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Assessment of Water Quality of Baitarani River

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***Abstract* - Levels of various physico-chemical parameters along with coli form cell units were determined for fourteen water samples in pre-monsoon, monsoon and post-monsoon periods between March-2014 to Feb-2015 to assess the water quality stations of Baitarani River. Most of the parameters were of maximum value in post-monsoon period. The samples were acidic in post-monsoon period where as slightly acidic to alkaline in other periods. The pH, EC, TDS, TH, the major cations and anions in all samples and DO values in most of the samples were well within the BIS and WHO limits. But turbidity, TSS, total and faecal coliform units and in some cases BOD values were beyond the limits indicating contaminated water bodies. Fe and Cr contributed a lot for high value of WQI. The sample from (S8) was found to be unsuitable for drinking and bathing purpose. The overall water quality assessment indicates proper treatment of river/stream water for public consumption. The possible sources of contamination are weathering of rocks, soil erosion, extensive mining operations and anthropogenic activities. TDS, SAR, Na%, RSC values indicated good quality of water samples for irrigation.**

Keyword: Water quality index, Contamination, Streams, Physico-chemical parameters, Coliform cell units, Irrigation, Weathering.

INTRODUCTION

The irrigation of agricultural crops with water of poor quality decreases the yield. A system for assessing the suitability of the available water for irrigation of the different crops, taking in consideration the results of the chemical analysis is needed to avoid emerging problems at using inadequate quality water. The system issues recommendations how to use the water for irrigation on the base of analysis on the basis of information on cultivated crops, soil, and agro-climatic characteristics of the region. The objectives of the study are protection of water resources, soil resource, crops, and consumers, sustainable agricultural development etc. is a precondition for the crop production, which eliminates the health risks for the consumers.

Agriculture is the most important economic activity constitutes the major source of food and earning. The water is the major source for irrigation in India. The quality of water for irrigation also depends on the nature, composition of the soil, sub-soil, depth of the water table, topography, climate, etc. The quality of water reflects inputs from the atmosphere, soil, and water-rock weathering and pollutant sources. It required for irrigation depends up on the dissolved salts like Na, Ca, and Mg & HCO_3 in water. The concentration of these salts and their ratio to one another are influence the quality of water for irrigation. However, such water influences crops yield.

LITERATURE REVIEW

River basins are highly vulnerable to contamination due to absorption and transportation of domestic, industrial and agricultural waste water. Anthropogenic influence as well as natural processes degrade surface waters and impair their use for drinking, industrial, agricultural and recreational purposes (Kumar and Dua, 2009). India is heading towards a fresh water crisis mainly due to improper management of water resources and environmental degradation. Hence various technologies and policies to ensure the safety of this valuable resource is the need of the hour for a developing country like India. According to WHO organization, about 80% of all the diseases in human beings are water borne. The presence of various toxic substances in the water bodies causes health hazards. In addition to various physico-chemical parameters, the microbiological quality of water is important for environmental health because of its relationship to disease transmission. It therefore becomes imperative to regularly monitor the water quality of various sources to devise ways and means for its protection and to prevent occurrence of health hazards (Das *et al.*, 2012), (Reza and Singh, 2010). W QI (Water quality index) is one of the most effective tool s to communicate information on overall quality status of water to the concerned user community and policy makers to shape sound public policy and implement the water quality improvement programmes efficiently (Tiwari and Mishra,1985), Kalavathy *et al.*, 2011) and can assess a stream/river's ability to host life and whether the overall quality of water bodies poses a potential threat to various uses of water (Kumar and Dua, 2009). The purpose of the present study is to assess the water quality for drinking and irrigation use of the local stations of Baitarani river flowing in respective areas using WQI along with some irrigational quality parameters, following Indian standard drinking water specification, IS 10500: 2012.

STUDY AREA

Baitarani River originates at an elevation of 900 m above mean sea level from Guptaganga hills of Gonasika of Keonjhar district. The beginning portion of Baitarani acts as the boundary between Odisha Jharkhand states. It flows in a north-easterly direction for about 80 km and then takes a south-east direction for the next about 170

