Journal of Water Resources and Ocean Science
2014; 3(1): 10-16
Published online March 30, 2014 (http://www.sciencepublishinggroup.com/j/wros)
doi: 10.11648/j.wros.20140301.13

Surface water quality of Gorai river of Bangladesh

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To cite this article:
S. Z. K. M. Shamsad, Kazi Zahidul Islam, Muhammad Sher Mahmud, A. Hakim. Surface Water Quality of Gorai River of Bangladesh. *Journal of Water Resources and Ocean Science.* Vol. 3, No. 1, 2014, pp. 10-16. doi: 10.11648/j.wros.20140301.13

Abstract: Some important characteristics of water quality of Gorai river system were evaluated for use in domestic, industrial, agriculture, recreation and aquaculture purposes. Twenty three water samples were collected both in the post monsoon period (November) and in the pre monsoon (May) period. The study revealed that most physical parameters and inorganic elements are not a serious problem for Gorai river system under decreased Ganges flow. A trend of organic and NO_3 pollution in some downstream areas of higher anthropogenic activities were observed. The water of Gorai river system is fairly rich with N, P and S probably due to urban run-off and livestock activities. No heavy metal toxicity was recorded. The Ca content was high in water samples representing Ganges calcareous floodplain.

Keywords: Water Quality, Gorai River, Pre Monsoon, Post Monsoon

1. Introduction

Bangladesh is the lowest riparian of three major river systems of South Asia, namely, the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna-Barak [1]. Among them, the Padma is the major river of Bangladesh, and most important in the cases of international water resources sharing issues [1,2,3]. The Ganges originates from the Gangetri iceberg of the Himalaya and enters Bangladesh as Padma via West Bengal of India at Rajshahi district [4].

The river Gorai is the lone and largest perennial distributary's of the Padma. The Padma and Gorai are the major rivers of Kushtia region and are also supplying fresh water to the Southwest region of Bangladesh for hundreds of years. This fresh water flow is the key to the maintenance of an environmental, social and ecological balance in the region [2,4].

The surface water system of Bangladesh consists of the major river networks, world largest delta and the massive flood plains, which become inundated for a short period during the monsoon season and used for cultivation for the rest of the year to supply most of the agricultural crops [4]. Bangladesh lies across the delta of four major rivers. These rivers and their distributaries discharge about 5 million cubic feet of water per second into the Bay of Bengal at peak periods. The rivers contribute to the agriculture and general economy of the country by providing navigation, fish, water for irrigation and fresh alluvial sediment replenishing the soil [4,5].

Water is essential to plant and animal life; it is our best solvent, it carries of our water, and it modifies our climate [6]. Water is an indispensable component of the earth environment. Water is not only essential to life but it is the predominant inorganic constituents of living matter, forming in general nearly three quarters of the weight of the living all [7,8,9].

Water is not only important because it contributes to plant growth, but also because it is a transporting agent for dissolved materials, nutrients, chemicals and solids [5,10].

The availability of water supply adequate in terms of both quantity and quality is essential to human existence [7,8]. Water quality is influenced both by natural and anthropogenic intervention where the former includes the local climate, geology etc. and the latter covers the construction of dams and embankments, agricultural practices, indiscriminate disposal of industrial effluents etc. [8,11].

Water quality is and will continue to be a major economic and environmental issue. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available. The situation is now changing in many areas of the world including Bangladesh [4,5,12]. Water quality study is necessary for its proper use. The study of water quality is of

much importance in production of crops. This water quality depends on many parameters among which the most important is the presence of the nutrients, responsible for fertility. Water quality refers to the characteristics of water those will influence its suitability for a specific use, i.e., how well the quality meets the need of the user [13].

