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RESEARCH ARTICLE

Diurnal Pattern in Water Quality Parameters near a Sewage Disposal Point of Dwarkeswar River Near Bankura, West Bengal

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ABSTRACT

A physicochemical and bacteriological investigation was carried out in a selected stretch of the river Dwarkeswar near a sewage disposal point at Bankura, West Bengal. Throughout the period (April, 2010) of survey of diurnal variation, the pH and temperature of river water at sewage mixing area were found to fluctuate between 7.0 and 8.4, and 30^{0}C and 35^{0}C respectively. The turbidity value ranged from 340 to 545 NTU and electrical conductivity from 0.68mS/cm to 2.4 mS/cm. The DO value was lower ranging from 0.4 to 1.6 mg/L along with the high BOD value (7.8- 8.2 mg/L) indicated the polluted nature of the river Dwarkeswar. The COD value was also noted high ranging from 9.2 mg/L to 11.2 mg/L. The sulfate content oscillated between 6.2 mg/L and 11.2 mg/L. High amount of total dissolved and suspended solids indicated the high pollution status of the river Dwarkeswar. Most of the parameters in the present study followed a definite diurnal fluctuation pattern which recorded maximum during 12.00hours and minimum during 18.00 hours. This situation was found to be similar in 100m downstream and 100m upstream region of the river. High degree of pollution in this stretch of the river Dwarkeswar might be due to the presence of high coliform and faecal streptococcal density. In all sites, the E. coli and faecal streptococci ratio were always more than, indicating the nature of pollution caused by sewage water. Most of the physicochemical as well as bacteriological parameters have either exceeded or nearing the permissible limit indicating grossly polluted condition of the river Dwarkeswar in this stretch.

Keywords: *Water Quality, Dwarkeswar River, Diurnal Pattern, Bankura, Sewage*

INTRODUCTION

The fluctuating physical and chemical characteristics of water and their interactions bear an effect on the biological features of aquatic ecosystem of rivers (Downing, 1971) and its catchments (Venter et al., 1997) and watersheds (Guissani et al., 2008). The natural and artificial contaminants affecting the physicochemical properties of rivers impart an indirect effect on the stability of the interacting biological resources, apart from degrading the environmental conditions (Miller and Miller, 2007). Several reports of the ill effects of the degrading aquatic environmental conditions from different rivers have been noted around the globe (Tiwary and Dhar, 1994; Djuikom et al., 2006; Zheng et al., 2008; Wang et al., 2008; Chang, 2008). Even high microbial growths were noted with the natural and artificial systems that increase eutrophication of water bodies (Mahagoub and Dirar, 1986; Fujita et al., 1987; Venter et al., 1997; Pennigngton et al., 2001; Kistemann et al., 2002; Tallon et al., 2005). In Indian context, rapid urbanization and industrialization, intensive agriculture and growing demands for energy during the last few decades has affected the physicochemical parameters and biological attributes of the ground and surface water (Jain et al., 2007). Studies on the rivers like Mahanadi, Narmada, Uppanar, Gola and the Ganges supported this view. River Ganges and its tributaries like Gomti have shown considerable amount of pollutants in background and surface waters (Singh et al., 2007; Jain et al., 2007). Precipitation in this region contributes to the chances of increased level of microbes in the water bodies. For instance in the high altitudes nearer to the origin of the river Ganges, coliform contamination has been noted (Sood et al., 2008). The microbial load in riverine ecosystem including catchment and watersheds is found to be an increasing function of several organic and inorganic pollutant contents in Gola (Chandra et al., 2006), Uppanar (Tonathan et al., 2008) and Narmada rivers (Sharma et al., 2008), India. River pollution monitoring and assessment is essential for understanding the anthropogenic effects and framing strategies for sustainable development. In this context the present study was undertaken to evaluate the pollution level and the microbial load in the river Dwarkeswar near Bankura town, West Bengal, India.

