iJET EXPLORE International Journal of Engineering & Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-3444

International Journal of Engineering and Technology Volume 2 No. 6, June, 2012

Spatiotemporal Assessment of Water Quality of the Sitalakhya River, Bangladesh

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ABSTRACT

In this study, the present status of water quality of the Sitalakhya river has been assessed through field tests and laboratory analyses of water samples from selected locations during the dry seasons of 2008 and 2009. To compare the dry season water quality with wet season, river water samples were also collected and analyzed from some of the selected sampling locations during the rainy/flood season in August 2008. Dissolved oxygen concentration of the Sitalakhya river from Tarabo to Siddirganj has been found to be close to anoxic level due to huge amount of pollution load in these areas. Progressive increases in the dissolved oxygen concentrations measured in the upper portion of the Sitalakhya river. Ammonia-Nitrogen concentrations varied from 0.05 mg/L to 13.42 mg/L along the Sitalakhya river in dry season. Highest ammonia concentration was found at Sarulia near Saidabad water treatment plant (WTP) intake in March 2009. Higher concentration of ammonia was observed during flood tide than ebb tide near Saidabad WTP intake. No significant variation in ammonia concentration with depth was observed. The 5-day Biochemical Oxygen Demand varied from 0.4 mg/L to 28.8 mg/L along the Sitalakhya river in dry season. Highest BOD_5 was also found at Sarulia near Saidabad WTP intake in February and March 2009. Spatial and temporal variations of BOD_5 were found similar to those of ammonia-nitrogen. Orthophosphate concentrations varied from 0.08 mg/L to 2.8 mg/L along the Sitalakhya river. The water quality of this river is deteriorating rapidly, especially during dry season at certain reaches of the river and pollution has extended upstream gradually towards Ghorasal.

Keywords: *Water quality, Sitalakhya river, BOD_5, Ammonia.*

1. INTRODUCTION

The surface water pollution issue is considered as one of the most serious problems in most developing countries. Most of the rivers in the urban areas of the developing world are the end points of effluents discharged from the industries [1]. In Dhaka, huge quantities of untreated domestic and industrial wastes are being released everyday in the Sitalakhya river flowing along the eastern side of the city. The water quality of this river is deteriorating rapidly, especially during dry season at certain reaches of the river [2-6]. The Sitalakhya river having a length of 113 km originates from the Old Brahmaputra and falls into the river Dhaleswari. It flows by the eastern side of Dhaka district. The river joins the river Balu at Demra, a small tributary flowing from the north of greater Dhaka. About 20 km downstream of Demra, the Sitalakhya joins the Dhaleswari. It is navigable by the country boats throughout the year. The river hardly spills over the banks and follows more or less a straight course. There are several different types of industries like textiles and dyeing, paper and pulp, jute, pharmaceuticals, fertilizers, etc of moderate to big size and several urban developments along the entire stretch of the river. These establishments contribute to the pollution load to the Sitalakhya river directly or through a number of wastewater khals (canals) like DND drainage khal, Majheepara khal, Killarpul khal, Kalibazar khal, Tanbazar khal, etc. Domestic and industrial wastewater from Dhaka city through Norai khal and from the Tongi industrial area through Tongi khal are disposed of in the river Balu. This also contributes to the pollution load to the river Sitalakhya. The water quality of this river is of particular importance not only for ecological and commercial reasons but also for concerns regarding safe drinking water supply as the largest surface water treatment plant in Bangladesh located at Saidabad draws water from it through the intake at Sarulia about 400 m downstream of its confluence with the Balu river. The Saidabad water treatment plant is facing serious problems in treatment process due to poor raw water quality, especially the presence of excess ammonia and algae concentration, at the intake areas during the dry season [7-8]. In this study, the present status of water quality of the Sitalakhya river has been assessed through field tests and laboratory analyses of water samples from selected locations during the dry seasons of 2008 and 2009. To compare the dry season water quality with wet season, river water samples

were also collected and analyzed from some of the selected sampling locations during the rainy/flood season in August 2008. To observe the depth variation and tidal effects on the water quality, river water samples were also collected and analyzed from some of the selected sampling locations at 0.6 m and 2.5 m below the water surface and during both ebb tide and flood tide in April 2009.

