within the tolerance limits for class B, except for the site-III as per IS: 2966-1982. The total coliform bacteria were found to be positively correlated with temperature in all the study sites. But it was significant in site-III ($r = 0.48$ at $p \leq 0.05$) (**Table 1, 2 and 3**). The observed correlation with physical parameter is in conformity with the findings of Faust *et al.* (1975). Faecal coliform in water mainly originates from human and animal excreta. Therefore, the measure of faecal coliform in water is the measure of the level of faecal contamination. Monthly variation in faecal coliform population at the three study sites revealed that there is an increasing pattern (**Fig. 8d**). When compared seasonally, the highest faecal coliform was also exhibited during rainy season and low during winter season (**Fig. 8d**). High values of faecal coliform population during monsoon may be attributed to high faecal matters runoff from the surrounding areas. Thus, it can be explained that the presence of faecal coliform might be originated from faecal material of both human beings and animals. From the present investigation, it was observed that faecal coliform was positively correlated with temperature in all the study sites but significant in site-I ($r = 0.62$ at $P \leq 0.01$) and site-II ($r = 0.78$ at $P \leq 0.01$). It was further observed that the faecal coliform was negatively correlated with DO but showed significant at site-II ($r = 0.48$ at $P \leq 0.05$) (**Table 1, 2 and 3**).

One-way ANOVA for various physico-chemical and biological characteristics amongst the three study sites (**Table 4**) showed that there were significant differences in the water properties in terms of pH, conductivity, phosphate, nitrate, potassium, total coliform, faecal coliform and macrophytic biomass. The one-way ANOVA for all the parameters amongst the sites and along time (monthly) showed significant differences in water properties except hardness, DO, BOD, total coliform and macrophytic biomass in all sites, conductivity at site-I, free CO_2 at site-II, phosphate at site-I and site-II, nitrate at site-I and site-II, sodium at site-I and site-II, potassium at site-I and site-III, faecal coliform at site-I respectively (**Table 5**). These differences in the water properties were perhaps due to the different patterns of land use along the TWRs resulting in allochthonous input containing sewage, household wastes and faecal matters and other non-point inputs during monsoon.

From the overall study of the physico-chemical variables of three TWRs, it was observed that the properties of the TWRs varied temporally due to changing climatic condition especially in relation to rainfall and especially due to interaction of local factors. When monthly data for the three different TWRs were considered, significant variation in some physio-chemical parameter of water samples collected at the three TWRs could be established (**Table 4**) perhaps since all the TWRs are located under a different land use patterns leading to the significant variations in water properties. It may be mentioned that in monsoon season when run-off from all sources was maximum there was a sudden peak in the BOD of TWRs which exceeded the prescribed limit of 3mg/L in all the sites studied. This indicated the deplorable conditions prevailing in the study area probably because of unplanned human habitation, prevalence of livestock rearing, unscientific sanitation and waste disposal systems.

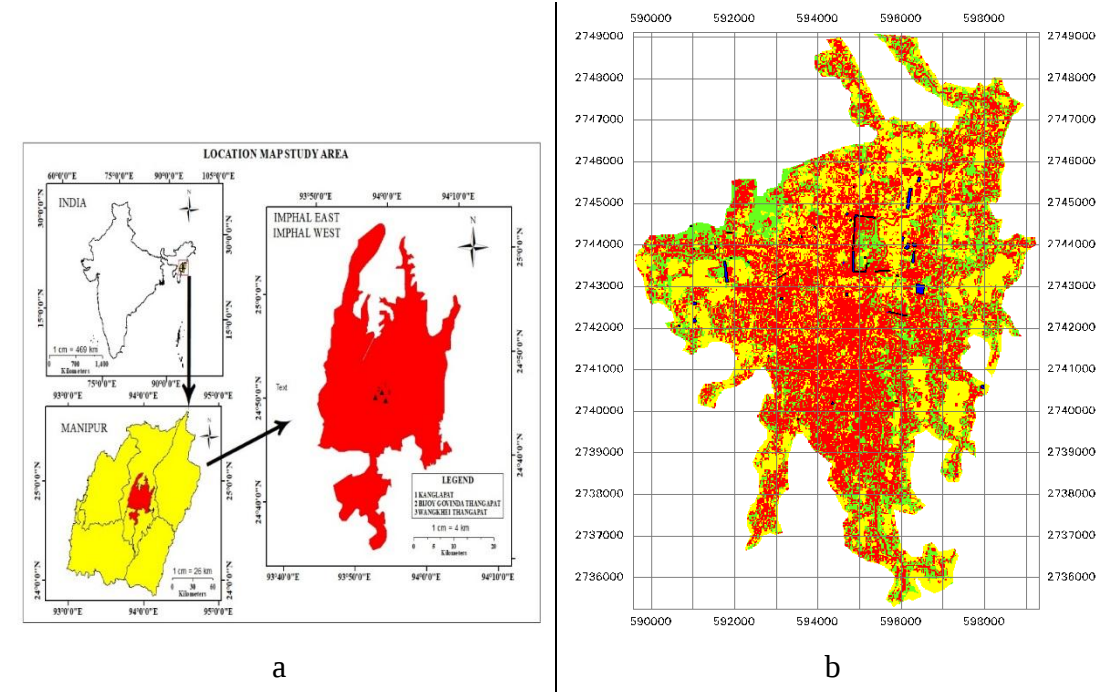
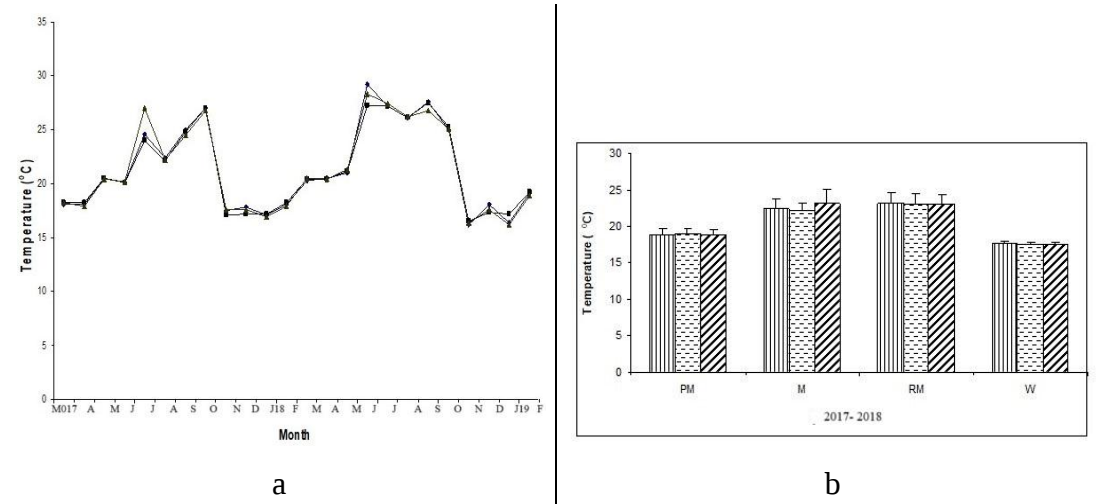
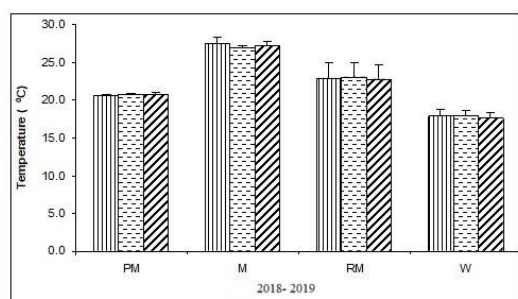
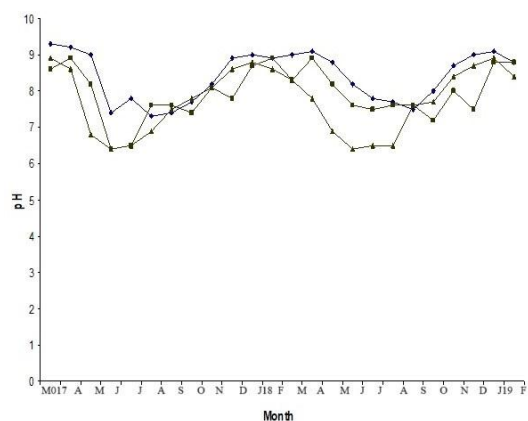