MATERIALS AND METHODS

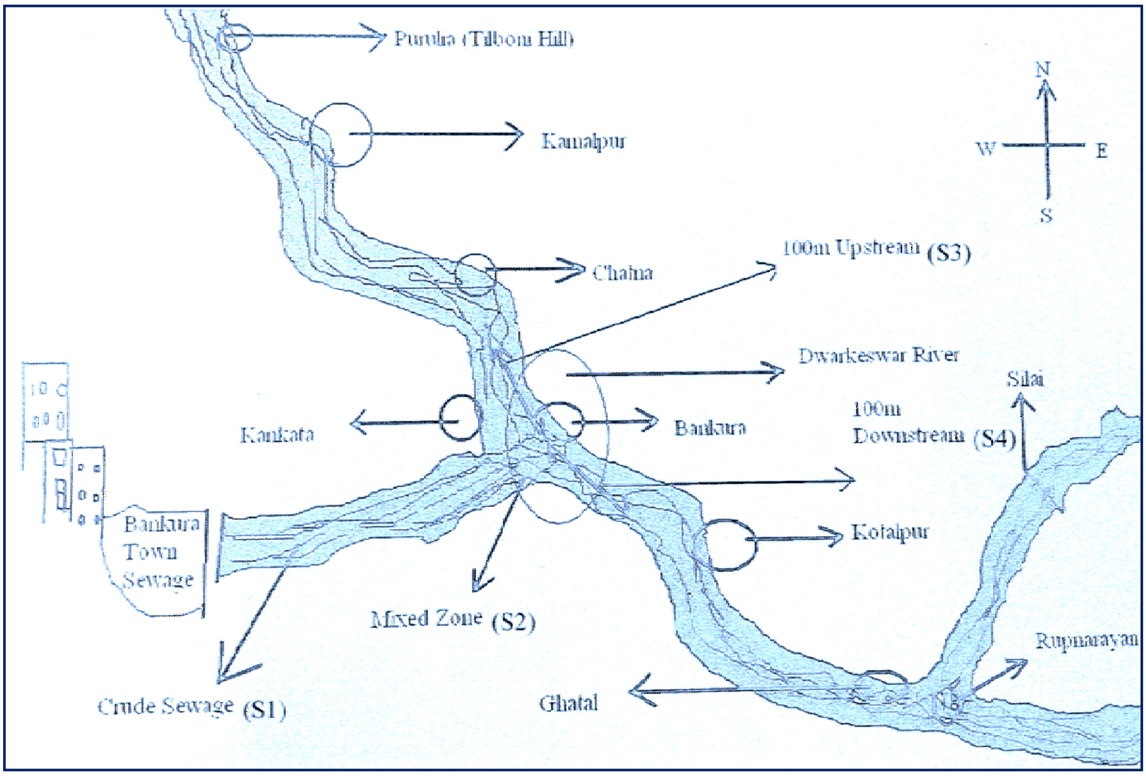
1. STUDY AREA

Dwarkeswar River originates from Tilboni hill in Purulia district and enters Bankura district near Chhatna. The Dwarkeswar River basin is one of the 26 river sub basin of the state and is under the Ganga Bhagirathi system. The basin, located between longitudes 86^0 31' and 87^0 51' E and latitudes 22^0 37' and 23^0 33' N, occupies a total area of about 4673 Km^2. The river is about 220km in length and passes through the three districts within the state, namely Purulia, Bankura and Hooghly, and releases ultimately into the Rupnarayan, a right bank tributary of the Bhagirathi-Hooghly. Geologically the upper Dwarkeswar basin is mainly hilly region in continuance of the Chhotonagpur plateau. The master slope of the area tends towards the southeast direction. In the extreme north western part towards Chhotonagpur plateau undulations are more pronounced.

2. SAMPLING POINTS

Water samples were collected from a selected stretch of river Dwarkeswar near Bankura town flowing from west to east direction. Samples were collected from three stations- a sewage disposal point (S2), a point 100m upstream in the northern site (S3) and another point at 100m downstream in the southern side of disposal point (S4). The sampling sites located along the river course are presented in figure 1. Crude sewage samples were also collected.