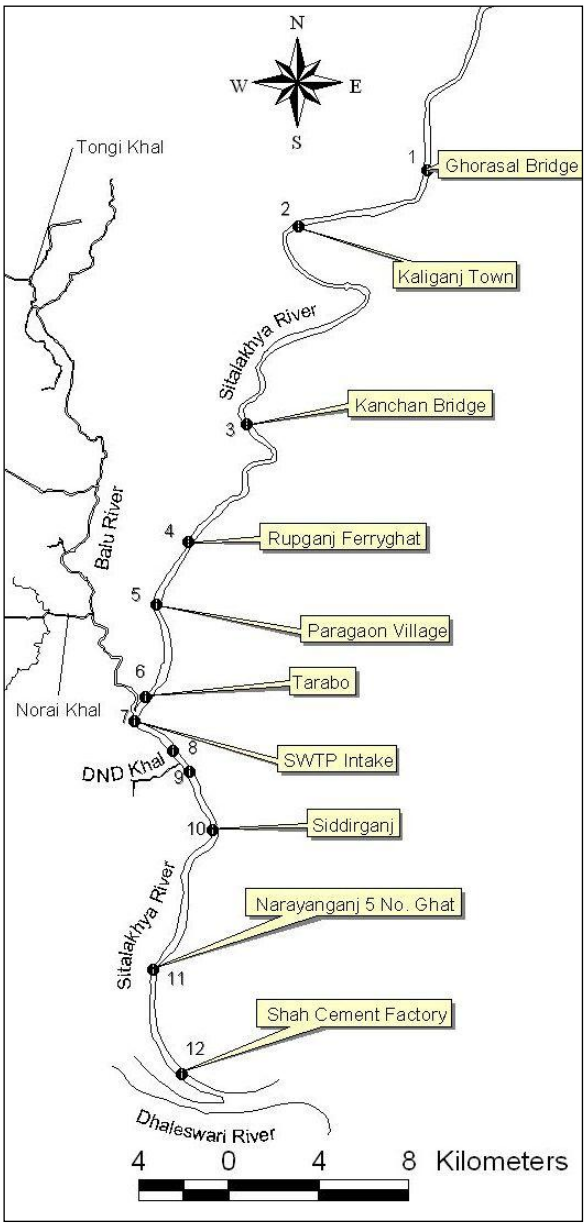

Fig 1: Study area showing sampling locations

2. METHODOLOGY

2.1 Sample Collection and Field Test

The downstream portion of the Sitalakhya river from Ghorasal highway bridge to confluence with Dhaleswari river was selected as the study reach to assess the existing water quality. River water samples were collected and analyzed from twelve sampling locations along the Sitalakhya river as shown in Fig.1, twice during the dry season of 2008 (March and April), and thrice during the dry season of 2009 (February, March and April) as water quality deteriorates in the dry season. To assess the water quality in wet season, river water samples were also collected and analyzed from some of the selected sampling locations near Saidabad WTP intake and DND khal during the rainy/flood season in August 2008. To observe the depth variation and tidal effects on the water quality, river water samples were also collected and analyzed from some of the selected sampling locations near Saidabad WTP intake and DND khal at 0.6 m and 2.5 m below the water surface and during both ebb tide and flood tide in April 2009. In-situ field measurements of dissolved oxygen (DO), pH, temperature, conductivity and Secchi depth were conducted at each sampling location. Temperature and DO were measured at 0.5 m to 0.6 m below the water surface with a portable DO meter (WTW). A standard 25 cm diameter Secchi disk, painted with alternate black and white quadrants, was used to measure the Secchi depth. The disk was lowered into the water until it just disappeared to the naked eye and the depth was recorded. pH was measured with a handheld pH meter and conductivity was measured using a portable conductivity meter (HACH). Water samples for the laboratory analyses were collected from the main stream along the centerline of the river at 0.5 m to 0.6 m below the water surface with a grab sampler using a boat as shown in Fig. 2, water samples were collected by completely filling in two 1-liter acid washed plastic bottles. Separate 1-liter pre-washed dark plastic bottles were used to collect samples from each location for the determination of phytoplankton chlorophyll-a. Before filling the samples, the bottles were rinsed with the water being collected.