Figure 1. (a). The location of 3 sites Kanglapat, Bijoy Govinda Thangapat, and Wangkhei Thangapat. (b). Satellite mapping of the study sites DATA SOURCE: IRS LIS III (2003), IRS PAN, SOI Toposheet MAP PROJECTION: UTM, Zone 46 SPHEROID: WGS84 DATUM: WGS84 UNIT: METERS

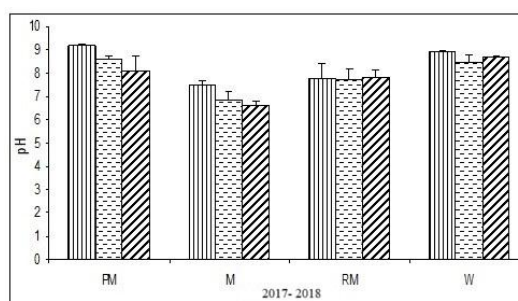




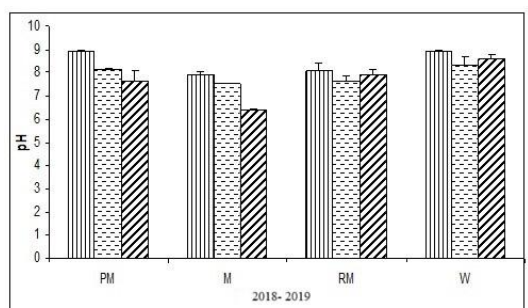
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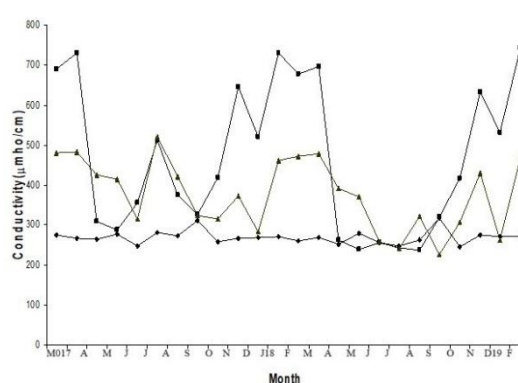


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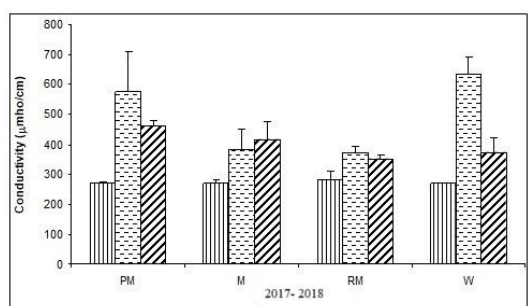


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Figure 2. (a, b, c, d, e, and f). Seasonal variation in in temperature ($^{\circ}$ c) at three different TWRs ♦ Site-I ■ site- II ▲ Site-III and pH across 2 years; Site I – Site II – Site III – PM – Pre-Monsoon M – Monsoon RM – Retreating Monsoon W – Winter.



