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Assessment of physico-chemical properties of water of Gorai river at Kushtia town in 2014: a case study

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ABSTRACT

The case study was conducted in 2014 to assess the physico-chemical properties of the water from the Gorai river in Kushtia, Bangladesh. To conduct this research, six samples from six points were collected from surface water of this river that covered only the Kushtia town. Samples were collected from Charulia, Barokhada, Jugia, Kamlapur, Thanapara and Ghoshpara at 1km interval. Another three samples were collected from Jagati sugar mill area and two domestic effluents those were discharged to the main river flow to evaluate the impact of these effluents on the river water quality. Different water quality parameters such as temperature, pH, Electrical Conductivity, Total Dissolved Solids, Dissolved Oxygen, Alkalinity, Hardness, Sodium, Potassium, Phosphate, Sulphate, Chloride, Iron, Lead, Cadmium and Chromium were examined. From this study it was observed that most of the parameters exceeded the permissible limits.

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I. Introduction

Bangladesh is predominately a flood plain land surface and it is criss-crossed by a very complex river system. This gives the country a riverine nature, which is present in the life style, customs and history of the country people (Alam, 2003). Bangladesh is a low lying flat country with big inland water bodies, including some of the biggest rivers in the world and is extremely vulnerable because of its geographical characteristics (Matin and Kamal, 2010). Bangladesh is an agricultural country. The rivers help us in irrigating agricultural crops (Akter, 2007). In Bangladesh, the water supply coverage has been increasing both in urban and rural areas since the 1980's. However, almost 88 percent of water is

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withdrawn for irrigation, animals while just 10 percent, and two percent use this for family members and also industry respectively (FAO, 2010).

Water quality refers to the chemical and physical characteristics of river water which enables it to maintain healthy aquatic life and meet human needs. River water quality can be influenced by several factors including the lithology of a watershed, climatic conditions, and atmospheric and anthropogenic inputs (Bellos and Sawidis, 2005). Both organic and inorganic waste effluents adversely interact with the river system and deteriorating the water quality of the rivers. For this reason, water causes the adverse effect on surrounding land and aquatic ecosystem as well as subsequent impact on the livelihood of the local community (Rahman et al. 2012; Meghla et al. 2013). The use of water in every sector requires a certain minimum quality of water with regard to the presence of dissolved and suspended materials of both chemical and biological nature (Goel, 2006). Surface water quality of the rivers of Bangladesh is highly polluting day by day (Hossain, 2001).

This study was conducted to measure the various physico-chemical parameters of water of the Gorai river, Kushtia in order to assess the status of river pollution related to water quality. The Gorai river catchment is a potential region for the south western part of Bangladesh, which passes through Kushtia town. The Gorai-Madhumati River is a principal distributary of the Ganges. The same river has been named as the Gorai in the upper course and the Madhumati in the lower course. The Gorai takes off from the Ganges at Talbaria, north of Kushtia town and 19 km downstream from Hardinge Bridge. The main river bifurcates and rejoins several times as it flows southeast to Mohammadpur upazila in Magura district. From here it changes its name to the Madhumati. The Gorai-Madhumati has a flood discharge of nearly 7,000 cumec but in winter it's flow goes down to as less as five cumec (Banglapedia, 2006).

II. Materials and Methods

Study area: The Gorai River, which passes through Kushtia town of Bangladesh and meets with the Madhumati River at Mohammadpur upazilla in Magura district. From origin place Talbaria to Kushtia town has been selected as the study area. A small part of the Gorai River was selected as sampling sites. Water sampling was started from the point, $89^0$06.773'E and $23^0$56.649'N, at an interval of 1 km for 6 km. The sampling sites were selected due to their extensive industrial and domestic operations with several point sources and non-point sources of pollution. The point sources include sugar mill's waste water and domestic waste water from Kushtia pourashova area including market. In addition, disposal of solid wastes and untreated sewage also contribute contaminant loads as point sources.