Fig 2: Photograph of collection of river water sample

2.2 Laboratory Analysis of Water Samples

Samples were prepared for chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5) and Chlorophyll-a determination immediately after transferring them to the laboratory. The remaining samples were preserved at 4°C in a refrigerator for further analysis. Ammonia, nitrogen and phosphorous determinations of the preserved samples were carried out within 48 hours. Chlorophyll-a was analyzed by the spectroscopic method [9]. Samples were filtered with the GF/C filters in the laboratory. The filters were then soaked in 15 ml centrifuge tubes containing 10 ml 90% acetone and were kept in dark environment at 4°C for 24 hours. After centrifuging the extracts for 10 minutes, Chlorophyll-a concentrations were estimated after measuring absorbance at different wavelengths according to the equations of Jeffrey and Humphrey [10]. COD, ammonia, nitrate, orthophosphate, total phosphate concentrations were determined with a spectrophotometer (HACH, DR/4000 UV). COD was measured using reactor digestion method (SM 5220 D), ammonia by the Nessler method (SM 4500-NH_3 B), nitrate by the cadmium reduction method (SM 4500-NO_3-N-F), orthophosphate by the ascorbic acid method (SM 4500-P E), total phosphate and organic phosphate by the acid persulfate digestion method (SM 4500-P B and E). Suspended solids were determined from the difference between the total solids and the dissolved solids concentrations using oven dry method (SM 2540 D). BOD_5 was measured using Winkler bottle method and organic nitrogen was determined using macro-kjeldahl method according to the procedure described in SM 5210 B and SM 4500-N_{org} B respectively [11].

3. RESULTS AND DISCUSSIONS

Figure 3 and 4 show the spatial variation of ammonia, COD, BOD_5, DO, Nitrate, organic nitrogen, orthophosphate, organic phosphorous, phytoplankton chlorophyll-a, suspended solid, Secchi depth and temperature along the Sitalakhya river in different months of dry season in 2008 and 2009. Figure 5 shows the seasonal variation of concentration of ammonia, COD, BOD_5, DO, nitrate and orthophosphate at the locations of Tarabo, Sarulia, u/s and d/s of DND drainage khal in the Sitalakhya river. Concentrations in March 2008 and August 2008 have been considered as the dry season and wet season data respectively. Figure 6 shows the depth and tidal variation of concentration of ammonia, COD, DO, nitrate, orthophosphate and total phosphate at the locations of Tarabo, Sarulia, u/s and d/s of DND drainage khal in the Sitalakhya river. Tables 1 to 4 show the mean, maximum and minimum values of various water quality parameters of samples collected at five different times from twelve locations in the Sitalakhya river during dry seasons of 2008 and 2009.

Ammonia (NH_3-N)

Total Ammonia concentrations (expressed as NH_3-N) varied from 0.05 to 13.42 mg/L along the Sitalakhya river in dry season. Highest ammonia concentration was found at Sarulia near Saidabad WTP intake in March 2009. Relatively high concentrations were found from Tarabo to Siddirganj as highly polluted Balu river meets the Sitalakhya river about 400 m upstream of the intake point. Besides this, DND drainage canal and a number of industries discharge untreated and/or partially treated effluents at this location. Lower ammonia concentration was observed from Kaliganj to Kanchan bridge due to less pollution load in this area. Lower ammonia concentration was also observed in the last week of April compared to those in February and March. Also lower level of ammonia was recorded upstream of the confluence with the Dhaleswari river due to dilution by greater amount of fresh water flows from Meghna river due to tidal effect. Increased ammonia concentrations during dry season are due to increased pollution loads and decreased fresh water flows. Much higher concentrations of ammonia were observed in dry season (7.95 mg/L) than in wet season (0.07 mg/L) near Saidabad WTP intake point along with all other sampling locations. Higher concentration of ammonia was observed during flood tide than ebb tide near Saidabad WTP intake as DND drainage canal discharges huge amount of ammonia (about 3538 kg/day) to Sitalakhya river. No significant variation in ammonia concentration with depth was observed.

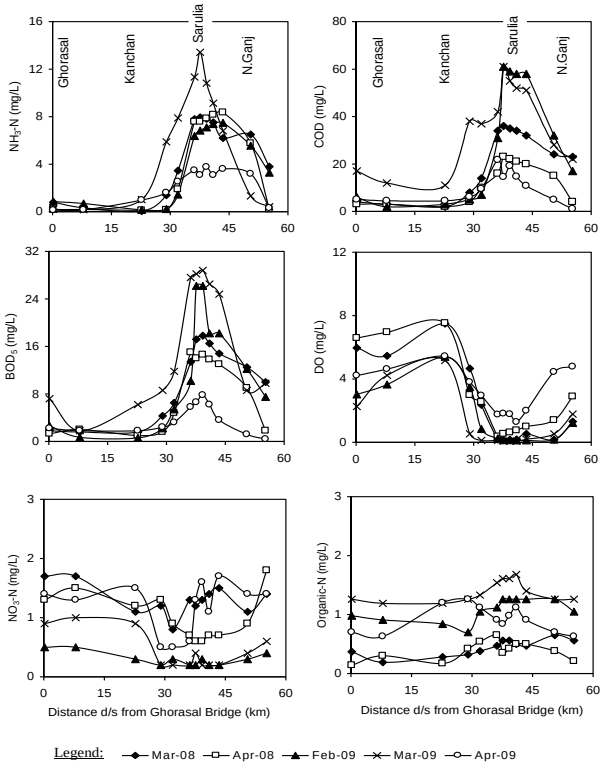

Fig 3: Spatial variation of NH_3-N, COD, BOD_5, DO, NO_3-N and Organic-N along the Sitalakhya river