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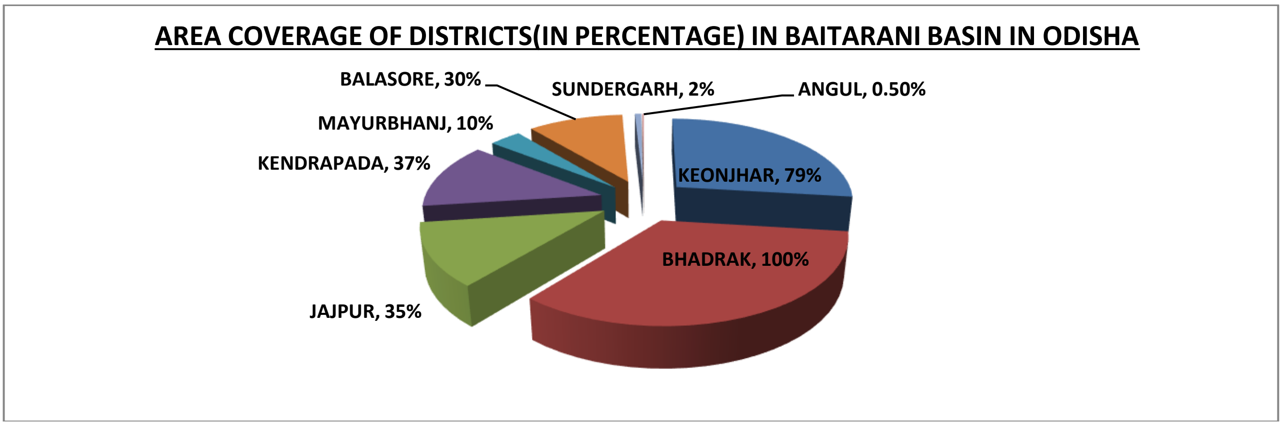
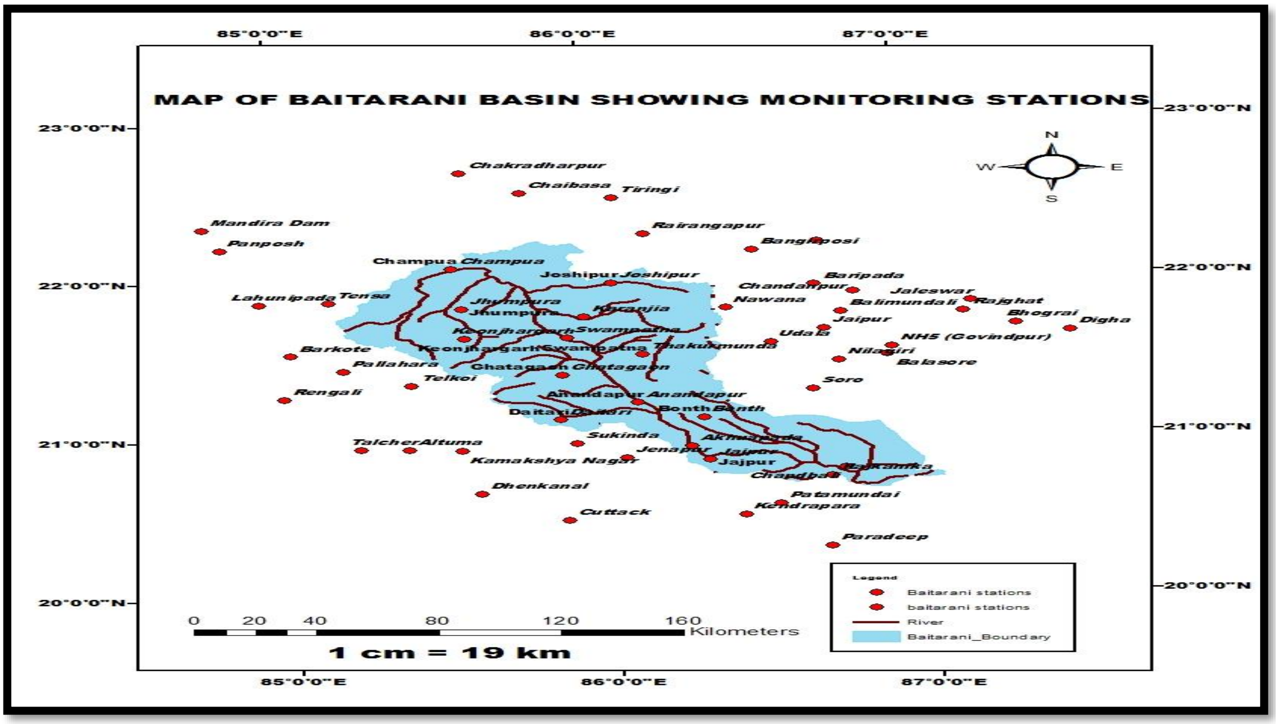
km to reach Jajpur. Here the river turns left to flow towards east and enter the littoral plain or delta. The river enters plains at Anandpur and creates deltaic zone below Akhuapada. The river traverses a total distance of 360 km in Odisha before joining with Dhamra river and finally into the Bay of Bengal, Deo, Salandi, Kanjhari, Musal, Arredi, Siri, Kukurkata, Kusei, Gahira and Remal are major tributaries of Baitarani river.

A major portion of the basin (94.8%) lies within the state of Odisha, while a small patch of up reach (5.2%) lies in Jharkhand state. The basin covers 8 revenue districts of the state. The main urban centres in Baitarani basin are keonjhar, Joda, Jajpur, Vyasana, Bhadrak, Anandpur, Chandabali and Dhamnagar.



The below (figure1&2) showing monitoring stations of Baitarani basin by the application of GIS Software.



(Figure1. Baitarani basin showing monitoring stations)