The main sources of fresh water in Bangladesh are the different surface water bodies including rivers, canals, lakes, ponds and beels. The Gorai, A major offshoot of the mighty Padma flows by Kushtia town. Due to loss in water flow in the Padma and carelessness and negligence, now-a-days the Gorai runs out of water for best periods of the year. Gorai is drying. Shrinking water flows and land grabbing has turned the Gorai river into a narrow canal [2]. The Gorai river is the main distributary of fresh water from the Padma/Ganges to the South-West region. The dry season flow of the Ganges has decreased and since 1988, there has been a resultant hastening of the natural decline of the Gorai River as it becomes totally cut-off from the Ganges during dry season [2]. However, the massive withdrawal of dry season Ganges outflow has already had a serious impact not only on water quality of the Padma/Ganges dependent areas but also on agriculture, fishery, forestry, industry and navigation over the last two decades [14] and the salinity is increasing in the river of coastal regions of Bangladesh and has increased at least 2 ppt over the last few years, which is a serious threat to overall environment [3]. So, a field research was conducted the dry season (November-May) to study the water quality of the Gorai river system of Kushtia region under decreased Ganges flow (DGF). The studied area lies in the Southwestern part of Bangladesh approximately between latitude 23°40′30″ and 24°89′ N and longitude 88°42′ and 89°21′30″. Being a deltaic part of the Gangetic deltaic plain, it is bounded in the North by Padma river, separating it from Natore and Pabna districts in the East by Pabna district; in the South by Meherpur, Chuadanga and Jhenaidah.

This research was aimed at making an environmental impact assessment of water quality deterioration caused by the decreased outflow of the river Ganges and evaluation of Gorai water quality for domestic, industrial, agriculture, recreation and aquaculture.

2. Materials and Methods

The study area lies in the Indian platform and Eocene Hinge zone passes through the Southeastern extremity of the study area. On the basis of a preliminary survey, twenty-three (23) water samples were collected from different locations at the Kushtia point of Gorai river. Sampling sites for water were selected as per sampling techniques [15] which represent the whole area of the Kushtia region of Gorai river. The high-density PVC bottles used for water sampling were thoroughly cleaned by rinsing with 8M HNO_3 followed by repeated washing with water sampled so as to avoid contamination [15]. The sampling bottles were kept air tight and labeled properly for identification.

Each sample was acidified in the field for Fe determination. Aeration during sampling was avoided as far as possible. Each sample was composite of 10 sub-samples to minimize errors and heterogeneity [5]. Variable determinants such as temperature, electrical conductivity (EC), pH and dissolved oxygen (DO) of water samples were measured in the spot using thermometer, portable EC meter, pH meter and DO meter respectively [15,16]. Samples collected from the study area were carefully transported to the laboratory, preserved in a refrigerator and were immediately analyzed for finding intended physical and chemical parameters of water.

Analyses of different physical and chemical parameters of Gorai river were carried out in the laboratory. The temperature of water samples were measured by the mercury thermometer (0°-50°C range) immediately after collection by dipping the thermometer in sample for about one minute [9]. Total suspended solids (TSS) were measured gravimetrically [8]. The pH of water samples were determined directly by a pH meter taking 50ml of filtered water sample in a 100ml clean beaker [17]. The total hardness (Ht) as $CaCO_3$, was directly measured titrimetrically [8]. A rapid determination of total dissolved solids (TDS) of water samples were made simply by multiplying the measured electrical conductivity (EC) values (in µS/cm) by 0.64 [17]. The electrical conductivity (EC) of water samples were measured both in spot and in the laboratory directly by Electrical Conductivity meter (EC meter) [17]. Both NH_4-N and NO_3-N were determined by micro Kjeldahl's distillation method [17]. Sodium and potassium of the filtered water samples were directly determined by flame photometry at 589nm and 766nm of wavelength respectively [17] and calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) concentration of water samples were measured directly by atomic absorption spectrophotometer [16]. The chloride content of the water samples were determined by Mohr volume method [17] and bicarbonate (HCO_3^-), carbonate (CO_3^{2-}) content of the water samples were determined volumetrically [17]. The sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) content were determined by spectrophotometer [17].

3. Result and Discussion

The physico-chemical characteristics of the water samples of the study area of the Kushtia point of Gorai river are presented in the tables 1 and 2 and the chemical constituents of water of the study area are presented in the tables 3, 4, 5 and 6.

The Average temperature of water samples of the study area was approximately 19.9ºC and in the range of 19ºC to 22ºC (Table 1) in the post monsoon period (November) and was approximately 32.8ºC (Range 32ºC to 33.5ºC) in the pre monsoon (May) period (Table 2). The temperature of water samples of both periods showed no extreme variations at the time of collection and found suitable for

domestic and industrial uses and irrigation purposes [8,9,18,19].