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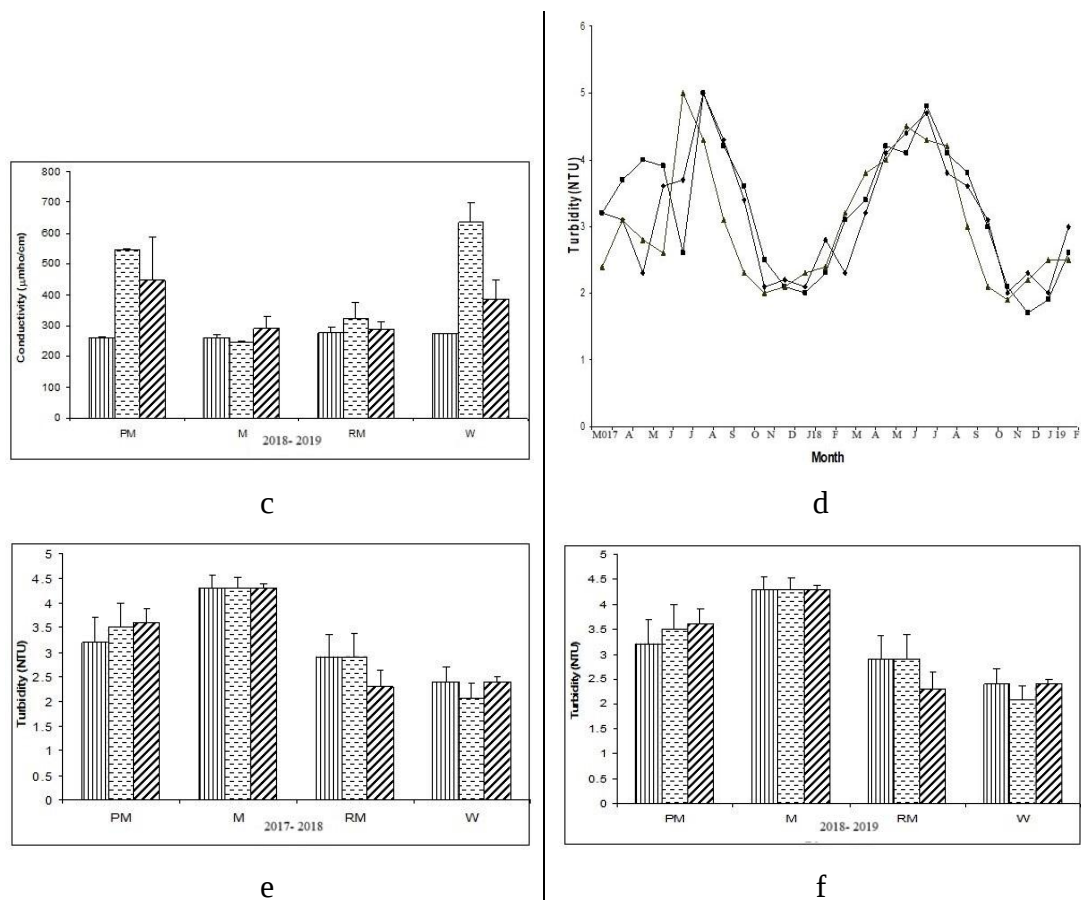
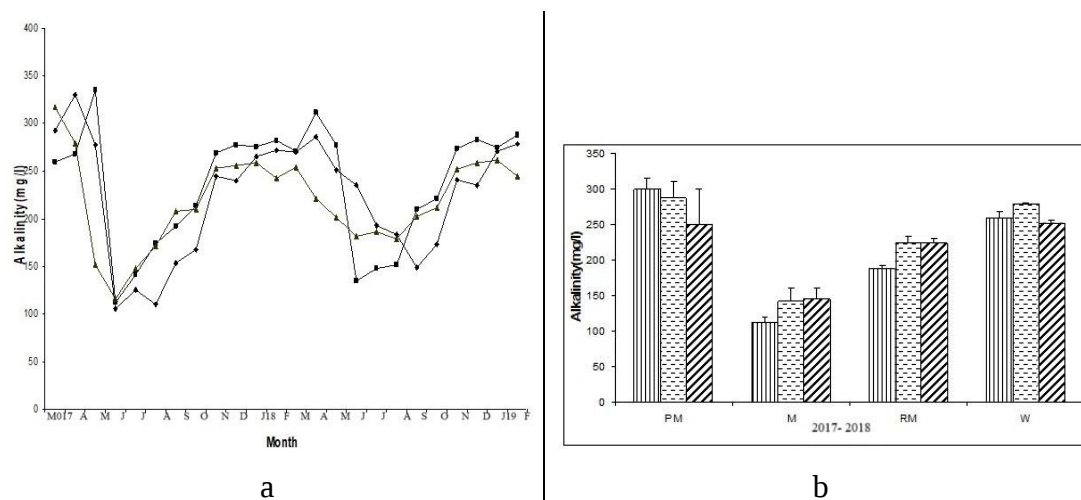
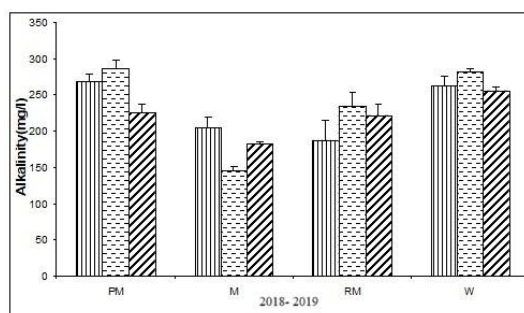
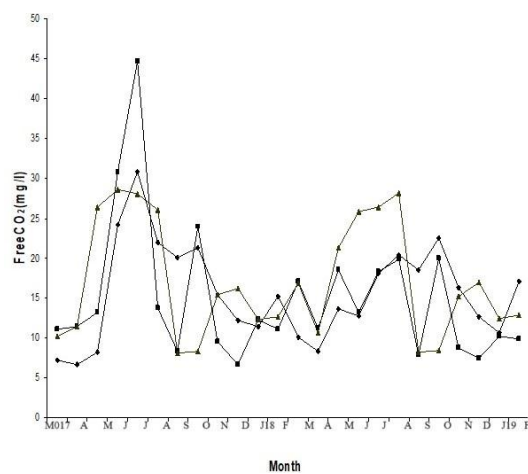


Figure 3. (a, b, c, d, e, and f). Seasonal variation in conductivity at three different TWRs ♦ Site-I ■ site- II ▲ Site-III and turbidity across 2 years; Site I – ▤ Site II – ▨ Site III – ▩ M – Pre-Monsoon M – Monsoon RM – Retreating Monsoon W – Winter.