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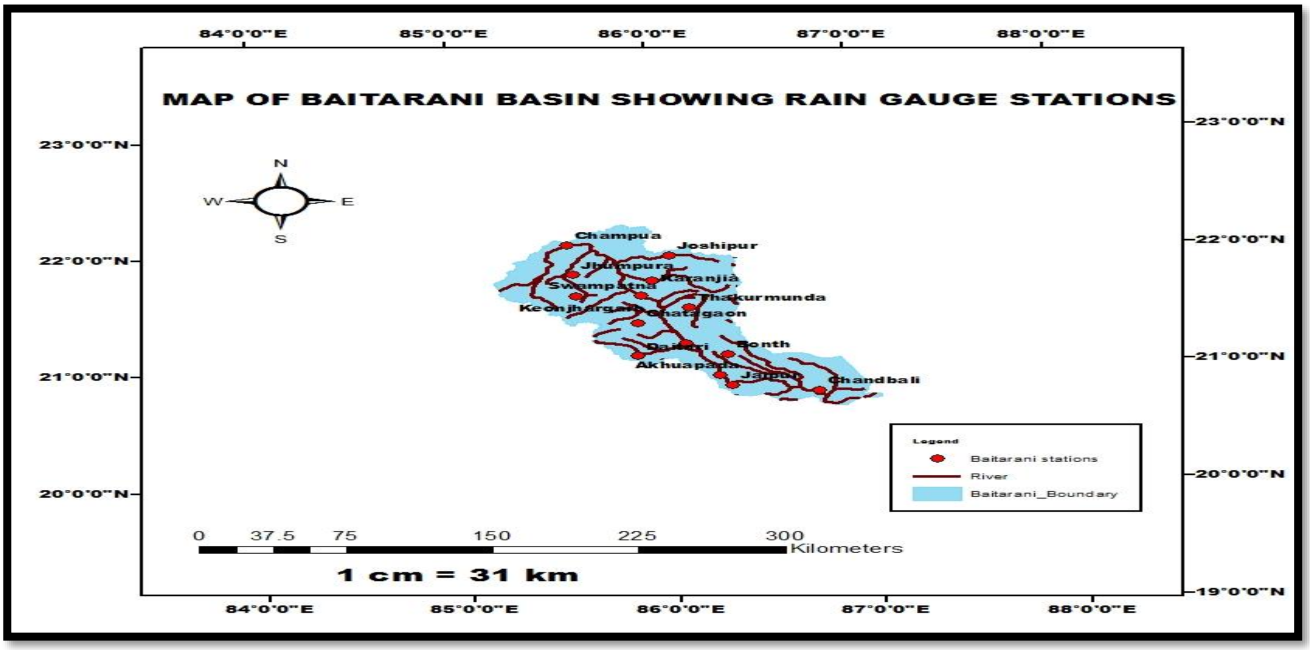

(Figure2. Baitarani basin showing Rain gauge stations)

MATERIALS AND METHODS

Geographic Information System:

GIS is a system of hardware and software used for storage, retrieval, mapping, and analysis of geographic data. A geographic information system, or GIS, is a computerized data management system used to capture, store, manage, retrieve, analyze, and display spatial information. GIS is an interdisciplinary tool, which has application in various fields such as Geography, Geology, Cartography, Engineering, Surveying, Rural & Urban planning, Agriculture, Water resources, etc.

Collection of Samples:

The present study was carried out for a period of one year 2014-15. Water samples were collected from 14 different places from local stations of Baitarani river (Table) in pre-monsoon (March-June-2014), monsoon (July-October-2014) and post monsoon (November-February-2015) periods at a regular interval of once in a month. Water samples were collected in acid- washed plastic bottles of one l tr. capacity having double stopper facilities to its full capacity without entrapping air bubbles inside. Two bottles of water was collected from each station i.e. one for analysis of physico-chemical parameters and other for heavy metals. About two ml. of concentrated HNO_3 was added to the second bottle of each station to preserve the heavy metals present in the sample. Also, water Samples were collected in sterile glass bottles and were preserved in an ice bucket at 4^0C for analysis of total coliforms and faecal coliforms.

Table1.WATER SAMPLING LOCATIONS

SAMPLE NO	MONITORING STATIONS
1	CHANDABALI
2	JAJPUR
3	AKHUAPADA
4	DAITARI
5	BONTH
6	ANANDAPUR
7	GHARTAGAON
8	THAKURMUNDA
9	SWAMPATNA
10	KEONJHARGARH
11	KARANJIA
12	JHUMPURA
13	JOSHIPUR
14	CHAMPUA

The collected samples were sent to water quality laboratory of Central Water Commission, Bhubaneswar for analysis of physico-chemical parameters like pH, turbidity, EC, TDS, TSS, total hardness, cations like Ca^{2+},Mg^{2+},Na^{+},K^{+}, and anions like,HCO_3^-, SO_4^{2-}, NO_3^-, PO_4^{3-},Cl^-. Analysis of heavy metals like Fe and Cr were done by AAS (Shimadzu

AA6300) and ICP-OES (PerkinElmer Optima 2100 DV) in IMMT, Bhubaneswar. However, pH, EC,were measured by using respective digital meters. Other parameters were measured by standard methodology of APHA (1998), (Trivedy and Goel, 1984). These parameters were compared with the standard guideline values, recomended by BIS-10500 (2012) and WHO (2006). WQI (Water quality index) was calculated (Kalavathy *et al.*, 2011), (Reza and Singh, 2005), (Mukherjee *et al*., 2012), (Ravikumar *et al*., 2013) for pre-monsoon, monsoon and post-monsoon periods to assess the suitability of water for drinking purposes and for biotic communities. For WQI calculation, total 14 parameters such as pH, turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), total dissolved solids (TDS), total suspended solid (TSS), total hardness (TH), calcium (Ca) ions, magnesium (Mg) ions, total Fe, Cr, Cl^-, SO_4^{2-} , NO_3^- were considered and desirable limit of each parameter was used as per BIS standard.