Table 1. *Physico-chemical properties of water of Gorai river system in the post-monsoon period under decreased Ganges flow*

Sample no	Location	Temp. °C	TSS mg/l	pH	DO Mg/l	EC µS/cm	TDS mg/l	Ht (mg/l) as $CaCO_3$	%OM
1	Talbaria	19.5	1.5	7.79	7.2	246	157	126	0.000
2	Baradia	19.5	1.3	7.68	7.2	238	152	122	0.014
3	Shalda	20.0	1.4	7.87	7.6	254	163	134	0.014
4	Ghoraghat	20.5	1.4	7.55	7.5	258	165	128	0.014
5	Goirtia	19.0	1.6	7.22	6.4	264	169	132	0.022
6	Shawria	19.5	0.9	7.48	6.6	254	163	142	0.028
7	Raidanga	19.5	1.7	7.43	6.8	257	164	136	0.022
8	Kaiya	20.0	1.9	7.52	6.8	208	133	114	0.022
9	Rainipara	21.0	1.8	7.37	6.9	217	139	122	0.014
10	Kashimpur	22.0	1.6	7.39	6.4	233	149	144	0.022
11	Daspur	22.0	1.6	7.60	6.0	243	155	148	0.028
12	Shawta	19.5	2.3	7.65	6.2	237	152	132	0.030
13	Borunia	19.5	2.4	7.48	6.6	250	160	126	0.040
14	Varola	20.	2.3	7.61	6.6	235	150	128	0.028
15	Charpara	20.0	2.3	7.64	6.7	231	148	118	0.028
16	Borudia ghat	19.5	2.4	7.72	6.5	228	146	126	0.030
17	Kumarkhali ghat	19.0	2.6	7.65	6.1	241	154	138	0.040
18	Khayarchara	19.0	2.8	7.44	6.5	243	155	134	0.028
19	Pathorbari	19.5	2.7	7.65	6.3	250	160	140	0.048
20	Kamlapur	20.0	2.7	7.77	6.7	242	155	138	0.040
21	Jagolbar	20.5	2.9	7.63	6.8	251	161	142	0.048
22	Janipur	20.5	3.0	7.66	6.6	264	169	130	0.040
23	Muragacha	20.5	3.0	7.75	6.7	254	163	134	0.048
SD		0.8257	0.153	0.1546	0.4030	14.0348	9.0263	8.6019	0.0121
Range		19-22	0.9-3.0	7.22-7.87	6.0-7.6	208-264	133-169	114-148	0-0.048
Average		20	2.09	7.6	7.0	243	156	132	0.028

TSS=Total Suspended Sediments; DO=Dissolved Oxygen; EC=Electrical Conductivity; TDS=Total Dissolved Solids; Ht=Hardness

Table 2. *Physico-chemical properties of water of Gorai river system in the pre-monsoon period under decreased Ganges flow*

Sample no	Temp. °C	TSS mg/l	pH	DO Mg/l	EC µS/cm	TDS mg/l	Ht (mg/l) as $CaCO_3$	%OM
1	32	1.3	7.66	7.2	233	149	138	0.008
2	32	1.4	7.64	7.7	248	159	114	0
3	32	1.5	7.65	7.6	264	169	126	0.013
4	32	1.4	7.56	6.5	265	170	136	0.016
5	32.5	1.5	7.66	6.6	250	160	156	0.013
6	32.5	1.1	7.65	6.8	228	146	124	0.016
7	32.5	0.9	7.63	6.5	241	154	142	0.008
8	32.5	1.3	7.67	6.9	235	150	130	0.013
9	33	1.5	7.69	6.4	219	140	116	0.023
10	33	1.8	7.64	6.1	241	154	132	0.020
11	33	2.0	7.65	6.3	241	154	132	0.016
12	33	1.9	7.66	6.2	237	152	112	0.023
13	33	2.0	7.68	6.6	248	159	154	0.008
14	33.5	2.3	7.63	6.0	237	152	128	0.020
15	33.5	2.3	7.66	5.8	233	149	126	0.016
16	33.5	2.2	7.70	6.6	242	155	126	0.016
17	33.5	2.4	7.78	6.1	243	156	128	0.020
18	33	1.9	7.77	6.5	270	173	132	0.023
19	33	2.5	7.90	6.4	231	148	158	0.036
20	33	2.4	7.79	7.1	251	161	132	0.028
21	33	2.4	7.80	6.5	228	146	132	0.043
22	33	2.5	7.82	6.3	278	178	140	0.043
23	33	2.5	7.76	6.7	264	169	118	0.043
SD	0.4910	0.134	0.0795	0.4726	14.984	9.6653	12.313	0.0117
Range	32-33.5	0.9-2.5	7.56-7.9	5.8-7.7	219-278	140-178	112-158	0-0.043
Average	32.8	1.96	7.69	6.58	244.65	156.65	131.83	0.0202

TSS=Total Suspended Sediments; DO=Dissolved Oxygen; EC=Electrical Conductivity; TDS=Total Dissolved Solids; Ht=Hardness

The pH value of water in the study area ranged from 7.22 to 7.87 (Table 1) in the post monsoon period and 7.56 to 7.90 (Table 2) in the pre monsoon period, which are within the permissible limit for irrigated agriculture [19,20] and industrial and domestic use [8].