Chemical Oxygen Demand (COD)

Chemical oxygen demand varied from 1 to 61 mg/L along the Sitalakhya river in dry season. Highest COD was also observed at Sarulia near Saidabad WTP intake in February and March 2009. Spatial, seasonal, tidal and depth variations of COD were found to be similar to those of ammonia.

Biochemical Oxygen Demand (BOD_5)

Biochemical oxygen demand varied from 0.4 to 28.8 mg/L along the Sitalakhya river in dry season. Highest BOD_5 was also found at Sarulia near Saidabad WTP intake in February and March 2009. Spatial, seasonal, tidal and depth variations of BOD_5 were found to be similar to those of ammonia. In wet seasons BOD_5 concentrations were found to be below the method detection limit.

Dissolved Oxygen (DO)

Dissolved oxygen is one of the most important parameter in water quality assessment. Its presence is essential to maintain variety of forms of life in the water. Effects of biodegradable waste discharge in a water body are largely determined by the oxygen balance of the system. It can be rapidly removed from the waters by discharge of the oxygen demanding waste. Dissolved oxygen varied from 0.07 to 7.52 mg/L along the Sitalakhya river in dry season. Maximum DO of 7.52 mg/L was found near Kanchan bridge in April 2008 and minimum DO of 0.07 mg/L was found near and downstream of Saidabad WTP intake in March 2009. Dissolved oxygen above critical level (4 mg/L) was observed from Kaliganj to Kanchan bridge due to less pollution load in this area. As expected, DO was found much higher during wet season than in dry season. DO decreased with depth of the water body as observed from the recorded data at 0.6m and 2.5m depths.

Nitrate (NO_3-N)

Generally, nitrate concentration (expressed as NO_3-N) varied from 0.2 to 1.8 mg/L. However 14.5 mg/L of NO_3-N was recorded upstream of Kanchpur bridge on 6th April 2009. This was probably due to oxidation of large amount of ammonia just prior to sampling. Concentrations of nitrate were found to be higher during dry season than in wet season.

Orthophosphate

Orthophosphate concentrations varied from 0.08 to 2.8 mg/L along the Sitalakhya river in dry season. Lower concentrations were found from Ghorasal to Rupganj and Narayanganj to Kalagachia. Higher concentrations were found from Rupganj to Narayanganj and the highest concentration was found near Saidabad WTP intake in March 2009. Concentrations of orthophosphate were found to be higher during dry season than in wet season. Similar variation was also observed for organic-P and Total-P.

Phytoplankton Chlorophyll-a

Phytoplankton Chlorophyll-a concentrations varied from 2.25 to 70.8 µg/L along the Sitalakhya river in dry season. Higher concentrations were observed during April from Tarabo to Siddirganj reach due to increased temperature (23.7º C to 32.8º C) and light penetration depth (0.22 m to 0.46 m).

Suspended Solids (TSS)

Suspended solids concentrations varied from 3 to 39 mg/L along the Sitalakhya river in dry season. Concentrations of TSS were found higher during wet season than in dry season due to increased sediment load at that time.

Temperature

Temperature varied from 22.9ºC to 36.0ºC along the Sitalakhya river in dry season during the sampling years. Higher temperature was observed during April, compared to February and March due to high air temperature. Higher temperatures were observed at Ghorasal and Siddhirganj near the outfalls of thermal effluent of power plants.

Secchi Depth

Secchi depth varied from 0.15 m to 2.18 m in dry season. Higher Secchi depths were observed from Kaliganj to Kanchan bridge due to less pollution in this area. Higher Secchi depths were observed during April, compared to February and March, possibly due to dilution caused by increased fresh water flows.

