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A Preliminary Assessment of Water Quality in Nambul River, Manipur, India

KEYWORDS: Imphal, Nambul river, Water quality, Effluents

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ABSTRACT *Eleven physico-chemical variables of the water of Nambul river were analyzed during the dry and wet seasons of the year 2011. The results reveal that site 2 (Thong Nambonbi) located in the heart of Imphal city was the most polluted site because of the considerable contaminant loads at this site. Compared to this site, the upstream site 1 (Mayang Langjing) and downstream site 3 (Wangoi) were less polluted. Comparatively higher values of EC and inorganic nutrients including chloride, nitrate and phosphate were found at this site during both seasons. Further, the study reveals that dissolved oxygen (DO) concentrations in river water is significantly affected by variables such as chloride, nitrate and inorganic phosphate, which exhibit significant negative correlations with DO at $p < 0.01$.*

Introduction

Water quality criteria, if maintained properly, are the most important indicators of the suitability of water for various direct and indirect consumption purposes (Kumar and Dua, 2009; Harieth et al., 2013). Water quality deterioration in rivers, lakes, streams, wetlands and other freshwater ecosystems has emerged as one of the greatest global concerns. Major factors responsible for widespread decline in water quality include discharge of industrial effluents, municipal wastes, agricultural run-offs, animal husbandry and aquacultural residues, chemicals from various sources, etc.

Nambul is an important river in the Imphal Valley of Manipur state in the northeastern region of India. With an estimated population of 0.28 million, the catchment of Nambul river generates about 72.23 tons of solid waste and 31.207 cubic meter of sewage every day. A matter of great concern is that this river drains into the Loktak Lake, a Ramsar Site (Government of Manipur, 2007) and the largest freshwater lake in North East India. Therefore, assessment of physico-chemical properties of the water of Nambul is not only important for determining the suitability of its water for various purposes, but also for protecting Loktak Lake. The present work was taken up as part of a larger study to assess the quality of the water of Nambul river.

Materials and Methods

Study area

Nambul river originates in the Kangchup Hill range in the western side of Manipur (elevation 1830 msl). With about 630 sq. km. of catchment area, it is one of the major watersheds of the west flowing rivers of Manipur and drains into Loktak Lake, which is a Wetland of International Importance (Ramsar site). Nambul river comprises of a number of small streams in its upper course. The river flows for a distance of about 10 km through the city limits of Imphal dividing the Imphal Municipality area into almost two equal halves (Fig.1).

Three collecting stations were selected on the river during the present study. Site 1 (Mayang Langjing) is located to the upstream of Imphal city. This site is in the foothills where several small tributaries join to form the main course of the river. Site 2 is at the base of Thong Nambonbi bridge in the heart of Imphal city where Naga Nullah, a drain overflowing with garbage, and receiving effluents from small scale industrial units including those undertaking repairs of lead battery, refrigerator, automobile, electrical and electronic appliances; printing press, dyes, beauty parlour and others; joins the river. Site 3 (Wangoi) is located further downstream near the outer boundary of Imphal West before entering Bishnupur District to reach Loktak Lake.