The hardness (Ht) in water of the study area of Gorai

river system ranged from 114 mg/l to 148 mg/l with an average value of 131.1 mg/l (Table 1) in the post monsoon period and 112 mg/l to 158 mg/l with an average value of 131.83 mg/l (Table 2) in the pre monsoon period. Significant changes in hardness due to seasonal variations were not observed in the Gorai river system as the natural processes by which water is made hard were not found to exist here [18]. According to hardness scale the water of the Kushtia point of Gorai river falls to the soft classes, which are suitable for most of the intended uses [8,18].

The electrical conductivity (EC) of water is an indicator of salinity hazard and gives the total salt concentration in water [21,22,23,24]. In the Gorai river system, the EC value of water at different locations varied from 208 to 264 µS/cm with an average value of 243.4 µS/cm (Table 1) in the post monsoon period and 214 to 278 µS/cm with an average value of 244.65 µS/cm (Table 2) in the pre monsoon period which are "excellent to good" for irrigation according to Wilcox (1955) irrigation water quality classification and surface water quality [18].

The TDS values of water of the study area ranged from 133 to 169 mg/l with an average value of 155.74 mg/l (Table 1) in the post monsoon period and 140 to 178 mg/l with an average value of 156.65 mg/l (Table 2) in the pre monsoon period. The TDS and EC values of the sampled water shows moderate concentration of dissolved solids and non-saline water [21,25,26] and within permissible limit for utilization [19,20].

From table 1 it can be seen that the Dissolve Oxygen (DO) content of the water sample of Gorai river varied considerably ranging from 6.0 to 7.6 mg/l with an average value of 7.0 mg/l in the post monsoon period and 5.8 to 7.7 mg/l with an average value of 6.58 mg/l (Table 2) in the pre monsoon period. It was observed that (Table 1 and 2) DO values of water bodies under study were higher in post monsoon than in pre monsoon period. The ambient temperature of the study area was colder in post monsoon than in the pre monsoon period, which may have influence to dissolve more oxygen in the colder climate than the warmer ones [8].

Table 1 shows that the range of organic matter (OM) content of the water samples is trace to 0.048% with an average value of 0.028% in the post monsoon period. The OM content varied from trace to 0.043% with an average value of 0.0202% in the post monsoon period. It is very interesting to note that following the similar trend as in salinity the OM content increases as water moves downstream from Charpara to Muragacha with increasing settlement areas and urban runoff [8].

Table 3. *Cationic composition (me/l) of water of Gorai river system in the post monsoon period under decreased Ganges flow*