Fig. 1: Different sampling sites in River Dwarkeswar



Water samples were collected during April, 2010 at 06.00 hours, 12.00 hours and 18.00 hours to know the diel variation of bacterial load as well as some physicochemical parameters. The sampling was done by first rinsing the clean sampling bottles with the river water before collecting the samples. 250ml capacity sterilized sampling bottles were used provided with tight fitting stopper. The stopper was opened below water surface at desired depth and allowed to be filled up completely. It was plugged immediately with the stopper under water. Each water sample was collected in triplicate. The pH and temperature of the sample were measured on the spot. Collected samples were brought to the Microbiology Laboratory, Department of Botany, University of Kalyani and immediately processed for physico-chemical and bacteriological analysis.

3. PHYSICOCHEMICAL ANALYSIS OF RIVER WATER

pH : The pH of the water sample were determined immediately after collection with the help of digital pH meter (Model No. Jenway 3510).

Temperature: The temperature of the water sample was recorded immediately after taking a sample with Zeal's (UK) mercury thermometer.

Turbidity: The turbidity was measured through Nephalometry (Nephalometer, Elico India Pvt. Ltd. Model No. CL 52).

Electrical conductivity: The electrical conductivity was measured with the help of digital conductivity meter (EI model No. 602).

Dissolved oxygen (DO): The DO concentration was measured following Ridal Stewart modification of Winkler's method (Golterman et al., 1978).

Biochemical Oxygen Demand (BOD): The BOD test was made by measuring the difference in DO of the original sample and sample after incubation in the dark at 20^{0}C for 5 days.

Chemical Oxygen Demand (COD): The COD was determined following the recommended method of Mitchel (1984).

Sulfate: Sulfate in water samples were determined by turbidimetric method outlined in Standard methods (APHA, 2002).

Total dissolved solids (TDS) and Total suspended solids (TSS): TDS and TSS were measured by gravimetric method (APHA, 2002).

4. THE BACTERIOLOGICAL STUDIES

4.1 ISOLATION OF SELECTED BACTERIA

The bacteria mentioned below were isolated on selected media following pour plate technique. They were incubated, subcultured and were finally characterized.

***Escherichia coli*:**The Eosine methylene Blue agar medium (Seeley and Van Demark, 1981) was used for isolating *E. coli*. For total coliform (TC) count, the incubation temperature was 37^{0}C and for faecal coliform (FC) it was 44.5^{0}C. The incubation period was 24h.

***Streptococcus faecalis*:** The sodium azide medium of Hannay and Norton (1980) was used for isolating faecal streptococci after incubation at 44.5^{0}C for 24h.

4.2 ENUMERATION OF SELECTED BACTERIA

Enumeration of each bacterium done in their respective defined media by five tube MPN technique (APHA, 2002).

4.3 CHARACTERIZATION OF SELECTED BACTERIAL STRAIN

Bacteria isolated from the river Dwarkeswar were subjected to Gram staining, capsule staining, spore staining and motility tests (Conn et al., 1957). For determining the optimal temperature for growth, the bacterial isolates were allowed to grow for 24h in nutrient medium at different temperatures (20^{0}C, 28^{0}C, 37^{0}C and 44^{0}C). In order to determine free oxygen requirement, the bacteria were inoculated in the nutrient agar stab and incubated under appropriate conditions. The bacteria were also subjected to biochemical tests such as test of, methyl red reaction, indole production, Voges Proskauer test and Gelatin liquefaction. Tests for sugar and sugar alcohol fermentation were done to observe the ability of bacteria to ferment certain sugars such as dextrose lactose, sucrose, fructose, maltose, xylose, rhamnose and mannitol.