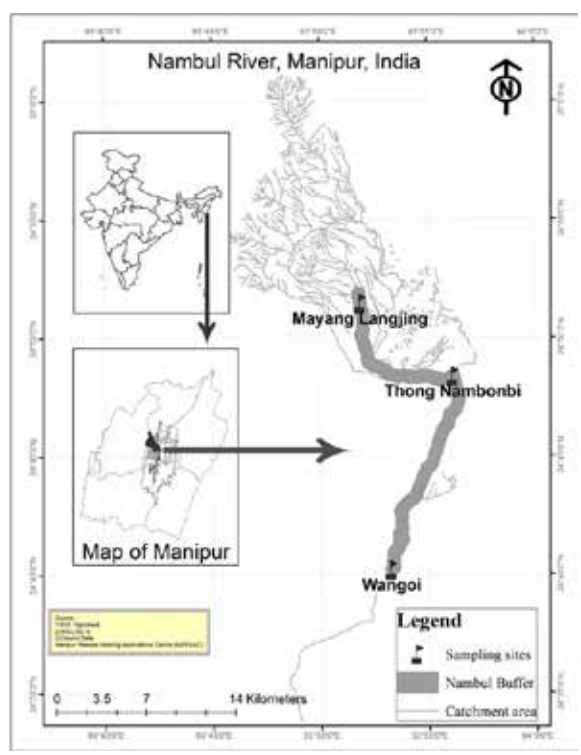

Figure 1: Location map of Nambul river showing the sampling sites

Sampling and water quality analysis

Collection of water samples was done as per standard protocols (APHA, 2005). Water temperature was measured with the help of a mercury thermometer; pH was measured

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using Eutech pH meter (Model pH 5/6 and Ion 5/6) and electrical conductivity and total dissolved solid concentrations were estimated with the help of handheld Eutech conductivity/TDS meter (Model CON 6/TDS 6). The other variables were analyzed in the laboratory following standard methods (APHA, 2005). A total of eleven variables namely, temperature, pH, electrical conductivity, total alkalinity, total hardness, total dissolved solids, free carbon dioxide, nitrate, inorganic phosphate, chloride and dissolved oxygen were taken up for the study. Statistical analyses of the findings were performed using SPSS 20. The temporal structure of the present work includes two seasons, namely dry (March to May, 2011) and wet (June to September, 2011). Sampling was done during early morning hours of the day. All the samples were collected in triplicates.

Results and Discussion

Physico-chemical study of the water of the river shows that the water of Nambul river has high levels of inorganic and organic contamination. The findings have been presented in Table 1 with mean values along with standard deviation. In order to find a meaningful analytical interpretation, Pearson correlation coefficient (r) was also calculated based on the data (Table 2).

Temperature is one of the most important variables which can influence water chemistry. During the study, average water temperature ranged from 21.20 ^{0}C at site 1 to 23.10 ^{0}C at site 3 in dry period. Higher temperatures ranging from 23.27 ^{0}C at site 1 to 24.90 ^{0}C at site 2 prevailed in the wet season.

Table 1. Concentrations of physico-chemical variables (mean±SD) of Nambul river water in Manipur, India

	Dry period			Wet period		
Variables	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
TEMP (°C)	21.20±0.17	22.37±0.06	23.10±0.10	23.27±0.12	24.90±0.17	23.93±0.15
pH	7.21±0.06	7.83±0.06	7.38±0.20	6.63±0.06	7.50±0.17	6.77±0.12
EC (µScm^{-1})	345.67±1.15	355.67±2.89	161.00±3.00	156.67±2.89	285.00±5.00	88.33±2.89
TA (mgL^{-1})	60.33±0.58	126.67±2.08	95.67±0.58	68.33±2.89	148.33±2.89	91.67±2.89
FCO_2 (mgL^{-1})	8.00±0.10	15.73±0.38	7.27±0.12	8.66±0.17	13.60±0.46	22.80±1.14
TDS (mgL^{-1})	85.33±1.53	151.33±2.31	97.33±1.15	28.33±2.89	63.33±2.89	56.67±5.77
HRDS (mgL^{-1})	50.33±0.58	92.67±1.15	67.67±0.58	65.33±2.89	102.33±2.52	61.67±2.89
Cl$^-$ (mgL^{-1})	16.53±0.47	31.00±1.38	34.37±0.21	32.25±0.06	53.23±0.15	32.20±0.17
NO_3 (mgL^{-1})	0.08±0.01	0.85±0.02	0.49±0.01	0.09±0.01	0.92±0.03	0.52±0.02
PO_4^{3-} (mgL^{-1})	0.04±0.01	0.68±0.01	0.36±0.01	0.08±0.01	0.88±0.02	0.84±0.02
DO (mgL^{-1})	5.74±0.03	4.88±0.01	5.48±0.01	6.43±0.12	4.25±0.02	4.82±0.03