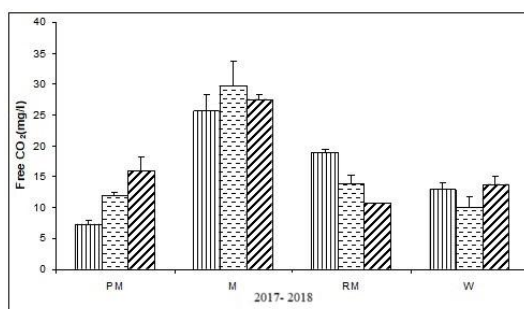




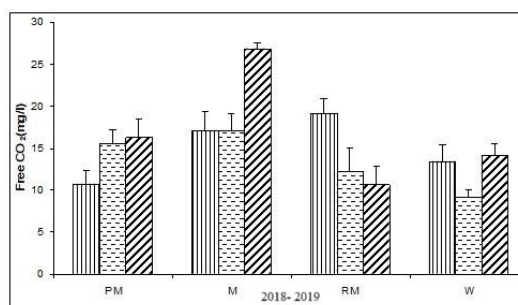
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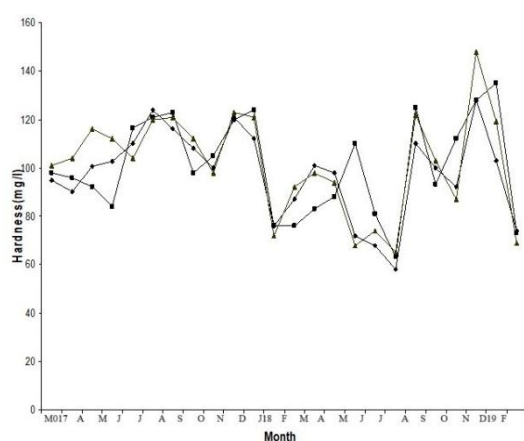


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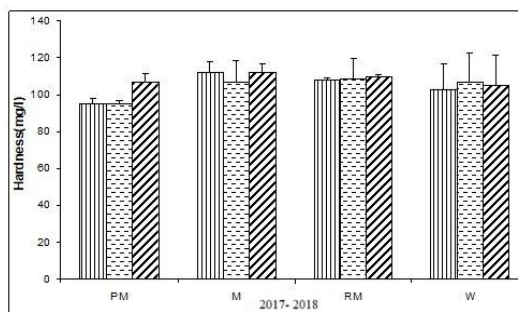


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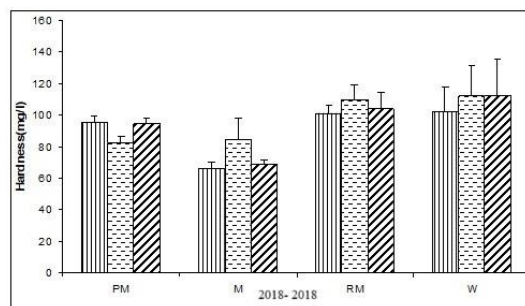
Figure 4. (a, b, c, d, e, and f). Seasonal variation in Alkalinity at three different TWRs ♦ Site-I ■ site- II ▲ Site-III and free CO₂ across 2 years; Site I – [||||] Site II – [---] Site III – [///] PM – Pre-Monsoon M – Monsoon RM – Retreating Monsoon W – Winter.



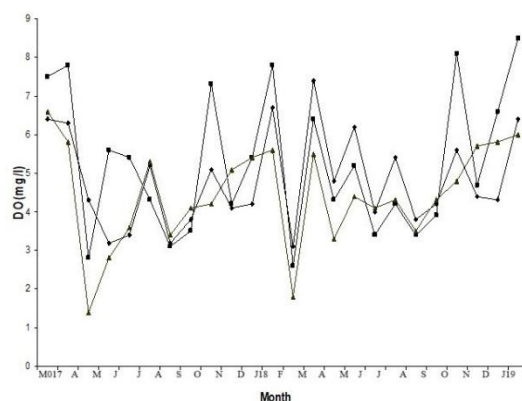
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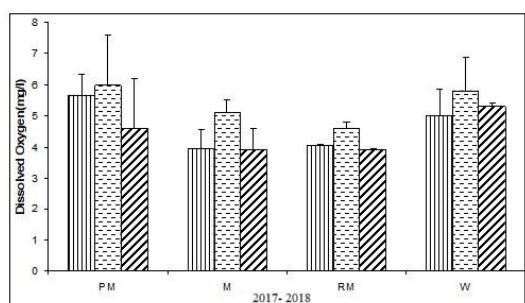
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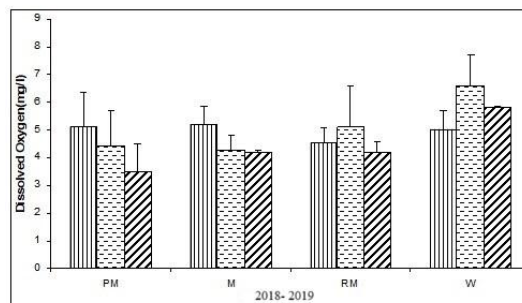
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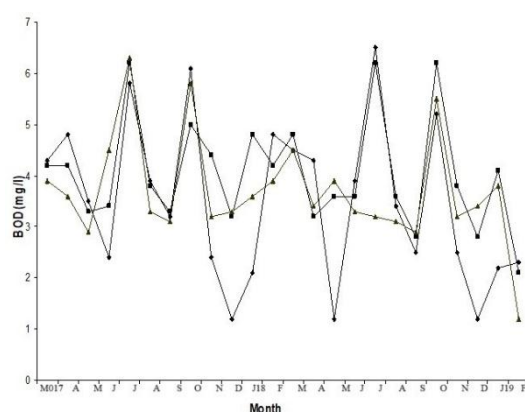


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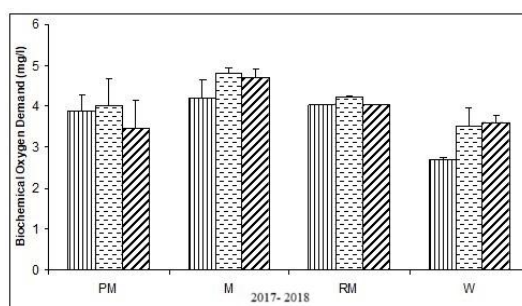