Table 01. Geolocation of the sampling sites of study area

Sampling points	Location	GPS Position	
		Latitude (N)	Longitude (E)
1	Charulia (water sample)	$23^0$56.649'	$89^0$06.773'
2	Barokhada (water sample)	$23^0$55.846'	$89^0$06.694'
3	Jugia (water sample)	$23^0$55.501'	$89^0$06.678'
4	Kamlapur (water sample)	$23^0$55.008'	$89^0$07.241'
5	Kamlapur (Jagati sugar mill effluent)	$23^0$55.001'	$89^0$07.235'
6	Kamlapur (domestic effluent)	$23^0$54.989'	$89^0$07.253'
7	Haripur (domestic effluent)	$23^0$54.876'	$89^0$07.680'
8	Thanapara (water sample)	$23^0$54.782'	$89^0$07.935'
9	Ghoshpara (water sample)	$23^0$54.718'	$89^0$08.165'

Sampling site: Nine water samples were collected from this study area. Among these, six samples were collected from the surface river water (5-10 cm) at selected 6 points. And other three samples were collected from the domestic waste water drain and Sugar mill effluent drain. The samples were

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collected in winter season. Locations were identified with location name and with the help of GPS (Model: eTrex, Garmin, Taiwan) reading which is shown in Table 01.