Table2.Water quality parameters with B.I.S Standard and unit weights

PARAMETERS	BIS STANDARDS	WEIGHTAGE (Wi)
pH	6.5-8.5	0.0054
Turbidity	5	0.00814
TDS	500	0.0000814
TSS	100	0.00029
DO	6	0.0068
BOD	3	0.0136
TH	300	0.000136
Ca	75	0.00054
Mg	30	0.00136
Fe	0.3	0.1357
Cr	0.05	0.814
Cl^-	250	0.000163
SO_4^{2-}	200	0.00021
NO_3^-	45	0.0009

RESULTS AND DISCUSSION

The analytical results obtained for various physico-chemical parameters from different sampling locations in the study period are summarized in Table 2 to 4. The pH values varied between 6.06 and 7.43 during the study period. Turbidity ranged from 8.2 to 65.4 NTU. Dissolved oxygen level varied between 4.78 and 8.01 mg/L and BOD ranged from 0.86 to5.16 mg/L. The observed EC values were in the range 96-393 µs/cm. The TDS, TSS and Total Hardness of the water samples varied from 74-247 mgL, 30-168 mg/l and 64-135 mg/l respectively in the study period. Various cations such as Ca^{2+}, Mg^{2+},Na^+, K^+, Fe and Cr concentrations varied as 12.83-29.74, 0.97-5.83 2.0-13.0, 0.7-3.7, 0.132-1.432 and 0.051-0.194 mg/L respectively. The concentrations of various anions HCO_3^-, SO_4^{2-} NO_3^-, $PO_4^{3-}$and Cl^- were in the range 41.92-91.46, 2.31-7.16, 0.65-5.30, 0.22-1.18 and 7.41-28.86 mg/L respectively. The total coliform and faecal coliform cells were observed from 970 to 15000 and 70 to 590 CFU/100ml respectively.

DRINKING WATER QUALITY

PH:

The water samples in study area were slightly acidic to alkaline in pre-monsoon and monsoon periods where as predominantly acidic in post- monsoon period. The minimum value was recorded in post-monsoon and maximum value was recorded during monsoon period. The pH values were within the BIS and WHO limits in almost all stations in the study period except the samples S8 and S12 with below the permissible limit. The recorded high pH values in pre-monsoon may be due to the solar radiation, penetration of water into the soil and high biological activity and the lower value observed during post-monsoon may be due to the influence of fresh water influx, seeping of drainage from mines, low temperature, automobiles and decomposition of organic matter.

TURBIDITY AND TSS

The turbidity of surface water is usually between 1 NTU and 5 NTU. Turbidity exceeds both the BIS and WHO standard limits within the study period. Though TSS was within the BIS and WHO limits in some of the stations in pre-monsoon and post-monsoon periods, it was beyond the limits in monsoon period. The water samples were found to be maximum turbid with highest suspended solids during the monsoon and of minimum value in pre-monsoon period, analogous to the results obtained by Mandal *et al*. (2012). This may be due to massive soil erosion, water discharge, urban and rural run- offs, effluents from mines and industries, domestic sewage, recreational use of the streams and river, algal growth, leachates and run off from the overburden dumps as explained by Parmar and Parmar (2010), Rath *et al*. (2010). As per USEPA Guidelines and Rath *et al*. (2010), reduced clarity due to high turbidity and TSS are likely to increase the suspended colloidal particles and contaminate the fresh water sources, often associated with higher levels of disease-causing micro organisms makes the water less desirable for many of its uses. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches. With respect to these parameters the water samples are not suitable for drinking.

EC, TDS, TH

Electrical conductivity (EC) of water is a direct function of total dissolved salts, which is a measure of salinity of water and presence of various cations and anions, minerals and metallic ions comprising both colloidal and dissolved solids as previously reported by Kumar and Dua (2009), Shetty *et al*. (2013). Total hardness in water is mainly imparted by the calcium and magnesium ions, which apart from sulphate, chloride and nitrate are found in combination with carbonates and bicarbonates as explained by Shetty *et al*. (2013), Singh *et al*. (2010). These three parameters are within the permissible limits of BIS and WHO standards. Higher values of EC and TDS were recorded in the water samples of streams in monsoon period and higher values were obtained in post-monsoon period in the water samples of river. Comparatively higher EC values with appreciable level of TDS along with higher TH in some samples like S2, S3, S6,S 8, S12 than others, in monsoon and post-monsoon. These observations are similar to those of Shetty *et al*. (2013). This may be due to multiple factors like weathering of rocks and minerals, the adverse effect of mining with high levels of suspended solids and dissolved solids along with heavy metals, (Rath *et al*., 2010), discharge of sewage from nearby market places and residential areas, agricultural runoff and anthropogenic activities (Singh *et al*., 2010; (Kalavathy *et al*., 2011; Rajathi *et al*., 2013). In the present study, the water samples are of moderately hard category as explained by Muniyan and Ambedkar (2011) and Ravikumar *et al*. (2013).

DO, BOD AND COLIFORM COUNTS

Though DO values are >6, and within limits of BIS and WHO in water samples at most of the stations, the values are not so higher value to consider water quality to be excellent type. The detected DO values of samples S2, S8 are below the the BIS and WHO limits. BOD values in some stations like S2, S5, S8, S10 and S12 are beyond the permissible limits. Maximum DO and BOD values were recorded in monsoon period where as minimum DO and BOD values were observed in pre-monsoon and post-monsoon period respectively for the analyzed samples. It is largely attributed to increase in aeration level due to fresh water influx in monsoon with increased flow current of river water. Similar observation was also found by Singh *et al*. (2013). Faecal coliforms originate in human and animal waste. Total coliforms include faecal and also other bacteria with similar properties which originate in soil and are non faecal. Much higher number of total coliform and faecal coliform cell units were found throughout the study period. Maximum units of coliform cells were detected during monsoon period than the respective levels in Pre-monsoon and Post- monsoon.