RESULTS AND DISCUSSION

The physicochemical properties of Dwarkeswar river water were presented in Table 1. The mean pH of the river water at disposal point of a sewage canal waste varied for a minimum of 7.4 at 06.00 hours (Table1) to maximum of 7.5 at 12.00 hours. The river water at 100m downstream from the disposal point showed a highest mean pH value of 8.0 at 12.00 hours with a lowest value of pH 7.2 at 06.00 hours. The pH was 7.4 at 18.00 hours (Table1). On the other hand, the river water at 100m upstream from the disposal point exhibited a highest mean pH value of 7.2 at 12.00 hours, followed by 7.1 at 06.00 hours and 7.0 at 18.00 hours (Table 1). However the crude sewage water had a mean pH value of 8.4 at 12.00 hours, 8.2 at 06.00 hours and 7.5 at 18.00 hours. The Dwarkeswar river water thus showed an alkaline situation consistently throughout its diel variation. Such alkaline pH was also observed in the River Ganga by other authors (Tripathi et al., 1991; Mishra and Tripathi, 2007). The consistent alkaline pH in river Dwarkeswar might favour growth and metabolism of microorganisms (Martin et al., 1982) as well as other living beings of the ecosystem (Villadolid et al., 1954).

The ambient water temperature of the river at sewage mixing area fluctuated between 33^{0}C at 18.00 hours (Table 1). At downstream 100m away from the disposal site the water temperature recorded were 35^{0}C at 12.00 hours, 33^{0}C at 18.00 hours and 34^{0}C at 06.00 hours (Table1). On the other hand, at 100m upstream from the disposal site, the water temperature was 33^{0}C at 12.00 hours, 32^{0}C at 18.00 hours and also 32^{0}C at 06.00 hours. The temperature in crude sewage varied from a minimum value of 32^{0}C at 06.00hours to the same at 18.00 hours (Table1). The fluctuation of temperature in river water was probably due to the discharge of sewage and domestic wastes which also cause thermal changes in natural waters. Diurnal changes in natural waters occur due to impinging solar radiation and the atmospheric temperature. The elevation in water temperature accelerates chemical reactions, minimizes solubility of gases, increases taste and odour and elevates biochemical activity of organisms.

Water transparency is an important factor that controls the energy relationship at different trophic levels. It is essentially a function of light reflection from the surface and is influenced by the absorption characteristics both of water and of its dissolved as well as particulate matter (Stepanek, 1959). Higher turbidity value of 540 NTU was noted in the disposal point at 12.00 hours. The minimum values of turbidity of 350 NTU in this area were recorded at 18.00 hours while at 06.00 hours the turbidity showed an intermediate value of 400 NTU (Table 1). At 100m downstream, the mean turbidity value oscillated between 340 NTU at 18.00 hours and 545 NTU at 12.00 hours with the intermediate value of 440 NTU at 06.00 hours. In crude sewage, however, high turbidity (542 NTU) was noted during 12.00 hours with the least value (538 NTU) at 06.00 hours. At 18.00 hours the turbidity showed a value of 540 NTU (Table 1).

The electrical conductivity (EC) values at the sewage disposal point exhibited a maximum value of 1.8 µS/cm at 12.00 hours followed by a value of 1.6 µS/cm during 06.00 hours and 1.2 µS/cm during 18.00 hours (Table 1). Such value at 100m downstream was found to be maximum (1.2 µS/cm) during 12.00 hours with the minimum (0.68 µS/cm) value during 06.00 hours. The EC value of 0.70 µS/cm was recorded during 18.00 hours. At 100m upstream, the EC value fluctuated between 0.90 µS/cm and 1.3 µS/cm. The highest EC values were noted during 12.00 hours and the lowest during 06.00 hours respectively. The crude sewage, however, showed highest value of 2.4 µS/cm at 12.00 hours and the lowest (1.6 µS/cm) during 18.00 hours. The intermediate value of EC (0.84 µS/cm) was noted during 06.00 hours (Table 1). The EC of the Dwarkeswar River samples were more or less similar to EC value of other Indian rivers (Edwin Chandrasekaran 1999; Usharani et al., 2010).