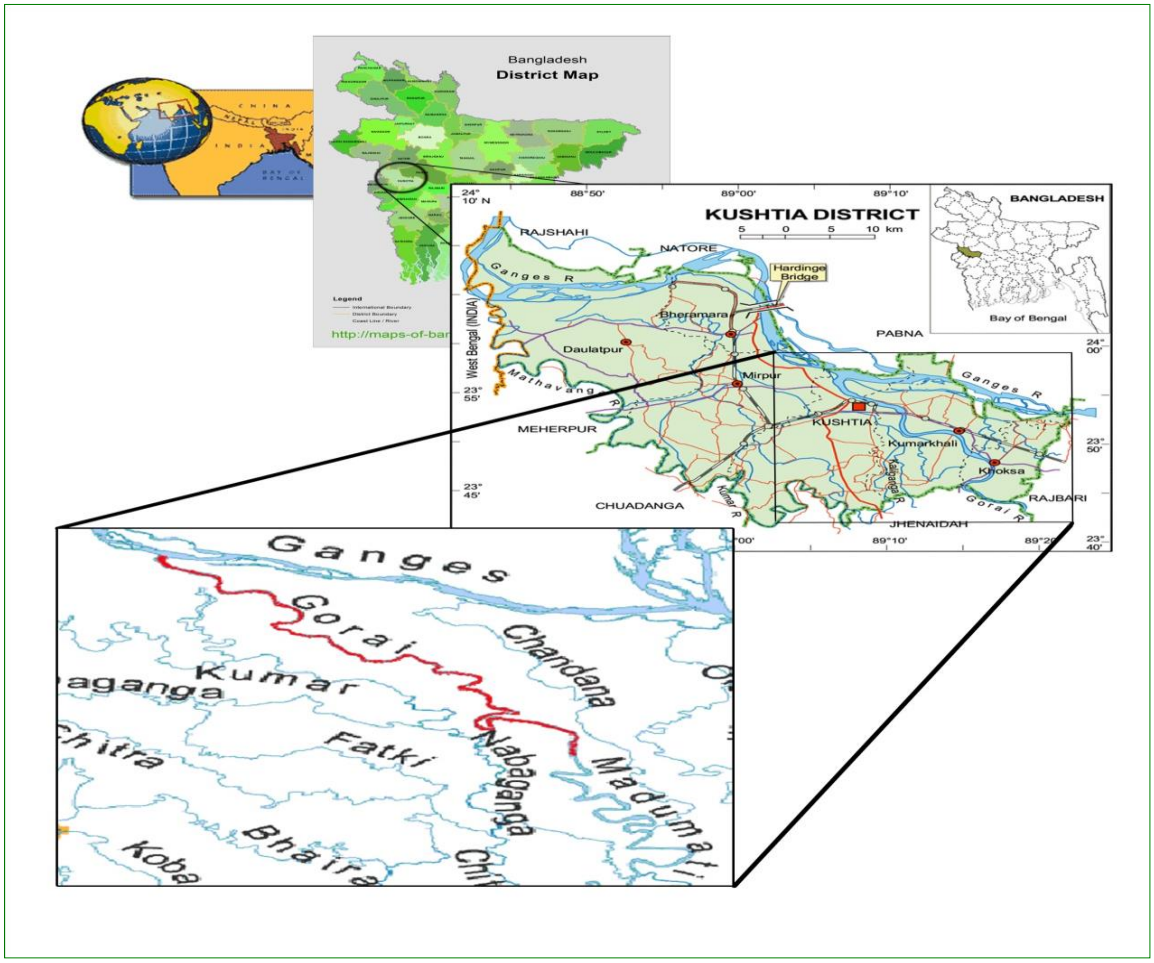

Figure 01. Location and layout of Kushtia town and Gorai river

Collection and preservation of samples: Sampling was carried out during November in 2014 from nine sampling locations as shown in Figure 01. The samples were collected from the river surface level (5-10 cm) during day time. A minimum of three samples were collected from each point. The water samples were collected in sterilized bottles with caps (250 mL). One of the three samples was preserved with nitric acid for heavy metal analysis for each point. The bottles were kept air tight and labeled properly for identification. The samples were brought to the BCSIR laboratory for analysis. They were thoroughly cleaned by rinsing with 0.1 N HNO_3 and deionized water, followed by repeated washing with river water to avoid contamination in the bottle.

Different water quality parameters were determined using the following methods: All the samples were analyzed under Soil, Agronomy and Environmental Section in BCSIR Lab. The instruments and methods used to complete the analysis are given in table 02.

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Table 02. Methods and instruments used in laboratory analysis

Parameters	Methods/Instruments	Unit	Parameters	Methods/Instruments	Unit
Temperature	Potable glass mercury thermometer	°C	Potassium	Flame photometric method (Flame photometer Model no. Jenway, PFP7	ppm
pH	pH meter (Model: EZDO, 6011)		Chloride	$AgNO_3$ Titrimetric method	mg/L
EC	EC meter (Model: HANNA Instrument, HI 98312)	µs/cm	Iron	Flame photometric method (Flame photometer Model no. Jenway, PFP7	ppm
TDS	TDS meter Model: HANNA Instrument, HI 98301)	ppm	Lead	Spectro photometer, HACH DR-2010 model	ppm
DO	DO meter (Model: EZDO, 7031)	mg/L	Cadmium	Spectro photometer, HACH DR-2010 model	ppm
Total hardness	EDTA method	mg/L	Chromium	Spectro photometer, HACH DR-2010 model	ppm
Total alkalinity	Titrimetric method	mg/L	Phosphate	Molybdenum blue method	ppm
Sodium	Flame photometric method (Flame photometer Model no. Jenway, PFP7)	ppm	Sulphate	Turbiditimetric method	ppm

III. Results and Discussion

Physical Parameters

Temperature: Temperature of water samples varied from 23.2°C to 25.3°C as Table 03. The temperature was relatively low, because the sampling was done in the month of November. The highest temperature (25.3°C) was found at Kamlapur and the lowest (23.2°C) was at Ghoshpara. Water temperature is one of the most important physical characteristics of aquatic systems. As water temperature rises, the rate of photosynthesis increases, thereby providing adequate amounts of nutrients (FOEN, 2011). According to te Department of Environment (DoE) standards for irrigation water all values of temperature were within the acceptable limit as Table 03.

pH: The pH of water samples ranged from 7.1 to 8.4 as Table 03. All the pH values were above 7, that indicated the basic condition. Among the sampling points, the highest pH value was found 8.4 at Ghoshpara. On the other hand, the lowest pH value was 7.1 at Barokhada and Jugia. It was noticed that at first the pH values decreased at three points but at next 3 points the pH values increased gradually. The pH value varied for each sampling point in the same river, which may have been due to the different source of wastes, rates of input and flow rates of the rivers. The values of pH fluctuated at various sampling points, but according to WHO standards for irrigation water, ECA-1995 and ECR-1997 standards for domestic water as Table 03, all the values were within the permissible limit.