Higher coliform population during monsoon is due to increased land run off and higher faecal inputs into the river and streams from various sources is similar to earlier findings of Rath *et al*. (2010), Srivastava and Srivastava (2011). Minimum units of coliform cells were detected in water samples of river and streams in post- monsoon and pre-monsoon period respectively. This scenario of coliform bacteria indicates microbial contamination thereby lowering the DO levels and raising BOD values of the water samples at some stations, particularly S2, S5, S6, S8, S12, as described by Mukherjee *et al*. (2012) and are risk to human health as per BIS, WHO guidelines. Thus, the water samples are not potable. Some stations like S2, S5, S8, S12 are also not suitable for beneficial uses, particularly in monsoon, as per the descriptions of Mukherjee *et al*. (2012), Shukla *et al*. (2011). Coliform bacteria may not cause disease, but used as one of the indicators of pathogenic contamination with the risk of water-borne diseases such as intestinal infections, dysentery, hepatitis, typhoid fever, cholera and other illnesses (Srivastava and Srivastava, 2011).

Table3. PHYSICO-CHEMICAL PARAMETERS OF BAITARANI RIVER IN PRE-MONSOON

PHYSICO-CHEMICAL PARAMETERS OF BAITARANI RIVER IN PRE-MONSOON																					
MONITORING STATIONS	pH	TURBIDITY	TDS	TSS	EC	DO	BOD	TH	HCO_3^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	TOTAL COLI	FEACAL COLI	Fe	Cr
		NTU	mg/L	mg/L	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100ml	CFU/100ml	mg/L	mg/L
CHANDABALI	7.1	8.2	74	30	96	7.84	1.02	64	41.92	2.4	1.22	0.35	9.43	14.83	1.58	2	1.5	970	80	0.192	0.058
JAJPUR	6.97	15.8	141	106	182	6.15	3.25	76	64.38	6.34	3.49	0.47	18.15	19.24	3.16	9.9	2.2	2000	200	0.831	0.125
AKHUAPADA	7.5	13.5	167	65	216	7.65	2.39	104	79.8	5.52	1.03	0.59	16.27	26.25	2.19	7	1.8	3750	210	0.502	0.086
DAITARI	7.21	17.3	108	51	137	6.84	1.62	88	56.44	3.41	0.92	0.25	10.92	21.64	3.48	4	1.4	3000	150	0.247	0.067
BONTH	7.4	20.5	153	92	206	5.82	2.09	79	74.31	5.14	0.83	0.28	15.08	18.64	3.89	9.2	2.1	2500	180	0.551	0.124
ANANDAPUR	7.35	15.1	160	85	243	7.46	1.23	80	65.18	2.65	1.91	0.43	12.07	20.86	2.5	4.6	1.1	3000	120	0.626	0.103
GHARTAGAON	6.73	10.4	97	52	120	8.01	0.86	71	55.4	3.65	0.81	0.35	7.87	16.51	2.61	4.3	0.7	2000	70	0.218	0.051
THAKURMUNDA	6.35	24.5	178	121	318	4.78	4.23	121	79.94	6.87	4.86	0.48	27.26	27.25	4.38	9.2	1.4	8000	360	1.084	0.172
SWAMPATNA	6.85	17.7	120	63	187	7.04	2.64	82	62.11	5.67	2.29	0.73	13.86	19.04	3.93	5.2	0.9	2500	150	0.445	0.095
KEONJHARGARH	7.12	25.2	131	80	223	7.15	1.25	91	69.92	4.66	1.64	0.44	13.68	23.77	1.93	5.7	2.6	3000	220	0.423	0.101
KARANJIA	7.06	21.3	115	87	192	7.22	1.17	77	64.73	5.81	1.32	1.01	15.07	20.42	3.98	7.5	2.7	5500	180	0.526	0.118
JHUMPURA	6.76	23.6	153	106	232	6.71	2.46	108	70.9	4.71	2.85	0.73	28.18	26.13	2.75	8.6	1.6	7000	280	0.587	0.129
JOSHIPUR	7.08	14.3	162	91	217	7.16	1.93	117	87.55	5.38	3.41	1.04	21.98	28.72	4.63	10.1	3.2	6000	200	0.388	0.108