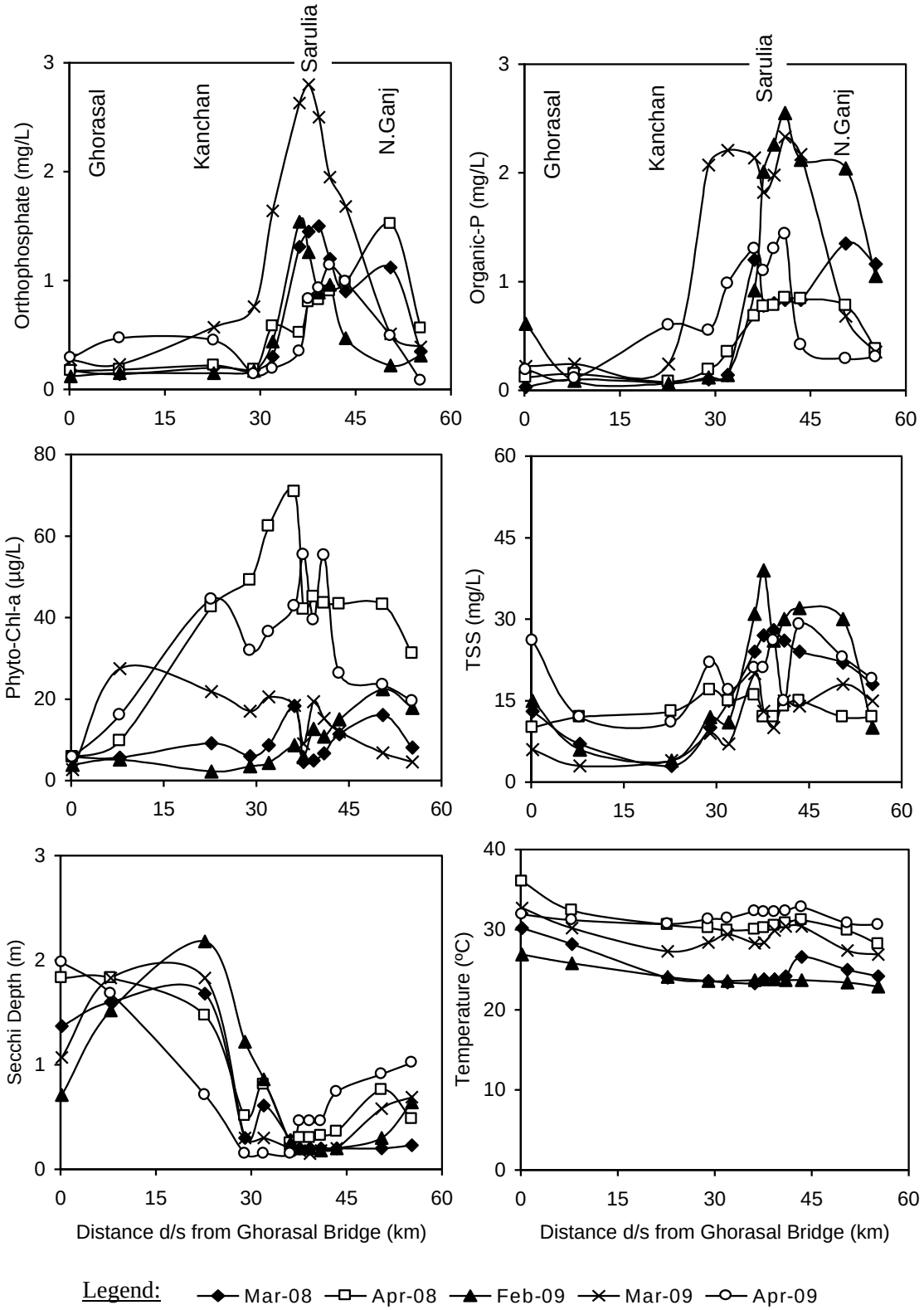

Fig 4: Spatial variation of Orthophosphate, Organic-P, Phyto-Chl-a, TSS, Secchi Depth and Temperature along the Sitalakhya river