Dissolved oxygen (DO) is one of the most reliable parameters in assessing the trophic status and magnitude of eutrophication in an aquatic ecosystem (Edmondson, 1966). The DO value in the sewage mixing area of the Dwarkeswar River oscillated between 0.7 mg/L at 12.00 hours and 1.1 mg/L at 18.00 hours during the period of survey (Table 1). On the other hand, at 100m upstream the DO value fluctuated between 0.8 mg/L at 12.00hours and 1.6 mg/L at 06.00 hours with the intermediate value (1.5 mg/L) at 06.00 hours. Such value in the downstream region ranged from 0.9 mg/L (at 12.00 hours) to 1.2 mg/L (at 18.00 hours) with the intermediate value of 1.1 mg/L at 06.00 hours. However the untreated sewage contained maximum DO (0.9 mg/L) during 18.00 hours with the minimum value of 0.4 mg/L at 1200 hours (Table 1). Lower DO values were also noted in the effluent discharge area of the river Ganga (Mishra and Tripathi, 2007).

The BOD at the disposal point varied from 6.6 mg/L (at 06.00 hours) to 8.2 mg/L (at 12.00 hours). At 18.00 hours the BOD value recorded was 7.1 mg/L. At 100m upstream the BOD value showed a fluctuation between 6.2 mg/L (at 06.00 hours) and 7.4 mg/L (at 12.00 hours). In this region, the river water had a mean BOD value of 7.1 mg/L at 06.00 hours. Similarly, at 100m downstream, such value fluctuated between 6.8 mg/L (at 06.00 hours) and 7.8 mg/L (at 12.00 hours) with the intermediate value of 7.1 mg/L noted during 1800 hours. However, the crude sewage had a high BOD value (6.8 mg/L) noted during 12.00 hours followed by 5.8 mg/L at 06.00 hours and 5.6 mg/L at 18.00 hours (Table 1). High BOD was also noted in the effluent discharged in other rivers (Mishra and Tripathi, 2007)

The COD values which are an index of pollutional strength were also investigated. At disposal point, high value was recorded at 12.00 hours (10.2 mg/L) while it was somewhat low (9.4 mg/L and 9.6 mg/L respectively). At 100 m downstream, the mean COD values were recorded as 10.2 mg/L at 12.00 hours, 9.8 mg/L at 06.00 hours and 9.4 mg/L at 18.00 hours. Similarly such values were found to be high (10.8 mg/L) at 12.00 hours at 100m upstream. In this region, the mean COD values at 06.00 hours and 12.00 hours were recorded as 9.6 mg/L and 9.2 mg/L respectively. However, in the crude sewage COD value exhibited a diurnal variation of 10.2 mg/L at 06.00 hours, 12.4 mg/L at 12.00 hours and 10.0 mg/L at 18.00 hours (Table 1). Though higher values of COD were recorded in other river also (Usharani et al., 2010).

The sulfate content of the river at disposal point showed a diurnal variation of 6.2 mg/L at 06.00 hours, 8.4 mg/L at 12.00 hours and 7.2 mg/L at 18.00 hours. At 100m downstream, the mean sulfate content in river water varied from minimum value (7.9 mg/L) at 18.00 hours to maximum value (8.2 mg/L) at 12.00 hours. At 06.00 hours the sulfate concentration was recorded as 8.0 mg/L. Similarly, at 100m upstream, sulfate content fluctuated from 7.2 mg/L at 18.00 hours, 7.1 mg/L at 06.00 hours to 7.9 mg/L at 12.00 hours. However, maximum sulfate content (11.2 mg/L) was noted in the crude sewage at 12.00 hours. In this crude sewage sulfate concentrations recorded was 10.8 mg/L and 11.0 mg/L at 06.00 hours and 18.00 hours respectively (Table 1).High sulfate content was noted also in a sewage contaminated site of athe river Ganga (Khanna et al., 2013).

The TDS value of the disposal point of the river varied between 12.8 mg/L at 06.00 hour and 34.7 mg/L at 12.00hours with the intermediate value of 22.3 mg/L at 18.00 hours. Such values at 100m downstream were recorded as 14.8 mg/L at 06.00 hours, 30.4 mg/L at 12.00 hours and 20.8 mg/L at 18.00 hours. Similarly, at 100m upstream the river water contained 14.5 mg/L at 06.00 hours, 16.8 mg/L at 12.00 hours and 9.4 mg/L at 18.00 hours. On the other hand, the crude sewage contained a higher TDS of 15.5 mg/L at 06.00 hours, 42.2 mg/L at 12.00 hours and 28.5 mg/L at 18.00 hours (Table 1). Khanna et al (2013) also recorded higher TDS count in sewage contaminated area of the river Ganga.