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Figure 5. (a, b, c, d, e, and f). Seasonal variation in Hardness at three different TWRs ♦ Site-I ■ site- II ▲ Site-III and Dissolved Oxygen across 2 years; Site I – Site II – Site III – PM – Pre-Monsoon M – Monsoon RM – Retreating Monsoon W – Winter.



a



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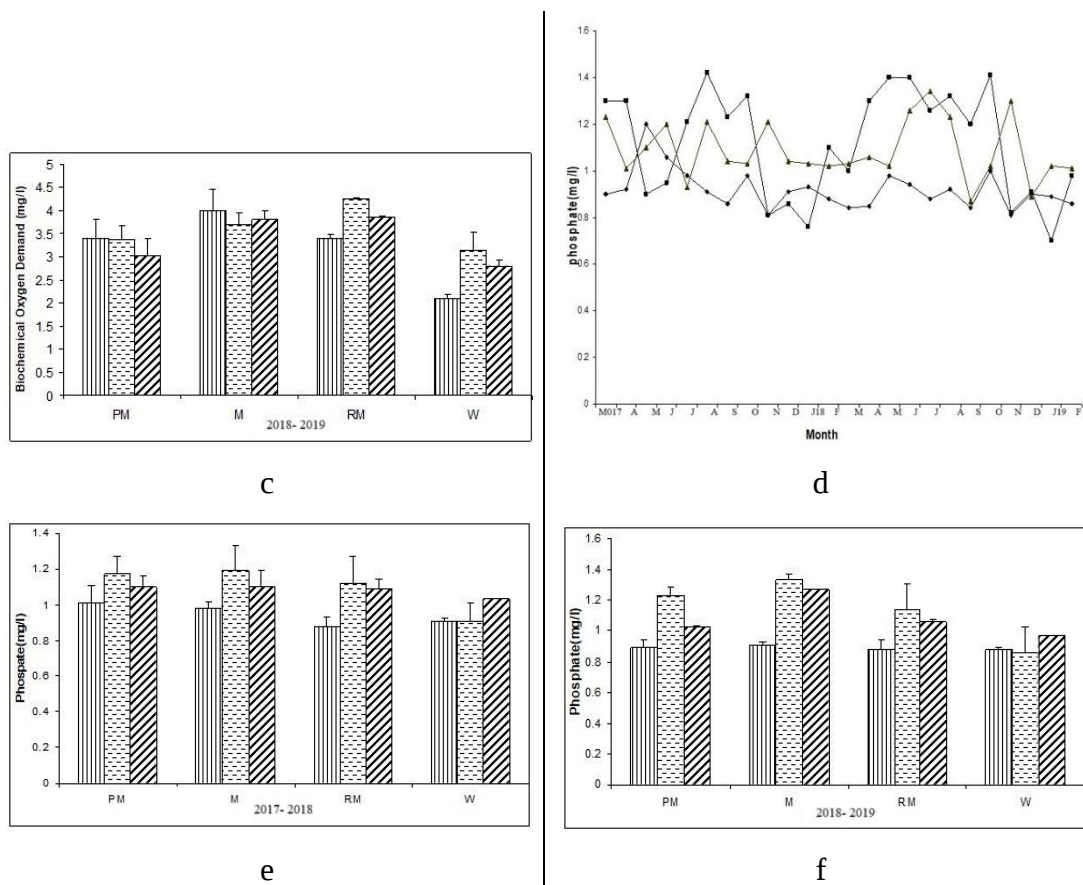
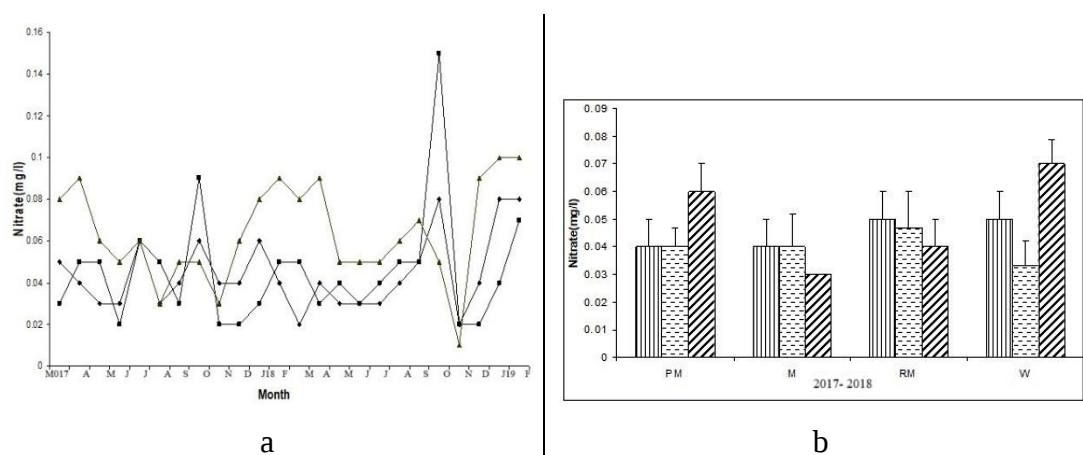
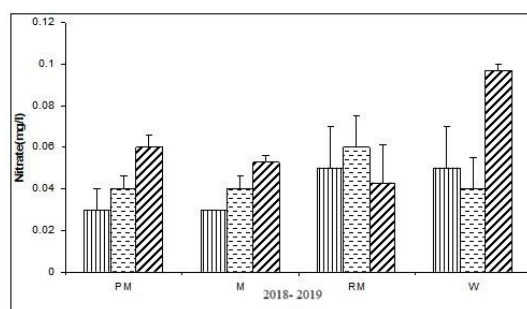
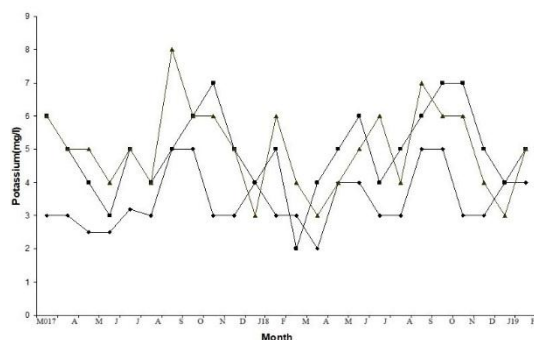


Figure 6. (a, b, c, d, e, and f). Seasonal variation in Biochemical Oxygen Demand at three different TWRs ♦ Site-I ■ site- II ▲ Site-III and Phosphate across 2 years; Site I – [diagonal lines] Site II – [dashed] Site III – [hatched] PM – Pre-Monsoon M – Monsoon RM – Retreating Monsoon W – Winter.