Electrical conductivity (EC): Conductivity itself is not a human or aquatic health concern, but it can serve as an indicator of other water quality problems. High values of EC show that a large amount of ionic substances are present in water (Kabir et al. 2002). Table 03 shows that the EC of all sampling points varied from 280 to 310 µs/cm. It was found that the EC values were similar at first 3 sampling points but varied for the next 3. The highest value of (EC 310 µs/cm) was found at Kamlapur and Ghoshpara and the lowest value (280 µs/cm) was at Thanapara. Other points' EC value was almost similar. It seems that most of the cases the EC were similar in the Gorai River water. According to WHO standards for irrigation water, the EC condition of river water was within permissible limit as Table 03. It indicates that there may no efficient sources of ionic substances or lack of proper dilution.

Total dissolved solids (TDS): In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles (Mahananda, 2010). TDS of water samples varied from 140 to 150 mg/L as Table 03. Except sampling points S4 and S8, TDS concentrations of all sampling points' were similar. The highest value 150 mg/L was found at Kamlapur and Ghoshpara and the lowest value was found 140 mg/L at S1, S2, S3 and S8. Figure 4.5 shows a clear picture of TDS condition at the Gorai River water. The average TDS concentrations at various sampling points were almost similar. According to WHO standards for irrigation water and USPH Standard for domestic water as Table 03, all these TDS values of river water at different points were within the permissible limit. It means that the Gorai River does not contain metals over the permissible limit.

Chemical Parameters

Dissolved Oxygen (DO): Dissolved oxygen is one of the most vital parameters in water quality assessment and reflects the physical and biological processes prevailing in the water (Trivedi and Goel, 1984).Where the rates of respiration and organic decomposition are high, the DO values usually remain lower, than where the rate of photosynthesis is high (Mishra et al. 2009). The DO concentration of water samples varied from 5.94 to 8.34mg/L (Table 03). Among the sampling points, the highest DO concentration was found 8.34 mg/L at Kamlapur and the lowest 5.94 mg/L was found at Ghoshpara. Table 03 shows the concentration of DO at various sampling points of river water. The average concentration of DO among sampling points was almost similar. According to ECA-1995 and ECR-1997 standards for domestic water as Table 03, DO levels of river water were within the permissible limit except Ghoshpara area. It indicates that except Ghoshpara, the rates of respiration and organic decomposition were high in the Gorai River.

Total hardness (TH): TH of all sampling points varied from 124 to 172 mg/L as Table 03. The TH of all selected sampling points was found almost same. The highest value (172 mg/L) was found at Ghoshpara and the lowest value (124 mg/L) was found at Barokhada. It was noticed that the concentration of TH was comparatively high in this river water (Table 03). General scale of hardness provided by Water Quality Association the value of Hardness of water as $CaCO_3$ ranged from120-180 mg/L which is hard (Lehr et al. 1980). According to WHO standards for irrigation water (Table 03), the hardness of the Gorai River water was within the permissible limit.

Alkalinity: Alkalinity of water samples varied from 112 to 168mg/L as Table 03. The values of alkalinity fluctuated at various sampling points. It was shown that the alkalinity of this river was moderate. The value of alkalinity increased at a sampling point and decreased its next point.

Sodium (Na^+): Sodium concentration of water samples varied from 10 to 20 mg/L as Table 03. The concentrations of first two sampling points were similar *i.e.* 10 mg/L and the concentration at next 4 sampling points were similar (20 mg/L). It was observed that the concentration of sodium at different sampling points were almost same. According to WHO standards for irrigation water, all values of Sodium exceeded the permissible limit, but according to ECA-1995 and ECR-1997 standards for domestic water, the concentrations were within the permissible limit.