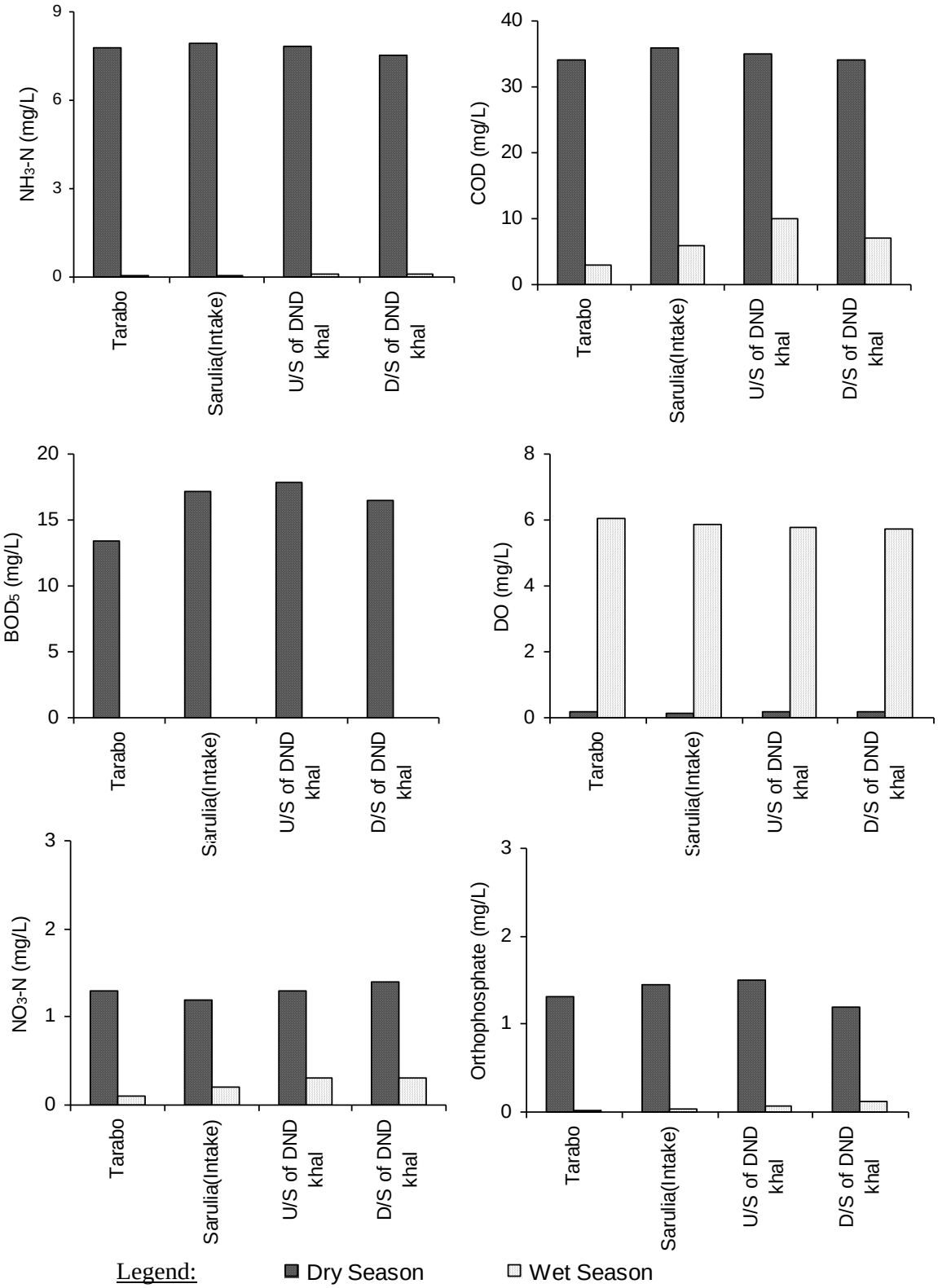

Fig 5: Seasonal variation of NH_3-N, COD, BOD_5, DO, NO_3-N and Orthophosphate at selected locations of the Sitalakhya river