Table4. PHYSICO-CHEMICAL PARAMETERS OF BAITARANI RIVER IN MONSOON

PHYSICO-CHEMICAL PARAMETERS OF BAITARANI RIVER IN MONSOON																					
MONITORING STATIONS	PH	TURBIDIY	TDS	TSS	EC	DO	BOD	TH	HCO_3^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	CL^-	CA^{2+}	MG^{2+}	NA^+	K^+	TOTAL COLI	FEACAL COLI	FE	CR
		NTU	MG/L	MG/L	MS/CM	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	CFU/100ML	CFU/100ML	MG/L	MG/L
CHANDABALI	7.26	27.3	98	85	108	7.57	2.63	78	52.17	3.21	1.31	0.22	7.41	17.45	1.59	2.9	1.4	4000	150	0.171	0.062
JAJPUR	6.92	53.8	178	151	205	6.07	4.36	86	58.08	5.19	2.92	0.6	14.85	16.05	3.1	9.6	3.4	10000	500	0.512	0.103
AKHUAPADA	7.43	47.6	202	112	287	7.12	2.01	98	70.41	4.02	2.23	0.61	16.77	23.25	1.59	8.3	2.3	8000	300	0.243	0.081
DAITARI	7.1	35.2	121	98	173	6.31	3.17	71	62.72	2.98	1.67	0.32	9.29	20.26	0.97	4.7	1.8	6000	270	0.194	0.075
BONTH	7.31	48.7	174	134	276	6.65	3.78	74	59.98	4.2	3.64	0.65	11.32	15.03	4.13	6.9	1.5	10500	480	0.317	0.12
ANANDAPUR	7.12	32.2	171	107	294	6.84	2.66	64	63.94	2.26	2.32	0.42	9.54	13.97	3.88	6.6	2.8	8500	270	0.425	0.088
GHARTAGAON	6.51	18.7	103	86	143	7.51	1.05	70	53.02	3.23	1.74	0.35	7.3	12.83	4.38	3.9	1.4	3000	160	0.211	0.053
THAKURMUNDA	6.44	65.4	218	168	372	5.87	5.16	108	45.83	4.9	5.3	0.96	17.51	19.26	5.11	10.7	1.8	15000	590	0.658	0.194
SWAMPATNA	7.03	36.3	126	121	176	7.25	2.73	79	61.01	2.93	4.84	0.43	16.13	17.03	4.53	8.8	1.2	8600	350	0.213	0.092
KEONJHARGARH	6.86	28.7	108	103	262	7.22	3.38	84	47.23	2.81	3.76	0.51	10.43	14.61	3.16	4.4	2.3	9000	320	0.304	0.125
KARANJIA	7.03	39.8	136	125	214	7.46	2.14	80	59.12	4.66	3.74	1.18	13.58	15.63	3.38	7.7	2.7	9000	400	0.291	0.107
JHUMPURA	6.68	45.1	185	146	271	7.01	4.23	112	68.21	4.37	5.21	0.75	18.96	19.1	3.76	9.5	1.9	11000	520	0.483	0.145
JOSHIPUR	7.01	36.3	208	127	302	7.87	2.85	119	74.31	3.27	4.05	0.96	22.12	25.35	4.04	6.8	3.7	8500	340	0.252	0.119

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Table5. PHYSICO-CHEMICAL PARAMETERS OF BAITARANI RIVER IN POST-MONSOON

PHYSICO-CHEMICAL PARAMETERS OF BAITARANI RIVER IN POST- MONSOON																					
MONITORING STATIONS	PH	TURBIDIY	TDS	TSS	EC	DO	BOD	TH	HCO_3^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	CL^-	CA^{2+}	MG^{2+}	NA^+	K^+	TOTAL COLI	FEACAL COLI	FE	CR
		NTU	MG/L	MG/L	MS/CM	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	CFU/100ML	CFU/100ML	MG/L	MG/L
CHANDABALI	6.93	14.1	106	103	138	7.16	3.14	85	59.91	3.07	0.93	0.31	10.59	14.35	4.66	3.6	2	6000	200	0.132	0.072
JAJPUR	6.57	28.3	164	113	285	5.83	4.13	97	61.56	7.16	2.48	0.67	27.15	22.04	5.83	13.3	1.9	7000	350	0.437	0.115
AKHUAPADA	7.16	17.5	182	89	305	6.41	2.65	105	81.21	4.9	3.66	0.66	19.21	27.25	3.16	9.5	1.6	3050	140	0.38	0.095
DAITARI	6.83	15.6	100	64	146	7.04	2.06	71	56.5	3.02	0.65	0.32	13.74	18.04	2.36	6.2	1.3	4000	180	0.358	0.103
BONTH	6.62	22.1	209	115	315	6.33	3.81	108	62.48	4.59	1.27	0.65	16.32	18.84	3.89	6.8	1.1	4600	370	0.408	0.142
ANANDAPUR	6.87	16.4	236	82	342	7.21	2.05	93	64.98	2.31	0.83	0.45	13.9	20.88	3.32	5.2	0.8	3000	200	0.672	0.114
GHARTAGAON	7.02	11.8	97	43	121	7.69	0.88	77	63.51	2.69	0.73	0.48	8.72	14.03	4.21	6.2	1.4	2500	90	0.265	0.062
THAKURMUNDA	6.06	38.7	247	127	393	5.03	4.54	135	84.54	6.63	2.84	0.66	26.05	24.87	5.59	11.9	2.2	11000	510	1.432	0.146
SWAMPATNA	7.2	17.5	131	70	206	7.23	1.13	88	72.97	3.05	1.85	0.82	15.81	20.04	4.81	7.3	1.6	4700	150	0.411	0.107
KEONJHARGARH	6.81	19.6	165	83	269	7.61	2.03	78	65.59	3.77	1.98	0.97	12.76	16.33	3.62	8	2.7	5000	180	0.367	0.101
KARANJIA	6.78	15.4	176	92	285	7.01	1.17	83	55.64	3.38	1.63	1.09	17.81	17.65	2.6	9	2.9	4000	140	0.486	0.117
JHUMPURA	6.26	26.2	212	108	307	7.07	3.11	104	87	5.38	3.35	0.92	22.65	23.45	5.58	11.9	2.5	4000	260	0.46	0.153
JOSHIPUR	6.85	17.6	201	102	288	7.3	1.24	130	91.46	6.1	4.15	1.17	28.86	29.74	5.47	13	2.9	5000	150	0.384	0.128