Potassium (K^+): Potassium concentration of water of the study area ranged 3.409 to 5.114 mg/L as Table 03. The highest concentration (5.114 mg/L) was found at the sampling point Kamlapur and the lowest was found at Barokhada and Jugia. There was a little difference among the various sampling points. According to DOE Standard for irrigation water, all values of potassium exceeded the permissible limit. But According to ECA-1995 and ECR-1997 standards for domestic water as Table 03, the concentrations were within permissible limit.

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Table 03. Comparison of the physico-chemical parameter with WHO-World Health Organization standards for irrigation water, ECA-1995 and ECR-1997 standards for domestic water

Parameter	Sampling stations/ Study results						WHO Standards	ECA-1995 and ECR-1997
	Charulia (S1)	Barokhada (S2)	Jugia (S3)	Kamlapur (S4)	Thanapara (S8)	Ghoshpara (S9)		
Physical parameter								
Temperature (ºC)	24	24.8	24.1	25.3	23.3	23.2	****20-30	***
pH	7.4	7.1	7.1	8.1	8.3	8.4	6.5-8.5	6.5-8.5
EC (µS/cm)	290	290	290	310	280	310	*700-3000	***
TDS (mg/L)	140	140	140	150	140	150	0-1000	**500
Chemical parameter								
DO (mg/L)	7.87	6.52	6.63	8.34	6.52	5.94	***	6
Total Hardness (mg/L)	148	124	128	152	144	172	500	***
Alkalinity (mg/L)	112	168	112	168	112	168	***	***
Na^+ (ppm)	10	10	20	20	20	20	8.70	200
K^+ (ppm)	3.75	3.409	3.409	5.114	4.091	4.432	****0.308	12
Fe^{2+} (ppm)	0.28	0.32	0.38	0.68	0.38	0.36	0.011	0.3
Pb (ppm)	BDL	BDL	BDL	BDL	BDL	BDL	***	0.05
Cd (ppm)	BDL	BDL	BDL	BDL	BDL	BDL	***	0.005
PO_4^{3-} (ppm)	1.472	2.392	1.1	0.735	0.368	0.01	****0.189	6
SO_4^{2-} (ppm)	11.934	37.742	15.14	40.545	64.107	53.397	8.33	400
Cr^+ (ppm)	BDL	BDL	BDL	BDL	BDL	BDL	***	*****0.05
Cl^- (mg/L)	0.367	0.459	0.55	0.55	0.459	0.367	7.04	150-600

DO=Dissolved Oxygen, EC=Electrical Conductivity, TDS=Total Dissolved Solid, COD=Chemical Oxygen Demand, Na^+=Sodium, K^+=Potassium, Ca^{2+}=Calcium, Mg^+=Magnesium, Fe^{3+}=Iron, SO_4^{2-}=Sulfate, PO_4^{3-}=Phosphate, Cl^- =Chloride, Pb=Lead, Cd=Cadmium, Cr=Chromium, BDL=Below Detection Level, WHO=World Health Organization standards for irrigation water, ECA=Environmental Conservation Act standards for domestic water, Environmental Conservation Rules standards for domestic water; *indicates UCCC=University of California Committee of Consultants, California (1974), Standard for irrigation water; **indicates USPH=Standard for domestic water (1980); ***Indicates that were not available. ****-DOE Standard for irrigation water (1997), *****indicates ISI=standard for domestic water (IS: 2296-1963).

Table 04. The physico-chemical parameters and their values of sugar mill and domestic effluents

Parameters	Jagati sugar mill effluent S5 (Kamlapur)	Domestic waste water	
		S6 (Kamlapur)	S7 (Haripur)
Physical parameters			
Temperature (^{0}C)	23.6	22.9	23
pH	8.3	8.2	8.1
EC (µS/cm)	1250	1110	1190
TDS (mg/L)	620	540	590
Chemical parameters			
DO (mg/L)	7.15	3.61	4.44
Total Hardness (mg/L)	304	372	392
Alkalinity (mg/L)	168	336	392
Na^+ (ppm)	70	80	90
K^+ (ppm)	22.159	15	21.477
Fe^{2+} (ppm)	0.3	0.24	0.32
Pb (ppm)	BDL	BDL	BDL
Cd (ppm)	BDL	BDL	BDL
PO_4^{3-}(ppm)	2.637	4.048	9.1
SO_4^{2-}(ppm)	21.42	12.087	20.043
Cr^+ (ppm)	0.0624	0.0701	0.0517
Cl^- (mg/L)	2.751	1.834	1.926