Sample no	Na	K	Ca	Mg	Fe	Mn	Zn	Cu	NH_4
1	0.61	0.070	1.8	0.51	0.023	0.0041	0.00056	Trace	0.031
2	0.63	0.071	1.8	0.51	0.025	0.0043	0.00062	Trace	0.0135
3	0.62	0.071	1.85	0.53	0.021	0.0039	0.00066	Trace	0.036
4	0.64	0.072	1.9	0.51	0.024	0.0051	0.0018	Trace	0.030
5	0.69	0.074	1.9	0.52	0.027	0.0048	0.0030	Trace	0.033
6	0.72	0.070	2	0.57	0.033	0.0052	0.0024	Trace	0.040
7	0.70	0.071	2	0.61	0.031	0.0055	0.0022	Trace	0.037
8	0.74	0.072	1.95	0.59	0.019	0.0054	0.00098	Trace	0.041
9	0.78	0.072	2	0.61	0.027	0.0055	0.00155	Trace	0.043
10	0.72	0.074	2.05	0.65	0.020	0.0053	0.0022	Trace	0.039
11	0.71	0.072	2	0.66	0.035	0.0049	0.0042	Trace	0.037
12	0.70	0.071	1.15	0.65	0.022	0.0053	0.00055	Trace	0.037
13	0.72	0.070	2	0.69	0.031	0.0054	0.0032	Trace	0.035
14	0.96	0.071	2.05	0.674	0.025	0.0059	0.0024	Trace	0.035
15	0.75	0.071	2.1	0.674	0.024	0.0051	0.0007	Trace	0.035
16	0.76	0.073	2.1	0.65	0.040	0.0053	0.0015	Trace	0.040
17	0.74	0.072	2.1	0.65	0.043	0.0042	0.0003	Trace	0.043
18	0.76	0.074	2.15	0.63	0.041	0.0047	0.0022	Trace	0.045
19	0.71	0.072	2.1	0.57	0.035	0.0051	0.00092	Trace	0.041
20	1.74	0.075	2.2	0.61	0.047	0.0055	0.00155	Trace	0.043
21	0.72	0.076	2.25	0.65	0.043	0.0053	0.0024	Trace	0.043
22	0.74	0.076	2.3	0.67	0.041	0.0060	0.0018	Trace	0.041
23	0.76	0.077	2.3	0.67	0.047	0.0056	0.0022	Trace	0.047
SD	0.0697	0.0020	0.2333	0.0606	0.0091	0.0007	0.00099		0.0069
Range	0.61-0.78	0.070-0.077	1.8-2.3	0.51-0.69	0.019-0.047	0.0039-0.0060	0.0003-0.0042		0.03-0.047
Average	0.71	0.0728	2.037	0.612	0.0323	0.0051	0.00173		0.0385

Ignoring the seasonal variation the average value of sodium (Na) and potassium (K) of the water samples of the study area was 0.71 me/l and 0.0728 me/l in the post monsoon period (Table 3) and 0792 me/l and 0.081 me/l in the pre monsoon period (Table 4). While the calcium (Ca) and magnesium (Mg) content of water samples ranged from 1.8 to 2.3 me/l and 0.51 to 0.69 me/l with an average value of 2.037 me/l and 0.612 me/l respectively in the post monsoon period (Table 3). In the pre monsoon period the Ca and Mg content ranged between 2.0 to 2.6 me/l and 0.05 to 0.856 me/l with an average value of 2.276 me/l and 0.698 me/l respectively (Table 4). It is evident that the values of Na, K, Ca and Mg content of the water samples were within the recommended limits for irrigation,

industrial, domestic and aesthetic purposes [19, 27].

Table 4. *Cationic composition (me/l) of water of Gorai river system in the pre monsoon period under decreased Ganges flow*

Sample no	Na	K	Ca	Mg	Fe	Mn	Zn	Cu	NH_4
1	0.70	0.077	2	0.58	0.028	0.0047	0.00064	Trace	0.033
2	0.72	0.077	2.1	0.59	0.033	0.0062	0.00066	Trace	0.041
3	0.70	0.077	2.1	0.61	0.022	0.0036	0.00070	Trace	0.049
4	0.74	0.079	2.15	0.53	0.040	0.0070	0.0024	Trace	0.033
5	0.76	0.081	2.25	0.55	0.037	0.0067	0.0032	Trace	0.041
6	0.76	0.077	2.15	0.674	0.063	0.0065	0.0030	Trace	0.049
7	0.74	0.077	2.05	0.69	0.040	0.0067	0.0042	Trace	0.041
8	0.804	0.077	2.7	0.724	0.018	0.0068	0.0024	Trace	0.049
9	1.28	0.077	2.4	0.724	0.034	0.0068	0.0018	Trace	0.049
10	0.0804	0.086	2.1	0.75	0.056	0.0063	0.00055	Trace	0.041
11	0.76	0.077	2	0.76	0.043	0.0064	0.00082	Trace	0.041
12	0.76	0.077	2.2	0.74	0.0314	0.0062	0.0018	Trace	0.041
13	0.72	0.077	2.15	0.79	0.035	0.0066	0.00098	Trace	0.041
14	0.76	0.077	2.15	0.724	0.00	0.0063	0.0024	Trace	0.041
15	0.87	0.079	2.25	0.78	0.027	0.0059	0.0226	Trace	0.041
16	0.804	0.079	2.3	0.75	0.047	0.0059	0.0030	Trace	0.066
17	0.804	0.084	2.3	0.69	0.047	0.0057	0.0018	Trace	0.049
18	0.805	0.082	2.35	0.708	0.050	0.0057	0.0022	Trace	0.049
19	0.72	0.077	2.4	0.67	0.038	0.0062	0.00098	Trace	0.033
20	0.804	0.090	2.5	0.69	0.062	0.0065	0.00046	Trace	0.049
21	0.83	0.097	2.55	0.724	0.041	0.0060	0.0018	Trace	0.049
22	0.76	0.097	2.6	0.76	0.044	0.0050	0.00155	Trace	0.049
23	0.804	0.084	2.6	0.856	0.089	0.0042	0.0022	Trace	0.058
SD	0.115	0.006	0.204	0.0806	0.0156	0.0087	0.0044		0.0078
Range	0.70-1.28	0.077-0.097	2.0-2.6	0.53-0.856	0.00-0.089	0.0036-0.0070	0.00055-0.0226		0.033-0.066
Average	0.79	0.080	2.28	0.70	0.028	0.0060	0.0028	___	0.045