Table6. CLASSIFICATION OF IRRIGATION WATER QUALITY

TDS		SAR	
Value	Water Quality	Value	Water Quality
<200	Low salinity	0-10	Excellent
200-500	Medium salinity	18-Oct	Good
500-1500	High salinity	18-26	Fair
>1500	Very high salinity	>26	Unsuitable
Na%		RSC (epm)	
Value	Water Quality	Value	Water Quality
<20	Excellent	<1.25	Safe/good
20–40	Good	1.25–2.50	Marginal/doubtful
40–60	Permissible	>2.50	Unsuitable
60–80	Doubtful		
>80	Unsuitable		

CATIONS AND ANIONS

Variation of concentrations of various cations and anions like Ca^{2+},Mg^{2+},Na^{+},K^{+},HCO_3^-,NO_3^-,SO_4^{2-},PO_4^{3-} and Cl^- of the water samples in different periods were not in a particular trend. Most of the samples were of higher concentrations of these ions in post-monsoon period than those of pre- monsoon and monsoon period where as in some samples higher concentrations were recorded in pre-monsoon period. NO_3^- concentration was recorded to be higher in monsoon period than the other periods. All these parameters were well within the BIS and WHO limits throughout the study period. Higher concentrations of these ions in pre -monsoon period is because of semi arid type of climate and low flow condition which promotes higher rate of evaporation causing increase in concentration of ions where as lower concentrations in post monsoon is due to recharge of water body and dilution factor as effect of the monsoon (Dash *et al*., 2014). Higher values of the parameters in post-monsoon period is the effect of monsoon such as influx of various eroded materials from mine sites, villages, market areas and agricultural fields along with soil erosion, weathering of rocks, atmospheric precipitations and anthropogenic activities like sewage disposal as well as recreational use of the streams and river. Similar results were presented by Prasath *et al*. (2013), Mandal *et al*. (2012), Singh *et al*. (2010). Generally Ca^{2+} in water is derived from minerals like limestone and dolomite and lithological calcareous constituents and the sources of Mg^{2+} are basic igneous rocks such as amphibolites; volcanic rocks such as basalts, metamorphic rocks such as talc and tremolite– schists; and sedimentary rocks such as dolomite. Olivine, augite, biotite, hornblende, serpentine and talc are some major magnesium-bearing minerals **(**Dubey *et al*., 2014).

Presence of Ca^{2+} and Mg^{2+} may also be due to the seepage of effluent and domestic wastes or cationic exchange with Na^+ (Kalavathy *et al*., 2011). However, the low concentrations of Ca and Mg do not mean that they are not influenced by the pollutants but it might be due to the reverse cationic exchange with Na^+ which was previously explained by Prasath *et al*. (2013). In the study area, the degree of variation of Na content is probably due to the differential weathering of the plagioclase feldspar of the parent rocks, domestic sewage and wastes as well as the base exchange of Ca and Mg. (Karanth, 1987). Minerals like orthoclase, microline, and muscovite are responsible for the K content in the water of the study area, the range of which is relatively low, because of its resistance towards dissolution and its adherence to clay minerals (Dash *et al*., 2014). Higher concentrations of sulphates, nitrates, chlorides and phosphates in water samples near to more populated and mines areas S2, S4, S5, S6, S8 may be due to mining and industrial discharges, presence of sodium and calcium chloride in natural water and high salinity, sewage and garbage disposal, fertilizers, decayed vegetables and animal matter and recreational use of water bodies (Kalavathy *et al*., 2011), (Abir, 2014), (Singh *et al*., 2010). The secondary source of sulphate may be weathering of traces of pyrites associated with iron minerals.

FE AND CR

The concentrations of Fe and Cr in the water samples show that most of the samples were of high metal contents in all seasons exceeding BIS limits. Fe in some stations is below the WHO limit. Higher concentrations of dissolved metals in pre-monsoon periods than that of monsoon and post-monsoon periods indicate the accumulation of the metals during low flow condition of the river. It may be attributed to high evaporation rate of surface water, followed by elevated temperature as described by Abdel (2001). According to Pandey (2009), in some cases, high concentration in post-monsoon period was due to effect of rain such as dissolution of rocks and minerals, run offs from mine sites, agricultural fields and urban as well as rural areas and atmospheric precipitation. The high concentrations of iron is due to runoff of iron- rich soil and mining activities of iron ore mines close to the streams (USEPA, 1994) as well as the leachates and run off from the overburden dumps (Rath *et al*., 2010). The observed high value of Cr in water may be due to physical and chemical weathering of rocks and soil, anthropogenic sources including mining, industrial, domestic waste and sewage effluents originating from nearby urban and rural areas draining and leaching into the river (Akhionbare, 2011)

IRRIGATION WATER QUALITY

The suitability of the water samples were assessed on the basis of classification of irrigation water with respect to TDS, SAR, RSC and Sodium % (Table 6) according to Richards (1954), Wilcox (1995), Ravikumar *et al*. (2013).The calculated irrigation quality indices indicated that all the samples in pre-monsoon period and 77% in monsoon and 61.5% in post-monsoon period are of low salinity category. 23% of samples in monsoon and 38.5% of sample in post-monsoon are of medium salinity. All the samples in the study period have SAR 0-10 and RSC less than 1.25. Considering the Na%, 54% samples in pre-monsoon 31% in monsoon and 15.4% in post-monsoon are of excellent quality. 46% of samples in pre-monsoon, 69% in monsoon and 84.6% of samples in post-monsoon period are of good quality for irrigation purpose. Thus, the overall assessment is that the water samples are safe and good for irrigation purpose.