TEMP (Temperature), EC (Electrical conductivity), TA (Total alkalinity), FCO_2 (Free carbon dioxide), TDS (Total dissolved solids), HRDS (Total hardness), Cl$^-$ (Chloride), NO_3^- (Nitrate), PO_4^{3-} (Inorganic phosphate), DO (Dissolved oxygen)

The study revealed that pH of Nambul water was alkaline in nature with mean values crossing 7 in almost all the sites. During dry period, all the three sites exhibited higher than neutral pH values with the highest average of 7.87 at site 2. The scenario was slightly different during wet period when site 2 was found to have an average pH value of 7.50 whereas site 1 and site 3 exhibited slightly acidic pH of 6.63 and 6.77, respectively. This trend is supported by the relative rise in alkalinity concentrations observed at Site 2 with values of 126.67 mg L^{-1} and 148.33 mg L^{-1} during the dry and wet seasons, respectively. This is also reflected in the significant positive correlation (r = 0.647, p = 0.01) between pH and total alkalinity. However, the slightly acidic nature of water at site 1 and 3 during wet season may be due to dilution by rain water through atmospheric carbon dioxide deposition and discharge of contaminated run-offs like sewage from different sources (Harieth et al., 2013). As the river courses from a more pristine area to commercial area and then to a thinly populated area, there are different levels of anthropogenic disturbances and further dilution from small streams that converge with this river in its downstream stretch. Dilution effect is also more prominent during wet season with higher values of free carbon dioxide observed during this period. The highest concentration of 22.80 mg L^{-1} was observed at site 3 (recovery zone) in the wet season during this study.

Electrical Conductivity (EC) is an excellent indicator of dissolved solutes mostly from anthropogenic sources. Changes in EC could thus be an indicator that a discharge or some other source of pollution has entered a stream (Olajire and Imeokparia, 2000; Najah et al., 2009; Sharma et al., 2011; Harieth et al., 2013). EC influences TDS which in turn is a measure of alkalinity of water. During the present study, EC was highest at site 2 with average values of 355.67 µScm^{-1} in dry period and 285.00 µScm^{-1} during wet season. On an average, electrical conductivity of the sampling sites crossed 100 µScm^{-1} during both the seasons. Higher EC value observed during dry season may be due to evaporation effect coupled with reduced stream flow which results in the concentration of salts and ions. The results obtained in the present study shows further deterioration from the conditions reported in some previous studies on the same river (Khangembam and Gupta, 2006; Vidyarani et al., 2008; Singh and Singh, 2010). Relatively high value of conductivity observed in site 2 may also be particularly due to high nutrient loads and sewerage discharge, especially via Naga Nullah and from the surroundings of this station which is the busiest residential and largest commercial area of the state. This fact is also supported by the higher values of several other variables such as total alkalinity, TDS, total hardness, chloride, nitrate and inorganic phosphate observed during both dry and wet seasons at site 2 (Table 1). Further, positive correlations among these variables (Table 2) indicate their common origin and contribution towards deterioration of water quality at site 2. The above observations can also be validated by seeing the average concentration of TDS at site 2 which is 151.33 mg L^{-1} during dry season and the highest hardness value of 102.33 mg L^{-1} during wet period which thus confirms high nutrient loads and waste discharges at this site.

Table 2: Pearson correlation coefficient ('r') among physico-chemical variables studied in Nambul river water in Manipur, India

	TEMP	pH	EC	TA	FCO_2	TDS	HRDS	Cl$^-$	NO_3^-	PO_4^{3-}	DO
TEMP	1										
pH	-.143	1									
EC	.115	.854**	1								
TA	.650**	.647**	.759**	1							
FCO_2	.510*	.024	.055	.425	1						
TDS	-.250	.789**	.685**	.471*	.127	1					
HRDS	.583*	.660**	.850**	.964**	.302	.444	1				
Cl$^-$	.580*	.667**	.707**	.984**	.466	.575*	.964**	1			
NO_3^-	.598**	.653**	.713**	.979**	.532*	.582*	.967**	.983**	1		
PO_4^{3-}	.616**	.672**	.764**	.993**	.433	.498*	.953**	.985**	.988**	1	
DO	-.579*	-.336	-.222	-.780**	-.391**	-.264	-.518*	-.679**	-.708**	-.736**	1