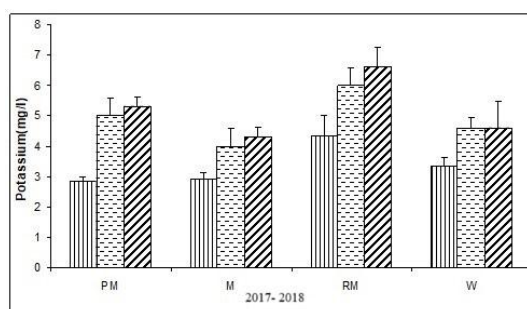




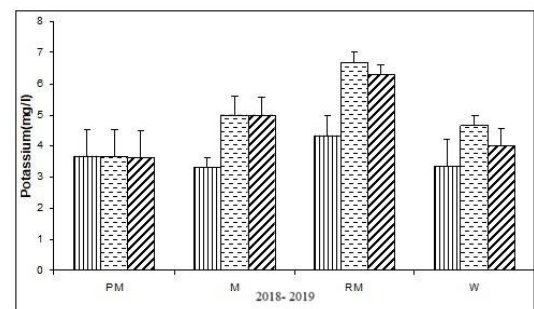
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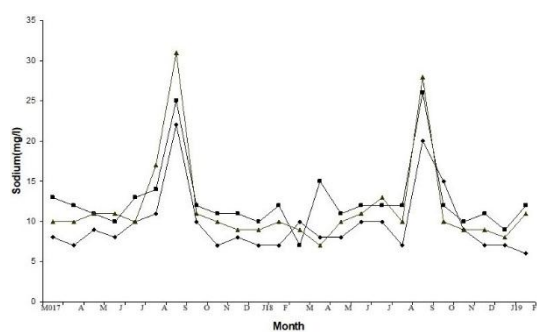


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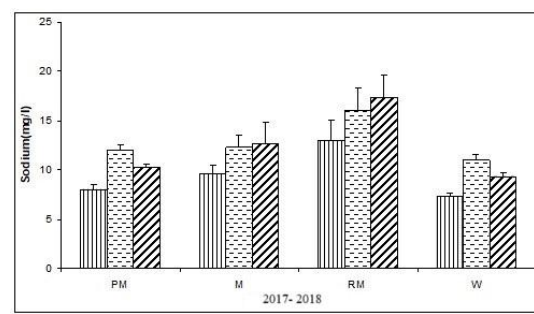


f

Figure 7. (a, b, c, d, e, and f). Seasonal variation in Nitrate at three different TWRs ♦ Site-I ■ site- II ▲ Site-III and Potassium across 2 years; Site I – Site II – Site III – PM – Pre-Monsoon M – Monsoon RM – Retreating Monsoon W – Winter.



a



b

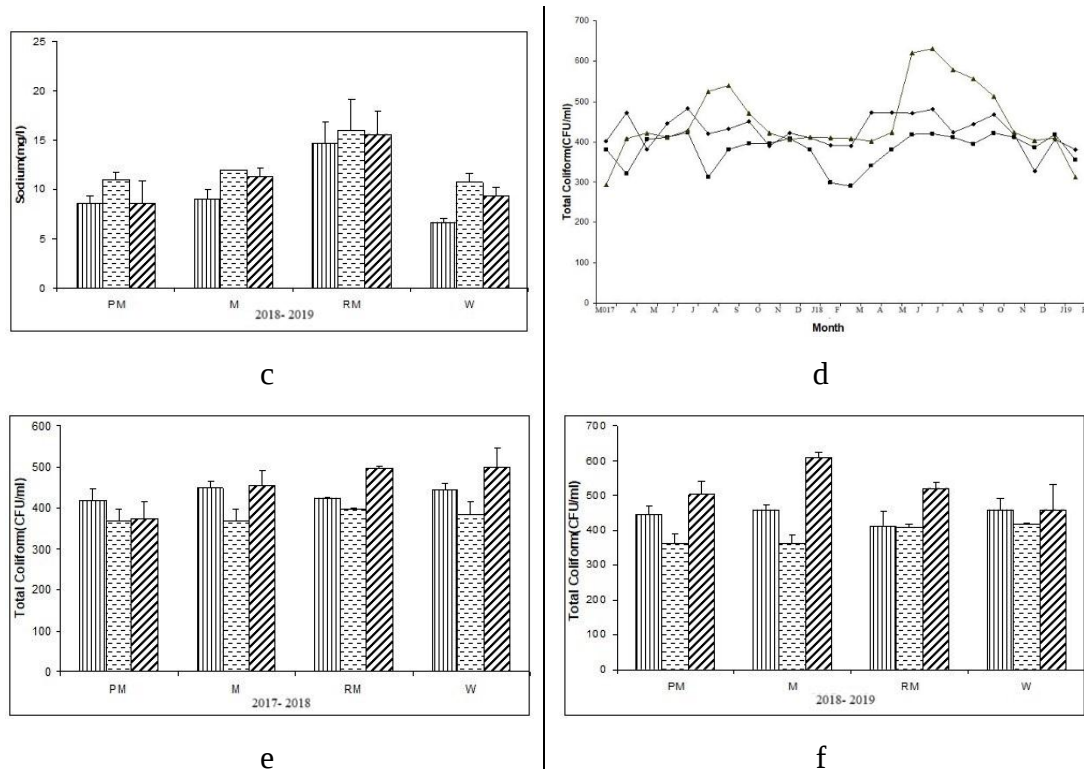
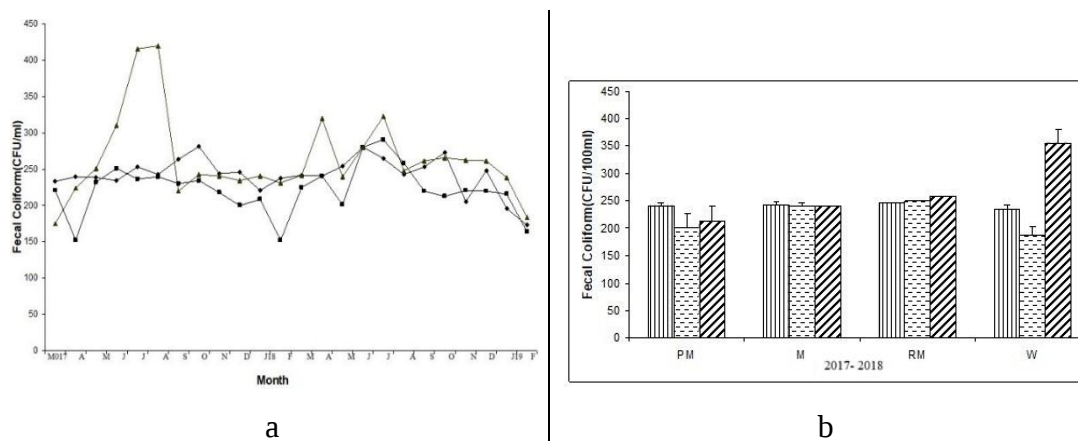
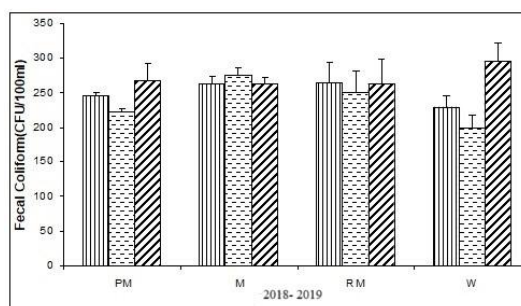