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Iron (Fe): Metal pollution in aquatic ecosystem is now a critical concern, as the effect of heavy metals toxicity and their accumulation in aquatic habitats (Waghmode and Muley, 2013), which occurs mainly through natural inputs such as weathering and erosion of rocks and anthropogenic sources including urban, industrial and agricultural activities, terrestrial runoff and sewage disposal (Çevik et al. 2009).

Iron concentration of water samples varied from 0.28 to 0.68 mg/L as Table 03. The values of iron were moderate. The highest concentration of Fe (0.68 mg/L) was found at Kamlapur and the lowest concentration was at Charulia. According to WHO standards for irrigation water Fe concentration of all sampling points were exceeded the permissible limit. And ECA-1995 and ECR-1997 standards for domestic water, iron concentration exceeded the permissible limit except sampling point Charulia as Table 03. It indicates that there were Fe sources near the study area. And most probably at Charulia, the dilution rate of Fe or flow rate of river water was high.

Sulphate (SO_4^{2-}): Sulphate in water body ranged as 11.93 to 64.10 mg/l which was very high as compare to WHO standards for irrigation water specifications of 8.33 mg/l as Table 03. Higher value (64.107 mg/L) of $SO_4^{2-}$was obtained at Thanapara and the lowest (11.93 mg/L) was at Charulia. The values fluctuated at different sampling points. Sulphur is present in Water bodies due to minerals, acid rains, industries releasing sulphur compounds into the atmosphere that are carried into river by rainfall. The range of sulphate in water was 143 to 161 mg/l. But according to ECA-1995 and ECR-1997 standards for domestic water as Table 03, the concentrations were found within the permissible limit.

Phosphate (PO_4^{3-}): Table 03 shows random concentration of phosphate at different sampling points. The highest value of PO_4^{3-}(2.392 ppm) was found at Barokhada. The concentrations of phosphate were found relatively low at various sampling points. PO_4^{3-} was found below the detection level at Ghoshpara. It indicates that there may not any active source of PO_4^{3-}. It reveals that the concentration of PO_4^{3-} gradually decreased from the source of origin of the Gorai River. According to DOE Standard for irrigation water, the concentrations of PO_4^{3-} exceeded the permissible limit except sampling point Ghoshpara. But according to ECA-1995 and ECR-1997 standards for domestic water as Table 03, PO_4^{3-} values were within the permissible limit. PO_4^{3-} is rarely found in high concentrations in waters as it is actively taken up by macrophytes and algae. However, high concentrations of PO_4^{3-} can show the presence of contamination and are largely responsible for eutrophic conditions (WHO, 1998).

Chloride (Cl^-): In the study area chloride concentration of water samples collected at different points ranged from 0.367 to 0.55 mg/L as Table 03. The values of chloride concentration were almost same. According to the WHO- World Health Organization standards for irrigation water and the ECA-1995 and the ECR-1997 standards for domestic water as Table 03, the concentrations of chloride were found within the permissible limit.

Lead, Cadmium and Chromium (Pb, Cd and Cr^+): The concentration of lead, cadmium and chromium were determined by spectrophotometer. The detection level of this instrument is 0.5 ppm. From the table 03, it is noticed that all the values of lead, cadmium and chromium concentration were below the detection level. It can be concluded that this river water was safe for various uses in respect of these heavy metals. The pH value also plays a key role in metal pollution and a higher pH retains a low concentration of metals in the river water. During the dry season, with a higher pH value, some metals form insoluble hydroxide compounds and precipitate into the sediment. This could be the reason for the unavailability of Lead, Cadmium and Chromium during the dry season.