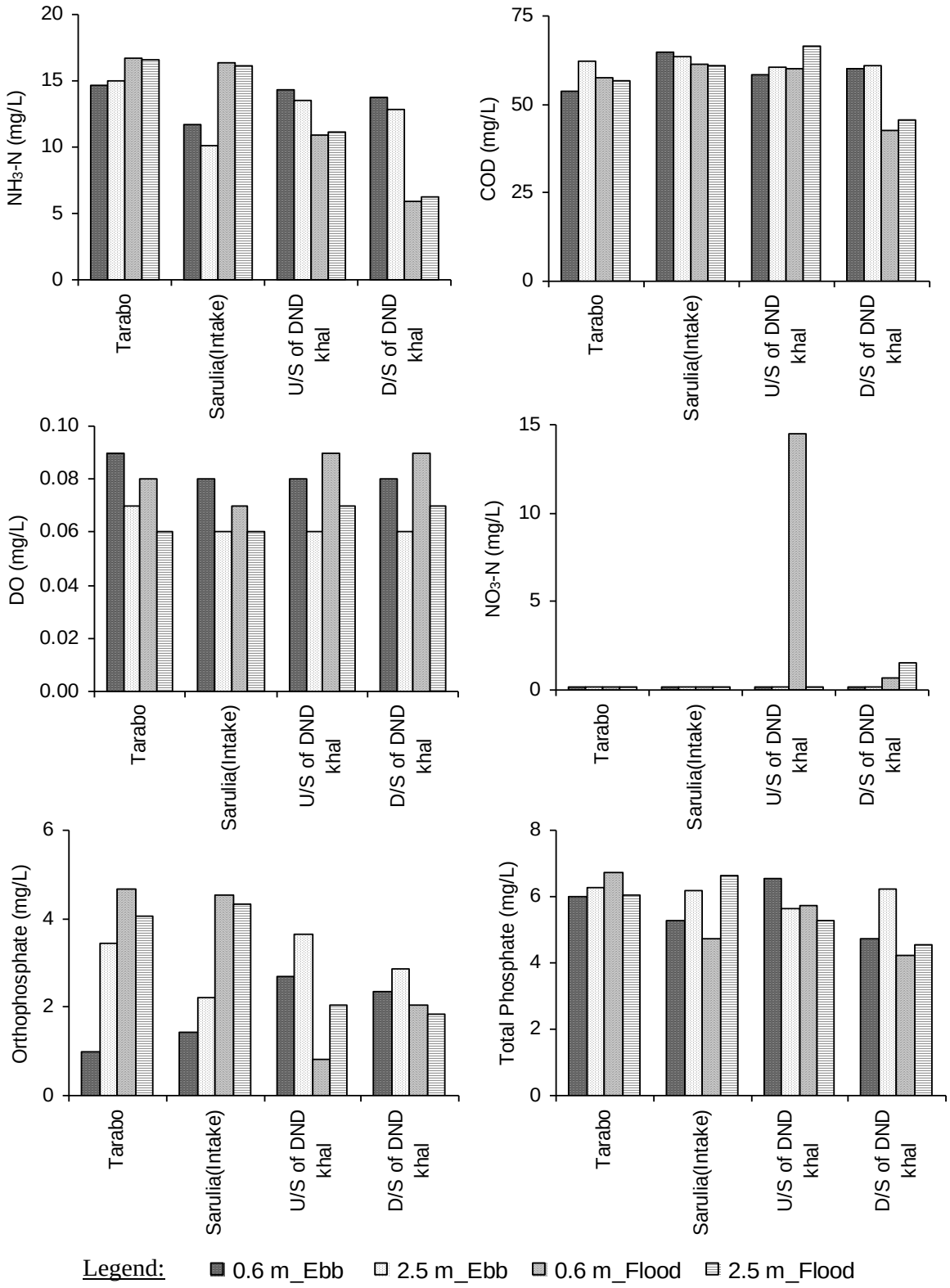

Fig 6: Depth and tidal variation of NH_3-N, COD, DO, NO_3-N, Orthophosphate and Total Phosphate at selected locations of the Sitalakhya river

Table Error! No text of specified style in document.**1: Mean, maximum and minimum values of the measured NH_3-N, BOD_5 and COD of the Sitalakhya river during dry seasons of 2008 and 2009**

Sample ID	NH_3-N (mg/L)			BOD_5 (mg/L)			COD (mg/L)		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
1	0.43	0.85	0.13	3.0	7.2	1.6	6.9	16.5	2.9
2	0.30	0.69	0.15	1.6	2.0	0.7	4.8	12.1	2.0
3	0.46	1.02	0.05	2.2	6.2	0.6	4.6	11.4	2.0
4	1.85	5.88	0.15	3.8	8.6	1.6	12.2	38.0	3.6
5	3.44	7.89	1.44	6.3	11.8	3.2	15.5	37.0	7.0
6	7.31	11.34	3.48	14.4	27.6	5.8	28.9	42.0	16.3
7	7.77	13.42	3.08	18.4	28.2	6.6	39.0	61.0	14.5
8	7.47	10.82	3.76	19.0	28.8	7.8	38.1	59.0	19.1
9	7.05	9.13	3.08	16.2	26.5	6.2	35.9	58.0	14.7
10	6.49	8.36	3.60	14.9	24.8	3.6	34.4	58.0	10.8
11	4.47	6.50	1.33	8.7	12.5	1.2	20.8	32.0	4.7
12	1.6	3.80	0.20	5.89	10.00	0.40	13.50	23.00	1.00

Table 1: Mean, maximum and minimum values of the measured Nitrate (NO_3-N), Organic-N and DO of the Sitalakhya river during dry seasons of 2008 and 2009