The TSS values varied in the river water in more or less similar way like TDS. At disposal points the TSS values were 8.6 mg/L at 06.00 hours, 12.0 mg/L at 12.00 hours and 6.4 mg/L at 18.00 hours. At 100m downstream, these values showed a diurnal fluctuation of 10.4 mg/L at 06.00 hours, 14.5mg/L at 12.00 hours and 8.0 mg/L at 18.00 hours. Similarly, fluctuations were noted at 100m upstream region of the river where the TSS values were 11.2 mg/L at 06.00 hours, 12.8 mg/L at 12.00 hours and 8.8 mg/L at 18.00 hours. However in crude sewage, the TSS values were recorded somewhat maximum. Here highest TSS was recorded as 20.2 mg/L at 12.00 hours, with the minimum value of 10.8 mg/L at 06.00 hours

(Table1). High value of TSS might be due to the resuspension of sand and clay particles and discharge of wastes in river water (Arora et al., 2013).
From the above study it was observed that at the sewage disposal point of the river water all the parameters except DO were minimum at dawn (around 06.00 hours), increased sharply to the maximum around 12.00 hours and the decreased gradually around 18.00 hours (Table1). Similar trends in diurnal pattern were noted at 100m downstream and 100m upstream areas from the disposal point. Interestingly, the crude sewage also followed the similar diurnal variation. The DO values at all sites including the crude sewage followed somewhat different fluctuation pattern. It's concentration were maximum at 06.00 hours and 18.00 hours which decreased sharply during 12.00 hours at all sites (Table 1). This might be due to the increased discharge of sewage materials during peak hour of daytime owing to much anthropogenic activities.

Table 1: Physicochemical parameters of Dwarkeswar river water near a sewage disposal point at Bankura, West Bengal

Parameters	06.00 hours				12.00 hours				18.00 hours			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
pH	8.2	7.4	7.1	7.2	8.4	7.5	7.2	8.0	7.5	7.4	7.0	7.4
Temperature(^{0}C)	32	33	32	34	35	35	33	35	30	34	32	33
Turbidity(NTU)	538	400	440	530	542	540	540	545	540	350	342	340
Electrical conductivity(μS/cm)	1.8	1.6	0.90	0.68	2.4	1.8	1.3	1.2	1.6	1.2	1.11	0.70
DO(mg/L)	0.8	0.9	1.6	1.1	0.4	0.7	0.8	0.9	0.9	1.1	1.5	1.2
BOD(mg/L)	5.8	6.6	6.2	6.8	6.8	8.2	7.4	7.8	5.6	7.1	7.1	6.6
COD(mg/L)	10.2	9.4	9.6	9.8	12.4	10.2	10.8	10.2	10.0	9.6	9.2	9.4
Sulfate(mg/L)	10.8	6.2	7.1	8.0	11.2	8.4	7,9	8.2	11.0	7.2	7.2	7.9
TDS(mg/L)	15.5	12.8	14.5	14.8	42.2	34.7	16.8	30.4	28.5	22.3	9.4	20.8
TSS(mg/L)	10.8	8.6	11.2	10.4	20.2	12.0	12.8	14.5	12.5	6.4	8.8	8.0

S1 raw sewage, S2 river water at sewage disposal point, S3 river water 100m upstream from disposal point, S4 river water 100m downstream from disposal point

The *E. coli* count in the sewage mixing area of the river showed a distinct diurnal variation. The highest count (41x10^2 MPN/ 100 ml) was noted during 12.00 hours and the lowest count (29x10^2 MPN/100ml) recorded during 18.00 hours (Table 2). Similar pattern of fluctuation was noted in case of *Streptococcus faecalis* and faecal *E. coli* (Table 2).