TEMP (Water Temperature), EC (Electrical Conductivity), TA (Total Alkalinity), FCO_2 (Free Carbon Dioxide), TDS (Total Dissolved Solids), HRDS (Total Hardness), Cl$^-$ (Chloride), NO_3^- (Nitrate), PO_4^{3-} (Inorganic Phosphate), DO (Dissolved Oxygen)
** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed).

Evaluation of dissolved ionic species like chloride, nitrate and inorganic phosphate assumes significance in understanding water chemistry in response to freshwater conservation, especially in contaminated rivers and streams (Huang et al., 2009; Li et al., 2011; Sharma et al., 2013; Harieth et al., 2013). Important anthropogenic sources of ionic species contamination in water include agricultural run-off, animal husbandry, aquaculture, municipal discharges, and industrial effluents, household chemicals like detergents, automobile exhaust and leachates from waste disposal sites (Sarin and Krishnaswami, 1984; Carpenter et al., 1998; Li et al., 2011; Harieth et al., 2013). Chloride in water has been heavily relied on as an indicator of pollution and a sudden increase in this parameter in water is an indicator of possible entry of sewage into a water body. It was found in the present study that site 2 at the meeting point of Naga Nullah and numerous small sewage dis-

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charges from the city exhibited the highest chloride concentrations in both the seasons (Table 1). However, there were no significant seasonal differences in chloride concentration during the present study. The higher chloride is also accompanied by higher EC, total alkalinity and total hardness values observed in the river water (355.67 µS cm^{-1}, 126.67 mg L^{-1} and 92.67 mg L^{-1}, respectively, during dry season; and 285.00 µS cm^{-1}, 148.33 mg L^{-1} and 102.33 mg L^{-1}, respectively, during wet season) indicating the presence of dissolved solutes in the water. The concentration of nitrate in the water of Nambul during both the seasons shows marked variations among the upstream less-polluted site which is much lower than site 2, the most contaminated station. It again gradually decreases towards the recovery site (Table 1). Nitrate concentration was found to be higher during wet period as compared to dry period probably due to more influx of organic wastes as well as agricultural run-off into the river water. Pearson correlation study of inorganic phosphate shows that it has significantly high positive correlations with alkalinity (0.997), total hardness (0.953) and EC (0.764) at significance level of 0.01, thus accounting for the presence of high organic and inorganic load in the water of this river. While an earlier study (Singh and Singh, 2010) revealed a strong correlation between nitrate and phosphate, the present study reveals significant positive correlations of phosphate with alkalinity, total hardness and EC. Thus the elevated levels of the anions increased EC, while they also had strong correlations among each other. Dissolved oxygen levels of the study sites in Nambul river during the two periods exhibited a decreasing trend from upstream towards downstream sites. It was relatively high during dry season in comparison to wet season except for site 1 where the highest concentration was recorded during the wet period (6.43 mg L^{-1}). This could be explained by the high water flow during the rainy days thereby increasing the amount of gas dissolved due to higher turbulence. The lowering of DO level spatially during this study can be attributed to the relative rise in the concentrations of such other variables which tend to consume the dissolved oxygen content of the water during waste decomposition. This can be validated from the high negative correlation observed between DO, chloride, nitrate and inorganic phosphate (Table 2).

The present study shows a relatively higher pollution level in the water of Nambul river at site 2 (Thong Nambonbi), which is at the heart of Imphal city receiving the city's domestic and commercial discharges directly. Among the variables, ionic contaminants including chloride, nitrate and inorganic phosphate contributed much to the deterioration of the water quality through depletion of dissolved oxygen level in both the observed periods. The Pearson correlation coefficient study tested among the different variables also confirms the findings.

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