Sample ID	Nitrate (NO_3-N) (mg/L)			Organic-N (mg/L)			DO (mg/L)		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
1	1.16	1.70	0.50	0.69	1.26	0.14	4.41	6.58	2.26
2	1.20	1.70	0.50	0.64	1.19	0.19	4.98	6.95	3.65
3	1.00	1.50	0.30	0.74	1.20	0.17	6.20	7.52	5.17
4	0.68	1.30	0.20	0.79	1.26	0.32	3.09	4.66	0.53
5	0.54	0.90	0.20	0.88	1.33	0.38	1.76	2.95	0.12
6	0.60	1.30	0.20	0.94	1.54	0.47	0.53	1.75	0.12
7	0.74	1.30	0.20	0.92	1.61	0.35	0.54	1.81	0.07
8	0.80	1.60	0.20	0.97	1.61	0.42	0.55	1.77	0.07
9	0.72	1.40	0.20	1.01	1.68	0.50	0.48	1.28	0.07
10	0.86	1.70	0.20	0.91	1.40	0.47	0.76	1.99	0.12
11	0.82	1.40	0.30	0.85	1.26	0.38	1.34	4.44	0.16

12	1.12	1.80	0.40	0.74	1.26	0.21	2.40	4.78	1.22

Table 2: Mean, maximum and minimum values of the measured Orthophosphate, Organic-P and Chlorophyll-a of the Sitalakhya river during dry seasons of 2008 and 2009

Sample	Orthophosphate (mg/L)			Organic-P (mg/L)			Chlorophyll-a (µg/L)		
ID	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
1	0.20	0.29	0.12	0.23	0.61	0.03	4.8	5.8	2.7
2	0.23	0.47	0.14	0.14	0.24	0.09	12.8	27.5	5.2
3	0.32	0.57	0.15	0.21	0.60	0.06	24.0	44.4	2.3
4	0.28	0.76	0.14	0.61	2.07	0.10	21.5	49.2	3.5
5	0.63	1.64	0.19	0.76	2.21	0.14	26.5	62.4	4.3
6	1.27	2.63	0.35	1.25	2.14	0.68	31.8	70.8	8.7
7	1.43	2.80	0.80	1.30	2.01	0.77	23.4	55.4	4.6
8	1.33	2.50	0.82	1.42	2.26	0.78	24.3	45.0	4.9
9	1.23	1.95	0.90	1.60	2.55	0.83	26.3	55.3	6.7
10	1.00	1.68	0.47	1.28	2.17	0.42	21.6	43.3	11.4
11	0.77	1.52	0.22	1.03	2.04	0.29	22.4	43.2	6.8
12	0.34	0.56	0.08	0.65	1.16	0.31	16.3	31.23	4.6

Table 3: Mean, maximum and minimum values of the measured TSS, Secchi depth and Temperature of the Sitalakhya river during dry seasons of 2008 and 2009

Sample	TSS (mg/L)			Secchi depth (m)			Temperature (ºC)		
ID	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
1	14	26	6	1.39	1.98	0.71	31.54	36.00	26.90
2	8	12	3	1.69	1.83	1.52	29.56	32.40	25.80
3	7	13	3	1.57	2.18	0.71	27.34	30.70	24.00
4	14	22	9	0.50	1.22	0.15	27.42	31.30	23.60
5	13	17	7	0.55	0.86	0.15	27.54	31.40	23.40
6	22	31	16	0.23	0.28	0.15	27.52	32.30	23.30
7	22	39	12	0.27	0.46	0.18	27.68	32.20	23.80
8	20	28	10	0.26	0.46	0.15	28.04	32.20	23.80
9	20	30	14	0.27	0.46	0.18	28.28	32.30	23.70
10	23	32	14	0.34	0.74	0.20	28.94	32.80	23.70

ISSN: 2049-3444

11	21	30	12	0.55	0.91	0.20	27.30	30.80	23.40
12	15	19	10	0.61	1.02	0.23	26.56	30.60	22.90

4. CONCLUSIONS

Higher concentrations of ammonia, COD, BOD_5, and Orthophosphate were found from Tarabo to Siddhirganj in dry season as highly polluted Balu river meets the Sitalakhya river about 400 m upstream of the intake point. Besides, DND drainage khal and a number of industries discharge their untreated effluents around this area. Lower ammonia concentration was observed from Kaliganj to Kanchan bridge stretch due to less pollution load in this area. Much higher concentrations of these water quality parameters were observed in dry season than in wet season. The water quality of this river is deteriorating rapidly, especially during dry season at certain reaches of the river and pollution has extended upstream gradually towards Ghorasal. It is recommended that no permission be given to install new industries along the bank of the Sitalakhya river as this river is used as a raw water source for drinking water supply. In addition, the option of relocating some of the major polluting industries from the banks of Sitalakhya river may be explored by concerned authorities.

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