The concentration of iron (Fe), manganese (Mn) and zinc (Zn) in the post monsoon period ranged from 0.019 to 0.047 me/l, 0.0039 to 0.006 me/l and 0.0003 to 0.0042 me/l with an average value of 0.0323 me/l, 0.0051 me/l and 0.00173 me/l respectively (Table 3); while in the pre monsoon period the concentration ranged from 0.018 to 0.089 me/l, 0.0036 to 0.007 me/l and 0.0005 to 0.0226 me/l averaging 0.028 me/l, 0.006 me/l and 0.0028 me/l respectively (Table 4). It is evident that all the values of Fe, Mn and Zn in the study area are within the recommended limits for irrigation, industrial, domestic and aesthetic purposes [19,28]. But the amount of copper (Cu) was found at a trace or not detectable in both the pre monsoon and post monsoon periods in the water of Gorai river system.

Table 5. *Anionic composition (me/l) of water of Gorai river system in the post monsoon period under decreased Ganges flow*

Sample no	CO_3	HCO_3	Cl	SO_4	NO_3	PO_4
1	0.2	2.41	0.35	0.049	0.037	0.012
2	0.25	2.47	0.35	0.049	0.040	0.0123
3	0.25	2.49	0.40	0.054	0.045	0.020
4	0.3	2.57	0.40	0.054	0.040	0.0088
5	0.3	2.63	0.35	0.057	0.034	0.0095
6	0.35	2.65	0.35	0.054	0.037	0.0081
7	0.3	2.71	0.30	0.054	0.034	0.0088
8	0.35	2.87	0.30	0.057	0.026	0.0088
9	0.35	3.10	0.25	0.057	0.022	0.0088
10	0.25	2.78	0.30	0.054	0.031	0.0095
11	0.25	2.98	0.30	0.065	0.031	0.0095
12	0.35	2.80	0.30	0.049	0.031	0.0081
13	0.35	2.72	0.30	0.003	0.034	0.0084
14	0.3	3.10	0.35	0.057	0.034	0.0088
15	0.25	2.80	0.40	0.057	0.0242	0.0081
16	0.3	2.98	0.40	0.054	0.031	0.0088
17	0.25	3.15	0.40	0.049	0.047	0.0095
18	0.3	3.06	0.45	0.054	0.037	0.010
19	0.35	3.15	0.35	0.054	0.041	0.012
20	0..5	3.245	0.35	0.049	0.034	0.0088
21	0.4	3.15	0.35	0.057	0.041	0.018
22	0.4	3.43	0.30	0.054	0.047	0.020
23	0.4	3.43	0.40	0.063	0.041	0.020
SD	0.06	0.30	0.049	0.012	0.0067	0.0041
Range	0.2-0.4	2.41-3.43	0.25-0.45	0.003-0.0524	0.022-0.047	0.0081-0.020
Average	0.32	2.90	0.35	0.052	0.036	0.011

When the ammonium (NH_4) content of water sample of the Gorai river system are in consideration in the post monsoon period, sample 4 (collected from Ghoraghat) shows the lowest and sample 23 (collected from Muragacha) shows the highest value of NH_4 content with the amount of 0.030 and 0.047 me/l respectively (Table 3). In the pre monsoon period (Table 4) the range of NH_4 content in the water of Gorai river system ranged from 0.033 to 0.066 me/l with an average value of 0.045 me/l. The water sample (sample no 16) collected from Borudia represent the highest value of NH_4.