Impact of Jagati sugar mill and domestic effluent on water quality of Gorai River: Generally, Table 03 and Table 04 show that the values of maximum selected parameters of sugar mill and domestic effluent were relatively higher than the other sampling points. The effluents coming from sugar mill and domestic activities contained various chemicals and organic matter. They might also be changed during their pathways due to addition or decay of some compounds. Some parameters exceeded their permissible limits which might degrade the water quality of river. Fig. 02 suggests that the EC and TDS of analyzed samples are highly positively correlated ($R^2 = 0.996$).

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From the comparison of Table 03 and Table 04, it was observed that the values of selected parameters of river water samples collected near the effluent outlet were lower than the effluent's value but higher than the upstream of river. It indicated that the effluent coming from sugar mill and domestic effluent influenced the river water.

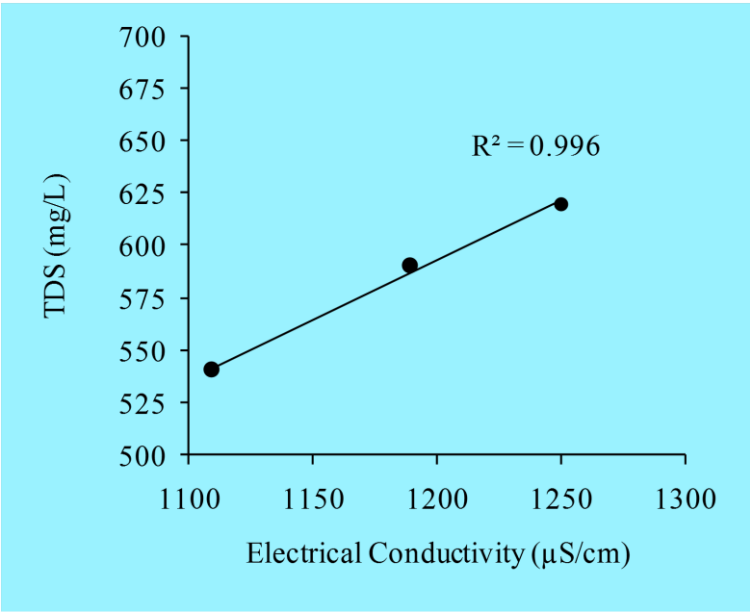

Figure 02. Relationship between total Dissolved Solids (TDS) and Electrical Conductivity (EC).

IV. Summary and Conclusion

This experiment was conducted in the area of the Gorai river where the effluent of sugar mill and domestic waste water discharged. For completing this study six samples were collected from surface water of river and three samples from effluent drain. Temperature of water samples recorded at different points and effluents was within allowable limit. All values of pH for water samples and effluent indicated that the water of this river was basic and were within permissible limit {6.5-8.5}. The Dissolved Oxygen (DO) concentrations were within the permissible limit (6) except the sampling point Ghosh para. Where, DO concentration of effluent exceeded the allowable limit. In this experiment, it was observed that the concentrations of total hardness of effluent were higher than the river water samples but didn't cross the permissible limit. EC, TDS and alkalinity were found within the permissible limit of this river water but for the effluent, the values of EC exceeded the allowable limit; TDS and alkalinity values were within the permissible limit.

Concentrations of sodium, potassium, sulphate and phosphate were found high in respect of irrigation water but normal in respect of domestic usage at various sampling points. In the case of effluent, Na^+ and SO_4^{2-} values were high in respect of irrigation water but normal in respect of domestic usage but K^+ and PO_4^{3-} concentrations exceeded the both limits. Overall Iron concentrations of both river water and effluent exceeded the permissible limit in respect of irrigation and domestic water. In the case of chloride, both river water and effluent values didn't cross the permissible limit. Then, the concentrations of lead, cadmium and chromium were below the detection level for river water. This could be reason for high pH. But for effluent, chromium values exceeded the limit of domestic water and in case of lead and cadmium were below the detection level. Therefore, the effluent coming from sugar mill and domestic effluent influenced the river water. It can be suggested that the water of the Gorai river would not be suitable for irrigation and domestic purposes without treatment.

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