Figure 8. (a, b, c, d, e, and f). Seasonal variation in Sodium at three different TWRs ♦ Site-I ■ site- II ▲ Site-III and Total Coliform across 2 years; Site I – Site II – Site III – PM – Pre-Monsoon M – Monsoon RM – Retreating Monsoon W – Winter.





C

Figure 9: (a, b and c): Seasonal variation in faecal coliform at three different TWRs ♦ Site-I ■ site-II ▲ Site-III across 2 years; Site I – Site II – Site III – PM – Pre-Monsoon M – Monsoon RM – Retreating Monsoon W – Winter.

Table 1. Correlation coefficient among various parameters at Site-I

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
X_1	1														
X_2	-0.6**	1													
X_3	-0.5*	0.93**	1												
X_4	0.7**	-0.65**	-0.58*	1											
X_5	0.15	-0.17	-0.16	0.08	1										
X_6	0.49*	-0.86**	-0.92**	0.49*	0.01	1									
X_7	-0.3	-0.19	-0.36	-0.11	0.21	0.25	1								
X_8	-0.2	0.45	0.55*	0.01	0.02	-0.50*	-0.35	1							
X_9	0.1	0.06	0.04	-0.08	0.31	0.06	-0.07	-0.49*	1						
X_{10}	0.1	-0.08	-0.07	-0.00	-0.01	0.12	-0.00	-0.37	-0.32	1					
X_{11}	-0.05	0.01	-0.06	-0.20	0.23	0.23	0.36	0.00	0.20	0.06	1				
X_{12}	0.4	-0.48*	-0.42	0.43	0.17	0.30	0.27	-0.42	0.06	0.05	-0.06	1			
X_{13}	0.3	-0.16	-0.11	0.07	0.30	0.11	0.06	-0.48*	0.26	0.33	0.10	0.52*	1		
X_{14}	0.3	-0.15	-0.14	0.46	0.10	0.20	-0.30	0.21	-0.16	-0.33	-0.01	-0.06	-0.14	1	
X_{15}	0.8**	-0.42	-0.28	0.48*	0.34	0.27	-0.19	-0.18	0.13	0.23	-0.04	0.44	0.45	0.24	1

X_1 = Temp, X_2 = pH, X_3 = Alkalinity, X_4 = Turbidity, X_5 = Conductivity, X_6 = Free CO_2 , X_7 = Hardness, X_8 = DO, X_9 = BOD, X_{10} = PO_4 , X_{11} = NO_3 , X_{12} = Na, X_{13} = K, X_{14} = Total coliform, X_{15} = Faecal coliform

**Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 2. Correlation coefficient among various parameters at Site-II

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
X_1	1														
X_2	-0.51*	1													
X_3	-0.67**	0.76**	1												
X_4	0.63**	-0.25	-0.44	1											
X_5	-0.64	0.52**	0.36	-0.46	1										
X_6	0.38	-0.72**	-0.57*	0.05	-0.39	1									
X_7	-0.11	-0.06	-0.05	-0.19	0.29	-0.10	1								
X_8	-0.46	0.42	0.06	-0.41	0.57*	-0.09	-0.00	1							
X_9	-0.29	0.22	0.45	-0.28	0.19	-0.16	0.04	-0.15	1						
X_{10}	0.60**	-0.08	-0.35	0.66**	-0.18	0.14	-0.21	0.03	0.37	1					
X_{11}	0.44	-0.145	-0.05	0.16	-0.09	0.41	-0.18	-0.27	0.32	0.37	1				
X_{12}	0.29	0.03	-0.16	0.29	0.19	-0.19	0.37	-0.04	-0.26	0.34	-0.09	1			
X_{13}	0.07	0.23	0.00	-0.16	0.25	-0.17	0.28	0.41	-0.01	0.21	0.016	0.25	1		
X_{14}	-0.40	0.13	0.11	-0.18	-0.01	-0.15	0.06	0.13	-0.23	-0.38	-0.79**	0.08	-0.07	1	
X_{15}	0.78**	-0.58*	-0.58*	0.49*	-0.73**	0.35	-0.04	-0.48*	-0.13	0.27	0.20	0.06	-0.00	-0.25	1