Table 6. *Anionic composition (me/l) of water of Gorai river system in the pre monsoon period under decreased Ganges flow*

Sample no	CO_3	HCO_3	Cl	SO_4	NO_3	PO_4
1	0.25	2.49	0.45	0.057	0.054	0.0123
2	0.25	2.59	0.45	0.060	0.052	0.0133
3	0.30	2.67	0.40	0.057	0.067	0.044
4	0.30	2.60	0.40	0.070	0.045	0.0095
5	0.40	2.80	0.35	0.070	0.037	0.012
6	0.50	2.80	0.45	0.076	0.040	0.0088
7	0.40	2.91	0.40	0.065	0.034	0.0095
8	0.50	3.245	0.40	0.065	0.022	0.0095
9	0.50	3.245	0.40	0.060	0.0242	0.0088
10	0.25	2.98	0.30	0.065	0.034	0.0095
11	0.30	3.245	0.40	0.070	0.034	0.010
12	0.50	3.245	0.35	0.049	0.034	0.0088
13	0.40	3.06	0.35	0.067	0.034	0.0088
14	0.25	3.245	0.40	0.063	0.042	0.0095
15	0.40	3.15	0.50	0.070	0.034	0.0088
16	0.30	3.245	0.50	0.065	0.036	0.0095
17	0.40	3.34	0.50	0.054	0.065	0.010
18	0.40	3.43	0.50	0.063	0.041	0.0095
19	0.30	3.43	0.35	0.057	0.054	0.014
20	0.40	3.51	0.40	0.063	0.032	0.0095
21	0.50	3.508	0.45	0.073	0.050	0.020
22	0.50	3.57	0.35	0.057	0.065	0.020
23	0.60	3.57	0.50	0.073	0.047	0.0114
SD	0.104	0.335	0.059	0.0068	0.0125	0.0076
Range	0.25-0.60	2.49-3.57	0.30-0.50	0.049-0.076	0.022-0.067	0.0088-0.044
Average	0.387	3.13	0.40	0.064	0.043	0.0125

Tables 5 and 6 show that the nitrate (NO_3) content of the water samples of Gorai river system of study area varied considerably ranging from 0.022 to 0.047 me/l and 0.022 to 0.067 me/l with an average value of 0.036 me/l and 0.043 me/l in the post monsoon period and in the pre monsoon period respectively. From the values there is an indication of NO_3 pollution in some areas of higher human and livestock population [8].

The average concentration of carbonate (CO_3), bicarbonate (HCO_3) and chloride of the samples were 0.317 me/l, 2.90 me/l and 0.348 me/l in post monsoon period; while in the pre monsoon period the values were 0.387 me/l, 3.13 me/l and 0.4 me/l respectively. The sulfate (SO_4) and phosphate (PO_4) concentration of the water samples of the study area ranged from 0.0003 to 0.63 me/l and 0.0081 to 0.02 me/l with an average value of 0.0529 me/l and 0.011 me/l in the post monsoon period; while in the pre monsoon period SO_4 and PO_4 concentration varied from 0.049 to 0.079 me/l and 0.0088 to 0.044 me/l averaging 0.064 me/l and 0.0125 me/l respectively.

4. Conclusion

The samples were analyzed for intended water quality parameters following internationally recognized and well established analytical techniques. From the present investigation it was observed that there were no extreme variations of river water temperature and the ambient temperature. Dissolved Oxygen (DO) of the water of study area was higher in the post monsoon than in the pre monsoon period. The pH values are within the permissible limit and no significant changes were observed due to seasonal variation. Hardness fall "soft" classes and are suitable for most of the intended uses. Electrical conductivity (EC) of collected water samples is "excellent to good". The TDS and EC values of the sampled water show moderate concentration of dissolved solids and non-saline water. There was a trend of increasing TDS, EC and OM as the water moves downstream. It is evident that all the values of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), ammonium (NH_4), nitrate (NO_3), carbonate (CO_3) and bicarbonate (HCO_3) falls under the permissible limit and there were no toxicity problem. Water samples showed no extreme variations in the concentrations of cations and anions and it was true for both post and pre monsoon periods. No toxic concentrations were observed for the heavy metals. Thus, most of the inorganic elements are not a serious problem in terms of water contamination in Gorai River. Higher concentrations of nitrogen and phosphorus were recorded especially around the locations of higher human population and livestock activities. As

Gorai River system meandering through Ganges calcareous alluvial floodplain its water has high Ca content.

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