Table7. SAR, NA% AND RSC IN PRE-MONSOON, MONSOON AND POST-MONSOON

MONITORING STATIONS		Pre-monsoon			Monsoon			Post monsoon	
	SAR	Na%	RSC	SAR	Na%	RSC	SAR	Na%	RSC
CHANDABALI	0.129	12.387	-0.183	0.181	14.139	-0.147	0.212	15.914	-0.117
JAJPUR	0.552	28.488	-0.162	0.575	32.308	-0.104	0.653	28.447	-0.571
AKHUAPADA	0.352	18.978	-0.182	0.451	24.583	-0.137	0.46	21.924	-0.289
DAITARI	0.212	13.325	-0.441	0.278	18.767	-0.063	0.365	21.689	-0.168
BONTH	0.505	26.557	-0.032	0.406	23.669	-0.107	0.373	20.461	-0.236
ANANDAPUR	0.253	15.458	-0.177	0.4	25.948	0.032	0.277	15.434	-0.25
GHARTAGAON	0.257	16.412	-0.131	0.158	12.877	-0.131	0.373	22.69	-0.005
THAKURMUNDA	0.433	20.26	-0.409	0.56	26.97	-0.613	0.562	25.198	-0.315
SWAMPATNA	0.285	16.47	-0.255	0.49	25.29	-0.223	0.379	20.365	-0.2
KEONJHARGARH	0.302	18.927	-0.199	0.273	20.231	-0.215	0.465	26.68	-0.038
KARANJIA	0.4	22.821	-0.285	0.461	27.584	-0.089	0.528	29.704	-0.183
JHUMPURA	0.429	21.418	-0.368	0.522	26.841	-0.144	0.572	26.29	-0.203
JOSHIPUR	0.461	22.313	-0.379	0.316	19.113	-0.379	0.577	24.893	-0.435

WQI

The water quality index does not show exact degree of pollution, rather it is used to assess water quality trends for the management purpose (Mukherjee *et al*., 2012). The WQI results represent the level of water quality in a given water basin. The computed WQI values are classified into five types, namely, excellent water (WQI<50), good water (50>WQ<100), poor water (100>WQI<200), very poor water (200>WQI<300) and water unsuitable for drinking (WQI>300).as described by Ravikumar (2013), Mukherjee *et al*. (2012) and Dubey *et al*. (2014). It was observed that WQI values ranged from 96 to 359.

Only 7.7% of sample is of good quality in pre-monsoon period and none of the sample is under this category in pre and post-monsoon period. 54 % of the samples in pre-monsoon, 61% of the samples in monsoon and 46% of the samples in post-monsoon are of poor quality. 31% of the samples in pre-monsoon and monsoon, 46% in post monsoon are of very poor quality. 7.7% of the samples are in each of the pre-monsoon, monsoon and post-monsoon periods are considered to be unsuitable for drinking. It clearly shows that none of the sampling stations have excellent water quality, indicating lack of access to safe potable water supply.

CONCLUSION

On the basis of the present study of various physico-chemical parameters, it was found that though the cations and anions along with pH are within the BIS and WHO standard limits for almost all samples of the local streams and Baitarani River, none of the samples is fit for direct human consumption with respect to water quality index. Maximum sampling stations are contaminated with high total coliform including faecal coliform bacteria. Water is slightly acidic at some stations, particularly in post-monsoon period and alkaline in most of the stations in monsoon and pre-monsoon period. Comparatively low DO and high BOD values along with high turbidity and TSS, high values of Fe and Cr indicate poor quality of water. In the present study, WQI reveals that degradation of water quality is due to high concentrations of Fe and Cr. None of the water samples was of excellent quality. Overall assessment is that almost all of the samples are poor to very poor quality. BOD, TSS, turbidity and coliform counts (CFU/100ml) as well as iron and chromium are relatively higher in local streams than that of Baitarani River. This may be due to low volume of water, low flow condition, dense population in the catchment area and flowing of streams in the close proximity of various iron and manganese mines. The sources of contamination are domestic sewage, disposal of garbage, soil erosion, mines run off and anthropogenic activities with extensive recreational use of the streams and the river. The sample S8 is of the most unsuitable with respect to WQI as well as other parameters because of anthropogenic activities through more population and presence of iron and manganese mines very close to the stream. Also, water samples at other stations such as S2, S5, S6, and S12 are of very poor quality.

The overall study of water quality clearly indicates that the water sources of the study area cannot be used for public consumption without any treatment though all samples are of good quality for irrigation purpose on the basis of TDS, SAR, RSC and Sodium% values. Lack of sanitary awareness mostly open defecation among the local people is one of the most important factors for the degradation of water quality in this area. Therefore, there is a need for proper management to check the disposal of wastes into the streams and river/river catchment and to control and monitor human activities along with public awareness to ensure its minimal negative effect on the water body. Deforestation should be strictly enforced to check the massive soil erosion. The present baseline information of the physico-chemical parameters of water samples would form a useful tool for further ecological and environmental assessment and monitoring of these water ecosystems, leading to the safe survival of the inhabitants in the study area.

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