Table 2: Bacteriological parameters of Dwarkeswar River water at different sampling sites

Bacteria	Count (MPN/100ml)x10^2								
	Disposal point			100 m downstream			100 m upstream		
	6.00 hours	12.00 hours	18.00 hours	06.00 hours	12.00 hours	18.00 hours	06.00 hours	12.00 hours	18.00 hours
Escherichia coli	31	41	29	29	25	22	20	22	16
Streptococcus faecalis	14	16	11	13	14	11	11	13	11
Faecal *E. coli*	29	25	20	20	22	16	16	20	13

Table 3: Bacteriological parameters of untreated sewage discharged in the Dwarkeswar river water near Bankura, West Bengal

Bacteria	Count (MPN /100 ml)x10^3		
	06.00 hours	12.00 hours	18.00 hours
Escherichia coli	110	140	130
Streptococcus faecalis	43	75	41
Faecal *E. coli*	41	43	41

In 100m downstream and 100m upstream areas of the river all the bacterial counts were lower during 06.00 hours, gradually increased to maximal count during 12.00 hours and then a slow decrease during 18.00 hours (Table 2). Similar fluctuation pattern was also noted in the crude sewage (Table 3). In crude sewage the bacterial load was higher during 12.00 hours in comparison to the bacterial count recorded at sewage mixing area and 100m downstream and upstream of the river. The total coliform count during the study far exceeded the permitted number (2300/100ml) as approved in USA in case of nonpotable water used for fishing (Lynch and Poole, 1979). This value is applicable only in case of total coliform which are not of faecal origin. Similar high counts of coliform in river water was revealed in the study of Mishra et al., (2012) who also found the coliform count beyond the permissible limits (WHO, 1985, 2011a, 2011b). The increased coliform counts can be attributed to the unrestricted inflow of domestic as well as industrial sewage effluents, unwise domestic use, livestock waste run-offs and public defecation along the banks. The ratio of Total *E. coli* and faecal *Streptococci* in the present study was always more than one, indicating the faecal nature of sewage or waste water (Table 4). The FC/FS ratio greater than 4 indicating the bacterial contamination, chiefly caused by human excreta (Geldreich, 1976). Usharani et al (2010) also found that the FC/FS ratio (14.6) in the Noyyal river water samples were found to be greater than one. The different pollution indicating bacteria were tentatively identified by their colony characteristics in the respective medium and the latter confirmed by a study of their cell morphology, Gram staining, motility and biochemical characteristics. The data was incorporated in Table 5.

Table 4: Ratio of total *E. coli* (TC) and faecal streptococci in raw sewage at different sites of the river water

Time	Raw sewage	Mixing zone	100m downstream	100m upstream
0600 hours	2.5	2.21	2.23	1.82
1200 hours	1.86	2.56	1.78	1.69
1800 hours	3.17	2.63	2	1.45

Table 5: Characteristics of bacteria isolated from river Dwarkeswar

Characters	Isolates number	
	***E. coli* DDP1**	***S. faecalis* DDP2**
Cell shape	Straight rod	Cocci in short chains
Cell size	1.4-3.2µ/0.5-1µ	0.5-1µ
Gram reaction	G(-ve)	G(+ve)
Capsule	-	-
Endospore	-	-
Aerobic growth	+	+
Motility	+	-
Optimum temperature for growth	37^{o}C	44^{o}C
Utilization of sugar & SugarAlcohol		
1. Dextrose	A,G	A
2. Lactose	A,G	A
3. Sucrose	-	A
4. Maltose	-	A
5. Xylose	G	A
6. Fructose	G	A
7. Rhamnose	-	A
8. MAnnitol	A,G	A
9. Indole test	+	-
10. Methyl Red test	+	-
11. Voges-Proskauer test	-	-
12. Gelatin liquefaction	+	-

+ indicates presence or positive reaction, - indicates absence or negative reaction, A acid, G Gas

A critical perusal of data obtained in the present study clearly revealed that the values of most of the physicochemical as well as bacteriological parameters have either exceeded or are nearly the permissible limits pointing to grossly polluted nature of the river Dwarkeswar, though more works on seasonal variation are needed. In such a situation, it is of utmost importance to adopt the antipollution measure to retain the purity of water.

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