X_1 = Temp, X_2 = pH, X_3 = Alkalinity, X_4 = Turbidity, X_5 = Conductivity, X_6 = Free CO_2 ,
 X_7 = Hardness, X_8 = DO, X_9 = BOD, X_{10} = PO_4 , X_{11} = NO_3 , X_{12} = Na, X_{13} = K, X_{14} =
 Total coliform, X_{15} = Faecal coliform

**Correlation is significant at the 0.01 level

*Correlation is significant at the 0.05 level

Table 3. Correlation coefficient among various parameters at Site-III

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
X_1	1														
X_2	-0.74**	1													
X_3	-0.52*	0.87**	1												
X_4	0.70**	0.71**	-0.47*	1											
X_5	-0.29	0.20	0.12	-0.24	1										
X_6	0.43	-0.83**	-0.74**	0.60**	-0.12	1									
X_7	-0.38	0.27	-0.03	-0.41	0.29	-0.28	1								
X_8	-0.32	0.58**	0.71**	-0.23	0.24	-0.55*	-0.11	1							
X_9	0.04	-0.10	-0.37	-0.19	0.21	0.13	0.33	-0.56*	1						
X_{10}	0.44	-0.58*	-0.32	0.55*	-0.12	0.44	-0.48*	0.03	-0.24	1					
X_{11}	-0.35	0.69**	0.67**	-0.27	0.09	-0.60**	-0.18	0.58*	-0.06	-0.18	1				
X_{12}	0.28	-0.18	-0.18	0.08	0.31	-0.13	0.28	-0.08	-0.14	0.01	-0.22	1			
X_{13}	0.21	0.08	0.15	-0.22	0.34	-0.31	-0.00	0.03	-0.01	-0.18	-0.08	0.62**	1		
X_{14}	0.48*	-0.43	-0.25	0.43	-0.46	0.27	0.25	0.10	-0.59**	0.22	-0.24	0.18	-0.09	1	
X_{15}	-0.28	0.24	0.14	-0.17	-0.41	-0.16	0.21	0.23	-0.18	-0.30	0.21	-0.32	-0.47**	0.46	1

X_1 = Temp, X_2 = pH, X_3 = Alkalinity, X_4 = Turbidity, X_5 = Conductivity, X_6 = Free CO_2 ,
 X_7 = Hardness, X_8 = DO, X_9 = BOD, X_{10} = PO_4 , X_{11} = NO_3 , X_{12} = Na, X_{13} = K, X_{14} =
 Total coliform, X_{15} = Faecal coliform, X_{16} = Biomass, X_{17} = NPP.

**Correlation is significant at the 0.01 level

*Correlation is significant at the 0.05 level

Table 4. One-way ANOVA for various physico-chemical and biological characteristics among the three study sites.

Parameter	F-value	Level of significance ($P \leq 0.05$)
Temperature (°C)	N.S.	N.S.
Conductivity($\mu\text{mho/cm}$)	4.763	0.012
Alkalinity (mg/L)	16.098	0.000
Free CO ₂	N.S.	N.S.
Turbidity (NTU)	N.S.	N.S.
Hardness (mg/L)	N.S.	N.S.
DO (mg/L)	N.S.	N.S.
BOD (mg/L)	N.S.	N.S.
PO ₄ (mg/L)	10.572	0.000
NO ₃ (mg/L)	5.192	0.008
Na (mg/L)	N.S.	N.S.
K (mg/L)	13.997	0.000
Total Coliform	18.132	0.000
Faecal Coliform	5.000	0.009

N.S. (Not significant) at $P \leq 0.05$

Table 5. Temporal variation in various physico-chemical and biological characteristics of three study sites based on one-way analysis of variance (ANOVA).

Parameter	Site	F-value	Level of significance ($P \leq 0.05$)
Temperature(°C)	I	8.980	0.001
	II	8.535	0.001
	III	10.080	0.000
pH	I	46.085	0.000
	II	9.401	0.000
	III	14.107	0.000
Alkalinity(mg/L)	I	18.256	0.000
	II	34.916	0.000
	III	6.841	0.002
Conductivity($\mu\text{mho/cm}$)	I	N.S.	N.S.
	II	8.557	0.001
	III	3.992	0.002
Free CO ₂ (mg/L)	I	12.848	0.000
	II	N.S.	N.S.
	III	3.202	0.045
Turbidity (NTU)	I	12.320	0.000
	II	15.331	0.000
	III	11.647	0.000

Hardness(mg/L)	I	N.S.	N.S.
	II	N.S.	N.S.
	III	N.S.	N.S.
DO (mg/L)	I	N.S.	N.S.
	II	N.S.	N.S.
	III	N.S.	N.S.
BOD (mg/L)	I	N.S.	N.S.
	II	N.S.	N.S.
	III	N.S.	N.S.
PO ₄ (mg/L)	I	N.S.	N.S.
	II	4.416	0.015
	III	N.S.	N.S.
NO ₃ (mg/L)	I	N.S.	N.S.
	II	N.S.	N.S.
	III	12.102	0.000
Na(mg/L)	I	N.S.	N.S.
	II	N.S.	N.S.
	III	3.208	0.045
K(mg/L)	I	N.S.	N.S.
	II	5.653	0.006
	III	N.S.	N.S.
Total coliform	I	N.S.	N.S.
	II	N.S.	N.S.
	III	N.S.	N.S.
Faecal coliform	I	N.S.	N.S.
	II	5.605	0.006
	III	3.978	0.022

N.S. (Not significant) at $P \leq 0.05$

Conclusion:

The present study is an attempt to ensure information concerning the traditional water reservoirs and the likely impact of the different land-use alternatives on the structural and functional values lying in the north eastern region of Manipur. There is a high possibility that these reservoirs become unsuitable for use soon if these reservoirs exploited in the present trend without proper management and restoration measures. The preparation of restoration strategies on the other hand requires scientific database on the important environmental characteristics of the threatened water reservoirs. This study, therefore, represents a base line data on the ecology of the reservoirs in relation to various ecological attributes and accordingly suitable management practices can be done.

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